NUTRITIONAL STUDIES ON GINGER
(*Zingiber officinale* Rosc.)

THESIS

By

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Submitted in partial fulfilment of the requirements for the Degree of

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in

HORTICULTURE

(VEGETABLE CROPS)

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DEDICATED
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CERTIFICATE - I

This is to certify that the thesis entitled **"Nutritional studies on ginger (Zingiber officinale Rosc.)"**, submitted in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE** in **HORTICULTURE (VEGETABLE CROPS)** of Dr Y S Parmar University of Horticulture and Forestry, is a faithful record of bonafide research work carried out by **Mr Nutan Mahajan** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 28th December, 1990

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CERTIFICATE - II

This is to certify that the thesis entitled **"Nutritional studies on ginger (<u>Zingiber</u> <u>officinale</u> Rosc.)"**, submitted by **Mr Nutan Mahajan (H-88-12-M)**, to the Dr YS Parmar University of Horticulture & Forestry, Solan in partial fulfilment of the degree of **MASTER OF SCIENCE** in **HORTICULTURE (VEGETABLE CROPS)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the Nominee of the Dean.

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Dated: 31st December,1990

(Nutan Mahajan)

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CHAPTER – I

INTRODUCTION

INTRODUCTION

Ginger (<u>Zingiber</u> <u>officinale</u> Rosc.) is an important spice crop of India known for its medicinal properties. It is a herbaceous perennial plant, belonging to family Zingiberaceae, is believed to be native of South-Eastern Asia (Purseglove et al., 1981). It is propagated through rhizomes, which put forth erect, leafy stem 30-90 cm in height. It is widely used in food, beverages, confectionary and medicine.

The crop is grown from almost the sea level up to an altitude of 1500 m. It is mostly grown on large scale in open areas, though it thrives well under partial shade. It comes up well on a variety of soils, if sufficiently well distributed rainfall or irrigation and adequate drainage facilities are provided. A deep, well drained friable loam, rich in humus is ideal. It may be grown alone or mixed with partial shade giving plants.

India enjoys from times immemorial a unique position in the production and export of ginger. Out of the total production of ginger in the world, nearly 50 per cent is met by India alone (George and Vellapan, 1980). In India, ginger is grown in an area of 52,460 hectares with a production of 1,27,000 tonnes (Dohroo, 1990). The country exported 4776 tonnes of dry ginger amounting to Rs.843 lakhs during the year 1988-89 (Anonymous, 1990). Ginger is cultivated in almost all the tropical and sub-tropical parts of India comprising the states of Kerala, Karnataka, Tamil Nadu, West Bengal, Bihar, Himachal Pradesh, Uttar Pradesh and Maharashtra. It is an important cash crop of Himachal Pradesh grown in districts Sirmour, Solan, Shimla, Bilaspur, Mandi and Kangra. During 1987-88, the area under ginger crop in Himachal Pradesh was 2100 ha with a production of 100 tonnes of dry ginger (Anonymous,1989).

Ginger requires heavy doses of manures and fertilizers (Randhawa and Nandpuri,1969; Muralidharan,1973; Lee and Asher, 1981). In the recent years with the adoption of high yielding varieties of crops and intensification of cropping, the deficiency of minor elements have also been reported from many parts of Northern India (Kumar and Marwaha,1984). It has also been reported that the use of high analysis NPK fertilizer leads toward, micro-nutrient deficiency (Grewal and Trehan,1979). Since not much relevant information is available on the requirement of the nutritional elements such as Mg, Zn, B and Mo in case of ginger, the present investigations were undertaken with the following objectives:

1) To study the effect of macro- and micro-nutrient elements on the yield and quality of ginger crop

2) To work out the economics of macro- and micro-nutrients in ginger; and

3) To observe the disease incidence, if any.

CHAPTER – II

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Information available on the effect of essential nutrient elements on the growth, yield and quality of ginger (Zingiber officinale Rosc.) is scanty. Not much work has so far been done on the concentration and uptake of nutrient elements by the ginger crop. Available literature on the effect of essential nutrient elements on the growth, yield, quality and their concentration and uptake by the ginger crop is summarised as under:

2.1 Effect of nutrient elements on the growth and yield of ginger

In Jamaica, a very high response to nitrogen was observed when applied at the rate of 3 cwt sulphate of ammonia (Anonymous,1953). Groszman (1954) recommended a top dressing of fertiliser mixture (10:8:7) at the rate of 500 kg ha^{-1} for high yield of ginger. Loknath and Dash (1964) while determining the optimum fertilisation and spacing of ginger recommended an optimum level of fertilisers at the rate of 60 lb N, 40 lb P and 60 lb K per acre for getting high yields. Chew (1969) obtained high fresh yields of ginger when fertilised with 65 lb N, 40 lb P_2O_5, 170-200 lb K_2O and 15 lb $CuSO_4$ per acre.

In Himachal Pradesh, application of 100 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare to ginger significantly increased plant height, branch number and yield of fresh ginger rhizomes; and a good growth and yield was obtained by the use of 100 kg N ha^{-1} in absence of P and K as compared to unfertilised control (Randhawa and Nandpuri,1969). Nair and Varma (1970) recorded a bumper crop of 43 tonnes of green ginger per ha from the variety Rio-de-Janeiro at Kerala by the application of 100 kg N, 100 kg P_2O_5 and 200 kg K_2O ha^{-1}. Dasaradhi et al.(1971) stressed the importance of nitrogen at active growth and tillering stage of ginger. Rajan and Singh (1972) reported that the application of urea along with saw dust to soil significantly increased the yield of ginger.

Saraswat (1972) found that in Indonesia, the application of P_2O_5 at 20 and 40 kg ha^{-1} increased the yield of ginger by 21.5 per cent and 11.5 per cent, respectively, whereas nitrogen was ineffective. Muralidharan (1973) reported that with the application of 50 kg N and 75 kg P_2O_5 per ha significantly increased the yield of ginger, while the application of N alone at the rates higher than 50 kg ha^{-1} significantly reduced the yield of ginger.

Muralidharan et al.(1973) found small, but non-significant responses of NPK at 40:40:80 and 60:60:120 kg ha^{-1}, respectively in case of ginger and reported a decrease in number of tillers when the NPK were applied beyond 70:70:140 kg ha^{-1}. Muralidharan et al.(1974) obtained a significantly high tillering and yield of ginger rhizomes when 70 kg N ha^{-1} was applied. Application of phosphorus had no effect, while potash at the rate of 140 kg ha^{-1}

significantly reduced the yield. Muralidharan and Ramankutty (1975) reported that the application of nitrogen at 60 kg ha^{-1} in two splits viz. 60 days and 120 days of planting significantly increased yield; but a non-significant increase was observed in number of tillers per clump as compared to control.

Application of N at 30 kg ha^{-1} doubled the yield of ginger and a further increase in yield by 75 per cent with N application at 90 kg ha^{-1} (Aclan and Quisumbing,1976). In Himachal Pradesh, Kingra and Gupta (1977) recommended use of 50 kg N and 50 kg P_2O_5 ha^{-1} along with 25-30 tonnes of FYM, while Sood and Sharma (1976) recommended 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1} for getting high yields of ginger.

Muralidharan and Ramankutty (1977) observed that the treatment combination of 120 kg K_2O and 10 kg Boron per ha gave the highest number of leaves and tillers per clump in case of ginger. They also reported that the plant characters were not influenced by potassium application and application of B over 50 kg ha^{-1} reduced the yield. Sadanandan and Sasidharan (1979) reported that the application of N beyond 50 kg ha^{-1} reduced the yield of ginger.

Lee et al.(1981) observed highest ginger rhizome yield with the application of N at 200-300 kg ha^{-1}, while Lee and Asher (1981) obtained similar results with the application of N at 336 kg ha^{-1}. Panigrahi and Patro (1985) reported that the application of N and K_2O each at 90 kg ha^{-1} significantly increased the yield of ginger. Sivaraman (1985) reported that under Vellanikkara conditions NPK at 40:40:30 kg ha^{-1} gave the highest ginger yield, however, at Pottangi, maximum yield was recorded with the application of 125:75:50 kg ha^{-1} of NPK.

Cho et al.(1987) found that the most favourable soil conditions for ginger growing were a pH of 6, 405 ppm available P_2O_5 and exchangeable cation levels of 9.5 me Ca, 2.7 me Mg and 1.3 me K per 100 gm soil and ginger yields were positively correlated with the soil organic matter.

Maity et al.(1988) recommended the optimum fertiliser rates of N at 120 kg, P_2O_5 at 60 kg and K_2O at 90 kg ha^{-1} for getting an optimum yield of ginger. Mohanty et al.(1988) found highest rhizome yield with the application of $N:P_2O_5:K_2O$ at 125:75:150 kg ha^{-1}, respectively. Neopaney (1988) recorded highest plant height, number of leaves $plant^{-1}$, rhizome length and yield ha^{-1} with the application of N, P_2O_5 and K_2O at 150, 80 and 60 kg ha^{-1} respectively; whereas highest rhizome breadth was obtained at the fertiliser combination of 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}.

2.2 Concentration and uptake of nutrient elements

The leaf N concentration of ginger shoots and rhizomes at early and late harvests increased with the total amount of N applied upto highest level of 336 kg N ha^{-1} (Lee and Asher,1981).

Nagarajan and Pillai (1979) reported that the rhizomes of "Wynad local" ginger variety removed 67 kg N, 21 kg P, 111 kg K, 11 kg Ca and 20 kg Mg per ha. He suggested that shoot portions should be put back to soil as they contained 50 per cent total N, 36 per cent total P, 41 per cent total K, 67 per cent total Ca and 57 per cent total Mg removed by the plant.

2.3 Effect of nutrient elements on quality of ginger

The ginger oil content was adversely affected by N applications (Saraswat,1972). Nair and Das (1980) reported that the foliar application of Urea + Planofix significantly increased the oleoresin content in ginger, but there was no effect on crude fibre content.

Neopaney (1988) reported that the highest doses of N from 75 kg ha^{-1} onwards decreased oleoresin content of ginger as the doses of superphosphate and potash remained same. He found maximum oleoresin and crude fibre contents with the application of NPK at 75:80:60 and 100:40:20 kg per ha, respectively. Pawar and Patil (1988) reported that the application of NPK did not affect volatile oil content in case of ginger.

2.4 Effect of nutrient elements on disease incidence

Application of NPK (50:25:30 ppm) with coconut cake reduced the incidence of rhizome rot in case of ginger (Rajan and Singh,1974). Muralidharan and Ramankutty (1975) reported that the intensity of soft rot in case of ginger was not affected by N applications. Muralidharan and Ramankutty (1977) concluded that the B at 50 kg ha^{-1} reduced the incidence of soft rot disease in ginger. Sadanandan and Iyer (1986) reported that the FYM application enhanced the incidence of soft rot of ginger.

Neopaney (1988) observed that the application of different fertiliser combinations of NPK failed to significantly affect the incidence of rhizome rot of ginger, and incidence ranged between 25.5 per cent to 38.1 per cent. Prakasam et al.(1988) reported that the application of N at 120 kg ha^{-1} and K at 70 and 120 kg ha^{-1} reduced the disease incidence in case of turmeric.

2.5 Correlation studies

Association of different growth characters and their bearing on yield is important for boosting crop production. The extent of observed relationship between two characters is known as simple or phenotypic correlation.

Mohanty and Sharma (1979) found that the number of tillers, secondary leaves, tertiary and total fingers, plant height, leaf breadth, growth of secondary fingers, number and weight of adventitious roots and straw had positive and significant correlation with yield in case of ginger. Sreekumar et al.(1980) found that the correlations were significant and positive between the plant height versus rhizome weight (r=0.71), tiller number versus rhizome weight (r-0.46) and leaf number versus rhizome weight (r=0.66) in the cultivars Thingpuri, Rio-de-Janeiro and China.

Marwaha (1984) observed a positive and significant correlation between plant height versus number of tillers (r=0.94), plant height versus number of leaves (r=0.99), plant height versus fresh weight of rhizomes (r=0.98), number of tillers versus fresh weight of rhizomes (r=0.98), number of tillers versus number of leaves (r=0.96) and number of leaves versus fresh weight of rhizomes (r=0.98). Rattan et al.(1988) found that plant height was significantly positively correlated with number of leaves, leaf length, rhizome length, rhizome breadth and yield per plot. They also observed that number of tillers were positively correlated with number of leaves and rhizome length, whereas number of leaves had significant positive correlation with rhizome length, rhizome breadth and yield per plant.

CHAPTER – III

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigations were carried out at Regional Research Station, Kandaghat, Department of Vegetable Crops, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) during the Kharif, 1989. Details of the experiment along with the material used and the techniques employed are given in this chapter.

3.1 GENERAL

3.1.1 Experimental site

The Research Station is situated mid-way between Solan and Shimla on National Highway-22, at an altitude of 1500 m above mean sea level; at a latitude of 30°57' North and longitude of 77°6' East .

3.1.2 Climate

Meteorological data for the crop period could not be recorded locally because of non-availability of observatory. Hence, the weather data recorded at Vegetable Research Station, Solan having more or less identical climatic conditions have been included and the mean weekly data have been appended in Appendix-A and illustrated graphically in Fig.1.

The overall weather was favourable for the crop growth.

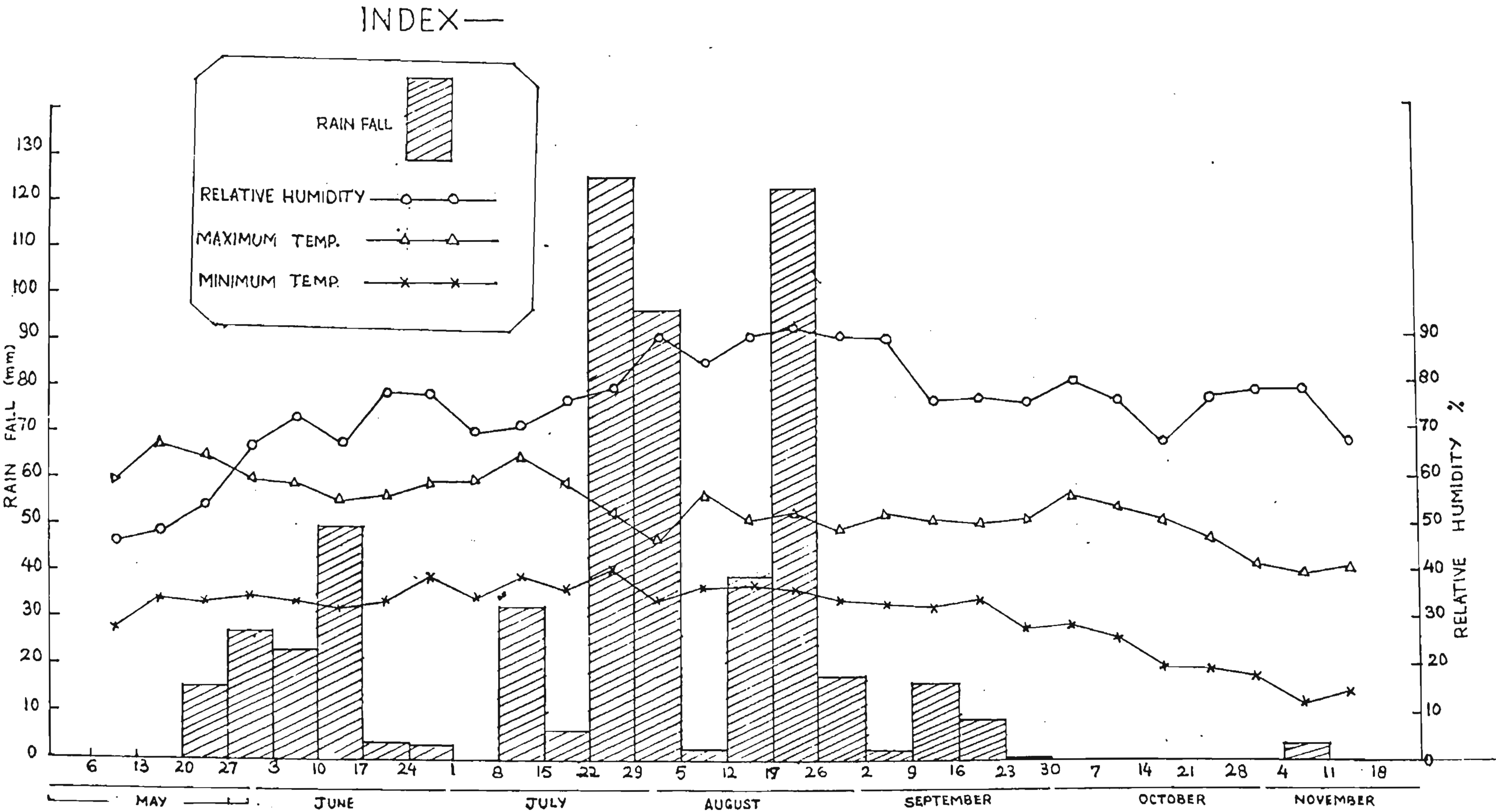

Fig.1 MEAN WEEKLY WEATHER DATA

3.2 PHYSICO-CHEMICAL PROPERTIES OF SOIL

A composite soil sample of the experimental site (0-15 cm depth) was taken before the start of experiment and analysed for physico-chemical characteristics. The physico-chemical properties of the experimental field have been shown in Table 3.1.

