UTILIZATION OF S° OF DIFFERENT PARTICLE SIZES BY TEA CROP AND ITS CARRY OVER STATUS

THESIS

By

PRAKASH CHAND

Submitted to

CHAUDHARY SARWAN KUMAR HIMACHAL PRADESH
KRISHI VISHVAVIDYALAYA PALAMPUR-176 062 (H.P.) INDIA

IN

Partial fulfilment of the requirements for the degree

OF

MASTER OF SCIENCE IN AGRICULTURE
(TEA HUSBANDRY & TECHNOLOGY)

2002

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Is there anything I can say
anything I can give
or do for you ?
Because all that I'm
all that I have
I owe to you. . . . . .

AFFECTIONATELY
DEDICATED TO REVEREND
PARENTS

who sacrificed their present
to make my future better

ACKNOWLEDGEMENTS

As a matter of eternal compliance, above all, I would like to thank soulfully the "Almighty God" who bestowed me with his blessing to go through this juncture.

Indeed the words at my command are not adequate either inform or in spirit, to convey my depth of feelings of gratitudes to Dr. D.K. Sharma, Professor, Department of Tea Husbandry and Technology, CSK HPKV, Palampur, the Chairman of my Advisory Committee for his superb guidance, persistent encouragement, continuous patience, sympathetic help and elegant criticism throughout the entire course of this investigation and in the completion of this manuscript. I shall ever be indebted to him for developing in me the desire of work hard through his valuable suggestions, the quest to delve into the facts and appreciable humanitarian behaviour, which evoked in the bestir to achieve the destination successfully resulting in this manuscript. To him, I owe a lot more than I can express.

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Time stop ticking, when I think of acknowledging my affectionate parents Smt. Champa and Sh. K.K. Thakur whose constant moral encouragement with a source of inspiration to burge a heed and imbibing the fact of impregnability. Their persuasion and sacrifice, heartfelt blessing and firm faith have made this manuscript a feeble recompense to translate their dreams into reality.

I bow with revence and gratitude to my sisters, brother-in-laws, younger brothers, nephew and niece whose inspiration, exhortation love and affection made my present work quick effective.

I would be crucial if a don't acknowledge the aid and stimuli of catteri company of my friend and classmates Neerav, Vivek, Vinod, Jagdish, Sanjeev Kumar, Anil Mahajan, Amit, Salej, Dhiman, Ankur, Sanjeev, Aman, Pankaj, Amit Sharma, Vishal, Bindu, Jitender, Bhagat my seniors, Aditya, Girish, Choudhary Ram, Puran, Vinay, Sandeep, Sunil, Aman and my juniors, Patyal, Sudhir, Ashok, Khubram, Shamsher, Ravinder, Rajeev, Babar, Harpreet for their whole heartful involvement and for providing direct and indirect help during my study period, that to with cheerful ebullience.

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A word of appreciation should be credited to Sh. Devi Lal Sharma for his painstaking efforts in typing this manuscript.

Needless to say, errors and omissions are mine.

Place: Palampur — *(PRAKASH C. THAKUR)*

Dated: the 2th July, 2002.

Dr. ***D.K. Sharma***
Professor

Dept. of Tea Husbandry & Technology
CSK HP Krishi Vishvavidyalaya, Palampur
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CERTIFICATE - I

This is to certify that the thesis entitled **"Utilization of S° of different particle sizes by tea crop and its carry over status"**, submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Tea Husbandry & Technology** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Mr. Prakash Chand** son of **Sh. K.K. Thakur** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

(D.K. Sharma)
Chairman,
Advisory Committee

Place : Palampur
Dated: the 3 July, 2002.

CERTIFICATE - II

This is to certify that the thesis entitled **"Utilization of S° of different particle sizes by tea crop and its carry over status"** submitted by **Mr. Prakash Chand** son of **Sh. K.K. Thakur** to the Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the subject of **Tea Husbandry & Technology** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

Dr. D.K. Sharma
Chairman,
Advisory Committee

External Examiner

Dr. K.L. Sharma (Member)

Dr. R.C. Jaggi (Member

Dr. B.C. Kaistha
Member (Dean's Nominee)

Head of the Department

Dean
Post Graduate Studies

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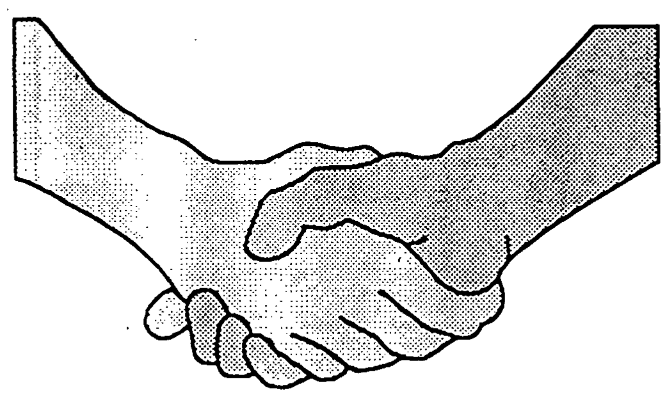


INTRODUCTION

Chapter-I

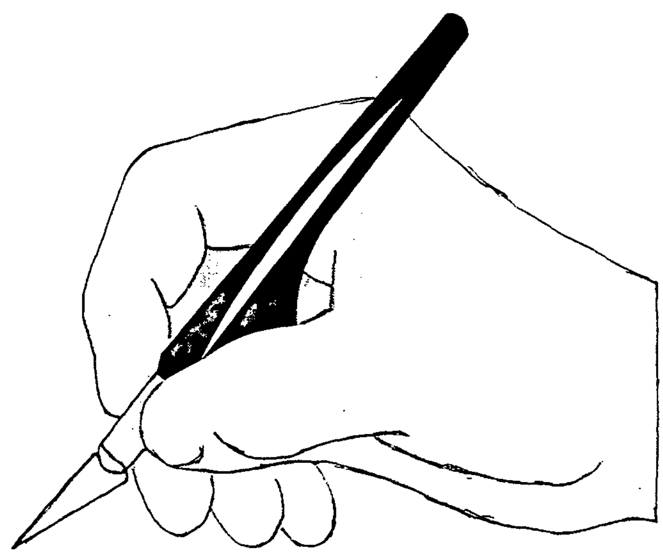
INTRODUCTION

Tea (*Camellia sinensis* (L) O. Kuntze), one of the most popular beverages world wide, is increasing in popularity because of its positive effect on human health. India, the largest producer and consumer of tea, cultivates over 4.37 lakh hectares, producing over 805 million kgs of tea in 1999 (Anon. 2000). Tea is an important crop of most of the hilly region (Kangra, Mandi and Chamba hills of Himachal Pradesh, Assam, Darjeeling hills of West Bengal, Neelgiri hills of Tamil Nadu) and as such prefers very acidic conditions. Tea is one of the commercial crops of Himachal Pradesh covering about 2325 hectares of area and producing 1500 thousand kgs of tea (Anon., 2000). The yield has been considered to be quite low as compared to other parts of the country. However, immense possibilities are there for increasing the productivity of green tea by 8-10 times through the adoption of various scientific agricultural techniques among which sulphur nutrition occupies an important aspect. The average removal of sulphur by tea crop to support a nominal yield of around 2000 kg/ha per year absorbs 20 kg S/ha (Bhat and Ranganathan, 1980). The rates of sulphur addition should be 2-4 times of the average S removal by the crop so as to compensate the losses through leaching, runoff, volatilization, immobilization and fixation. The sulphur is now being recognised as the 4th major nutrient.

In tea crop, importance of sulphur is next to nitrogen, only gypsum and single superphosphate used to be the major sources of sulphur before 1990. However, the increasing costs and the opportunity for aerial application has made elemental sulphur (S°) with several advantages Firstly, it increases availability of P by replacing and releasing the phosphorus from the fixation sites of acidic soils (Jaggi, 1992). This fact assumes greater significance because of the substantial amount of applied fertilizer, P fixed by Fe and Al, ions. Secondly, being a slow release SO_4^{-2} source, S° application could reduce leaching and run off losses of SO_4^{-2} particularly under heavy rainfall conditions in hilly areas. Thirdly, it could have a prolonged residual effect on the S nutrition of succeeding crops (Boswell and Friesen, 1993). Fourthly, being a concentrated source of S, handling and transportation of S° is for more economical and convenient in the undulating terrain for hilly regions. Biochemical oxidation of S° converts it into sulphate (SO_4^{-2}) form, which is the only plant- available form. The rate at which the oxidation occurs is dependent on the particle size of the material (Li, and Caldwell, 1966).

In view of the several advantages of the use of S° or S fertilizer under Himachal conditions, obviously the first step is to determine the optimum particle size of S°, which converts into available form (SO_4^{-2}) at a rate simulating with plant needs so that its losses in different ways are minimized. No work of this type has been conducted so for in H.P. at least on tea. Hence, the study entitled, "Utilization of S° of different particle sizes by tea crop and its carry-over status" has been initiated with the following objectives:

1. To compare the performance of S° of different particle sizes on yield and quality of tea using gypsum and agricultural pyrite as standards.
2. To study the utilization of applied S° of different particle sizes through the yield and quality of current crop.
3. To study the residual status of S in different forms (Total-S, Organic-S, Sulphate-S) due to application of S° at different particle sizes.
4. To identify that particle size of S° whose oxidation into sulphate-S (Plant available form of S°) simulates closest with the crop need, spares maximum of the rest of S° for the next crop, and thus loses the least in leaching, run off and fixation losses.



REVIEW OF LITERATURE

Chapter-II

REVIEW OF LITERATURE

Nutrition plays a major role in tea plantation. Plant nutrient supply in tea is aimed to suppress the reproductive phase and to exhibit the vegetative growth during growing seasons and to make available all the essential nutrients, which are deficient in soil in optimum quantities as required by tea bushes for a set productivity level.

Unlike, other plantations, the harvestable product of tea is directly obtained from foliage. Since huge quantities of nutrients are removed from the soil through harvests every year, therefore, there is a functional relationship between yield, quality of produce and mineral nutrition of the tea crop. Keeping in view the above observations and the present investigations, the available literature has been reviewed under the following heads:

2.1 Effect of S and different particle sizes of sulphur application on tea yield

2.2 Effect of S and different particle sizes of sulphur application on tea quality

2.3. Effect of different particle sizes of sulphur on physio-chemical properties of soil.

2.1 Effect of S and different particle sizes of sulphur application on tea yield

Sulphur fertilization to tea has been suggested by various workers to increase yield of tea. Kanwar and Singh (1965) conducted studies on the effect of sulphur on tea crop and reported that fertilizer containing sulphur has more beneficial effect on tea yield.

Kanwar and Takkar (1966) studied the responses of tea crop to the application of sulphur in tea soils of Dharmshala and found that S addition increased the yields of tea significantly when applied in the form of sulphate of ammonia on a sandy loam soils of pH 4.8. While in other locations where the pH was higher, the application of elemental S was better (Jones and Ruckman, 1969).

Bhavanadan and Sunderalingam (1971) reported that the tea growing soils of South India, where they used sulphate of ammonia, urea and CAN for the period 1961 to 1971 on tea and observed that sulphate of ammonia gave higher yields than the urea at the highest level (336 kg/ha).

Otheino (1980) stressed the need of sulphur application to tea along with other fertilizer of NPK in different countries for better growth and yield. Bhat and Ranganathan (1980) studied that tea bushes required 1 kg of sulphur for each 100 kg of made tea. According to them, a normal yield level of 2000 kg of made tea absorbs 20 kg S/ha and to compensate for leaching and other limitations of sulphur availability an application of 2 to 4 times, the quantity absorbed should be observed.

Watson and Wettasinghe (1982) studied the effect of three fertilizers viz., sulphate of ammonia, urea and calcium ammonium nitrate on the leaf nutrient composition of tea grown in Sri Lanka and observed that sulphate of ammonia gave the highest yield upto 5349 kg/ha and in these plots, the leaf N, P and Mn content were highest and leaf Mg was the lowest.

Natesan (1989) highlighted the importance of sulphur nutrition of tea crop. Application of elemental sulphur @ 20 to 40 kg sulphur/ ha increased tea yields significantly (Sinha *et al.,* 1992). Gohain and Dutta (1994) investigated the effect of application of urea-N, rock phosphate and muriate of potash on S nutrition of tea in relation to soil and leaf sulphur status and reported that the harvested tea crop was found to remove only a small amount of sulphur and that was only 6 kg S/ha/year for a crop of 3000 KMTH.

Barbora (1995) observed that sulphur management for tea in North-East India and concluded that sulphur had positive effect on yield of 20 kg/ha/year. Available soil sulphur increased by 4 mg/kg per 20 kg/ha/year applied S. Yield increased with increase in available soil sulphur from 23 to 36 mg/kg.

Chakravartee (1996) found that the effect of sulphur on yield of tea in North East India and reported that better yield response to increasing levels of sulphur application was observed in low organic matter soils to the extent of 8.1 per cent and on the other hand, yield increase was low (2 %) in high organic matter soils. This indicates that in organic rich soils, the benefit from sulphur fertilization was very low as compared to low organic soils, which might be due to sufficient amount of available soil sulphur already present in these soils. In another trial carried out in Assam, the response to sulphur fertilization by tea crop was found to be curvilinear, showing an optimum yield of 3987 KMTH corresponding to an optimum dose of S at 45 kg/ha. Further increase in the application of sulphur depressed yield which could possibly be due to some nutritional imbalance of sulphur in the plant with respect to other nutrients.

2.2 Effect of S and different particle size of sulphur application on tea quality

Numerous studies have indicated that sulphur application improve the quality of various crops by increasing protein content, chlorophyll content, oil content and sulphur content etc.

In tea crop, sulphur applications were found to increase the chlorophyll content of the green tea leaves (Kanwar and Takkar, 1966).

Takea (1979) revealed that the effect of sulphur as sulphate of ammonia on tea crop in Kanayacho, Japan and reported that amino acid content of tea leaves increase with sulphate of ammonia when applied, during the late spring until early summer in the new shoots planted in late June and early August. Ye and Ye (1993) observed that the polyphenol content of the tea shoots decreased by 22.4 to 30.3 per cent the sugar content by 1.4 to 5.9 per cent and the starch content by 2.6 to 9.5 per cent with sulphur treatments. Polyphenol oxidase (catchol oxidase) activity decreased linearly with increasing sulphur indicating the inhibition of polyphenol metabolism by sulphur application.

Ye (1993) observed that caffeine was linearly correlated with sulphur dose of protein content of tea leaves increased with increasing sulphur dose. Total nitrogen, total phosphorus and nitrate reductase activity increased with increasing sulphur dose, while dose above 71.2 mg/kg decreased phenylalanine ammonia layse activity.

Wu and Jianyun (1994) revealed that sulphur can significantly increase not only amino acid content but also flavour and aroma component in tea.

Yong *et al.* (1994), while studying sulphur nutrition for tea plant on tea quality in pot and field experiments, observed that at certain level of sulphur, the nitrate reductase activity, the free amino acid content, especially theanine and aspartic acid content of fresh leaves increased significantly, but the polyphenol oxidase activity and the polyphenol metabolism decreased significantly resulting in dropping of polyphenol/amino acid value which was good for the quality of green tea.

Barbora (1995), while working on sulphur management for tea in North-East India, reported that sulphur had positive effect on quality of tea at 20 kg S/ha. However, further increase in sulphur applications did not show any additional quality advantage. Thearubigins and total colour was highest with 20 kg S/ha. High performance, liquid chromatography analysis of black tea liquor revealed that sulphur application increased the theaflavins group of compounds especially theaflavins and theaflavin - 3 gallate. Flavonol glycosides such as rutin and quercetin glycosides also increased marginally, which may have resulted in brighter colour and possibly increased flavour during processing leading to better over all quality.

Chakravartee (1996) found that total and available status of soil sulphur varied with agroclimate zones. The threshhold level of available soil sulphur has been found to lie between 35 and 40 ppm. Quality parameters like theaflavins, thearubigins and flavanol glycosides increased by the application of sulphur 20-40 kg/ha. The taster's score in respect of liquor, quality of liquor and evaluations of made tea were higher in teas receiving sulphur fertilization than those without. Ali *et al.* (1997) studied the influence of nitrogen, sulphur and boron on certain quality parameters of black tea and observed that S showed linear positive correlation with theaflavin content and brightness of made tea. Thearubigin content and total colour were also marginally improved by sulphur upto a certain level.

2.3 Effect of different particle sizes of sulphur on physico-chemical properties of soil

Jones and Ruckman (1966) compared the effect of gypsum and fine (100 mesh) elemental sulphur (S°) on total sulphur uptake on annual grassland and found for first season sulphur uptake by the forage to be equal for both sulphur sources with sulphur uptake declining for both sources in subsequent seasons. The greatest yield was produced from elemental sulphur in the first and second years with residual through the forth year with gypsum, first year gave the largest yield but residual sulphur was evident through three years. Jones and Ruckman (1969) studied particle size fraction of elemental S in a sub clover grass pasture resulted in marked difference in sulphur uptake pattern over a seven year period.

Singh *et al.* (1990) studied the effects of different sources of iron and sulphur on nutrient concentration by groundnut and reported that application of sulphur had significantly increased the uptake of nitrogen.

Jagtap and Mohite (1994) observed that the available sulphur and iron in the soil increased and soil pH decreased initially and thereafter increased slightly, when saline sodic calcareous soil incubated with pyrite. Kuligod *et al.* (1994) studied the influence of elemental sulphur on nutrient uptake by wheat and concluded that the application of sulphur fertilizers increased the uptake of N, P, K, Ca, S, Zn, Fe and Mn by the crop.

Barbora (1995) studied the effect of sulphur management in tea and reported that available soil sulphur increased by 4 mg/kg per annual application of 20 kg S/ha, using elemental sulphur over a 6 years period. Different sources of sulphur (iron pyrites, sulphur pyrite, gypsum) were all the efficient in augmenting the available soil sulphur.

Boswell (1997) studied the effect of S° of different particle sizes to dry land lucerne and revealed that particles < 150 fm were 90 per cent oxidised within 1 year of application and best suited to annual application, particles of 250-500 fm were oxidised over about 3 year and were suited to biennial or triennial applications.

Kaplan and Orman (1998) studied the effect of S° and sulphur containing waste in a calcareous soil and reported that elemental sulphur and waste application increased the uptake of P, Fe, Zn, Mn and Cu.

Wani and Refique (2000) studied the effect of different levels of sulphur on nutrient uptake of rice and revealed that S, N, P and K uptake increased with increasing level over control.

Sakal *et al.* (2000) studied the relative performance of some sulphur sources on sulphur nutrition of crops and reported that sulphur concentration and uptake progressively increased with rising sulphur level.

Singh *et al.* (2000) reported that in acidic soils, total uptake increased with successive sulphur application in comparison to control.

MATERIAL AND METHODS

Chapter-III

MATERIAL AND METHODS

The current research study entitled "Utilization of S° of different particle sizes by tea crop and its carry over status" includes the effects of different sources of sulphur in terms of yield and quality parameters of tea plantation.

Representative soil samples before the fertilizer application were collected to determine N, P, K, S pH, organic carbon and texture. Shoots samples (two leaves and bud) were also collected during summer monsoon and back end season from each 21 plots to determine the major N, P, K and S content.

The tea leaves were manufactured as per standard procedure suggested by Ullah (1986) to assess the effects of sulphur application on quality parameter viz., Theaflavins (%TF), Thearubigins (%TR), Total colour (%TC) and per cent Brightness (%B). The detailed description of such studies is as under:

3.1 General description of the study area

3.2 Detail of field experiment

3.2.1 Layout of experiment

3.3 Collection and preparation of samples

3.3.1 Collection of soil samples

3.3.2 Collection of leaf samples

3.3.3 Preparation of soil samples

3.3.4 Preparation of leaf samples

3.4 Field study

3.4.1 Yield data record

3.5 Method used for soil analysis

3.6 Method used for leaf analysis

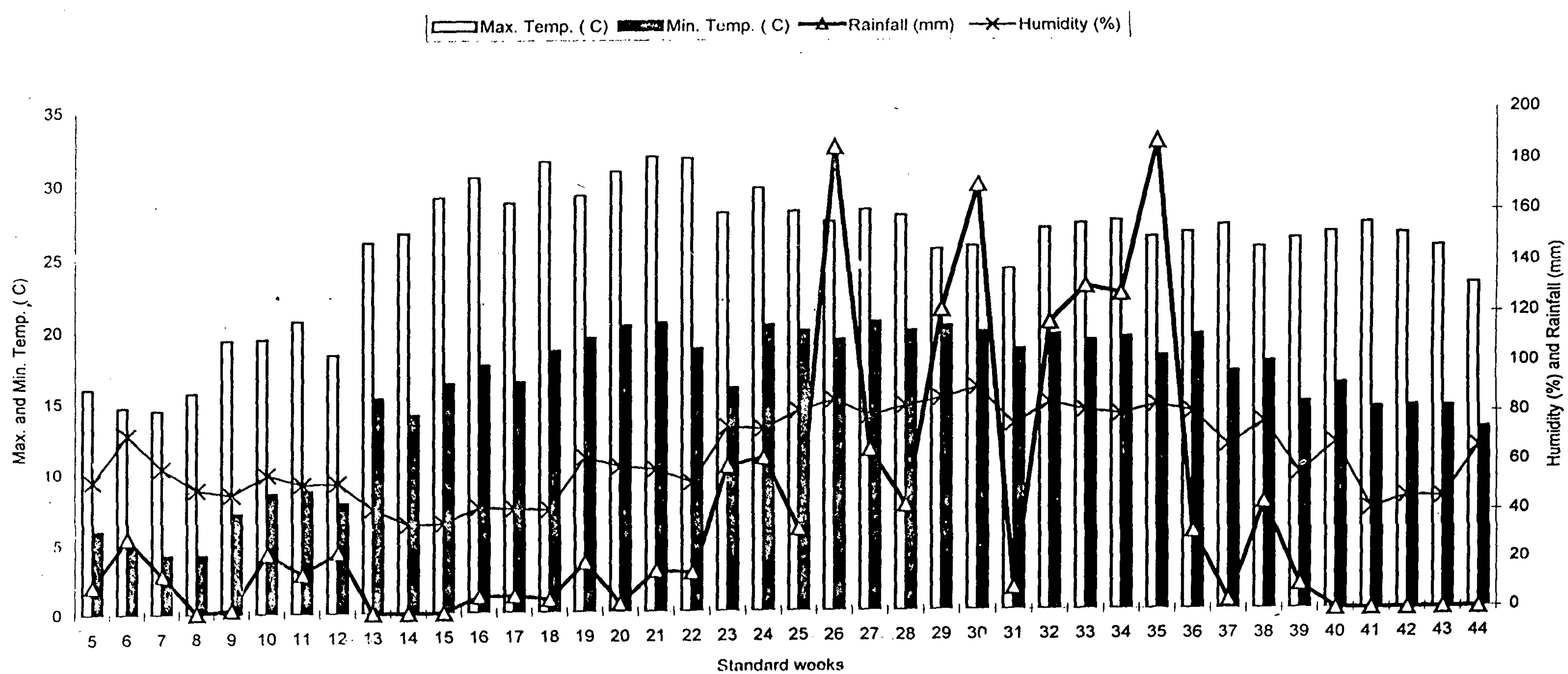
3.7 Estimation of tea quality parameters

3.8 Per cent utilization of sulphur

3.9 Statistical analysis of the data

3.1 General description of the study area

The climate of the area under study is humid temperate with a moderately hot summer and severe cold winter. The rainfall around Palampur is very high averaging to about 2800 mm. The distribution of rainfall is uneven which is understandable from the point that 62 per cent of it is received during July and August. The study area is situated in the foot hills of the Dhauladhar hill range which represents a high rainfall zone in Himachal Pradesh. The soils have medium to high acidity and by the large, have been reported to be deficient in sulphur and phosphorus and rich in organic matter.