It is evident from the data in Table 3.1 that the soil was loamy in texture, neutral in reaction, high in organic carbon, available K and P and medium in N, B, Mo and Zn.

3.3 EXPERIMENTAL DETAILS

The experiment was conducted in Randomized Block Design with three replications.

3.3.1 Detail of treatments

The experiment consisted of ten treatments. The detail of treatments is given below:

Table 3.1. Physico-chemical characteristics of the soil before the start of the experiment

Soil characteristics	Content	Method employed
A. Mechanical analysis		
Coarse sand (%)	32.12	International pipette method (Piper,1966)
Fine sand (%)	13.54	
Silt (%)	30.72	
Clay (%)	22.80	
Texture	Loam	
B. Chemical analysis		
pH	7.3	(1:2.5 soil water suspension). Glass electrode pH meter (Jackson, 1967)
Organic carbon(%)	1.95	Walkley and Black's Rapid titration method (Piper,1966)
Available nitrogen (kg ha^{-1})	291.65	Alkaline permanganate method (Subbiah and Asija,1956)
Available phosphorus(kg ha^{-1})	46.6	Olsen's method (Piper,1966)
Available potassium(kg ha^{-1})	352.09	Ammonium acetate method using flame photometer (Jackson,1967)
Exchangeable Ca (ppm)	1053	Ca and Mg were extracted with neutral ammonium acetate (pH 7.0) and determined by Versenate method (Kanwar and Chopra,1976)
Exchangeable Mg (ppm)	688.2	
Available Zn (ppm)	1.16	Extracted with DTPA solution (Lindsay and Norvell,1969) and determined by Atomic Absorption Spectrophotometry.
Available B (ppm)	0.96	Extracted in hot water (Wear,1965) and determined by carmine method (Hatcher and Wilcox,1950).
Available Mo (ppm)	0.18	Extracted with acid ammonium oxalate (pH 3.3) solution (Grigg, 1953) and determined by thiocyanate orange red colour method (Jackson, 1967).

Treatment symbol	Nutrient element applied	Application rate
T_1	Control	No fertiliser application
T_2	N	100 kg ha^{-1}
T_3	N:P	100:50 kg ha^{-1}
T_4	N:P:K	100:50:50 kg ha^{-1}
T_5	N:P:K + Zn	100:50:50 + $ZnSO_4$ 20 kg ha^{-1}
T_6	N:P:K + Mg	100:50:50 + $MgSO_4$ 10 kg ha^{-1}
T_7	N:P:K + B	100:50:50 + Borax 10 kg ha^{-1}
T_8	N:P:K + Mo	100:50:50 + Ammonium molybdate 1 kg ha^{-1}
T_9	N:P:K + Zn + Mg + B + Mo	100:50:50 + $ZnSO_4$ 20 kg + $MgSO_4$ 10 kg + Borax 10 kg + Ammonium molybdate 1 kg ha^{-1}
T_{10}	N:P:K + 2 foliar sprays of Jagromin-99* (chelated form of micro-nutrients) at rhizome initiation stage and one month after first spray	100:50:50 kg ha^{-1} + 0.7% in one spray

* Composition of Jagromin-99 is given in Appendix-H

Replications : 3

Plot size

Gross 3 m x 1.8 m (6 rows 3 m long)

Net 2 m x 1.2 m (4 inner rows)

Variety used Local (seed procured through the Dept.of Agriculture)

3.4 FIELD CULTURE

3.4.1 Layout of experiment

The layout of experiment with randomization of various treatments has been given in Fig.2.

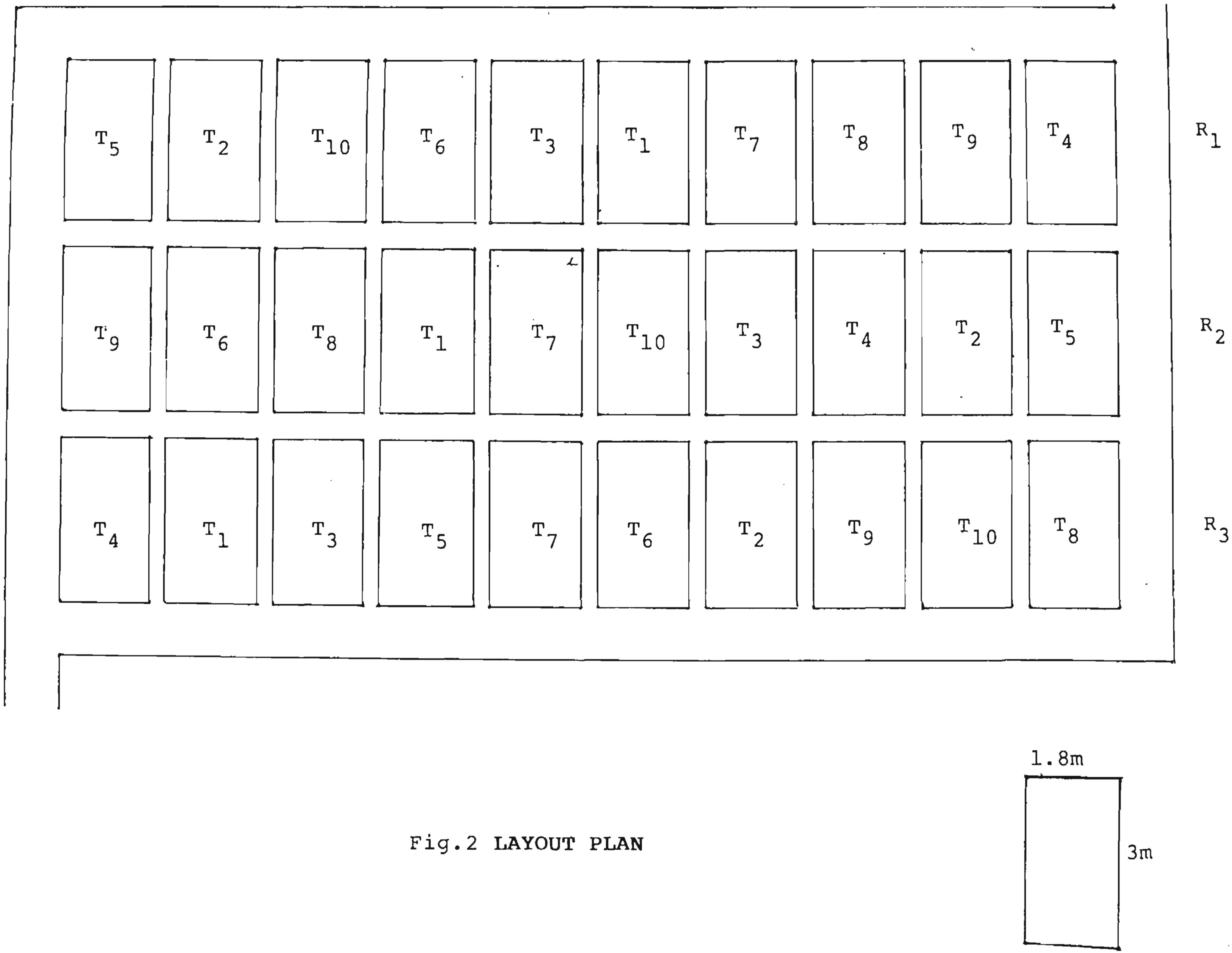

Fig.2 LAYOUT PLAN

3.4.2 Preparation of field

The experimental field was prepared with the help of 3 ploughings given by desi plough, each ploughing followed by planking. The experimental area was divided into three blocks for three replications and 10 plots within each block labelled well.

3.4.3 Manure and fertiliser application

FYM @ 30 t ha^{-1} was applied to each plot and mixed well with the soil. Full dose of P and K and Zn, Mg, B and Mo and ⅓ N was applied at the time of sowing. Remaining N was applied in two splits viz. ⅓ at rhizome initiation and ⅓ at tillering stage. Calcium ammonium nitrate (25% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O) were the sources used for nitrogen, phosphorus and potassium respectively. Two foliar sprays of Jagromin-99 were given; first at rhizome initiation and second one month after the first coinciding the rhizome development stage.

3.4.4 Sowing of seed rhizomes

The weight of the each seed rhizome fingers ranged between 15 to 20 g. The sowing was done on May 15, 1989. The seed was placed in 30 cm apart furrows and seed to seed distance was kept at 20 cm. Prior to sowing, rhizomes were treated with Dithane M-45 @ 0.25 per cent and Bavistin @ 0.05 per cent for one hour and dried in shade for twenty four hours for check against the rhizome rot.

3.4.5 Harvesting

The border rows were harvested separately and removed from the plots. Net plots were harvested afterwards and rhizomes from these plots kept separately.

3.5 OBSERVATIONS RECORDED

3.5.1 Growth parameters

For recording the observations on growth parameters under study, five plants in each treatment were randomly selected from the net plot.

3.5.1.1 **Pseudo-stem length:** Stem length was measured in cm, from ground level to the top of the tallest leaf sheath and was recorded as average stem length per plant.

3.5.1.2 **Number of tillers per plant:** Average number of tillers per plant for every plot were worked out.

3.5.1.3 **Number of leaves per plant:** Average number of leaves from each selected plant were counted and worked out for each plot.

3.5.1.4 **Leaf area:** 20 leaves from each plot were selected and leaf area in cm^2 was taken on automatic leaf area meter.

3.5.2 Yield parameters

The evaluated yield and yield contributing characters are as follows:

3.5.2.1 **Rhizome size**: The size of the rhizomes was worked out in terms of length and breadth.

3.5.2.1.1 **Rhizome length**: Rhizome length was recorded in cm for every rhizome of five randomly selected plants per plot and average worked out for each plot.

3.5.2.1.2 **Rhizome breadth**: Rhizome breadth was measured at three places in cm and average width calculated.

3.5.2.2 **Yield per plant**: The average fresh weight of the rhizomes of the five selected plants was recorded and averaged as yield per plant in g.

3.5.2.3 **Rhizome yield per hectare**: The yield (q ha^{-1}) was calculated on the basis of net plot ($2 \times 1.2\ m^2$) yield.

3.5.3 Dry matter accumulation

Two plants (from border rows) at random were selected from each plot at every growth stage viz., rhizome initiation (76 days after sowing), tillering (101 days after sowing) and harvest stage (185 days after sowing) and separated into tops and rhizomes. These samples were washed with tap water to make them free of extraneous matter and then with 0.1 N HCl, single distilled water and finally with double distilled water. The samples were oven dried at $65 \pm 5°C$ for four days till constant weight. Dry weight thus obtained, was expressed in kg ha^{-1} for rhizomes and tops separately by the following formula:

$$\text{Dry matter accumulation} (\text{kg ha}^{-1}) = \frac{\text{Dry weight of two plants(g)} \times 10000}{0.12 \times 1000}$$

3.6 CHEMICAL STUDIES

3.6.1 Plant studies

Oven dried rhizomes and tops samples as described in section 3.5.3 were ground to powdery mass and subjected to chemical analysis.

The samples were digested in 4:1 nitric acid perchloric acid mixture. The digest was dissolved in double distilled water and filtered into 100 ml volumetric flask. In order to have complete transfer of the digested material, three washings of the digestion flask were given with double distilled water and volume made to 100 ml. P in the extract were determined by Vanadomolybdo-phosphoric yellow colour method (Jackson,1973). Ca and Mg in the extract were determined by versenate method (Richard,1954) and K was determined by flame photometrically (Jackson,1967). Zn was determined on Atomic Absorption Spectrophotometer.

For estimation of N, the plant material was digested in concentrated H_2SO_4, in the presence of digestion mixture (400 g K_2SO_4 + 20 g $CuSO_4$ + 3 g HgO + 1 g Se-powder, thoroughly mixed). After digestion the NH_4-N was estimated by colorimetric method as described by Baethgen and Alley (1989).

Separate dry ashing for B and Mo was done in muffle furnace for 6 hours at 550°C. Then ash was taken in 10 ml of 1 N HCl. B and Mo were then determined by carmine method (Hatcher and Wilcox,1950) and potassium thiocyanate orange red colour method (Jackson,1967), respectively, using Spectronic-20 spectrophotometer.

3.6.2 Soil chemical studies

After the harvest of crop, surface soil samples (0-15 cm depth) were collected from each plot. Samples were dried, ground and mixed thoroughly and used for the determination of available nutrient contents viz., N, P, K, Ca, Mg, Zn, B and Mo by using the standard methods as given in Table 3.1.

3.6.3 Nutrient uptake

3.6.3.1 Macro Nutrients: Macronutrient uptake by rhizomes and tops (in kg ha^{-1}) was worked out according to the formula:

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

3.6.3.2 Micro Nutrients: Micronutrient uptake was calculated (in g ha^{-1}) for rhizomes and tops separately using the formula:

$$\text{Nutrient uptake(g ha}^{-1}\text{)} = \frac{\text{Nutrient content(ppm)} \times \text{Dry matter(kg ha}^{-1}\text{)} \times 1000}{10000 \times 100}$$

Total nutrient uptake by ginger plant was calculated by summing up the nutrient uptakes by rhizomes and tops treatmentwise for each stage separately.

3.7 QUALITY PARAMETERS AND INCIDENCE OF RHIZOME ROT

3.7.1 Quality parameters

3.7.1.1 <u>Crude fibre content</u>: The estimation of crude fibre content was done by the acid-alkali digestion (ashing) method with 5 g sample as described by Sankaram (1966) and calculated in per cent dry weight.

3.7.1.2 <u>Oleoresin content</u>: The oleoresin content was determined by using acetone as a solvent as per procedure outlined by the Association of Official Analytical Chemists (Horwitz, 1980) and measured in per cent recovery.

3.7.1.3 <u>Oil content</u>: The oil content was determined by using Clevenger apparatus as per procedure outlined by Association of Official Analytical Chemists (Horwitz,1980) and calculated in per cent dry weight.

3.7.2 Incidence of rhizome rot

The incidence of rhizome rot was worked out by observing the symptoms on plants of every plot and expressed as per cent rhizome rot.

3.8 ECONOMIC ANALYSIS

After taking into consideration the variable as well as fixed inputs and corresponding rates, the cost incurred on each treatment was worked out (Appendix-G). Simultaneously gross returns were worked out for each treatment based on market rates of the produce. Net returns were then worked out by deducting the cost incurred from the gross returns of the particular treatment.