Appendix 1 : Mean weekly meteorological data during the field experimentation period (Feb. - Oct., 2000)

The field experiment was conducted during 2000 at Tea Experimental Farm of the Department of Tea Husbandry and Technology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental area is situated at an elevation of 1291m above mean sea level with latitude 36°6' N and longitude 76°3' E, receiving rainfall of 2016 mm and having maximum temperature around 23.9°C and minimum temperature around 13.9°C during this period. The mean relative humidity in the region varies from 45 to 85 per cent, which is at its low in April and November, whereas at its peak in July and August (Appendix-1). The place is characterized by severe winters and mild summer (Verma *et al.,* 1976).

3.2 Detail of experiment

3.2.1 Layout of experiment

The experiment that aimed at studying the responses of tea crop chinery hybrid type of tea (*Camellia sinensis*) to applied S was initiated with effect from February 2000 at the Tea Experimental Station of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experiment was laid out in Randomized Block Design (RBD) comprised of seven treatments of sulphur through gypsum, agri. pyrite (available form) and elemental sulphur (S°) of different particle size of sulphur (< 0.25 mm, <0.5mm, < 1mm and <2mm), replicated thrice. Each plot (45 sq meters) consisted of 20 bushes established at 1.5m x 1.5m spacing. N, P_2O_5 and K_2O (90 kg/ha, 90 kg/ha and 45 kg/ha, respectively) were applied as basal dose to each plot. Nitrogen and sulphur were applied through (12:32:16) NPK mixture + urea and elemental sulphur of different particle sizes along with available gypsum and Agri. pyrite (60 kg/ha). The fertilizers were applied during the month of February by top dressing around the bushes uniformly.

The physico-chemical properties of the soil were determined before fertilizer application for the year 2000 and are given in the Table 3.1.

3.3 Collection and preparation of samples

3.3.1 Collection of soil samples

In order to determine the initial physico-chemical properties and status of soil, composite soil sample (0-15cm depth) were collected before the application of fertilizer nutrients as well as the end of experiment and were run for mechanical and chemical analysis.

3.3.2 Collection of leaf samples

Tea shoots consisting of (two leaves and a bud) were collected at different plucking seasons i.e. summer, monsoon and back end seasons for the determination of NPK and S concentration at different stages and also assessment of quality parameters such as

Table 3.1 Physico-chemical properties of the study area

Sr. No.	Properties	Values
1.	pH	5.4
2.	Organic carbon	1.04
3.	Available N (kg/ha)	312
4.	Available P (kg/ha)	22.5
5.	Available K (kg/ha)	202.7
6.	Available S (ppm)	22.7
7.	Sulphate sulphur (ppm)	13.4
8.	Organic sulphur (ppm)	212.2
9.	Total sulphur (ppm)	260.2
10.	Mechanical analysis	
	i. Sand (%)	38.0
	ii. Silt (%)	42.3
	iii. Clay (%)	28.2
11.	Texture class	Silty clay loam

Theaflavins (%TF), Thearubigins (%TR), Total colour (%TC) and Per cent brightness (%B).

3.3.3 Preparation of soil samples

The soil samples collected before the fertilizer application as well as at the end of experiment were dried, ground, passed through 20 mesh (2mm sieve) and were finally stored in polythene bags for the determination of different nutrients.

3.3.4 Preparation of leaf samples

A portion of plucked leaf shoots collected during different seasons was immediately put to steaming to stop the metabolic activity, followed by drying at 60 - 65° for 48 hours. The dried samples were crushed and packed in air tight polythene bags for the estimation of N, P, K and S content. The rest of the portion of the samples were manufactured in Piezyroller as per instructions contained in Tea Encyclopedia (Wood *et al,* 1980) and finally packed in air tight polythene bags as black tea samples (orthodox) for the assessment of quality parameters such as theaflavins (TF), thearubigins (TR), total colour (TC) and Per cent brightness (% B).

3.4 Field study

3.4.1 Yield data record

Regular plucking was done at 7-10 days interval during different growing seasons viz., summer season (April to June), monsoon season (July to August) and back end of season (September to October) crop yield was expressed in kilogram made tea per hectare (KMTH) taking an average of 25 per cent recovery of green leaf during the entire growing season.

3.5 Soil analysis

3.5.1 pH

pH was determined with the help of Beckman pH meter using glass electrodes in 1:2.5 soil water ratio.

3.5.2 Organic carbon

Organic carbom was determined by Rapid titration method as described by Walkley and Black (1934).

3.5.3 Nitrogen

Aailable N was determined by alkaline permanganate method as outlined by Subbiah and Asija (1956).

3.5.4 Phosphorus

Available P was determined by extracting the soil with 0.5 M $NaHCO_3$ (pH 8.5) method as outlined by Olsen *et al.* (1954).

3.5.5 Potassium

The available potash was determined as suggested by Jackson (1973).

3.5.6 Mechanical analysis

Mechanical analysis was done using International Pippette method as suggested by Black (1965).

3.5.7 Sulphur - SO_4^{-2}

Sodium chloride extractable sulphate sulphur was determined by turbidity method using spectrophotometer at a wavelength of 340 mm as per method suggested by Cottenie (1979).

3.5.8 Forms of sulphur

(a) Total sulphur : The amount of total sulphur was determined by the method of Butter and Chenery (1959) being described briefly as under:

Fusion: Soil was fused with Na_2CO_3 and $NaHO_3$ in the ratio of platinum crucible at 450°C in an electric furnance till ashing was complete.

Dissolution: After ashing, the sample was shaken with distilled water and was made to a specified amount of volume.

Determination (development of turbidity): Sulphate was determined after developing the turbidity with back crystal on Spectrophotometer at a wavelength of 420mm as per method proposed by Chesnin and Yein (1951).

(b) Organic sulphur: Organic sulphur was determined as per the methods proposed by Bradsely and Lancaster (1960) whose brief detail is as under:

Leaching: The soil was leached with distilled water in the ratio of and them with 10 per cent HCl to remove SO_4^{-2}-S and finally washed with distilled water to remove excess of HCl until no chlorides were present and then the soil was evaporated to dryness after adding H_2O_2.

Shaking: After cooling 1 per cent Nacl solution was added and shaken for half an hour.

Determination: Sulphate was determined in the filtrate by the method of Chesnin and Yein (1951).

(c) Sulphate-S: Sulphate-S was determined by the method of Willams and Steinbergs (1959).

3.6 Leaf analysis

3.6.1 Nitrogen

For nitrogen (N), digestion of the samples was carried out using H_2SO_4 and digestion mixture. The total N in the digested material was estimated by Microkjeldhal procedure (Jackson, 1973).

3.6.3 Sulphur

S was determined by turbidity method using Spectrophotometer at a wavelength of 420 nm as per method outlined by Cottenie (1979).

3.7 Estimation of tea quality parameter

The liquid characteristics of made tea such as Theaflavins (%TF), Thearubigins (%TR), Total colour (%TC) and per cent Brightness (%B) were estimated by the method suggested by Ullah (1986).

3.8 Per cent utilization of sulphur

$$\% \text{ utilization} = \frac{nt - no}{n} \times 100$$

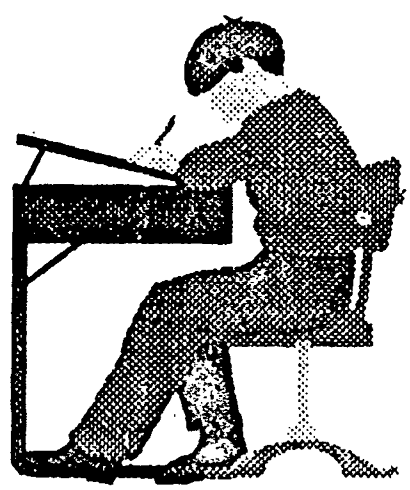
where nt = Nutrient uptake in treated plot

no = Nutrient uptake in control plot

n = Amount of nutrient applied

3.9 Statistical analysis of the data

The data obtained during the course of study was subjected to statistical analysis such as single and multiple correlations by using the microstat computer software and ANOVA table were computed based on the procedure described by Gomez and Gomez (1984).



RESULTS

Chapter-IV

RESULTS

The present investigation entitled "Utilization of S° of different particle sizes by tea crop and its carry over status" was carried out in the Department of Tea Husbandry and Technology of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The result investigation have been described in this chapter under the following heads:

4.1 Effect of different particle sizes of sulphur on the yield of made tea

4.2 Effect of different particle sizes of sulphur on the quality of made tea

4.3 Effect of different particle sizes of sulphur on nutrient concentration and uptake

4.4 Per cent utilization of applied sulphur in tea crop

4.5 Physico-chemical properties of soil

4.6 Residual status of sulphur

4.7 Correlation studies

4.1 Effect of different particle sizes of sulphur on the yield of made tea (kg/ha)

Individual effect of different particle sizes of sulphur was studied on the yield of tea in three seasons i.e. summer season, monsoon season and back end season during the year 2000. Pooled analysis of the whole year was also made and results described along with all the treatments application affected the yield of made tea to a significant extent in the three seasons of crop (Table 4.1).

Amongst all the treatments. application of medium fine sulphur significantly produced highest yield in all the three seasons and also on the pooled basis followed by gypsum and agricultural pyrite sources of sulphur, which were statistically at par in all the three seasons and also on the pooled basis. However, rest of the treatments were lowest in yield and statistically at par with control plots.

Table 4.1 Effect of different particle sizes of sulphur on yield of made tea (kg/ha)

Treatment	Season-I	Season-II	Season- III	Total
Control	892.7	483.7	140.4	1516.7
Gypsum	1049.4	660.7	192.3	1902.4
Agripyrite	1032.0	581.7	191.7	1805.3
Fine S	905.8	510.7	186.0	1602.4
Medium fine S	1117.4	696.0	201.0	2014.4
Medium coarse S	1000.0	572.4	190.7	1743.0
Coarse S	966.7	551.4	166.7	1691.7
CD (5%)	111.1	35.4	30.1	119.1

4.2 Effect of different particle sizes of sulphur on the quality of made tea

Effects of different particle sizes of sulphur were studied on quality parameters i.e. theaflavins (%TF), thearubigins (%TR), total colour (%TC) and per cent brightness (% B) of tea liquor in three seasons of the year 2000 and results are being described as under:

4.2.1 Theaflavins of made tea

Theaflavins content of made tea was significantly influenced by the seasonal variation, under different particle sizes of sulphur applications over the control during all the three seasons (Table 4.2). The percentage of theaflavins was statistically at par with the application of gypsum, Agri. pyrite, fine sulphur, medium fine sulphur and medium coarse sulphur, but showed a significant increase in the theaflavins content over control in all the three seasons. Maximum percentage of theaflavins content was observed with the application of Agri. pyrite in first and third season, whereas, medium fine sulphur showed highest percentage of theaflavins content in second season.

4.2.2 Thearubigins of made tea

The percentage of thearubigins content of made tea was found to be nonsignificant in all the three seasons irrespective to any treatment. However, Agri. pyrite gave the highest value of thearubigins

Table 4.2 Effect of different particle sizes of sulphur on the quality parameters of made tea

Treatment	% TF	% TR	% TC	% B
Season- I				
Control	0.10	4.89	1.30	17.22
Gypsum	0.20	5.36	1.61	18.06
Agripyrite	0.21	6.58	1.82	18.29
Fine S	0.16	5.59	1.74	17.83
Medium fine S	0.20	5.88	1.93	18.96
Medium coarse S	0.19	5.66	1.74	18.34
Coarse S	0.16	4.89	1.59	17.72
CD (5%)	0.03	NS	0.26	0.29
Season- II				
Control	0.10	6.17	1.07	14.60
Gypsum	0.15	8.23	1.83	15.36
Agripyrite	0.16	8.05	1.54	15.60
Fine S	0.15	7.89	1.37	14.96
Medium fine S	0.17	8.15	1.79	15.75
Medium coarse S	0.14	7.46	1.51	15.08
Coarse S	0.12	7.22	1.20	14.99
CD (5%)	0.02	NS	0.19	0.39
Season- III				
Control	0.10	4.96	1.34	16.82
Gypsum	0.15	5.78	1.77	17.45
Agripyrite	0.18	6.12	1.61	17.59
Fine S	0.15	5.53	1.63	17.31
Medium fine S	0.16	6.17	1.68	17.98
Medium coarse S	0.14	5.14	1.54	17.21
Coarse S	0.11	5.06	1.58	17.09
CD (5%)	0.03	NS	NS	0.32

in first season followed by medium fine sulphur. The gypsum application showed highest value of thearubigins in the second season followed by medium fine sulphur, whereas medium fine sulphur showed highest value of thearubigins content in third season.

4.2.3 Total colour

The total colour of tea infusion increased significantly with the application of different particle sizes of sulphur over the control. Maximum percentage of total colour was found with the application of medium fine sulphur (1.93 %) in first season, whereas highest total colour (1.83 %) was obtained with gypsum application during second season. The variation of total colour was found to be nonsignificant in the third season.

4.2.4 Brightness of made tea

Sulphur had a pronounced effect on the brightness of tea liquor in all the seasons of the crop as revealed from the study of Table 4.2. The per cent brightness was influenced by the seasonal variation at different particle sizes of sulphur application with peak values 18.96, and 17.98 per cent with medium fine sulphur application in first and third season, respectively, whereas gypsum, Agri. pyrite and medium fine sulphur were statistically at par in second season, but showed significant increase in per cent brightness over control.

4.3 Effect of different particle sizes of sulphur on nutrient concentration and uptake

4.3.1 Nitrogen concentration

The perusal of data presented in Table 4.3 indicates that medium fine sulphur application showed significantly higher nitrogen content (5.54%) in tea shoots followed by application of medium coarse sulphur (5.37%), agri. pyrite (5.30%), gypsum (5.27%) and fine sulphur (5.25 %), respectively, which remained statistically at par with each other in first season. However, lowest total N content was found in coarse sulphur, which was at par with control.

Table 4.3 Effect of different particle sizes of sulphur on N content (%) in tea shoots

Treatment	Season-I	Season-II	Season- III	Mean
Control	5.08	3.62	3.73	4.14
Gypsum	5.27	3.53	3.63	4.14
Agripyrite	5.30	3.67	3.58	4.18
Fine S	5.23	3.53	3.58	4.11
Medium fine S	5.54	3.97	3.89	4.47
Medium coarse S	5.37	3.48	3.56	4.14
Coarse S	5.12	3.41	3.44	3.99
CD (5%)	0.14	0.11	0.20	0.08

In case of second season, as per Table 4.3, it is revealed that medium fine sulphur registered significantly highest total N content in tea shoots (3.97%) followed by agri. pyrite, gypsum and fine sulphur, while coarse sulphur application encounting for lowest total N content (3.41%).

Similarly, in third season, again medium fine sulphur showed significantly highest total N content in tea shoots (3.89%) followed by other treatments, whereas coarse sulphur treatment encounted for lowest total N content (3.44%). The mean value of all the three seasons revealed that medium fine sulphur significantly recorded highest total N content (4.47%) followed by agri. pyrite, gypsum, medium coarse sulphur and fine sulphur which were statistically at par with each other, whereas coarse sulphur registered lowest total N content in tea shoots.

4.3.2 P concentration

Data appended in Table 4.4 showed that medium fine sulphur recorded highest P content as compared to the other treatments during all the three seasons as well as in mean value, however, results were nonsignificant.

Table 4.4 Effect of different particle sizes of sulphur on P content (%) in tea shoots

Treatment	Season-I	Season-II	Season- III	Mean
Control	0.31	0.38	0.39	0.37
Gypsum	0.34	0.40	0.34	0.35
Agripyrite	0.35	0.37	0.38	0.37
Fine S	0.37	0.38	0.37	0.37
Medium fine S	0.39	0.40	0.39	0.39
Medium coarse S	0.37	0.40	0.37	0.38
Coarse S	0.32	0.36	0.32	0.34
CD (5%)	NS	NS	NS	NS

4.3.3 K concentration

Potassium concentration was significantly effected by the application of sulphur in all the treatments (Table 4.5) during all the three seasons as well as mean value for whole year. All the treatments containing sulphur were statistically at par with each other, whereas control gave the lowest potassium concentration in tea leaves during all the three seasons.

Table 4.5 Effect of different particle sizes of sulphur on K content (%) in tea shoots

Treatment	Season-I	Season-II	Season- III	Mean
Control	0.27	0.24	0.21	0.24
Gypsum	0.30	0.27	0.25	0.27
Agripyrite	0.30	0.27	0.26	0.27
Fine S	0.29	0.25	0.25	0.26
Medium fine S	0.30	0.27	0.26	0.27
Medium coarse S	0.30	0.26	0.25	0.27
Coarse S	0.29	0.26	0.24	0.26
CD (5%)	0.02	0.02	0.01	0.01

4.3.4 S concentration

Perusal of data presented in Table 4.6 showed that in case of total sulphur content in tea shoots, highest magnitude was observed in medium course sulphur but lowest magnitude was registered in agri. pyrite and control plot in all the three seasons, however, results were nonsignificant. In mean value, all the treatments containing sulphur behaved statistically at par, whereas, control plot recorded lowest content of sulphur in tea shoots.

Table 4.6 Effect of different particle sizes of sulphur on S content (%) in tea shoots

Treatment	Season-I	Season-II	Season- III	Mean
Control	0.26	0.10	0.10	0.14
Gypsum	0.30	0.11	0.13	0.18
Agripyrite	0.26	0.12	0.14	0.17
Fine S	0.29	0.12	0.13	0.18
Medium fine S	0.30	0.12	0.13	0.18
Medium coarse S	0.31	0.11	0.12	0.18
Coarse S	0.28	0.11	0.12	0.17
CD (5%)	NS	NS	NS	NS

4.3.5 Nitrogen uptake

Different particle sizes of sulphur significantly effected the N uptake of crop during all the season of crop (Table 4.7). Perusal of data indicates that the maximum value of nitrogen uptake was obtained with application of medium fine sulphur viz., 61.95, 27.83 and 7.48 kg/ha in all the three seasons of crop, respectively. Exactly similar trend was also observed in case of mean value of the year. However, in case of third season, medium coarse sulphur, gypsum, agri. pyrite and fine sulphur were found to be statistically at par with medium fine sulphur.

Table 4.7 Effect of different particle sizes of sulphur on Nitrogen uptake (kg/ha)

Treatment	Season-I	Season-II	Season- III	Mean
Control	45.37	17.47	5.01	22.61
Gypsum	52.60	20.27	6.90	26.59
Agripyrite	54.72	21.32	6.86	27.63
Fine S	47.32	18.03	6.65	24.00
Medium fine S	61.95	27.83	7.48	32.42
Medium coarse S	54.77	24.06	6.77	28.53
Coarse S	49.48	18.85	5.74	24.69
CD (5%)	5.41	1.47	1.20	1.78

4.3.6 Phosphorus uptake

Phosphorus uptake was significantly effected by all the treatments in first and second season as well as for the mean value of year, whereas it was nonsignificant during second season of crop. It was found to be maximum with the application of medium fine sulphur i.e. 4.36 and 2.60 kg/ha in first and mean value of the year, respectively, whereas in second season, it was found maximum with the application of medium coarse sulphur (2.75 kg/ha), while with medium fine sulphur (2.67 kg/ha) was found to be statistically at par with medium coarse sulphur. However, the value of phosphorus uptake was nonsignificant in the third season (Table 4.8).

Table 4.8 Effect of different particle sizes of sulphur on Phosphorus uptake (kg/ha)

Treatment	Season-I	Season-II	Season- III	Mean
Control	2.79	1.98	0.53	1.77
Gypsum	3.29	2.26	0.64	2.06
Agripyrite	3.57	2.16	0.72	2.15
Fine S	3.35	1.95	0.69	1.99
Medium fine S	4.36	2.67	0.75	2.60
Medium coarse S	3.75	2.75	0.70	2.40
Coarse S	3.12	1.89	0.53	1.88
CD (5%)	0.51	0.28	NS	0.19

4.3.7 Potassium uptake

Potassium uptake was also effected significantly with the application of different particle sizes of sulphur as presented in Table 4.9. Higher uptake of potassium was significantly observed with the application of different particle sizes of sulphur over the control in all the three seasons as well as whole of the year. Highest potassium

Table 4.9 Effect of different particle sizes of sulphur on Potassium uptake (kg/ha)

Treatment	Season-I	Season-II	Season- III	Mean
Control	2.41	1.15	0.29	1.28
Gypsum	3.02	1.53	0.44	1.66
Agripyrite	3.05	1.54	0.47	1.69
Fine S	2.65	1.26	0.46	1.46
Medium fine S	3.31	1.87	0.50	1.89
Medium coarse S	3.10	1.82	0.46	1.79
Coarse S	2.87	1.42	0.40	1.57
CD (5%)	0.26	0.10	0.07	0.09

uptake was observed with the application of medium fine sulphur (3.31 kg/ha), while medium coarse sulphur and agri. pyrite were found to be statistically at par with medium fine sulphur in the first season. Again potassium uptake was maximum with the application of medium fine sulphur (1.87 kg/ha), but medium coarse sulphur was found to be at par with medium fine sulphur. Maximum value of potassium uptake was recorded with the treatment of medium fine sulphur in third season, whereas agri. pyrite, fine sulphur, medium coarse sulphur and gypsum were found to be statistically at par with each other and medium fine sulphur. Mean value of all the three seasons showed that medium fine sulphur gave the significant highest value of potassium uptake (1.89 kg/ha) followed by medium coarse sulphur, agri. pyrite, gypsum, coarse sulphur and fine sulphur, respectively.