3.9 STATISTICAL ANALYSIS

All the data relating to growth and yield studies, chemical studies, quality parameters, economic analysis and for nutrient uptake were statistically analysed by following the procedure described by Cochran and Cox (1963). The treatment effects were tested at 5 per cent level of significance.

3.9.1 Correlation studies

The coefficient of correlation (r) was calculated by the formulae:

$$r_{XY} = \frac{\sum XY - \frac{\sum X . \sum Y}{n}}{\sqrt{\sum X^2 - \frac{(\sum X)^2}{n}} \sqrt{\sum Y^2 - \frac{(\sum Y)^2}{n}}}$$

where,

$\sum XY$	=	sum of products of the corresponding values of X and Y
$\sum X^2$	=	sum of square of variable X
$\sum Y^2$	=	sum of square of variable Y
$\sum X$	=	sum of all the variables of X
$\sum Y$	=	sum of all the variables of Y
n	=	number of observations/treatment
r	=	Pearson's coefficient of correlation

CHAPTER – IV

EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

Experimental results obtained from the field experiment conducted at the Regional Research Station, Kandaghat during Kharif 1989 have been presented in this chapter with the help of data tables and suitable illustrations under four broad sub-headings.

I) Crop growth and yield studies
II) Quality studies and incidence of rhizome rot
III) Plant and soil chemical studies
IV) Correlation studies and economic analysis

4.1 CROP GROWTH AND YIELD STUDIES

The data pertaining to effect of various treatments on pseudo-stem length (cm), number of tillers plant^{-1}, number of leaves plant^{-1}, leaf area (cm^2), rhizome size in terms of rhizome length (cm) and rhizome breadth (cm), yield plant^{-1} (g), rhizome yield ha^{-1} (q) and dry matter accumulation (kg ha^{-1}) in tops and rhizome at different stages of growth have been presented in Table 4.1 to 4.3, and their corresponding analysis of variance have been appended in Appendix-B.

4.1.1 Crop growth studies

4.1.1.1 Pseudo-stem length

Data pertaining to mean length of pseudo-stem, as affected by various fertiliser treatments, are given in Table 4.1 and illustrated graphically in Fig.3.

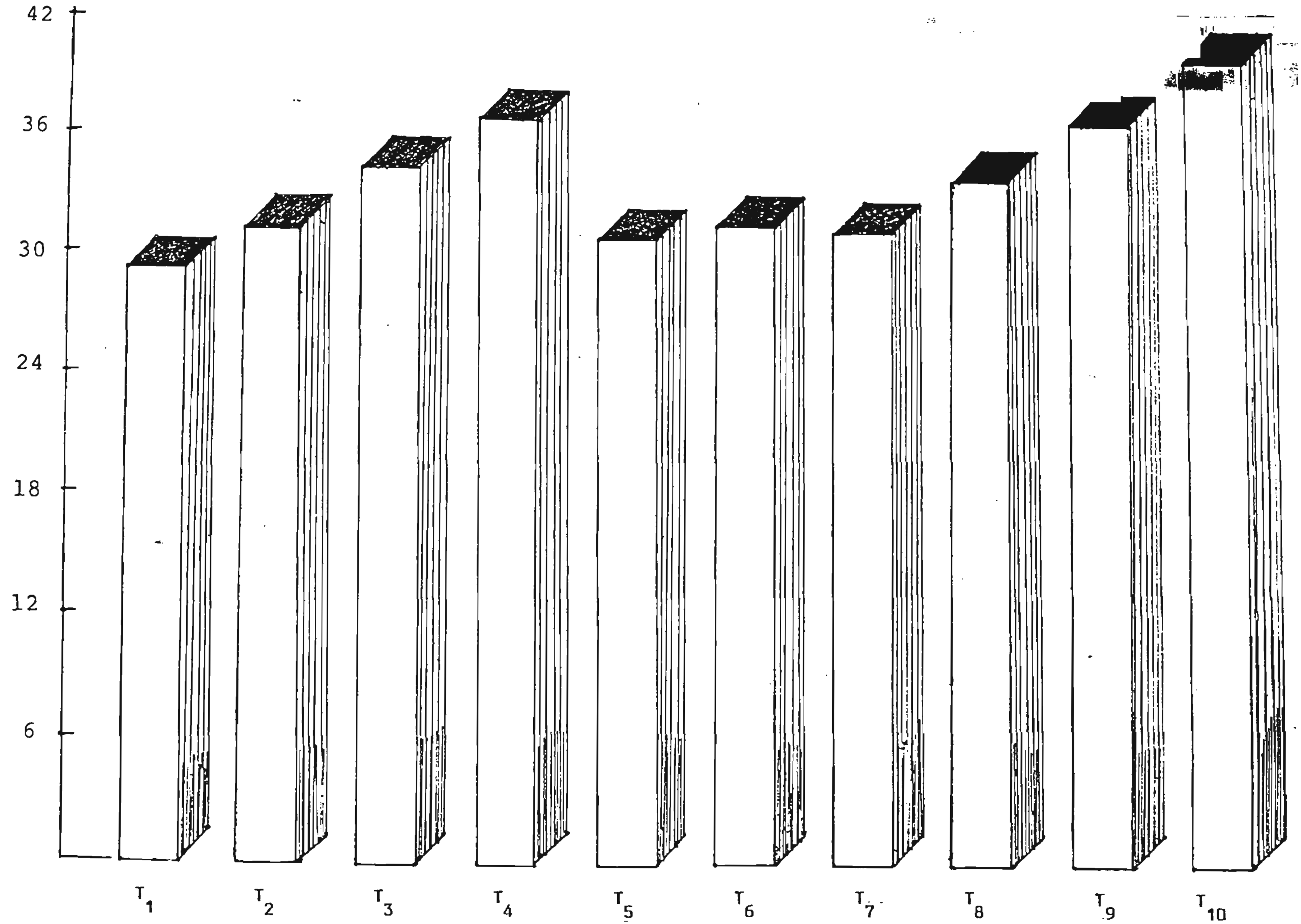

Fig.3 MEAN PSEUDO-STEM LENGTH (cm)

A perusal of the Table 4.1 revealed that the plants of treatment T_{10} registered maximum pseudostem length (39.56 cm) and were statistically superior to all other treatments and were followed by T_4 and T_9, which were at par with each other. On the other hand, the minimum pseudo-stem length (29.12 cm) was observed in case of control (T_1), which was at par with T_5. No significant differences were observed in plant height of treatments T_3, T_8; T_6, T_2, T_7 and T_5.

4.1.1.2 Number of tillers per plant

Observations on mean number of tillers per plant, as affected by various treatments, are detailed in the Table 4.1.

An examination of the data revealed that all the fertiliser treatments were statistically superior to control (T_1), which produced lowest number of tillers (2.4) per plant.

Highest number of tillers (5.8) per plant were recorded in T_{10} which was at par with T_4. The differences between treatments T_4 and T_9 were found to be non-significant. Similarly, no significant differences were observed among various treatments viz., T_9, T_3, T_2, T_6, T_8 and all these treatments remained statistically superior to T_5.

4.1.1.3 Number of leaves per plant

Data on average number of leaves per plant, as affected

Table 4.1 Pseudo-stem length, number of tillers plant^{-1}, No.of leaves plant^{-1} and leaf area (cm^{2}) as influenced by various treatments in ginger

Treatments	Pseudo-stem length(cm)	Number of tillers plant^{-1}	Number of leaves plant^{-1}	Leaf area (cm^{2})
T_1	29.12	2.40	24.13	28.36
T_2	31.15	4.40	37.87	28.51
T_3	34.31	4.67	39.20	28.79
T_4	36.55	5.40	41.20	29.07
T_5	30.46	2.93	25.00	28.47
T_6	31.24	4.33	38.60	28.64
T_7	30.91	3.33	29.93	28.49
T_8	33.51	4.33	39.00	28.78
T_9	36.32	5.20	41.07	29.18
T_{10}	39.56	5.80	41.80	28.86
S.Ed.	0.78	0.23	0.95	0.05
C.D. at 5%	1.65	0.48	1.99	0.11

by various fertiliser treatments, have been tabulated in the Table 4.1

It is evident from the data that T_{10} produced higher number of leaves per plant (41.8), closely followed by T_4, T_9 and T_2 and was statistically superior to rest of the treatments. The least number of leaves were produced by T_1 (24.13) and it was at par with T_5. No appreciable differences were observed among treatments T_2, T_3, T_8, T_6; but all these treatments were statistically superior to T_7.

4.1.1.4 Leaf area

The results on mean leaf area, as influenced by various fertiliser treatments have been embodied in the Table 4.1.

An examination of the data revealed that the leaf area (cm) was significantly increased by all the fertiliser treatments as compared to control. With the combined application of minor elements viz., Zn, Mg, B, Mo and NPK (T_9), there was a significant increase in leaf area as compared to rest of the treatments. T_4 (NPK) ranked second in respect of leaf area and was significantly superior to T_{10}, T_3, the latter two being at par with each other. Treatment T_6 was significantly superior to treatments T_5 and T_7, which were statistically similar to each other.

4.1.2 Yield parameters

4.1.2.1 Rhizome size

The effect of various fertiliser treatments on rhizome size in terms of rhizome length (cm) and breadth (cm) have been given in the Table 4.2.

4.1.2.1.1 Rhizome length: It is evident from Table 4.2 that mean rhizome length, as affected by various fertiliser treatments, ranged from 8.15 to 12.58 cm, being lowest in treatment T_1 and highest in treatment T_{10}. Treatment T_{10} was statistically superior to all the treatments excepting T_4, T_9 and T_3. An increase in rhizome length of 4.17 cm, 3.03 cm, 1.26 cm was recorded in case of T_4 (NPK) over T_1 (control), T_2 (N) and T_3 (NP), respectively. No appreciable differences were observed among treatments T_9, T_3, T_8; T_3, T_8, T_6; T_6, T_2, T_7; T_2, T_7, T_5 and T_1. There was a decrease in rhizome length with soil application of minor elements along with NPK.

4.1.2.1.2 Rhizome breadth: An examination of Table 4.2 revealed that T_4 registered maximum rhizome breadth (6.94 cm), which was closely followed by T_9, T_{10} and T_8; while minimum rhizome breadth (4.52 cm) was observed in case of control (T_1), which was comparable with T_5 and T_7. Treatments T_2 and T_3 exhibited a significant difference, but both were at par with T_6.

Table 4.2 Ginger yield per plant and per ha and rhizome size as influenced by various treatments

Treatments	Yield plant^{-1} (g)	Per cent increase over control	Rhizome yield ha^{-1} (q)	Per cent increase over control	Rhizome size	
					Rhizome length (cm)	Rhizome breadth (cm)
T_1	62.73	-	63.61	-	8.15	4.52
T_2	112.73	79.71	98.61	55.02	9.29	5.69
T_3	115.27	83.76	103.61	62.88	11.06	5.31
T_4	125.87	100.65	117.22	84.28	12.32	6.94
T_5	72.67	15.85	71.81	12.89	8.43	4.61
T_6	112.20	78.86	99.86	56.99	9.63	5.65
T_7	82.73	31.88	77.08	21.18	8.69	4.68
T_8	113.93	81.62	102.49	61.12	10.59	6.69
T_9	125.87	100.65	116.25	82.75	11.73	6.85
T_{10}	128.93	105.53	121.39	90.83	12.58	6.82
S.Ed.	6.53	-	6.07	-	0.76	0.17
C.D. at 5%	13.72	-	12.76	-	1.60	0.36

4.1.2.2 Yield per plant

Observations on rhizome yield per plant (g), as influenced by different fertiliser treatments, have been summarised in Table 4.2 and illustrated graphically in 4(b)..

It was found that the highest rhizome yield per plant was recorded in case of treatment T_{10} (128.93 g $plant^{-1}$), which remained at par with T_9, T_4 and T_3 and markedly superior to all other treatments. Yield per plant increased with the application of NPK fertilisers (T_4) by 100.65 per cent, 11.66 per cent and 9.2 per cent over control (T_1), N (T_2) and NP (T_3), respectively. No significant differences were observed among treatments T_4, T_9, T_3, T_8, T_2, T_6; T_7, T_5 and T_1. Yield per plant was found to be decreased with the soil application of minor alements viz., Zn, Mg, B and Mo. Maximum decrease in yield per plant was found in case of T_5 (53.2 g $plant^{-1}$) followed by T_7 (43.14 g $plant^{-1}$) over T_4.

4.1.2.3 Rhizome yield

The rhizome yield (q ha^{-1}) as influenced by various treatments has been summarised in Table 4.2 and illustrated graphically in Fig.4(a).

An examination of the data revealed that the rhizome yield increased with the application of NPK (T_4) fertilisers by 84.28 per cent, 18.87 per cent and 13.14 per cent over

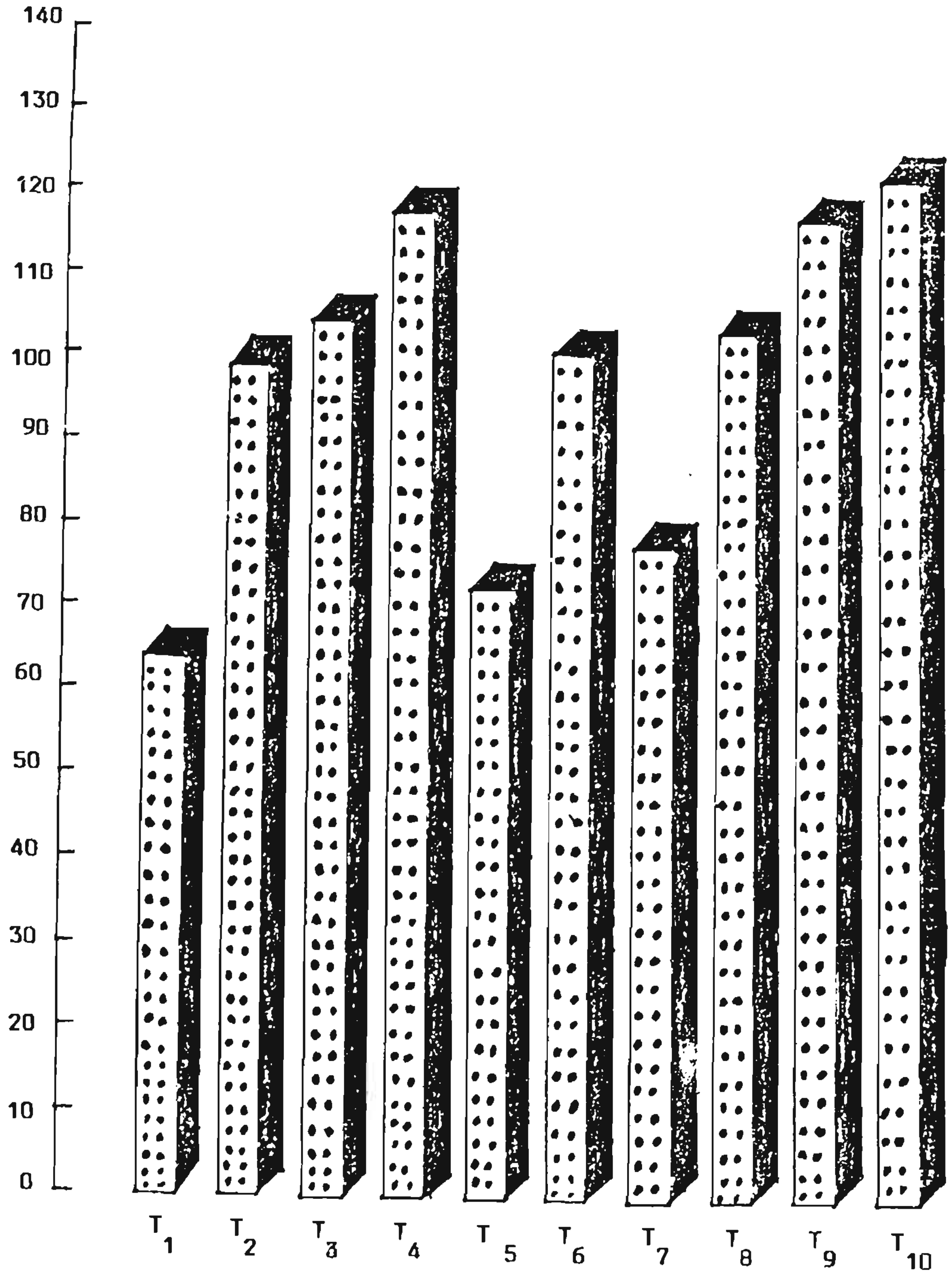

Fig. 4(a) GINGER RHIZOME YIELD (Q ha^{-1})

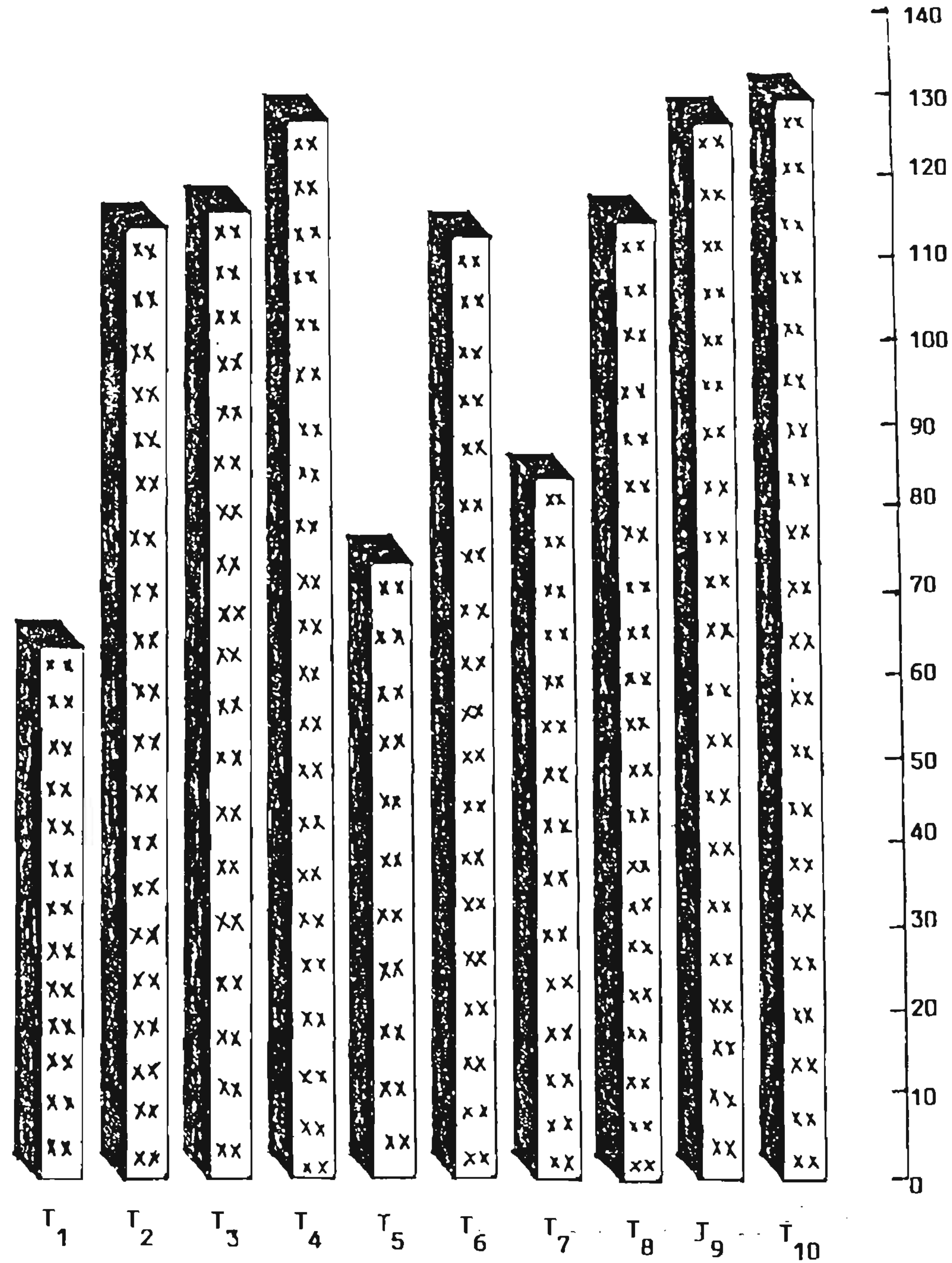

Fig.4(b) GINGER RHIZOME YIELD (g $plant^{-1}$)

control (T_1), N (T_2) and NP (T_3), respectively. The highest yield (121.39 q) was recorded with the application of recommended doses of NPK (100:50:50 kg ha^{-1}) fertilisers followed by two foliar sprays of Jagromin-99 (T_{10}), which was significantly superior to rest of the treatments excepting T_4 and T_9, which remained at par with T_{10} and each other. No significant differences were observed among treatments T_9, T_3; T_3, T_8, T_6, T_2; T_5, T_7; T_5 and T_1. The rhizome yields decreased with the soil application of minor elements viz., Zn, Mg, B and Mo. The maximum decrease of 45.4 q ha^{-1} and 40.1 q ha^{-1} was noted with application of Zn (20 kg $ZnSO_4$ ha^{-1}) and B (10 kg Borax ha^{-1}), respectively over NPK.

4.1.3 Dry matter accumulation

Data on the dry matter accumulation (kg ha^{-1}) by tops and rhizomes at different stages of growth are presented in Table 4.3 and have been illustrated graphically in Fig.5.

It is evident from the data that the application of NPK (T_4) produced highest dry matter through tops; however, at par with T_{10} and T_9, significantly superior to rest of the treatments at the rhizome initiation stage. In case of rhizomes, T_{10} produced highest dry matter, which remained at par with T_9 and T_4. All the treatments were significantly superior to control (T_1) in respect of dry matter accumulation through tops and rhizomes at rhizome initiation stage. No significant differences were observed

Table 4.3 Dry matter accumulation (kg ha^{-1}) in tops and rhizomes at different stages of growth of ginger as affected by various treatments

Treatments	STAGES					
	Rhizome initiation		Tillering		Harvest	
	Tops	Rhizomes	Tops	Rhizomes	Tops	Rhizomes
T_1	362.22	209.45	661.11	1100.00	904.33	2039.44
T_2	417.78	345.00	786.11	1655.56	1182.44	3781.11
T_3	433.34	353.33	811.11	1700.00	1226.00	3936.11
T_4	469.44	395.55	913.89	1876.67	1322.75	4444.44
T_5	398.89	276.67	736.11	1441.66	1035.78	2632.22
T_6	421.67	342.22	841.66	1708.33	1189.67	4047.78
T_7	405.55	285.00	763.89	1580.56	1118.45	2990.55
T_8	431.67	348.89	877.78	1752.78	1264.63	4130.56
T_9	463.89	395.55	897.22	1858.33	1273.45	4457.78
T_{10}	467.22	397.78	941.66	1922.22	1325.11	4573.89
S.Ed.	8.47	7.95	24.08	41.86	31.97	223.03
C.D.at 5%	17.79	16.71	50.60	87.95	67.16	465.59

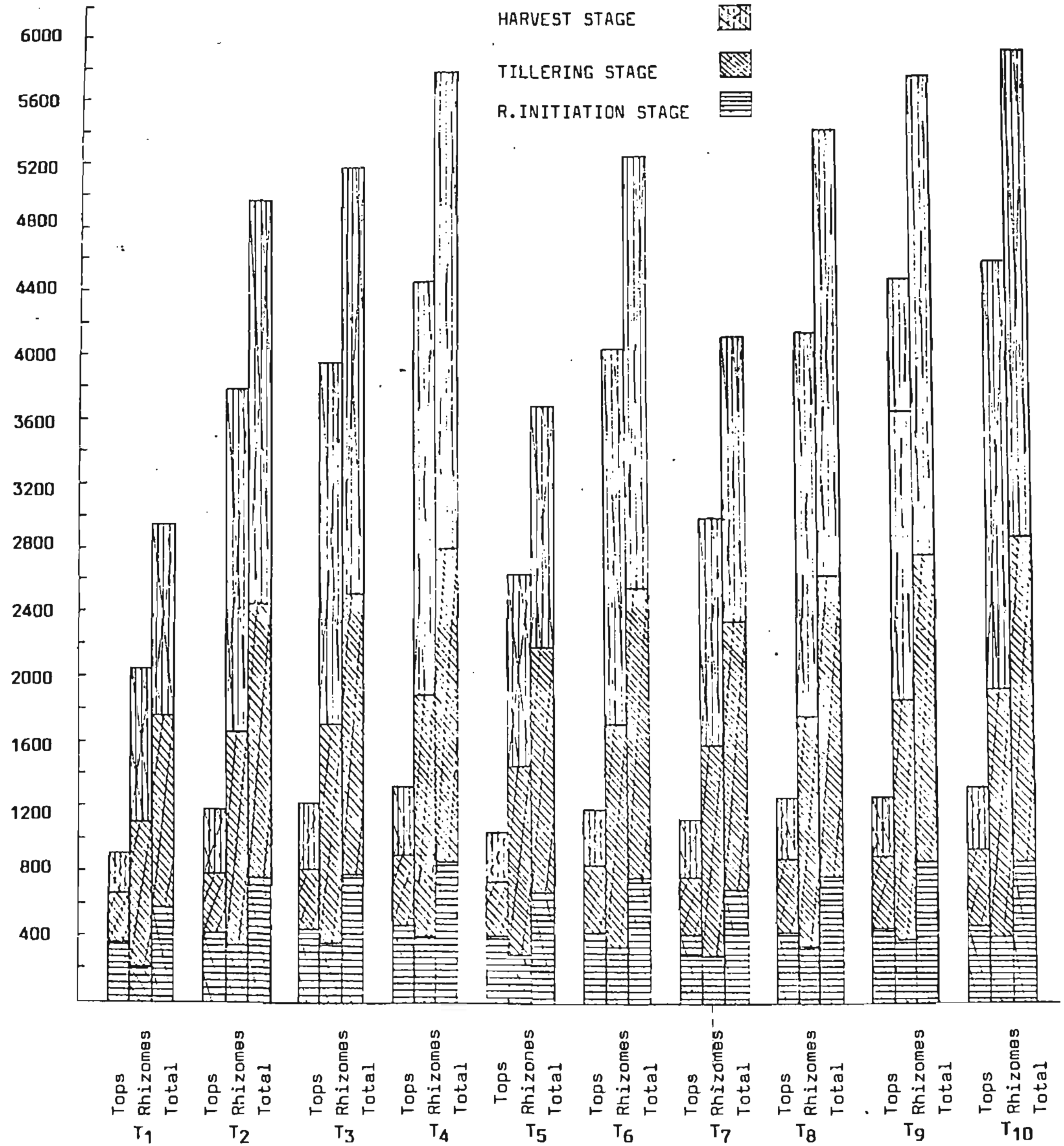

Fig. 5 DRY MATTER ACCUMULATION (kg ha^{-1})

between tratments T_3, T_8, T_6 and T_2.

Treatment T_{10} accounted for the highest dry matter production through the tops and rhizomes at the tillering stage , which was at par with T_9 and T_4. T_8 was found to be statistically at par with T_9, T_4 and T_6 in respect of dry matter production through tops. In case of rhizomes, no appreciable differences were observed between treatments T_8, T_6 and T_3. All the treatments were significantly superior to control in respect of dry matter production through tops and rhizomes at tillering stage.

At the harvest stage, treatment T_{10}, behaving statistically alike with T_9, T_8 and T_4, produced highest dry matter through the tops and rhizomes. No significant differences were observed between treatments T_9, T_8, T_3; T_3, T_6, T_2 and T_2 and T_7 in respect of dry matter production through tops. Treatment T_9, closely followed by T_4, T_8 and T_6, was significantly superior to T_3, T_2, T_7 which were again at par with each other, in respect of dry matter production through the rhizomes at the harvest stage. It was found that all the treatments were superior to control (T_1) in respect of dry matter accumulation by tops and rhizomes.

4.2 QUALITY STUDIES AND INCIDENCE OF RHIZOME ROT

Data on oil content (%), oleoresin content (%), crude fibre content (%) and incidence of rhizome rot have been presented in Table 4.4 and corresponding analysis of variance are appended in Appendix-C.

4.2.1 Quality studies

4.2.1.1 Ginger oil content

None of the fertiliser treatments could significantly affect the ginger oil content (%) as shown in the Table 4.4. However, the application of NPK + B (T_7) accounted for highest ginger oil content (1.96%) and T_2 the lowest.

4.2.1.2 Oleoresin content

Data pertaining to per cent oleoresin content as influenced by various fertiliser treatments are presented in the Table 4.4.

Highest oleoresin content in rhizomes (5.59%) was recorded with the application of NPK + B (T_7), which was closely followed by T_6. No significant differences were observed among treatments T_6, T_5, T_8 and T_9, while the latter two also observed to be not significantly different from T_9 and T_{10}. Application of nitrogen (T_2) accounted for the lowest oleoresin content, although statistically at par with T_1, T_3, T_{10} and T_4, the former two being at par with T_9, while the latter two with T_8 also.

4.2.1.3 Crude fibre content

Observations on the per cent crude fibre content as affected by various fertiliser treatments are summarised in

Table 4.4 Effect of various treatments on the ginger oil content(%), oleoresin content(%), crude fibre content(%) and incidence of rhizome rot

Treatments	Ginger oil content(%)	Oleoresin content(%)	Crude fibre content(%)	Incidence of rhizome rot(%)
T_1	1.71	5.29	3.88	22.11(27.97)
T_2	1.67	5.25	3.92	22.59(28.07)
T_3	1.75	5.31	3.73	26.03(30.67)
T_4	1.75	5.34	3.83	24.21(29.33)
T_5	1.83	5.47	3.72	14.06(21.92)
T_6	1.88	5.49	3.60	24.91(29.85)
T_7	1.96	5.59	3.63	21.92(27.77)
T_8	1.79	5.42	3.77	22.19(27.81)
T_9	1.88	5.39	3.62	24.23(29.37)
T_{10}	1.79	5.33	3.78	23.07(28.63)
S.Ed.	0.153	0.051	0.096	3.503
C.D.at 5%	NS	0.11	0.202	NS

Figures in the parentheses represents Arc Sine transformed values the Table 4.4.

The crude fibre content was found to be highest (3.92%) with the application of N (T_2) followed by T_1, T_4, T_{10}, T_8, T_3 and T_5. Lowest crude fibre content was observed in case of treatment T_6 (NPK + Mg); which was statistically similar to T_9, T_7, T_5, T_3, T_8 and T_{10}, the latter five treatments being again on par with T_4.

4.2.2 Incidence of rhizome rot

A statistical analysis of the data showed that the fertiliser treatment failed to affect the incidence of rhizome rot (Table 4.4).

However, application of NPK + Zn (T_5) accounted for lowest (14.06%) incidence of rhizome rot in ginger followed by T_7 (21.92%), T_1 (22.11%) and T_8 (22.19%). Highest incidence of rhizome rot (26.03%) was recorded with the application of NP (T_3), followed by T_9 (24.23%), and T_4 (24.21%).

4.3 PLANT AND SOIL CHEMICAL STUDIES

4.3.1 Nutrient content in ginger plant

The data pertaining to effect of various treatments on nutrient content in tops and rhizomes of ginger at different stages of growth have been given in Tables 4.5 to 4.12 and the corresponding analysis of variance have been appended in Appendix-D.

4.3.1.1 Nitrogen content

Observations on the content of nitrogen in ginger plant tops and rhizomes at different stages of crop growth are given in the Table 4.5.