4.3.8 Sulphur uptake

As observed in other nutrients, by and large sulphur uptake was also affected positively with the application of different particle sizes of sulphur in different season of the crop. Application of different particle sizes of sulphur (Table 4.10) increased sulphur uptake significantly in second and third season and also in whole year over control except first season. Significant highest sulphur uptake was recorded with the application of medium fine sulphur (0.82 kg/ha) during second season, whereas medium coarse sulphur, agri. pyrite and gypsum were found to be statistically at par with medium fine sulphur. Maximum value of sulphur uptake was noticed with the application of agri. pyrite in third season, whereas rest of the sulphur treatments were found to be statistically at par with each other. In case of mean value of all seasons, the significant highest value (1.48 kg/ha) was again observed with the application of medium fine sulphur, while medium coarse sulphur and gypsum were found to be statistically at par with medium fine sulphur.

Table 4.10 Effect of different particle sizes of sulphur on Sulphur uptake (kg/ha)

Treatment	Season-I	Season-II	Season- III	Mean
Control	2.32	0.38	0.11	0.94
Gypsum	2.97	0.64	0.25	1.29
Agripyrite	2.72	0.68	0.26	1.22
Fine S	2.59	0.59	0.23	1.14
Medium fine S	3.37	0.82	0.25	1.48
Medium coarse S	3.15	0.78	0.23	1.39
Coarse S	2.70	0.64	0.21	1.18
CD (5%)	NS	0.19	0.07	0.22

4.4 Per cent utilization of applied sulphur in tea

The data presented in Table 4.11 revealed that total per cent utilization of sulphur by medium fine sulphur (2.70%) was significantly highest but statistically at par with medium coarse sulphur. However, per cent utilization of sulphur was lowest in case of coarse and fine sulphur. Per cent utilization of applied sulphur through different particle sizes was found to be nonsignificant in first season whereas medium fine sulphur had significantly higher (0.73%) per cent sulphur utilization over the other sources in second season. However, the per cent sulphur utilization of all different treatments was significantly lowest in third season as compared to first and second season.

Table 4.11 Effect of different particle sizes of sulphur on per cent utilization of applied sulphur in tea crop

Treatment	Season-I	Season-II	Season- III	Total
Control	-	-	-	-
Gypsum	1.08	0.41	0.23	1.72
Agripyrite	0.64	0.49	0.24	1.37
Fine S	0.45	0.35	0.19	0.99
Medium fine S	1.74	0.73	0.23	2.70
Medium coarse S	1.39	0.66	0.20	2.25
Coarse S	0.62	0.33	0.15	1.10
CD (5%)	NS	0.25	0.13	0.38

4.5 Effect of different particle sizes of sulphur on physico-chemical properties of soil

Perusal of data presented in Table 4.12 revealed that application of different particle sizes of sulphur on top soil had reduced the pH of soil over the control, whereas lowest pH values were observed in gypsum and fine sulphur treatments. Which were statistically at par with Agri. pyrite, medium fine sulphur, medium coarse sulphur and coarse sulphur treatments.

Nonsignificant values were obtained in case of percent organic carbon in all treatments (Table 4.12). However, maximum values of organic carbon was observed with application of coarse sulphur with minimum value in control.

Table 4.12 Effect of different particle sizes of sulphur on physico-chemical properties of soil

Treatment	pH	OC (%)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Control	5.8	1.01	350.2	26.9	191.7
Gypsum	5.4	1.09	287.4	28.4	216.3
Agripyrite	5.5	1.18	339.7	23.8	227.6
Fine S	5.4	1.25	329.3	30.7	217.6
Medium fine S	5.5	1.16	329.0	34.4	203.0
Medium coarse S	5.6	1.26	339.7	32.9	206.3
Coarse S	5.6	1.28	334.4	31.4	212.6
CD (5%)	0.2	NS	NS	3.90	NS

There was no significant difference in values of available nitrogen in all the treatments. In case of available phosphorus, significant higher build up of phosphorus was recorded with the application of medium fine sulphur (34.4 kg/ha) while rest of treatments were statistically at par with control except medium coarse and coarse sulphur.

In case of potassium, the values were nonsignificant for all the treatments, however, maximum value was obtained with agri. pyrite (227.6 kg/ha) and minimum value with control.

4.6 Residual status of sulphur

Application of all treatments exerted significant effect on available sulphur (Table 4.13). The value was maximum in case of agri. pyrite (30.83 ppm) followed by gypsum, medium coarse sulphur, medium fine sulphur which was statistically at par with each other as well as with agri. pyrite, while fine sulphur showed the lowest value (21.97 ppm) followed by control. Different particle sizes of sulphur also exerted significant effect on sulphate sulphur of soil, whereas, agri. pyrite and coarse sulphur showed highest values but statistically at par followed by medium fine sulphur, medium coarse sulphur, fine sulphur and gypsum, respectively.

Study of Table 4.13 revealed that there was no significant difference amongst various treatments for organic sulphur. However, Agr. pyrite showed highest value (22.67 ppm) of sulphate sulphur followed by medium coarse sulphur, fine sulphur, medium fine sulphur, coarse sulphur, gypsum and control treatments.

Similar results were obtained for total sulphur which showed no significant difference among various treatments. However, the data revealed that agr. pyrite and gypsum were highest and at par followed by medium fine sulphur, fine sulphur. medium coarse sulphur, coarse sulphur and control, respectively.

Table 4.13 Effect of different particle sizes of sulphur on different form of sulphur in soil (ppm)

Treatment	Available-S	SO_4^{-2}-sulphur	Organic-S	Total-S
Control	18.33	10.67	168.00	242.67
Gypsum	28.75	12.33	181.33	321.33
Agripyrite	30.83	15.00	227.67	321.33
Fine S	21.97	12.67	217.33	254.00
Medium fine S	27.08	13.33	213.67	261.33
Medium coarse S	28.33	13.00	221.33	250.00
Coarse S	26.25	14.00	201.33	247.33
CD (5%)	3.98	2.21	NS	NS

4.7 Correlation studies

4.7.1 Nutrient content in tea leaves of first season correlated with yield and quality parameters of first, second and third crop

An examination of Table 4.14 revealed significant positive correlation between N content and yield (r = 0.55*, 0.80* and 0.62*), total colour content (r = 0.62*, 0.69* and 0.59*) and per cent brightness (r = 0.84*, 0.59* and 0.70*) during all the three seasons, while it was positively correlated with thearubigins of the first and second season (r = 0.47*) and theaflavins of the second season (r = 0.61*). Phosphorus content of first season leaves exerted a significant positive relationship with yield of second and third season (r = 0.49* and 0.57*), theaflavins content in second and third season (r = 0.45* and 0.52*), thearubigins of second and third season (r = 0.44* and 0.45*), total colour of the first, and third season (r = 0.61* and 0.45*) and per cent brightness of first and third season crop (r = 0.48* and 0.48*).

Similarly positive significant correlation between K content of first season leaves with the yield of second and third season was observed (r = 0.46* and 0.59*). Also an association of K content of first season leaves with the theaflavins of the first, second and third season was noticed (r = 0.69*, 0.47* and 0.68*), thearubigins content of first and second season (r = 0.45* and

Table 4.14 Correlation between nutrient content of first season tea leaves with yield and quality parameter of first, second and third season crop

Nutrient	Season-I					Season-II					Season-III				
content	Yield	TF	TR	TC	%B	Yield	TF	TR	TC	%B	Yield	TF	TR	TC	%B
Nitrogen	0.55*	0.29	0.47*	0.62*	0.84*	0.80*	0.61*	0.60*	0.69*	0.59*	0.62*	0.41	0.38	0.59*	0.70*
Phosphorus	0.12	0.25	0.32	0.61*	0.48*	0.49*	0.45*	0.44*	0.42	0.43	0.57*	0.52*	0.45*	0.45*	0.48*
Potassium	0.19	0.69*	0.45*	0.64*	0.46*	0.46*	0.47*	0.57*	0.55*	0.25	0.59*	0.68*	0.29	0.69*	0.48*
Sulphur	0.38	0.13	0.04	0.17	0.44*	0.48*	0.21	0.37	0.45*	0.20	0.31	0.06	0.09	0.25	0.23

* Significant at 5 % level

0.57*), total colour content of three seasons (r = 0.64*, 0.55* and 0.69*) and per cent brightness of first and third season crop (r = 0.46* and 0.48*).

Correlation of significant magnitude and positive nature was recorded between S content of the first season tea leaves and yield of second season crop (r = 0.48*), total colour of the second season crop (r = 0.45*) and per cent brightness in first season (r = 0.44*) and per cent brightness in first season (r = 0.44*).

4.7.2 Nutrient content in tea leaves of the second season correlated with yield and quality parameters of second and third season crop

A study of Table 4.15 revealed significant positive correlation between N content of tea leaves of second season, with the theaflavins content of the second season (r = 0.53*), thearubigins content of third season (r = 0.64*), total colour of the second season (r = 0.45*) and per cent brightness in second and third seasons (r = 0.47* and 0.66*).

Similarly, K content of the second season leaves was found significantly positively correlated with the yield of second season crop (r = 0.50*), theaflavins content (r = 0.61* and 0.65*), thearubigins content (r=0.64* and 0.60*) and per cent brightness (r = 0.59* and

Table 4.15 Correlation between nutrient content of second season tea leaves with yield and quality parameter of second and third season crop

Nutrient content	Season-II					Season-III				
	Yield	TF	TR	TC	%B	Yield	TF	TR	TC	%B
Nitrogen	0.41	0.53*	0.26	0.45*	0.47*	0.19	0.30	0.64*	0.35	0.66*
Phosphorus	-0.03	-0.19	-0.24	-0.01	0.01	-0.19	-0.19	-0.16	-0.18	-0.21
Potassium	0.50*	0.61*	0.57*	0.64*	0.59	0.41	0.65*	0.52*	0.60*	0.66*
Sulphur	0.42	0.48*	0.55*	0.41	0.28	0.65*	0.21	0.34	0.44*	0.39

* Significant at 5 % level

0.66*) of the second and third season. However, sulphur content in second season tea leaves had shown positive correlation with the theaflavins content (r = 0.48*) and thearubigins content (r = 0.55*) and with yield and total colour of the third season (r = 0.65* and 0.44*).

4.7.3 Nutrient content in tea leaves of the third season correlated with yield and quality parameters of the third season crop

A study of Table 4.16 showed that potassium content of tea leaves had significant positive relationship with yield (r = 0.75*),

Table 4.16 Correlation between nutrient content of third season tea leaves with yield and quality parameter of third season crop

Season- III

Nutrient content Brightness	Yield (KMTH)	Theaflavins (%)	Therubigins (%)	Total	Per cent colour (%)
Nitrogen	-0.003	-0.07	0.33	0.15	0.32
Phosphorus	0.03	0.14	0.33	0.09	0.27
Potassium	0.75*	0.64*	0.62*	0.58*	0.56*
Sulphur	0.61*	0.47*	0.49*	0.60*	0.61*

* Significant at 5% level

theaflavins content (r = 0.64*), thearubigins content (r = 0.62*), total colour (r = 0.58*) and per cent brightness (r = 0.56*) of made tea in third season. Sulphur content of tea shoots was found significantly positively related with yield (r = 0.61*) and all the quality parameters i.e. theaflavins (r = 0.47*), thearubigins (r = 0.49*), total colour (r = 0.60*) and per cent brightness (r = 0.61*) of third season crop.