The nitrogen content in the ginger , in general, was found to be maximum at rhizome initiation stage which thereafter started decreasing with advancement of the crop growth.

The ginger tops of treatment T_8 contained the maximum N content at rhizome initiation stage,which was statistically at par with T_2, T_5, T_6, T_9 and T_{10}, while at tillering stage treatment T_6, behaving statistically alike with T_5, was found to contain the highest N content. Similarly, treatment T_6, being statistically indistinguishable from T_5, T_8, T_2, T_{10}, T_3, was found to have the maximum N content in the tops at the harvest stage. Plant tops obtained from control (T_1) contained lowest N content at all the stages of growth, however, were at par with T_7 at rhizome initiation and harvest stage.

None of the fertiliser treatments could significantly affect the N content in the rhizomes at rhizome initiation stage. Whereas at the tillering stage, maximum N content in the rhizomes was recorded in case of treatment T_2, which was statistically at par with T_6, T_5, T_8, T_3 and T_4. Treatment T_6 was found to contain highest N content in the rhizome at the harvest stage, though remained at par with T_5, T_8, T_2, T_9 and T_{10}. Lowest N content in the rhizomes

Table 4.5 Nitrogen content(%) in ginger tops and rhizomes at different stages of growth as affected by various treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Harvest stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	3.05	2.71	1.76	1.96	1.66	1.56
T_2	3.41	3.11	2.00	2.08	1.90	1.77
T_3	3.24	3.05	1.94	2.05	1.80	1.71
T_4	3.23	3.08	1.99	2.03	1.78	1.72
T_5	3.40	3.22	2.07	2.10	1.85	1.81
T_6	3.36	3.27	2.08	2.15	1.89	1.83
T_7	3.21	3.02	1.89	2.02	1.73	1.61
T_8	3.44	3.12	2.03	2.09	1.80	1.79
T_9	3.27	3.02	1.92	2.12	1.68	1.75
T_{10}	3.27	3.04	1.98	2.06	1.74	1.74
S.Ed.	0.082	0.051	0.068	0.082	0.067	0.050
C.D. at 5%	0.174	0.107	0.143	NS	0.140	0.106

was recorded in the control (T_1) at all stages of growth, however, it was at par with T_9, T_7, T_{10}, T_4, T_3 and T_8 at tillering and T_7 at harvest stage.

4.3.1.2 Phosphorus content

Data on the phosphorus content in tops and rhizomes as affected by various fertiliser treatments are tabulated in the Table 4.6.

In general, the content of P in the tops and rhizomes decreased with advancement in age. However, this decrease was more pronounced in the tops than in the rhizomes.

Application of NP (T_3) produced ginger tops with highest P content at rhizome initiation and tillering stage, which was at par with T_{10}, T_7, T_4 in the former and with T_4, T_7, T_{10} and T_8 in the latter stage. Application of N (T_2) was found to decrease the P content in the tops at the harvest stage as compared to T_1 (control); while the application of P increased the P content in the tops. Treatment T_4 recorded highest P content in the tops, which remained statistically at par with all other treatments except T_2 and T_1. Lowest P content was observed in treatments T_1 and T_2, which were statistically at par with each other and with T_5 and T_9 at rhizome initiation and tillering stages.

Similar trend in respect of P content in rhizomes was recorded at the rhizome initiation and tillering stages.

Table 4.6 Phosphorus content(%) in ginger tops and rhizomes at different stages of growth as affected by various treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Harvest stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	0.461	0.400	0.259	0.208	0.207	0.176
T_2	0.469	0.389	0.241	0.211	0.222	0.198
T_3	0.586	0.499	0.299	0.283	0.282	0.219
T_4	0.547	0.483	0.301	0.281	0.272	0.218
T_5	0.505	0.417	0.271	0.259	0.238	0.199
T_6	0.523	0.453	0.285	0.265	0.254	0.213
T_7	0.533	0.480	0.296	0.267	0.270	0.214
T_8	0.536	0.466	0.292	0.263	0.267	0.221
T_9	0.502	0.418	0.274	0.245	0.232	0.200
T_{10}	0.553	0.472	0.297	0.271	0.267	0.215
S.Ed.	0.023	0.022	0.016	0.012	0.008	0.012
C.D. at 5%	0.0489	0.0459	0.0326	0.0243	0.0172	NS

The fertiliser treatments failed to affect the P content in rhizomes at the harvest stage.

4.3.1.3 Potassium content

K content in tops and rhizomes at different stages of growth as influenced by various fertiliser tratments is presented in the Table 4.7.

A perusal of the data revealed that the K content, in general, decreased with the advancement of growth of ginger plant. This decline was more rapid in the tops then in the rhizomes. It was observed that the application of N or NP decreased the K content in rhizomes and tops at all stages of growth.

None of the fertiliser treatments could significantly affect the K content in the tops at rhizome initiation and harvest stages. However, T_7 produced tops with highest K content in both the stages. K content in the tops was significantly affected by the various fertiliser treatments at tillering stage. Highest K content was recorded in case of treatment T_{10}, closely followed by T_5, T_7, T_4, T_8, T_9 and T_6; while the lowest K content was registered in T_3 which was comparable with T_1, T_2 and T_6.

K application significantly increased the K content in the rhizomes at rhizome initiation stage, being highest in the treatment T_5 which was statistically at par with

Table 4.7 Potassium content(%) in ginger tops and rhizomes at different stages of growth as affected by various fertiliser treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Rhizome stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	4.188	3.800	2.338	2.838	2.488	2.263
T_2	4.150	3.850	2.300	2.763	2.463	2.213
T_3	4.138	3.763	2.238	2.729	2.413	2.200
T_4	4.350	4.025	2.325	2.988	2.550	2.463
T_5	4.325	4.063	2.413	3.025	2.538	2.538
T_6	4.264	3.938	2.200	2.913	2.500	2.325
T_7	4.375	4.038	2.400	2.950	2.525	2.438
T_8	4.300	4.013	2.375	2.938	2.563	2.400
T_9	4.225	3.975	2.250	2.925	2.488	2.338
T_{10}	4.313	4.075	2.275	3.000	2.575	2.363
S.Ed.	0.095	0.096	0.079	0.088	0.079	0.087
C.D. at 5%	NS	0.201	NS	0.184	NS	0.183

T_{10}, T_4, T_7, T_8, T_9 and T_6. At the tillering stage, the K content in the rhizomes was not significantly affected by various treatments. T_5, behaving statistically alike with T_4, T_7, T_8 and T_{10}, significantly increased the K content in the rhizomes of harvest stage as compared to other treatments. Application of NP (T_3) produced rhizomes with lowest K content at all stages, which was statistically at par with T_2 and T_1 at rhizome initiation and T_2, T_1, T_6, T_9 and T_{10} at harvest stage.

4.3.1.4 Calcium content

The effect of various treatments on the Ca content in tops and rhizomes at different stages of growth is presented in Table 4.8.

It is evident from the data in Table 4.8 that the Ca concentration in tops and rhizomes was found to be highest at tillering stage and thereafter, a decline in the Ca concentration was observed.

The Ca concentration in the tops was significantly affected by the application of nutrient elements as compared to control at rhizome initiation stage. Highest Ca content was recorded in case of treatment T_7, which was statistically at par with all other treatments except control. At the tillering stage treatments failed to significantly affect the Ca concentration. Treatment T_7 produced tops with highest Ca content at the harvest stage, which was

Table 4.8 Calcium content(%) in ginger tops and rhizomes at different stages of growth as affected by various treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Harvest stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	1.053	1.235	1.079	0.143	0.163	0.159
T_2	1.274	1.391	1.287	0.159	0.198	0.186
T_3	1.287	1.430	1.261	0.160	0.195	0.192
T_4	1.209	1.443	1.235	0.152	0.190	0.184
T_5	1.261	1.417	1.339	0.152	0.200	0.189
T_6	1.209	1.378	1.270	0.157	0.187	0.178
T_7	1.313	1.482	1.378	0.177	0.202	0.199
T_8	1.300	1.456	1.313	0.173	0.196	0.194
T_9	1.287	1.443	1.300	0.161	0.185	0.196
T_{10}	1.196	1.404	1.287	0.157	0.188	0.187
S.Ed.	0.067	0.094	0.066	0.007	0.009	0.007
C.D.at 5%	0.140	NS	0.138	0.014	0.018	0.015

statistically at par with all the treatments except T_4 and T_1. All the fertilised treatments significantly increased the Ca content as compared to T_1.

At the rhizome initiation stage, treatment T_7, behaving statistically similar to T_8, produced rhizomes with significantly higher Ca content; while the lowest Ca content was recorded in treatment T_1 which was statistically comparable with T_4 and T_5. Ca content was significantly increased by the fertiliser treatment as compared to control, being highest in treatment T_7. Treatment T_7, exhibiting no statistical differences to T_4, T_6 and T_1, produced rhizomes with highest Ca content at the harvest stage and all the fertiliser treatments were statistically superior to control (T_1).

4.3.1.5 Magnesium content

The data on the Mg content in tops and rhizomes at different stages of growth as affected by various treatments are presented in the Table 4.9.

The Mg content in the tops was found to be maximum at tillering stage and thereafter, there was a sharp decline in the Mg content; while in case of rhizomes there was a gradual decline with the advancement of growth stage.

Application of Mg with NPK (T_6) significantly increased the Mg content in the tops at rhizome initiation stage.

Table 4.9 Magnesium content(%) in ginger tops and rhizomes at different stages of growth as affected by various treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Harvest stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	0.411	0.471	0.314	0.151	0.127	0.121
T_2	0.458	0.508	0.319	0.165	0.146	0.129
T_3	0.430	0.525	0.335	0.169	0.154	0.145
T_4	0.437	0.507	0.340	0.157	0.149	0.150
T_5	0.466	0.492	0.338	0.161	0.153	0.152
T_6	0.537	0.576	0.377	0.178	0.169	0.166
T_7	0.496	0.503	0.335	0.167	0.152	0.145
T_8	0.462	0.499	0.324	0.157	0.147	0.144
T_9	0.530	0.558	0.352	0.180	0.166	0.163
T_{10}	0.445	0.480	0.329	0.162	0.158	0.153
S.Ed.	0.026	0.030	0.023	0.012	0.011	0.012
C.D.at 5%	0.054	0.062	NS	NS	NS	0.024

At the tillering stage also, T_6 produced tops with high Mg content, though statistically at par with T_9 and T_3. The Mg concentration at harvest stage was not significantly influenced by various treatments. Treatment T_1 was found to produce tops with lowest Mg content at rhizome initiation and tillering stages, which was statistically comparable with T_3, T_4, T_{10}, T_2, T_8 and T_5 in case of former and with T_3, T_2, T_4, T_7, T_8; T_5 and T_{10} in case of latter stage.

The treatments failed to significantly influence the Mg cosntent in case of rhizomes at rhizome initiation and tillering stages, however, T_9 produced rhizomes with high Mg content.

At the harvest stage, treatment T_6 produced rhizomes with highest Mg concentration which remained statistically at par with all the treatments except T_2 and T_1 ; while treatment T_1, statistically comparable with T_2 and T_3, produced rhizomes with lowest Mg concentration.

4.3.1.6 Zinc content

Observations on Zn content in tops and rhizomes at different stages of growth as affected by various treatments are presented in Table 4.10.

A perusal of the data in Table 4.10 reveals that the Zn content, in general, decreased with the advancement of growth stage in the ginger plant.

Table 4.10 Zinc content(ppm) in ginger tops and rhizomes at different stages of growth as affected by various treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Harvest stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	35.33	33.33	23.33	17.33	13.33	12.67
T_2	40.67	37.33	24.33	22.33	18.00	16.00
T_3	37.67	35.00	23.67	19.00	15.33	14.00
T_4	39.33	36.67	25.00	20.33	17.67	16.67
T_5	49.33	44.33	30.33	26.33	25.33	23.67
T_6	43.67	39.33	28.33	21.67	19.67	14.33
T_7	41.00	38.00	25.67	22.33	18.00	15.67
T_8	41.67	37.67	26.00	18.33	18.33	16.33
T_9	48.00	45.33	32.67	26.67	21.67	20.00
T_{10}	40.00	39.00	29.33	23.33	20.33	17.67
S.Ed.	2.698	2.137	1.990	2.049	1.839	1.525
C.D.at 5%	5.67	4.49	4.17	4.30	3.86	3.15

Maximum Zn concentration at the rhizome initiation stage was recorded in the tops obtained from plots treated with NPK + Zn (T_5), which was statistically at par with T_9 and T_6. Application of Zn significantly increased the Zn content in the tops at tillering stage. In this stage, treatment T_9, statistically on par with T_5, was significantly superior to rest of the treatments. At the harvest stage, T_9, behaving statistically similar with T_5 and T_{10}, significantly increased the Zn in the tops. Lowest Zn content in the tops was found in case of T_1, which was statistically at par with T_3, T_4, T_{10} and T_2 at rhizome initiation stage, with T_3, T_4, T_2 and T_8 at tillering stage and with T_3, T_2, T_4, T_7 and T_8 at harvest stage.

Rhizomes obtained from treatment T_9 were found to be highest in respect of Zn content at rhizome initiation stage, however, were statistically similar with T_5 and T_{10}. At tillering stage, treatment T_5, behaving statistically alike with T_9, produced rhizomes with highest Zn content. Zn content in rhizomes was significantly influenced by the application of NPK + Zn (T_5) at the harvest stage. The Zn content was found to be lowest in case treatment T_1 at all stages of growth, which was statistically at par with T_8, T_3 and T_4 at rhizome initiation stage, with T_3 at tillering stage and with T_3, T_6 and T_7 at harvest stage.

4.3.1.7 Boron content

The data on the B content in tops and rhizomes at different stages of growth are presented in Table 4.11. It is evident from the data in Table 4.11 that the B content in the tops decreased with the advancement of crop growth. In case of rhizomes, B content declined after the tillering stage.

Application of B in combination with NPK (T_7) significantly increased the B content in the tops at all the crop growth stages as compared to all other treatments. Lowest B content in the tops was recorded in case of control (T_1) at rhizome initiation and tillering stages, which was statistically at par with T_6, T_2, T_{10} and T_4 in the former and with T_4, T_3 and T_2 in the latter growth stage. At the harvest stage, plant tops obtained from plots treatment with N (T_2) were lowest in B content, which was statistically similar with T_3, T_1, T_4, T_8, T_5 and T_6.

None of the treatments could significantly affect the B content in the rhizomes at all stages of growth. However, B content was higher in the rhizomes obtained from plots treated with B.

4.3.1.8 Molybdenum content

Observations on the Mo content in tops and rhizomes at different stages ,as influenced by various fertiliser treatments,are presented in the Table 4.12.

Table 4.11 Boron content(ppm) in ginger tops and rhizomes at different stages of growth as affected by various treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Harvest stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	38.83	33.44	23.33	14.39	15.00	11.50
T_2	40.28	33.67	21.83	14.50	15.11	11.83
T_3	42.67	35.00	22.00	15.15	15.56	11.78
T_4	39.28	35.61	23.50	14.85	16.52	12.11
T_5	44.22	36.56	25.00	14.85	15.46	12.06
T_6	41.39	38.00	25.33	14.55	15.13	12.22
T_7	48.51	45.78	31.00	15.67	16.89	12.94
T_8	44.00	38.83	24.72	14.69	15.44	12.33
T_9	42.89	39.89	26.22	15.89	16.33	12.78
T_{10}	39.67	38.39	27.00	15.17	15.74	12.44
S.Ed.	1.813	1.235	1.696	1.112	1.298	1.023
C.D.at 5%	3.81	2.60	3.56	NS	NS	NS

Table 4.12 Molybdenum content(ppm) in ginger tops and rhizomes at different stages of growth as affected by various treatments

Treatments	Tops			Rhizomes		
	Rhizome initiation stage	Tillering stage	Harvest stage	Rhizome initiation stage	Tillering stage	Harvest stage
T_1	1.283	1.143	0.720	0.790	0.713	0.650
T_2	1.320	1.227	0.803	0.803	0.752	0.703
T_3	1.267	1.233	0.820	0.753	0.730	0.647
T_4	1.233	1.170	0.750	0.730	0.712	0.680
T_5	1.303	1.283	0.827	0.773	0.740	0.653
T_6	1.290	1.143	0.770	0.770	0.717	0.633
T_7	1.280	1.180	0.687	0.712	0.613	0.580
T_8	1.377	1.330	0.893	0.943	0.853	0.767
T_9	1.377	1.330	0.910	0.973	0.820	0.773
T_{10}	1.240	1.230	0.870	0.750	0.760	0.753
S.Ed.	0.131	0.104	0.094	0.109	0.089	0.101
C.D.at 5%	NS	NS	NS	NS	NS	NS

As in case of N, P, K, the Mo content also declined with the advancement in growth stage in both rhizomes and tops. It was found that all the treatments failed to significantly affect the Mo concentration in the tops and rhizomes at all stages of growth.

Highest Mo content in the tops and rhizomes at all stages of growth was observed in case of treatments T_8 and T_9, respectively. Treatment T_7 accounted for the minimum content of Mo in the rhizomes at all stages of growth. Lowest content of Mo in tops at rhizome initiation stage, tillering stage and harvest stage was observed in case of treatments T_4, T_1 and T_6 and T_1, respectively.

4.3.2 Nutrient uptake by ginger plant

Data on nutrient uptake through ginger tops and rhizomes have been summarised in Tables 4.13 to 4.20 and their analysis of variance have been appended in Appendix-E.

4.3.2.1 Nitrogen uptake

The N uptake through plant tops and rhizomes, as affected by various treatments, at different stages of growth has been presented in Table 4.13. Total N uptake by ginger plant has also been illustrated diagrammatically in Fig.6.

A perusal of the data in Table 4.13 revealed that the rate of nitrogen uptake was highest, in respect of

Table 4.13 Nitrogen uptake (kg ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	4.11	11.04	15.15	18.24	17.92	36.16	31.85	15.89	47.74
T_2	7.16	14.24	21.40	31.48	24.43	55.91	66.74	23.68	90.42
T_3	7.23	14.06	21.29	30.51	24.73	55.24	67.39	23.77	91.16
T_4	8.01	15.15	23.16	33.33	28.20	61.53	76.63	26.30	102.93
T_5	5.82	13.58	19.40	26.66	23.67	50.33	47.67	21.45	69.12
T_6	7.35	14.18	21.53	32.30	27.55	59.85	74.19	24.75	98.94
T_7	5.74	13.03	18.77	27.29	23.09	50.38	48.18	21.12	69.30
T_8	7.30	14.87	22.17	31.55	27.25	58.80	74.00	25.63	99.63
T_9	8.38	15.19	23.57	31.22	27.09	58.31	78.03	24.51	102.54
T_{10}	8.19	15.27	23.46	33.45	28.63	62.08	79.71	26.16	105.87
S.Ed.	0.334	0.527	0.582	1.416	0.974	2.656	4.722	0.976	4.755
C.D.at 5%	0.70	1.11	1.22	2.98	2.05	5.58	9.92	2.05	9.99

total plant, in between tillering and harvest stages, when N was directly administered to soil as a fertiliser. All the fertiliser treatments under study were significantly superior to control at all stages of crop growth in respect of total nitrogen uptake and uptake by different plant parts. In case of tops, maximum nitrogen accumulation was found at tillering stage and thereafter, a decline in the nitrogen accumulation was observed; while rhizomes continued to be accumulating N till harvest stage.

Tops accumulated higher proportion of N at rhizome initiation stage as compared to rhizomes in all the treatments under investigation. Highest N uptake in the whole plant and rhizomes (23.57 and 8.38 kg ha^{-1}, respectively) was recorded in treatment T_9, which was at par with treatments T_{10} and T_4. T_{10} registered higher nitrogen uptake (15.27 kg ha^{-1}) in the tops at rhizome initiation stage, which was statistically indistinguishable from T_9, T_4, T_8, T_2 and T_6.

The N uptake at tillering stage through rhizomes, tops and whole plant was found to be maximum (62.08, 33.45, 28.63 kg ha^{-1}) in T_{10}, which was statistically at par with treatments T_4, T_6, T_8 and T_9. Out of the total N removed by the whole plant at tillering stage, rhizomes accumulated higher N quantity as compared to the tops owing to the higher dry matter.

At the harvest stage, like the tillering stage,

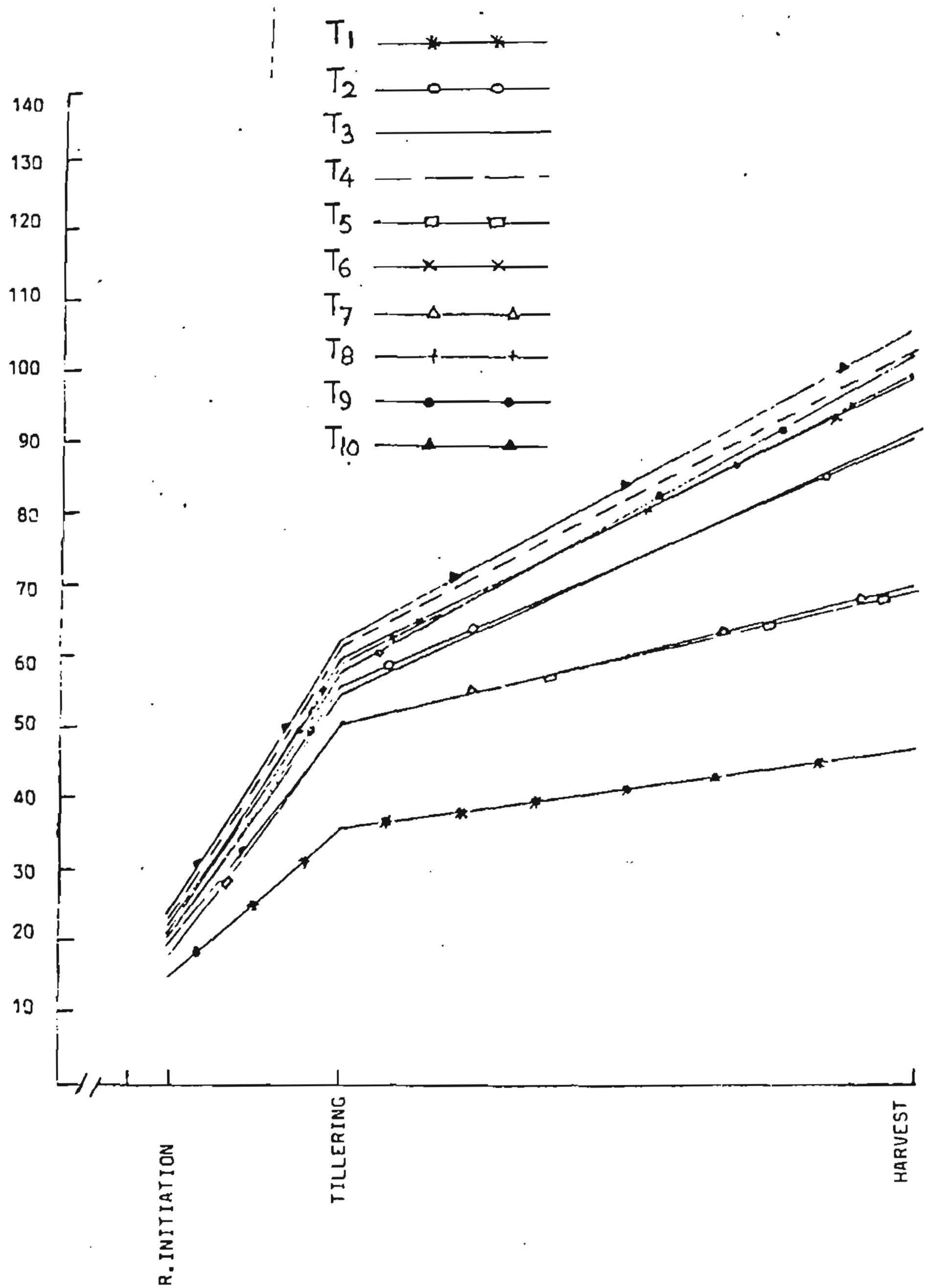

Fig.6. TOTAL N UPTAKE (kg ha^{-1})

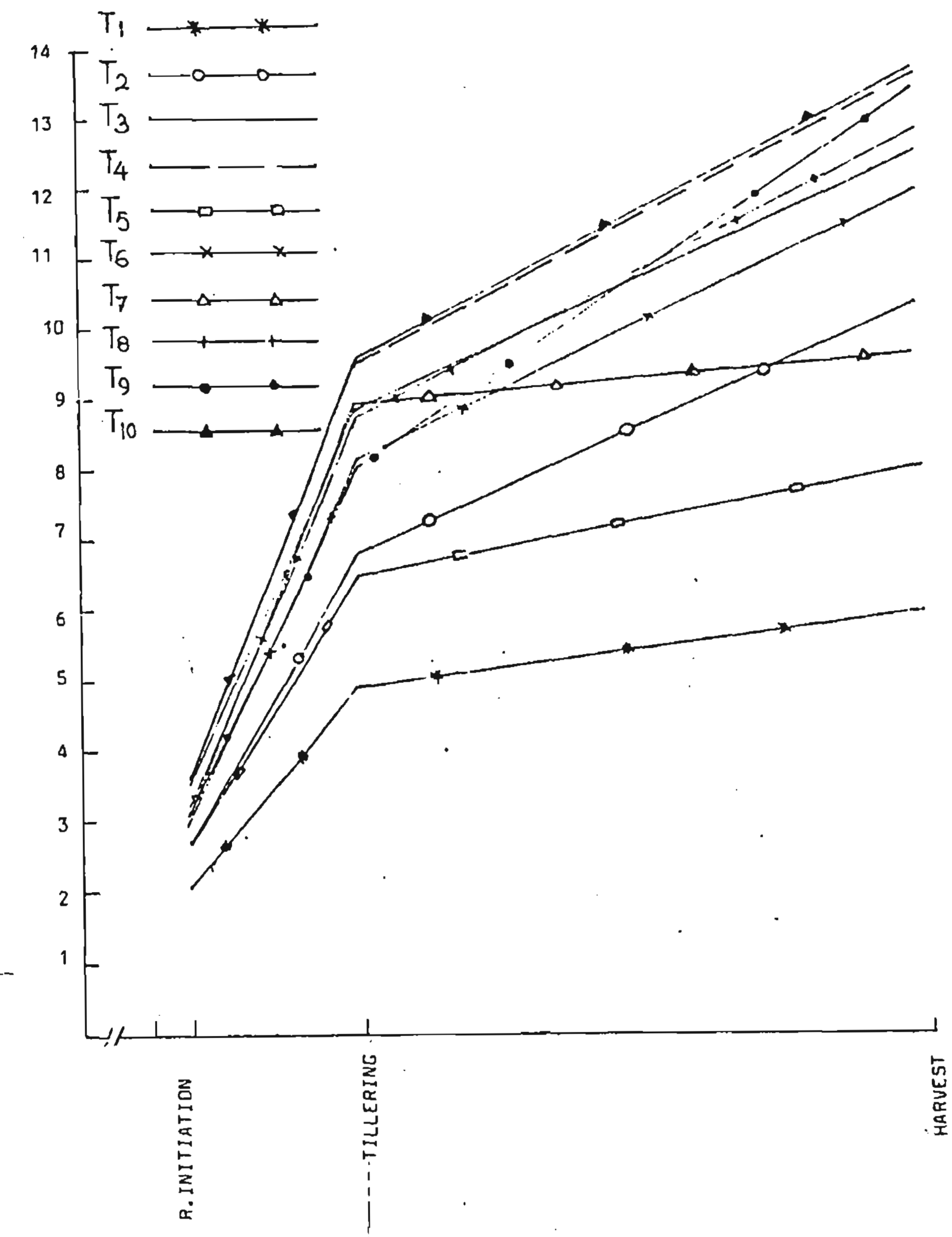

Fig.7. TOTAL P UPTAKE (kg ha^{-1})

T_{10} removed highest quantity of N in the whole plant and in the rhizomes (105.87 and 79.71 kg ha^{-1}, respectively) and was statistically comparable with T_4, T_9, T_8 and T_6, but superior to rest of the treatments. In case of tops, maximum uptake of N was found in T_4, closely followed by T_{10}, T_8, T_6 and T_9. Rhizomes accounted for 66.72, 73.81, 73.92, 74.45 and 75.29 per cent of total N removed in case of treatments T_1, T_2, T_3, T_4 and T_{10}, respectively.

4.3.2.2 Phosphorus uptake

The P uptake (kg ha^{-1}), by different plant parts, at different stages of growth, as affected by various treatments has been presented in Table 4.14. The total P uptake by ginger plant has been illustrated diagramatically in Fig.7.

An examination of the data reveals that the rhizomes continued to accumulate P till harvest stage; while the tops accumulated P till tillering stage and thereafter, there was a decline in the P accumulation.

The P uptake was significantly influenced by fertiliser applications at rhizome initiation stage. It was found that the removal of P by tops was higher than rhizomes. At rhizome initiation stage, highest uptake of P in the whole plant (3.66 kg ha^{-1}) and in the tops (2.58 kg ha^{-1}) was found in treatment T_{10}, which was comparable with T_4 and T_3. P removal by rhizomes was found to be equal among

Table 4.14 Phosphorus uptake (kg ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	0.44	1.67	2.11	2.28	2.65	4.93	3.61	2.34	5.95
T_2	0.73	1.96	2.69	3.77	3.05	6.82	7.49	2.84	10.33
T_3	1.00	2.54	3.54	4.80	4.05	8.85	8.62	3.66	12.28
T_4	1.08	2.57	3.65	5.10	4.41	9.51	9.67	3.98	13.65
T_5	0.72	2.01	2.73	3.44	3.07	6.51	5.21	2.81	8.02
T_6	0.91	2.25	3.16	4.34	3.81	8.15	8.57	3.40	11.97
T_7	0.76	2.22	2.98	4.26	3.67	7.93	6.36	3.31	9.67
T_8	0.92	2.32	3.24	4.71	4.06	8.77	9.12	3.68	12.80
T_9	0.97	2.32	3.29	4.31	3.75	8.06	8.92	3.50	12.42
T_{10}	1.08	2.58	3.66	5.14	4.46	9.60	9.81	3.94	13.75
S.Ed.	0.043	0.104	0.095	0.192	0.228	0.322	0.582	0.167	0.627
C.D. at 5%	0.09	0.22	0.20	0.40	0.48	0.67	1.22	0.35	1.32

T_{10} and T_4 (1.08 kg ha^{-1}), which were at par with T_3 and significantly superior to rest of the treatments. No significant differences in respect of P uptake by the whole plant were observed between treatments T_9, T_8; T_6; T_6, T_7; and T_5 and T_2. It was found that all the treatments were superior to control in respect of P removal. Rhizomes removed higher quantities of P as compared to tops at tillering stage under all the treatment excepting control (T_1). As in rhizome initiation stage, T_{10} removed highest (9.60 kg ha^{-1}) amount of P, closely followed by T_4 in the whole plant and was significantly superior to rest of the treatments studied. P accumulation at tillering stage of rhizomes and tops was found to be maximum (5.4 and 4.46 kg ha^{-1}) in T_{10}, which was statistically at par with T_4 and T_3 and significantly higher than all other treatments. Lowest uptake of P was found in case of control (T_1).