DISCUSSION

Chapter-V

DISCUSSION

The result of the present investigation entitled "Utilization of S° of different particle sizes by tea crop and its carry over status" conducted at the Tea Experimental Farm of the Department of Tea Husbandry and Technology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during the year 2000 have been described in details in preceding chapter. Cause and effect relationship pertaining to the important findings/results have been discussed in present chapter under the following heads:

5.1 Effect of different particle sizes of S on the yield of made tea

5.2 Effect of different particle sizes of S on the quality of made tea

5.3 Effect of different particle sizes of S on nutrient concentration

5.4 Effect of different particle sizes of S on nutrient uptake

5.5 Effect of different particle sizes of S on per cent utilization of applied sulphur

5.6 Effect of different particle sizes of S on the physico-chemical properties of soil

5.7 Residual status of S in soil

5.8 Correlation studies

5.1 Effect of different particle sizes of S on the yield of made tea

The yield of made tea was significantly influenced by the application of different particle sizes of sulphur. Significant increase in the tea yield with the application of elemental sulphur @ 20-40 kg/ha was also recorded by Sinha *et al.* (1992). Bhat and Ranganathan (1980) also observed that tea bushes required 1 kg of sulphur for each 100 kg of made tea. According to them a normal yield level of 200 kg of made tea bushes 20 kg S/ha and to compensate for leaching and other limitation of sulphur availability an application of 2 to 4 times of quantity observed should be advocated.

Amongst of all the treatments, the highest yield of made tea was recorded with medium fine sulphur in all the three seasons and on total yield basis. This might be due to more rapid oxidation of the smaller particles of applied sulphur and thus more and easy availability of sulphate sulphur to plants (Jones and Ruckman, 1969). The total yield, shown by gypsum which is statistically at par with medium fine sulphur might be due to presence of optimum particle sizes of sulphur in gypsum, which might have oxidised rapidly, thus making sulphate sulphur available to plants.

In case of smaller particle sizes (<0.25 mm), the sulphur utilization is least because of rapid oxidation which results in the accumulation of high sulphur concentration in the soil, which were prone to leaching and runoff losses due to heavy rain particularly on land with slope topography. Rest of treatments containing greater particle sizes of sulphur showed lower yield might be due to delayed availability of sulphate sulphur to plant due to slower oxidation.

5.2 Effect of different particle sizes of S on the quality of made tea

The results pertaining to quality parameters of made tea such as theaflavins (%TF), thearubigins (%TR), total colour (%TC) and per cent brightness (%B) had increased with the application of different particle sizes of sulphur, at different plucking stages of tea crop. The values of theaflavins, total colour and per cent brightness were significantly influenced, whereas thearubigins were nonsignificant in all the three seasons over control. Gypsum, agri. pyrite, medium fine sulphur and medium coarse sulphur showed higher value of theaflavins content in all the three seasons. Medium fine sulphur showed the highest value of total colour followed by agri.pyrite, fine sulphur and medium coarse sulphur, although statistically at par with each other during first season, whereas gypsum and medium fine sulphur gave higher total colour, although statistically at par with each other during second season. None of particle sizes of sulphur had any significant effect on total colour in the third season.

Medium fine sulphur showed highest per cent brightness during first and third season, whereas during second season, although exerted higher value of per cent brightness yet was statistically at par with agri. pyrite and gypsum. Since theaflavins, total colour and per cent brightness significantly increased with sulphur application, hence quality is improved as reported by Robert (1962).

Barbora (1995) explained that sulphur application increased the theaflavins group of compounds, especially theaflavins and theaflavin-3 gallate. Flavanol glycosides such as rutin and quercertin glycoside also were increased marginally, which might have resulted in brighter colour and possibly increased flavour during processing leading to better over all quality. It was also reported that various amino acid content increased by the addition of sulphur and the chromatographic analysis of aromatic components of made tea indicate that sulphur treatments enhanced linalool and B-lonone (Flavour components and fragrance quality of made tea, Wu and Jianyun, 1994). These values were further facilitated by application of optimum size of sulphur particles due to easy availability to tea plants.

5.3 Effect of different particle sizes of S on nutrient concentration in tea shoots

The data presented in Table 4.3 reveals that medium fine sulphur application showed significantly higher nitrogen content in tea shoots in all the three seasons. Singh *et al.* (1990) reported significant increase in nitrogen content in groundnut with the sulphur application. However, amongst different particle sizes of sulphur medium fine sulphur showed significantly highest value, might be due to desired particle size of sulphur which underwent easy oxidation under prevalent agro-climatic conditions, thus making easy availability of sulphate sulphur to tea plants.

Although the effect of application of different particle sizes of sulphur on phosphorus concentration in tea shoots was nonsignificant in all the three seasons, yet medium fine sulphur exerted a higher value of phosphorus content as compared to other treatments.

Potassium concentration was significantly effected by the application of all the treatments (Table 4.5) in all the three seasons as well as mean value for whole year. Although these treatments were statistically at par with each other, whereas, control gave the lowest potassium content in tea leaves. Application of sulphur was found to increase the potassium concentration in rice, mustard and groundnut as reported by Singh (1971), Rathee and Chahal (1977). Singh and Singh (1990) also reported that the application of sulphur in the form of elemental sulphur to linseed crop had increased the potassium content. In case of sulphur content in tea leaves although values were nonsignificant in all the treatments, yet mean value of all the three seasons behaved statistically at par with control plot, which had the lowest content of sulphur in tea leaves.

5.4 Effect of different particle sizes of S on the nutrient uptake

Significantly higher uptake of N, P, K and S was noticed during all seasons of crop following different particle sizes of sulphur application. The significant higher uptake of nitrogen was noticed in all the three seasons with the application of different particle sizes of sulphur. The significant increase in nitrogen uptake was reported by Singh *et al.* (1990) in groundnut and Ghosh *et al.* (1990) in sugarcane with the sulphur application. However, amongst different particle sizes of sulphur, medium fine sulphur showed significantly highest value, might be due to desired particle size of sulphur, which underwent easy oxidation under prevalent agroclimatic conditions, thus making easy availability of sulphate sulphur to tea plants.

There was significant higher phosphorus uptake during first and second seasons of crop but nonsignificant effect was noticed during third season by the application of different particle sizes of sulphur. The mean value of phosphorus uptake was significantly higher over control with the application of medium fine sulphur. The increased phosphorus uptake with sulphur application might be due to its reaction, with soluble aluminium and increased the extractability of aluminium phosphorus, which was further facilitated by optimum size of medium fine sulphur.

Potassium uptake increased significantly over control with the application of medium fine sulphur in all the three seasons. The increased potassium availability was attributed to the destruction of illitic clay minerals due to optimum sizes of sulphur treatment resulting in release and uptake of K (Lietzke and Peterson, 1987). The significant increase in the N, P, K and S uptake in linseed (Jaggi *et al.,* 1995) was also reported with sulphur application.

There was significant higher sulphur uptake during second and third season but nonsignificant effect was observed during first season by the different treatments. The mean value of sulphur uptake was significantly higher over control, with the application of medium fine sulphur followed by medium coarse sulphur and gypsum. The significant increase in sulphur uptake was possibly due to increased growth and hence yield of tea crop, which was further facilitated by optimum size of particle of medium fine sulphur application. The increase in sulphur uptake was also reported by Ghulam Nabi *et al.* (1990).

5.5 Effect of different particle sizes of S on per cent utilization of applied sulphur

Study of Table 4.11 revealed that amongst various treatments of sulphur sources as well as sulphur particle sizes, maximum utilization (2.70%) of applied sulphur was observed in the elemental sulphur with particle sizes of 0.25 - 0.49 mm followed by particle size of 0.5 - 1.00mm and gypsum, while rest of treatments showed intermediate trend. However, the elemental particle size of sulphur (<0.25 mm) showed least utilization. This shows that optimum particle sizes of the elemental sulphur or the sulphur sources is mendatory for better utilization and better uptake of sulphur by the tea crop.

The maximum per cent utilization shown by the sulphur particle with size 0.25 - 0.49mm might be due to exposure of larger surface area of sulphur for quick oxidation to sulphate sulphur and hence availability to tea plants. While further increase in particle size of sulphur again reduced the sulphur utilization in all the three seasons, which may attributed to the fact that larger sized particles has small surface area available to the sulphur oxidation by the environmental agencies and microbes, which ultimately reduce the sulphur availability as well as its utilization by tea crop. In case of smaller sulphur particle size (< 0.25mm) the sulphur utilization is least. This is due to fact that lower particle sizes expose tremendously, large surface area of sulphur to environmental agencies for quicker oxidation, which results in the accumulation of high sulphur concentration in the soil and are prone to leaching and runoff losses due to heavy rains, particularly on sloppy land supporting tea plantations in the hills.

5.6 Effect of different particle sizes of S on the physico-chemical properties of soil

The study of physico-chemical properties of the soil provided a thorough understanding of the nature and properties of tea soils after application of various treatments.

Texture: The particle sizes distribution and the textural class was generally considered as an indicator of distinct soil conditions. The pattern of particle size distribution revealed that sand is the predominant fraction followed by clay and silt. However, the effect of different particle sizes of sulphur on the texture of the soil was found to be nonsignificant.

The influence of applied sulphur particle sizes and sources on the soil pH revealed a significant decrease in the mean pH of the soil over control (Table 4.12). Lindemann *et al.* (1991) also observed a significant decrease in the pH of Belon soil irrespective of the sources of S applied. Comparatively low decrease in pH due to sulphur application through pyrites and elemental sulphur might also explain slow rate of oxidation of these materials in the soil (Neilsen *et al.,* 1993).

Organic carbon and available nitrogen of the soil was found to be nonsignificant, irrespective of particle sizes and sources. The significant increase in available P in soil due to application of different particle sizes of S° and sources except agri. pyrite was observed over the control. Available P status was increased with sulphur application might be due to its reaction with soluble aluminium that was made available due to sulphur application and easy extractability of Al-P unlike in case of Fe-P. Similar observation was observed by Rao (1995). The low available P in case of agri. pyrite might be due to slow supply of readily available form of sulphate sulphur, which do not help in easy extractability of Al-P.

Available K content of the soil increased with the application of different particle sizes of sulphur, but found to be nonsignificant. This might due to the destruction of illitic clay minerals with the application of high sulphur treatment, which lead to release K (Lietzke and Peterson, 1987).

5.7 Residual status of S in soil

Effect of various particle sizes of sulphur was studied on the different forms of sulphur in the soil after crop harvest and presented in the Table 4.13, which revealed that amongst various forms, available sulphur and sulphate sulphur exhibited significant effect on various treatments, whereas organic-S and total-S were nonsignificant. The agri. pyrite showed highest value of available sulphur followed by gypsum, medium coarse sulphur, medium fine sulphur and coarse sulphur which were statistically at par with each other. In case of sulphate sulphur again agri.pyrite exhibited highest value (15 ppm) followed by coarse sulphur, medium fine sulphur and medium coarse sulphur which were statistically at par with each other. Fine sulphur and gypsum showed least values. Although organic-S and total sulphur content of soil were nonsignificant, yet agri.pyrite showed the highest value of organic-S and total sulphur content in soil, which might be due to prolonged residual effect and slower oxidation of sulphur which did not simulate closest with crop need like other particle sizes of sulphur.

5.8 Correlation studies

Nitrogen content of first season crop were found significantly positively correlated with yield of first, second and third season crop, respectively (r = 0.55*, 0.80* and 0.62*) as indicated in Table 4.14. This could be possibly due to the more availability of N in the plant during first season, which responded upto the second season but with the passage of time availability decreased. Antiya (1984) noticed significant positive correlation between N content of the flushes and yield of tea crop. A significant positive correlation between N content of first season tea leaves with total colour and per cent brightness of all the seasons, theaflavins of the second season and thearubigins of the first and second season crop was found to exist (r = 0.62*, 0.69*, 0.59*, 0.84*, 0.59*, 0.70*, 0.61*, 0.47* and 0.60*).