At the harvest stage, T_{10} was found to be best in respect of P uptake by whole plant (13.75 kg ha^{-1}) and rhizomes (9.81 kg ha^{-1}), which was comparable with T_4 and T_8. The P removal by tops was found to be highest (3.98 kg ha^{-1}) in T_4, closely followed by T_{10}, T_8 and T_6. Treatment T_1 registered the lowest uptake of P (2.34 kg ha^{-1}) in case of tops and all the fertiliser treatments under study were significantly superior to it. The rhizomes accumulated 60.67, 72.51, 70.19, 70.84 and 71.34 per cent of Total P removed by whole plant in treatments T_1, T_2, T_3, T_4 and T_{10}, respectively at the harvest stage.

4.3.2.3 Potassium uptake

The K uptake through plant tops and rhizomes, as influenced by various treatments, at different stages of growth has been presented in Table 4.15. The total K uptake by ginger plant at different stages of growth has been illustrated graphically in Fig.8.

It is evident from the data (Table 4.15) that the rhizomes continued to remove K from the soil till harvest stage; while the tops removed K till tillering stage and afterwards, there was a decline in the K accumulation. However, the uptake of K by the whole plant increased with the age of the plant. There was a significant increase in K uptake with the fertiliser application as compared to control, by the different plant parts at all stages of growth.

A perusal of the data in Table 4.15 revealed that the maximum uptake of K at rhizome initiation stage by the whole plant (32.23 kg ha^{-1}) and the tops (20.41 kg ha^{-1}) was recorded in case of T_4, which was at par with T_{10} and T_9. No significant differences were observed between treatments T_6, T_3, T_2; T_2, T_7; T_7 and T_5 in respect of K uptake by the whole plant. The removal of K by rhizomes was lower under all the treatments studied as compared to tops. Highest uptake of K by rhizomes was recorded in treatment T_{10} (11.93 kg ha^{-1}), closely followed by treatments T_4 and T_9. Treatments T_8, T_6, T_3 and T_2 did not

Table 4.15 Potassium uptake (kg ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	5.94	15.17	21.11	27.40	25.13	52.53	46.16	21.15	67.31
T_2	9.53	17.34	26.87	40.78	30.27	71.05	83.52	27.22	110.74
T_3	9.64	17.94	27.58	41.03	30.52	71.55	86.79	27.45	114.24
T_4	11.82	20.41	32.23	47.88	36.78	84.66	109.51	30.74	140.25
T_5	8.37	17.25	25.62	36.56	29.90	66.46	66.69	24.99	91.68
T_6	9.97	17.91	27.88	42.73	33.17	75.90	94.06	26.17	120.23
T_7	8.42	17.74	26.16	39.94	30.95	70.79	73.25	26.81	100.06
T_8	10.26	18.55	28.81	44.92	35.01	79.73	99.24	29.99	129.23
T_9	11.58	19.60	31.18	46.24	35.65	81.89	104.20	28.69	132.89
T_{10}	11.93	20.16	32.09	49.48	38.34	87.82	108.17	30.14	138.31
S.Ed.	0.457	0.452	0.552	1.840	1.274	1.874	6.610	0.948	6.827
C.D.at 5%	0.96	0.95	1.16	3.87	2.27	3.94	13.89	1.99	14.34

differ significantly with each other.

Treatment T_{10} was found to accumulate high K (87.82 kg ha^{-1}), closely followed by T_4 and was significantly superior to all other treatments in respect of total K uptake at tillering stage (Table 4.13). In this stage, the rhizomes removed higher proportion of K as compared to tops. Treatment T_{10} accumulated highest K in the rhizomes (49.48 kg ha^{-1}) and in the tops (38.34 kg ha^{-1}) and was significantly superior to all the treatments except T_4, which was at par with T_{10}. No significant differences were observed between treatments T_4, T_9, T_8; T_9, T_8, T_6; T_6, T_7, T_3, [illegible], T_2 and T_5 in both rhizomes and tops at tillering stage.

Treatment T_4 registered highest uptake (140.25 kg ha^{-1}) of K by the total plant at harvest stage which was found to be statistically similar with T_{10}, T_9 and T_8; while the treatment T_6 was comparable with T_9 and T_8, but was significantly lower than T_{10} and T_4. Almost similar trend was recorded in case of rhizomes and tops at harvest stage as in whole plant in which highest K uptake was again recorded in treatment T_4 (109.51 and 30.74 kg ha^{-1}, respectively), closely followed by T_{10}, T_8 and T_9. Untreated control (T_1) removed lowest quantity of K in the ginger plant at all growth stages and all other treatments were superior to T_1. Rhizomes accounted for 65.68, 75.42, 75.97, 78.08, 78.21 per cent of total K removed at harvest stage in treatments T_1, T_2, T_3, T_4 and T_{10}, respectively.

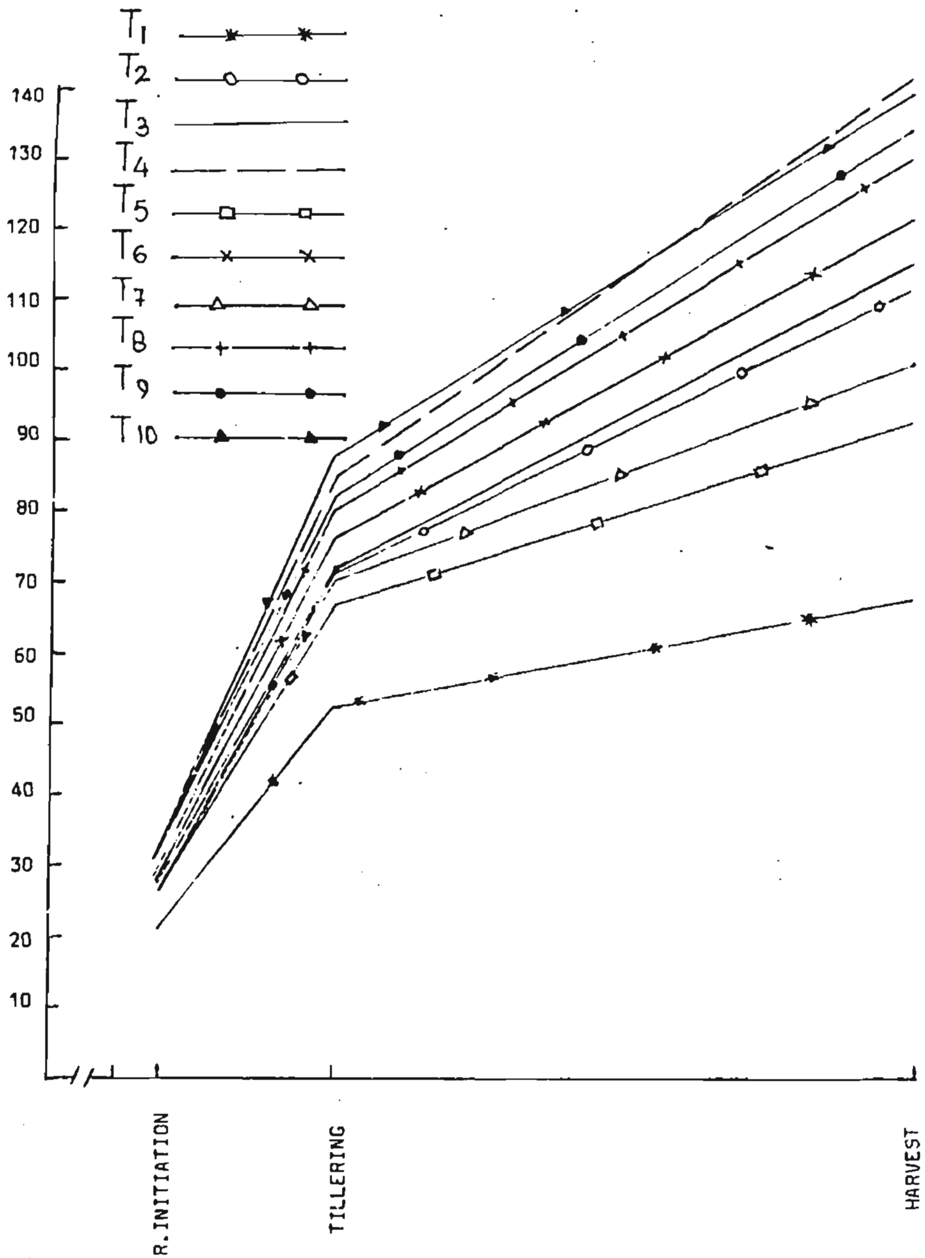

Fig.8. TOTAL K UPTAKE (kg ha^{-1})

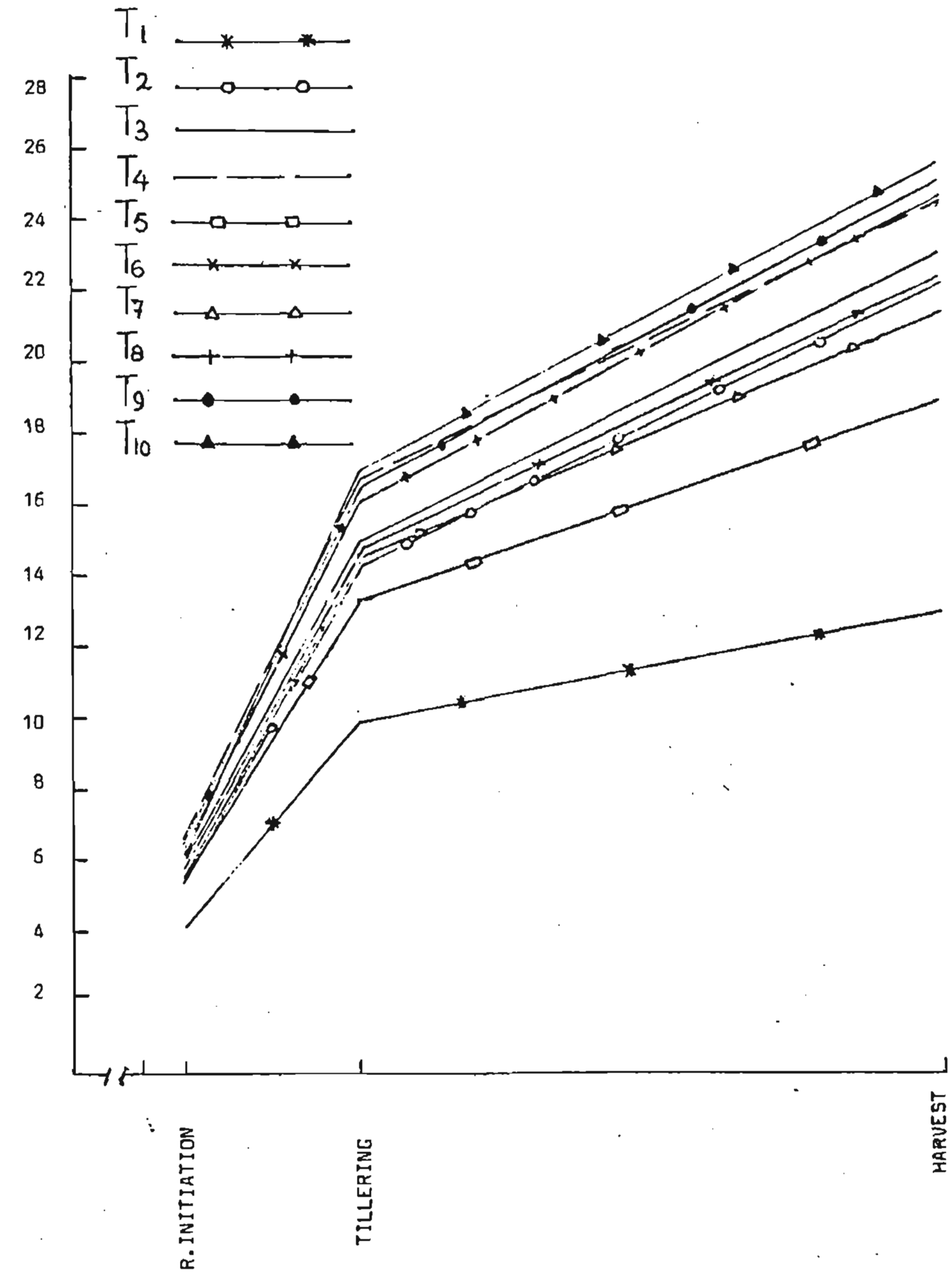

Fig.9. TOTAL Ca UPTAKE (kg ha^{-1})

4.3.2.4 Calcium uptake

Data on the uptake of Ca (kg ha^{-1}) by different plant parts, at different stages of growth, as influenced by various fertiliser treatments of the study, are summarised in Table 4.16. The total Ca uptake by ginger plant at different stages of growth has also been illustrated diagrammatically in Fig.9.

The data reveal a gradual increase in Ca accumulation in different plant parts commensurate with the advancement in growth. The Ca uptake by tops, rhizomes and total plant was significantly influenced by various fertiliser treatments over the control at all stages of growth. The tops removed a larger proportion of calcium as compared to rhizomes in all the treatments at all stages of growth.

Highest Ca uptake (kg ha^{-1}) by the plant as a whole and tops at rhizome initiation stage was recorded in treatment T_9 (6.62, 5.88 kg ha^{-1}, respectively), closely followed by T_4, T_8, T_{10} and T_3 and was statistically superior to rest of the treatments. The Ca removal by rhizomes at rhizome initiation stage was again found to be maximum in treatment T_9 (0.64 kg ha^{-1}), which was comparable with T_{10}, T_4, T_8 and statistically higher than rest of the treatments. T_1 registered lowest accumulation of Ca in the total plant (4.12 kg ha^{-1}), tops (3.82 kg ha^{-1}) and rhizomes (0.30 kg ha^{-1}).

Table 4.16 Calcium uptake (kg ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	0.30	3.82	4.12	1.78	8.16	9.94	3.23	9.75	12.98
T_2	0.55	5.32	5.87	3.28	10.95	14.23	7.03	15.21	22.24
T_3	0.57	5.57	6.14	3.32	11.61	14.93	7.55	15.48	23.03
T_4	0.60	5.67	6.27	3.56	13.16	16.72	8.19	16.33	24.52
T_5	0.42	5.03	5.45	2.89	10.42	13.31	4.99	13.87	18.86
T_6	0.54	5.10	5.64	3.19	11.58	14.77	7.22	15.18	22.40
T_7	0.50	5.32	5.82	3.18	11.34	14.52	5.96	15.42	21.38
T_8	0.60	5.62	6.22	3.44	12.66	16.10	7.99	16.60	24.59
T_9	0.64	5.98	6.62	3.43	12.96	16.39	8.76	16.55	25.31
T_{10}	0.62	5.58	6.20	3.62	13.25	16.87	8.55	17.06	25.61
S.Ed.	0.02	0.28	0.28	0.16	0.80	0.78	0.52	0.87	1.07
C.D.at 5%	0.049	0.58	0.58	0.346	1.678	1.646	1.089	1.831	2.24

At tillering stage, T_{10} recorded highest Ca accumulation (16.86 kg ha^{-1}) in the total plant and was at par with T_4, T_9 and T_8. Ca uptake by the tops was found to be maximum (16.87 kg ha^{-1}) in T_{10},which was statistically similar to T_4, T_7, T_8, T_3 and T_6, but superior to other treatments. In case of rhizomes, T_{10}, behaved statistically similar to T_4, T_8, T_9, T_3 and T_2, accounted for higher removal of Ca (3.62 kg ha^{-1}) than T_6, T_7 and T_5 at tillering stage.

Uptake of Ca by the total plant was found to be maximum in T_{10} (25.6 kg ha^{-1}), though statistically alike to T_9, T_4 and T_8 and superior to all other treatments at the final harvest stage. In the tops also, T_{10} removed significantly more Ca (17.06 kg ha^{-1}) than T_2, T_6 and T_5, but was statistically not different from T_8, T_9, T_4, T_3 and T_7. Rhizomes at the final harvest stage accumulated more Ca under T_9 (8.76 kg ha^{-1}), remaining at par with T_{10}, T_4, T_8 and significantly higher than rest of the treatments studied. Unfertilised control (T_1) accounted for lowest accumulation of Ca in both tops and rhizomes and all the fertiliser treatments were superior to it.