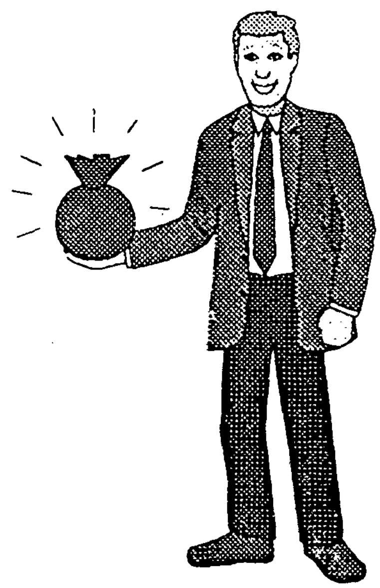
Phosphorus content of tea leaves of first season were found positively associated with total colour and per cent brightness of first and third season crop (r = 0.61*, 0.48*, 0.45* and 0.48*). Further, the P content of second and third season were found significantly and positively correlated with the yield, theaflavins and thearubigins of the same season crop (r = 0.49*, 0.45*, 0.44*, 0.57*, 0.52* and 0.45*), which indicates that the P response is observed during the second and third season of the crop after the application. Correlation of significant magnitude and positive nature were observed between K content of first season tea leaves and yield of second and third season, theaflavins content and total colour of all the seasons, thearubigins content of the first and second and per cent brightness first and third season (r = 0.69*, 0.47*, 0.68*, 0.64*, 0.55*, 0.69*, 0.45*, 0.57*, 0.46*, 0.48*). In case of P, similar response with K were observed in the present investigation.

Significant and positive association was observed between S content and brightness of the first season, i.e. 0.44*. Correlation of significant magnitude and positive nature were observed between S content of first season tea leaves and tea yield and total colour of second season (r = 0.46* and 0.45*).

Nitrogen content of second season tea leaves exhibited significant positive correlation with theaflavins, total colour and per cent brightness of the same season (r= 0.53*, 0.45* and 0.47*), whereas the significant correlation between nitrogen content of second season and quality parameters of third season was restricted only to thearubigins and per cent brightness i.e. 0.64* and 0.66*.

Correlation between K content of second season and other quality parameters such as theaflavins, thearubigins, total colour and per cent brightness including yield of the same season and excluding yield of the third season was found significant (r = 0.61*, 0.57*, 0.64*, 0.59* and 0.50* season-II; 0.65*, 0.52*, 060* and 0.66* season-III).

Significant correlation was also observed between K content of third season and all other quality parameters during this season (r = 0.64*, 0.62*, 0.58*, 0.56* and 0.75* season-III). These results show that this kind of correlation pattern might be due to the fact that K responses are observed after a long period of application (as basal dose). Significant positive correlation were observed between sulphur content of second season and theaflavins and thearubigins of same season (r = 0.48* and 0.55*) and total colour, yield of the third season (r = 0.44*, 0.65*). The sulphur content of the third season leaves was found positively correlated with yield and quality parameters such as theaflavins, thearubigins, total colour and brightness of the same season i.e. r = 0.61*, 0.47*, 0.49*, 0.60* and 0.61*.



SUMMARY

Chapter-V

SUMMARY

The present investigation entitled "Utilization of S° of different particle sizes by tea crop and its carry over status" was under taken with the following objectives:

1. To compare the performance of S° of different particle sizes on yield and quality of tea using gypsum and agricultural pyrite as standards.
2. To study the utilization of applied S° of different particle sizes through the yield and quality of current crop.
3. To study the residual status of S in different forms (Total -S, Organic-S, Sulphate-S) due to application of S° at different particle sizes.
4. To identify that particle size of S° whose oxidation into sulphate-S (Plant available form of S°) simulates closest with the crop need, spares maximum of the rest of S° for the next crop, and thus loses the least in leaching, run off and fixation losses.

In order to achieve these objectives, a field experiment was laid out during 2000 on mature tea plantation in the Department of Tea Husbandry and Technology, CSK HPKV, Palampur. The experiment was laid out in Randomized Block Design (RBD) comprising of seven treatments of different particle sizes of sulphur applied through gypsum, agri. pyrite (available form) and elemental sulphur of sizes (<0.25mm, < 0.50mm, < 1.00mm and <2.00mm), replicated thrice. Each plot (45 sq.m) consists of 20 bushes established at 1.5 x 1.5m spacing. Basal dose of nitrogen, phosphorus and potassium were also applied @ 90, 90 and 45 kg/ha, respectively. Nitrogen and sulphur were applied through (12:32:16) NPK mixture + urea and through elemental sulphur of different particle sizes along with available gypsum and agri. pyrite @ 60 kg/ha. The fertilizers were applied during the month of February by the top dressing around the bushes uniformly.

In order to determine the initial status of soil, composite soil sample (0-15cm) were collected before applying fertilizers, collected soil sample were crushed, dried and finally passed through 2 mm sieve and then analysed as per standard procedure for determining pH, organic carbon, available N, P, K, S, texture and different forms of S (total, organic and sulphate) of the soil.

Tea shoots of two leaves and bud were plucked in summer, monsoon and back end seasons. A portion of plucked shoots were steamed, dried, crushed and finally packed in polythene bags for determination of NPK and S content during different seasons. The rest of the portion was manufactured as black tea samples (orthodox) as per standard procedure for the assessment of quality parameters such as theaflavins, thearubigins, total colour and per cent brightness. At the end of the season, again soil samples at the depth of 0-15 cm were collected, dried, crushed, passed through 2 mm sieve and analysed for available N, P, K, S, texture, pH, organic carbon and different forms of S (total, organic and sulphate-S) of soil.

Yield data was recorded by regular plucking at 7-10 days intervals during the different growing seasons as green leaf yield. The green leaf yield was expressed in kilograms of made tea per hectare (KMTH) taking an average or 25 per cent recovery of green leaf during the entire growing seasons. Nutrient uptake was calculated from nutrient content and yield data in order to study the effect of different particle sizes of sulphur, nutrient content of tea leaves were correlated with yield and quality parameters (theaflavins, thearubigins, total colour and per cent brightness) of tea. Per cent utilization of different particle sizes of sulphur applied along with status of soil after crop harvest were also worked out. The salient findings emanating from the study have been summarised as under:

Made tea yield was significantly increased by all the treatments in all the three seasons. The maximum yield was observed with application of medium fine S (0.25mm - 0.49mm) in all the three seasons as well as on the pooled basis.

Theaflavins content of made tea was highest with the application of agri. pyrite in first and third season whereas medium fine sulphur showed highest theaflavins in second season. Maximum percentage of total colour was found with the application of medium fine sulphur in first season while during second season, it was maximum with the application of gypsum. Per cent brightness was found maximum with the application of medium fine S in all the three seasons, however, there was no significant effect on thearubigins content. Nutrient uptake of N, P, K and S was significantly influenced by all the treatments. The maximum nutrient (N, P, K and S) uptake was notices with the application of medium fine sulphur during all the season as well as on pooled basis.

Maximum utilization of applied sulphur was observed in the elemental sulphur particle sizes of 0.25 - 0.49 mm (medium fine sulphur) followed by particle sizes of 0.5 - 1.00 mm (medium coarse) and gypsum sulphur sources, while rest of treatments, showed intermediate trend. However, the elemental particle size of (<0.25 mm) showed least utilization.

pH of the soil was influenced by the application of different particle sizes of sulphur. Available phosphorus of soil was significantly effected by all the treatment but highest value was obtained with the application of medium fine sulphur. While residual status of organic carbon available nitrogen, available potassium was found to be nonsignificant.

Available sulphur and sulphate sulphur of soil was found maximum with the application of agri.pyrite. Whereas, residual status of organic-S and total-S was found to be nonsignificant with the application of all the treatments, however, agri. pyrite showed the highest values for both organic and total sulphur content in soil.

Nitrogen content of first season crop was significantly correlated with yield, total colour, brightness in all the three seasons while it was positively correlated with therubigins of first and second season and theaflavins of second season.

Phosphorus content was positively correlated with yield, theaflavins, thearubigins in second and third seasons and total colour, per cent brightness in first and third season. Potassium content of first season crop was significantly correlated with yield in second and third season and it was positively correlated with theaflavins, total colour during all the three seasons, thearubigins of first and second season and per cent brightness of first and third season. Sulphur content of first season crop was significantly correlated with second season, per cent brightness of first season and total colour of second season.

Nitrogen content of second season crop showed significant correlation with per cent brightness in second and third season, theaflavins and total colour of second season and thearubigins of third season. Potassium content of second season crop showed positive correlation with yield of second season crop and quality parameters of second and third season. Sulphur content of second season crop was positively correlated with yield of third season, theaflavins and thearubigins of second season and total colour of third season.

Potassium and sulphur content of third season tea leaves showed positive association with yield and quality parameters of third season.

CONCLUSION

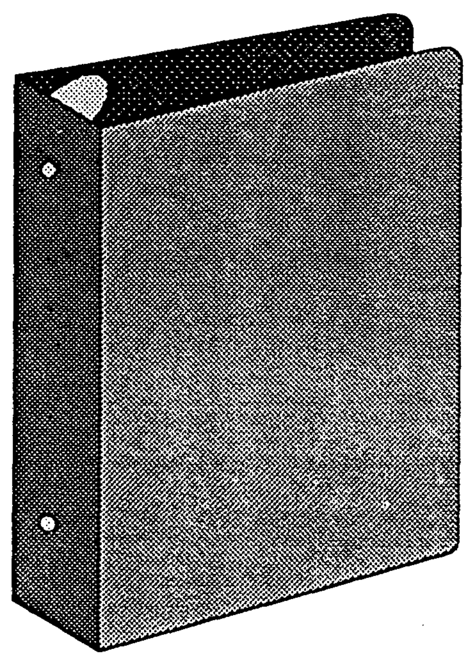
On the basis of one year field study, it was observed that under mid hill sub-humid conditions of (Zone-II) of Himachal Pradesh, made tea yield was significantly improved in all the three seasons by the different particle sizes of sulphur.

It was inferred from the study that significant yield of made tea was recorded with the application of medium fine sulphur (0.25 -0.49 mm) in all the three seasons as well as on the mean value basis.

In case of quality studies, application of medium fine sulphur showed significantly improvement in tea liquor.

The nutrient uptake (N, P, K and S) was also significantly higher in medium fine sulphur, which resulted in maximum utilization of applied sulphur over the whole period of experimentation.

In the end of experimentation period, it was observed that in soil available S was found significantly higher in fine sulphur particle sizes, whereas sulphate -S, organic -S and Total-S were found highest by the application of agri. pyrite in all the three seasons.



LITERATURE CITED

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Ali, T.S., Deka, A. and Barbora, A.C. 1997. Influence of nitrogen, sulphur and boron on certain quality parameters of black tea. Journal of Interacademicia 1 (3) : 233-239.

Annonymous. 2000. Fertilizer statistics. The Fertilizer Association of India, New Delhi, III : 52.

Antiya, S.E. 1984. Critical levels of nitrogen contents in tea leaves. Subtropicheskie Kul'tury 4 : 39-43.

Barbora, A.C. 1995. Sulphur management for tea in North Eastern India. Sulhur in Agriculture 19 : 9-15.

Bhat, S.S. and Ranganathan, V. 1980. Sulphur requirement of tea fields in South India. The Planters Chronicle pp. 529-531.

Bhavanadan, V.P. and Sunderalingam, S. 1971. The effect of nitrogen fertilizers on soil acidity. Soil urease activity and leaf nutrient content on yield of tea. Tea quarterly 42 : 40-47.

Black, C.A., Evans, L.E., Ensminger, J., White, L. and Clarke, J.F. 1965. Methods of Soil Analysis Part-II. Chemical and microbiological properties (Ist ed.). American Society of Agronomy, Madison (Wisconsin) U.S.A.

Boswell, C.C. 1997. Dryland lucerne responses to elemental sulphur of different particle sizes applied at different rates and frequencies in North Otago, New Zealand. New Zealand Journal of Agricultural Research 40 : 283-295.

Boswell, C.C. and Friesen, D.K. 1993. Elemental sulphur fertilizers and their use on crops and pastures. Fertilizer Research 35 : 127-149.

Bradsely, C.E. and Lancaster, J.D. 1960. Determination of reserve sulphur and soluble sulphate in soils. Journal of the American Society of Soil Science 24 : 265-268.

Butter, B. and Chenery, E.M. 1958. A rapid method for the determination total sulphur in soil and plants. The Analyst 84 : 239-245.

Chakravartee, J. 1996. Effect of sulphur on yield and quality of tea in North Eastern India. Two and a Bud 43 : 18-22.

Chesnin, L. and Yein, C.H. 1951. Turbidimeteric determination of available sulphur. Proceedings of the American Society of Soil Science 15 : 149.

Cottenie, A. 1979. Analytical methods for plants and soils. State University Ohent, Belgium.

Ghosh, A.K., Rai, R.K., Saxena, Y.R. and Shrivastava, A.K. 1990. Effect of sulphur application on the nutritional status, yield and quality of sugarcane. Journal of the Indian Society of Soil Science 38 : 73-76.

Ghulam Nabi, Rahmatullah and Salim, M. 1990. Utilization of sulphur by groundnut on two udic Haplustalfs. Journal of Indian Society of Soil Science 38 : 70-72.

Gohain, K.K. and Dutta, A. 1994. Effect of application of urea-N, rock phosphate and muriate of potash on sulphur nutrition of tea. Two and a Bud 41 : 25-27.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research (II Ed.), John Wiley and Sons, New York.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India, New Delhi.

Jaggi, R.C. 1992. Effect of P and S on black gram yield and nutrient uptake in acid hill soil. Indian Journal of Agronomy 37 : 261-264.

Jaggi, R.C., Kanwal, R.S. and Dixit, S.P. 1995. Effect of fertilizer N and S interaction on composition and uptake of nutrients by linseed on acid aflisol. Journal of the Indian Society of Soil Science 43 : 611-615.

Jagtap, P.B. and Mohite, A.V. 1994. Release of sulphur and iron from pyrites in saline sodic calcareous soils and soil reaction. Journal of Maharashtra Agriculture University 19 : 11-15.

Jones, M.B. and Ruckman, J.E. 1966. Gypsum and elemental sulphur as fertilizers on annual grassland. Journal of Agronomy 58 : 409-412.

Jones, M.B. and Ruckman, J.E. 1969. Effect of particle size on long term availability of sulphur on annual type grasslands. Journal of Agronomy 61 : 936-939.

Kanwar, J.S. and Singh, H.G. 1965. Effect of sulphur in tea yield. Journal of Research, Punjab Agricultural University, Ludhiana, pp. 246-252.

Kanwar, J.S. and Takkar, P.N. 1966. Responses to sulphur in tea soils of Punjab. Journal of Research Punjab Agricultural University, Ludhiana 3 : 246-252.

Kaplan, M. and Orman, S. 1998. Effect of elemental sulphur and sulphur containing waste in calcareous soil in Turkey. Journal of Plant Nutrition 21 : 1655-1665.

Kuligod, V.B., Satyanarayana, T. and Shirol, A.M. 1994. Influence of elemental and zinc sulphate on yield and nutrient uptake by wheat in typic chromusterts. Farming Systems 10 : 47-49.

Li, P. and Caldwell, A.C. 1966. The oxidation of elemental sulphur in soil. Journal of the American Society of Soil Science 30 : 370-372.

Lindemann, W.C., Aburto, J.H., Haffiner, W.M. and Bono, A.A. 1991. Effect of sulphur source on sulphur oxidation. Journal of the American Society of Soil Science 55 : 85-90.

Lietzke, D.A. and Peterson, D.V. 1987. Effect of soil acidification on chemical and mineralogical properties of a limed soil. Journal of the American Society of Soil Science 51 : 620-625.

Natesan, S. 1989. *Physico-chemical studies on soils of tea growing* areas in South India. The Planters Chronicle 84 : 41-49.

Neilsen, D., Hoque, E.J., Hoyt, P.B. and Drought, B. 1993. Oxidation of elemental sulphur and acidulation of calcareous orchard soils in Southern British Colombia. Canadian Journal of Soil Science 73 : 103-104.

Olsen, S.R., Cole, C.W., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with $NaHCO_3$. U.S.D.A. Circ. pp. 939.

Otheino, C.O. 1980. Nutrient requirement of tea. Tea 1 : 11-20.

Rao, T.N. 1995. Studies on the effect of different sources of sulphur on the growth and development, nutrient uptake and quality parameters in young tea (*Camellia sinensis* (L.) O. Kuntze) cv. Kangra Asha in an acid soils of Himachal Pradesh. Ph.D. Thesis submitted to Himachal Pradesh Krishi Vishvavidyalaya, Palampur.

Rathee, O.P. and Chahal, R.S. 1977. Effect of phosphorus and sulphur *application on the yield and chemical composition* of groundnut in Ambala soils. Journal of Research, Haryana Agricultural University, Hissar 7 : 173-177.

Robert, E.A.H. 1962. Economic importance of flavonoid substances. Tea formation in the chemistry of flavonoid compounds. (T.A. Geissman, ed.), Pergman Press, pp. 468-512.

Sakal, R., Singh, A.P., Sinha, R.B. and Ismail, M. 2000. Relative performance of some sulphur sources on sulphur nutrition of crop in calcareous soils. Annals of Agriculture Research 21 : 206-211.

Singh, A.L., Joshi, Y.C. and Chaudhary, V. 1990. Effect of different sources of iron and sulphur on nutrient concentration and uptake by groundnut. Fertilizer Research 24 : 97-103.

Singh, H.G. 1971. Effect of sulphur on tissue composition and prevention of chronosis in rice seedlings. Indian Journal of Agronomy 16 : 143-148.

Singh, R.P. and Singh, V. 1990. Effect of sulphur, magnesium and potassium on yield and uptake by linseed. Journal of the Indian Society of Soil Science 38 : 169-170.

Singh, S., Sinha, S.K., Singh, R.N., Saha, P.B., Gupta, B.P. and Singh, S. 2000. Yield, sulphur uptake and oil content of niger as influenced by applied sulphur on acidic soils of Bihar Plateau. Journal of the Indian Society of Soil Science 48 : 121-124.

Sinha, M.P., Thakur, K.C., Sharma, S.N., Sakia, D.N. and Phaken. 1992. Effect of sulphur on yield of mature tea. In: 31st Tocklai Conference "Challenges of Nineties", January 20-21, 9.

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

Takea, T. 1979. Effect of ammonium fertilizer on the amino acid concentration of tea shoots during summer. Study of tea No. 5678-81, N.R.I.T. Kanaya- Cho, Japan.

Ullah, M.R. 1986. A rapid procedure for estimating theaflavins and thearubigins of black tea. Two and a Bud 33 : 46-48.

Verma, S.D., Kaistha, B.P. and Sharma, P.K. 1976. Soil toposequence studies on a land scape segment of temperate humid climate in Himachal Pradesh - Morphological and physio-chemical properties and classification. Fertilizer Technology 13 : 224-229.

Walkley, A. and Black, I.A. 1934. An examination of the degistreff method for determination soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37 : 29-38.

Wani, M.A. and Refique, M.M. 2000. Effect of different levels of sulphur on yield and nutrient uptake of rice (*Oryza sativa*). Advances in Plant Sciences 13 : 139-143.

Watson, M. and Wettasinghe, D.T. 1982. Effect of nitrogen fertilizer on the leaf nutrient composition of low grown tea in Sri Lanka. Tea Quarterly 51 : 27-30.

Williams, C.H. and Steinbergs, A. 1959. Soil sulphur fraction and chemical indices of available sulphur in some Australian soils. Australian Journal of Agriculture Research 10 : 340.

Wood, D.J., Trinick, J.M., Bora, B.C. and Baruah, T.C. 1980. Miniature manufacture. Tea Encyclopaedia 102/2 (K-1) : 1-7.

Wu-Xun and Jianyun, R. 1994. Integrated crop management in tea. Proceedings of International Seminar held on April 26-27 at Colambo, Sri Lanka pp. 203-214.

Ye, Yong. 1993. Effect of sulphur (S) on the carbon metabolism of tea plants. Tea in Yunnan 2 : 26-28.

Ye, Yong and Ye, Y. 1993. Effect of sulphur (S) on nitrogen metabolism of tea plants. Tea-in-Fujian 1 : 14.

Yong, Ye., Wu-Xun and Yao- Guokun. 1994. Sulphur nutrition for tea plant and its effect on tea quality. Journal of Tea Science 14 : 123-128.

APPENDIX

Appendix 1: Mean weekly meteorological data during the field experimentation period (Feb. - Oct., 2000)

Standard weeks	Max. Temp. (^{0}C)	Min. Temp. (^{0}C)	Rainfall (mm)	Humidity (%)
5	16.0	6.0	11.4	54.0
6	14.7	4.9	31.3	72.9
7	14.5	4.3	15.8	59.4
8	15.7	4.3	0.40	50.6
9	19.4	7.2	1.80	48.6
10	19.5	8.6	24.6	56.6
11	20.7	8.8	16.0	52.6
12	18.4	7.9	25.0	53.1
13	26.1	15.3	0.00	42.4
14	26.7	14.1	0.00	36.3
15	29.1	16.3	0.00	36.6
16	30.5	17.6	6.40	42.9
17	28.7	16.4	6.60	42.3
18	31.6	18.6	5.20	42.0
19	29.2	19.5	20.2	63.0
20	30.9	20.3	3.20	59.3
21	31.9	20.5	16.6	58.0
22	31.8	18.7	15.8	52.6
23	28.0	15.9	59.2	75.1
24	29.7	20.3	62.6	74.3
25	28.1	19.9	33.8	81.6
26	27.4	19.3	185.8	85.7
27	28.2	20.5	65.8	79.3
28	27.8	19.9	43.2	83.4
29	25.5	20.2	121.8	86.4
30	25.7	19.8	170.8	90.6
31	24.1	18.6	8.80	75.9
32	26.9	19.6	116.8	84.4
33	27.2	19.2	130.8	81.4
34	27.4	19.4	127.9	79.7
35	26.3	18.1	187.8	83.6
36	26.6	19.6	32.2	80.7
37	27.1	17.0	3.50	67.1
38	25.6	17.7	44.0	76.6
39	26.2	14.8	10.0	55.7
40	26.6	16.1	0.00	67.9
41	27.2	14.4	0.00	41.0
42	26.5	14.5	0.00	45.9
43	25.6	14.4	0.00	45.4
44	23.0	12.9	0.00	66.0