4.3.2.5 Magnesium uptake

Observations on the Mg uptake by the ginger plant at different stages of growth are given in Table 4.17 and illustrated graphically in Fig.10.

Table 4.17 Magnesium uptake (kg ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	0.31	1.48	1.79	1.39	3.12	4.51	2.48	2.84	5.32
T_2	0.57	1.92	2.49	2.41	4.00	6.41	4.88	3.78	8.66
T_3	0.60	1.86	2.46	2.62	4.26	6.88	5.73	4.11	9.84
T_4	0.62	2.05	2.67	2.79	4.63	7.42	6.67	4.50	11.17
T_5	0.45	1.86	2.31	2.21	3.63	5.84	4.04	3.50	7.54
T_6	0.61	2.27	2.88	2.88	4.84	7.72	6.74	4.48	11.22
T_7	0.47	2.01	2.48	2.39	3.85	6.24	4.32	3.75	8.07
T_8	0.55	2.00	2.55	2.58	4.35	6.93	5.96	4.07	10.03
T_9	0.71	2.47	3.18	3.08	5.00	8.08	7.28	4.87	12.15
T_{10}	0.65	2.08	2.73	3.03	4.52	7.55	7.00	4.36	11.36
S.Ed.	0.037	0.144	0.137	0.181	0.293	0.350	0.573	0.249	0.625
C.D.at 5%	0.077	0.302	0.287	0.380	0.616	0.736	1.204	0.523	1.313

An examination of the data in the Table 4.17 reveals that the Mg removal by the total plant and rhizomes increased with the advancement of growth, whereas there was a drop in the Mg accumulation after tillering stage in the tops under all the treatments. Mg accumulation in the tops was more than that of rhizomes upto tillering stage and, thereafter, rhizomes accounted for more Mg accumulation than tops in all the treatments excepting T_1.

Application of minor elements viz. Zn, Mg, B, Mo in combination with NPK (T_9) significantly influenced the Mg uptake by the total plant as compared to rest of the treatments at rhizome initiation stage. In case of tops also, T_9 though statistically similar to T_6, significantly increased the Mg uptake as compared to all other treatments studied. T_9, being statistically at par with T_{10}, accounted for significantly higher removal of Mg than rest of treatments in rhizomes at rhizome initiation stage. Lowest removal of Mg in the ginger plant (rhizomes and tops) was found in treatment T_1, where no fertiliser were applied.

At tillering stage also, T_9 accumulated highest Mg in the total plant, rhizomes and tops (8.08, 3.08, 5.00 kg ha^{-1}, respectively), however, was statistically at par with T_6, T_{10} and T_4, but significantly superior to rest of the treatments studied. Lowest uptake of Mg was again recorded in unfertilised control in the tops, rhizomes and total plant.

Similar pattern regarding Mg accumulation at final

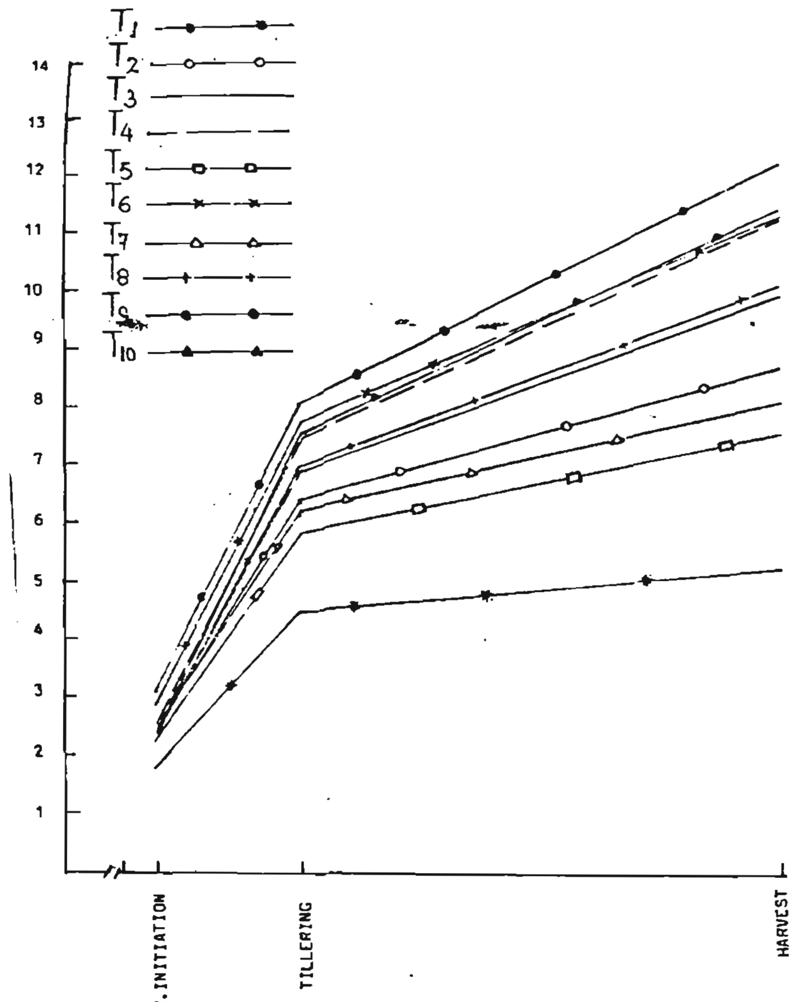

Fig.10. TOTAL Mg UPTAKE (kg ha^{-1})

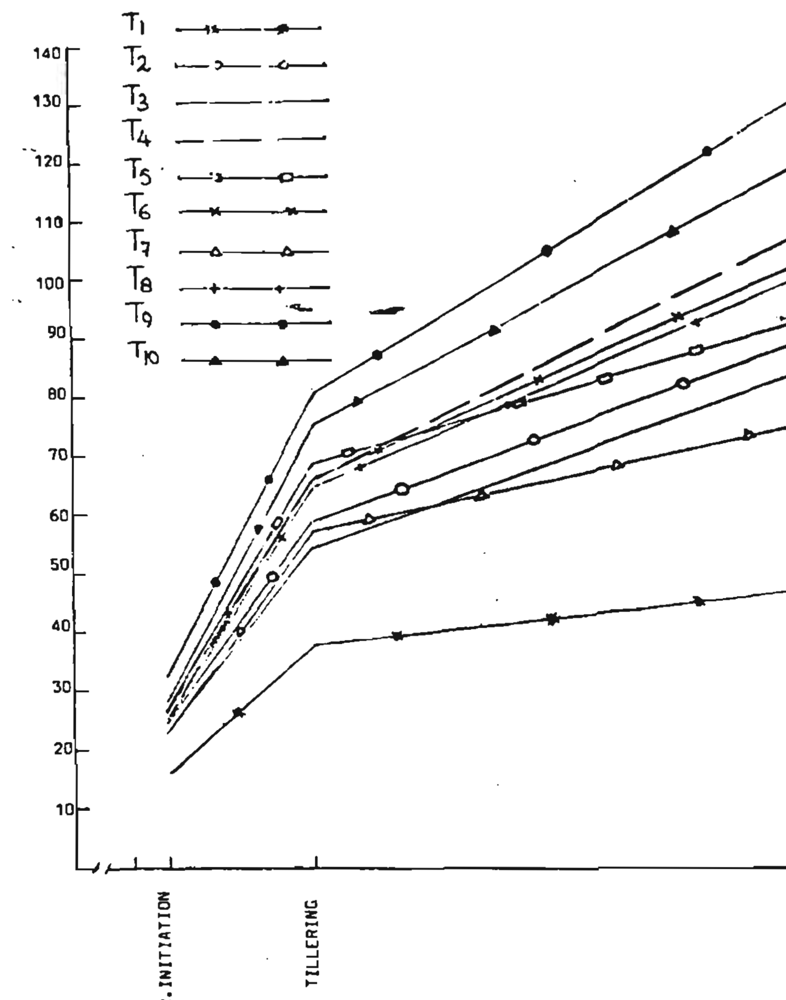

Fig.11. TOTAL Zn UPTAKE (g ha^{-1})

harvest stage by rhizomes, tops and total plant was recorded as found at tillering stage. Total plant, rhizomes and tops obtained from plots treated with NPK + ZN + Mg + B + Mo (T_9), being at par with T_{10}, T_4, T_6, removed highest Mg, while unfertilised control (T_1) being lowest. Rhizomes accounted for 46.62 per cent, 56.35 per cent, 58.23 per cent, 59.71 per cent, 59.92 per cent, 60.07 per cent, 61.62 per cent of the total Mg removed in treatments T_1, T_2, T_3, T_4, T_9, T_6 and T_{10}, respectively at final harvest stage.

4.3.2.6 Zinc uptake

The Zn uptake by different plant parts of different stages of growth as influenced by various treatments is presented in Table 4.18. Total zinc uptake by ginger plant at different stages of growth has been illustrated graphically in Fig.11.

An examination of the data (Table 4.18) reveals a gradual increase in the Zn uptake by whole plant and rhizome with the advancement in growth stage as affected by various treatments. Zn accumulation in the tops increased consistently upto tillering stage in all the treatments and thereafter, no definite trend was followed in the fertiliser treatments under study. The Zn accumulation in the whole plant, tops and rhizomes was significantly influenced with the application of fertilisers.

Table 4.18 Zinc uptake (g ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	3.62	12.09	15.71	14.58	23.41	37.99	26.24	21.10	47.34
T_2	7.21	16.99	24.70	29.93	29.32	59.25	60.91	28.71	89.62
T_3	7.71	16.33	23.04	26.08	28.41	54.49	55.06	29.01	84.07
T_4	8.03	18.48	26.51	33.16	33.55	66.71	74.17	33.07	107.24
T_5	7.28	19.69	26.97	36.50	32.66	69.16	62.09	31.42	93.51
T_6	7.40	18.42	25.82	33.55	33.15	66.70	69.05	33.78	102.83
T_7	6.34	16.59	22.93	28.47	29.05	57.52	47.01	28.75	75.76
T_8	6.38	17.99	24.37	32.11	32.85	64.96	67.40	33.02	100.42
T_9	10.56	22.24	32.80	40.27	40.66	80.93	89.35	41.68	131.03
T_{10}	9.28	18.67	27.95	39.05	36.65	75.70	80.91	38.92	119.83
S.Ed.	0.572	1.168	1.255	3.187	1.732	4.497	7.398	2.951	7.530
C.D.at 5%	1.20	2.45	2.64	6.70	3.64	9.45	15.54	6.20	15.82

A perusal of the data in the Table 4.18 reveals that the tops removed a higher proportion of Zn than the rhizomes at the rhizome initiation stage in all the treatments studied. Application of minor nutrient elements viz. Zn, B, Mo, Mg in combination with NPK (T_9) had a significant positive affect on the Zn uptake by the whole plant, tops and rhizomes as compared to other fertiliser treatments at rhizome initiation stage. Lowest accumulation of Zn in the whole plant, tops and rhizomes was found in case of treatment T_1 and all other treatments were superior to it.

Treatment T_9 (80.92 g ha^{-1}), though being statistically at par with T_{10} and superior to rest of the treatments, accounted for the highest removal of Zn (80.93 g ha^{-1}) in the whole plant at tillering stage. The tops removed higher Zn than rhizomes except in case of treatments T_2, T_6 and T_{10} at tillering stage. The Zn accumulation in the rhizomes of tillering stage was highest in T_9, closely followed by T_{10} and T_5; but superior to rest of the treatments studied. In case of tops also, treatment T_9 significantly affected the Zn uptake. Lowest Zn removal by whole plant, tops and rhizomes was observed in treatment T_1 and all other fertiliser treatments were superior to it.

At the harvest stage also, T_9, behaving statistically similar to T_{10}, accumulated highest Zn in the whole plant (131.03 g ha^{-1}) and tops (41.68 g ha^{-1}). Rhizomes recovered from T_9 removed maximum Zn, but was statistically at par with T_{10} and T_4. Treatment T_1 accounted for lowest Zn removal by whole plant, rhizomes and tops at the harvest stage and all the other fertiliser treatments removed a significantly higher amount of Zn than it. Rhizomes at the final harvest stage accounted for 55.43 per cent, 67.96 per cent, 65.49 per cent, 69.16 per cent, 66.39 per cent, 68.19 per cent, 67.52 per cent of the total Zn removal in case of treatments T_1, T_2, T_3, T_4, T_5, T_9 and T_{10}.

4.3.2.7 Boron uptake

The data pertaining to B uptake, by different plant parts, at different stages of growth, as influenced by various fertiliser treatments are summarised in the Table 4.19. Total removal of B by ginger plant at different stages of growth has been illustrated graphically in Fig. 12.

B uptake by tops reached maximum at tillering stage and then declined (Table 4.19). Contrary to tops, B uptake by rhizomes and total plant continued to increase upto harvest. The B distribution trend in different plant parts at rhizome initiation and tillering stage showed that tops accumulated higher proportion of total B removed than rhizomes. At the harvest stage, reverse trend was followed in all the treatments.

A perusal of the data reveals that highest uptake of

Table 4.19 Boron uptake (g ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	3.01	14.08	17.09	16.50	22.11	38.61	23.54	21.10	44.64
T_2	5.00	16.82	21.82	25.08	26.46	51.54	45.10	25.86	70.96
T_3	5.35	18.50	23.85	26.46	28.38	54.84	46.31	26.91	73.22
T_4	5.87	18.43	24.30	31.01	32.54	63.55	53.69	30.47	84.16
T_5	4.11	17.63	21.74	22.27	26.92	49.19	31.79	25.88	57.67
T_6	4.99	17.45	22.44	25.90	32.03	57.93	49.68	30.17	79.85
T_7	4.47	19.68	24.15	26.67	34.99	61.66	38.83	34.66	73.49
T_8	5.13	18.99	24.12	27.08	33.86	60.94	50.88	31.28	82.16
T_9	6.30	19.91	26.21	30.36	35.80	66.16	56.93	33.48	90.41
T_{10}	6.03	18.52	24.55	30.24	36.15	66.39	56.90	35.78	92.78
S.Ed.	0.427	1.732	0.898	2.400	1.280	1.730	5.143	2.319	6.218
C.D.at 5%	0.90	3.64	1.89	5.04	2.68	3.63	10.81	4.87	13.06

B (26.21 g ha^{-1}) at rhizome initiation stage by the tops, rhizomes and whole plant was observed in the plots treated with minor elements viz. Zn, B, Mo, Mg in combination with NPK (T_9), superior in case of whole plant and was at par with all treatments excepting unfertilised control (T_1) in case of tops, in respect of B accumumulation. No significant differences in respect of B accumulation by rhizomes at rhizome initiation stage were observed between T_9, T_{10}, T_4 and all these treatments were significantly superior to rest of the treatments. Lowest B accumulation in tops, rhizomes and whole plant at rhizome initiation stage was found in case of unfertilised plots (T_1) and other treatments were superior to T_1.

At tillering stage, T_{10} register ed highest uptake of B in the whole plant (66.39 g ha^{-1}) and tops, though being statistically at par with T_9 and T_4, in the former and T_9, T_7, T_8 in the latter case and was superior to rest of the treatments. The rhizomes obtained from plots fertilised with NPK (T_4) behaving staistically similar to T_9, T_{10}, T_8, T_7, T_3, accumulated highest B (31.01 g ha^{-1}) as compared to T_6, T_2, T_5 and T_1. B removal by whole plant, tops and rhizomes at tillering stage was found to be lowest in T_1 and all the remaining treatments were statistically superior to it.

T_{10}, remaining statistically alike with T_9, T_4, T_8 and T_6, accumulated significantly higher B (92.67 g ha^{-1}) in ginger plant at harvest stage than remaining treatments.

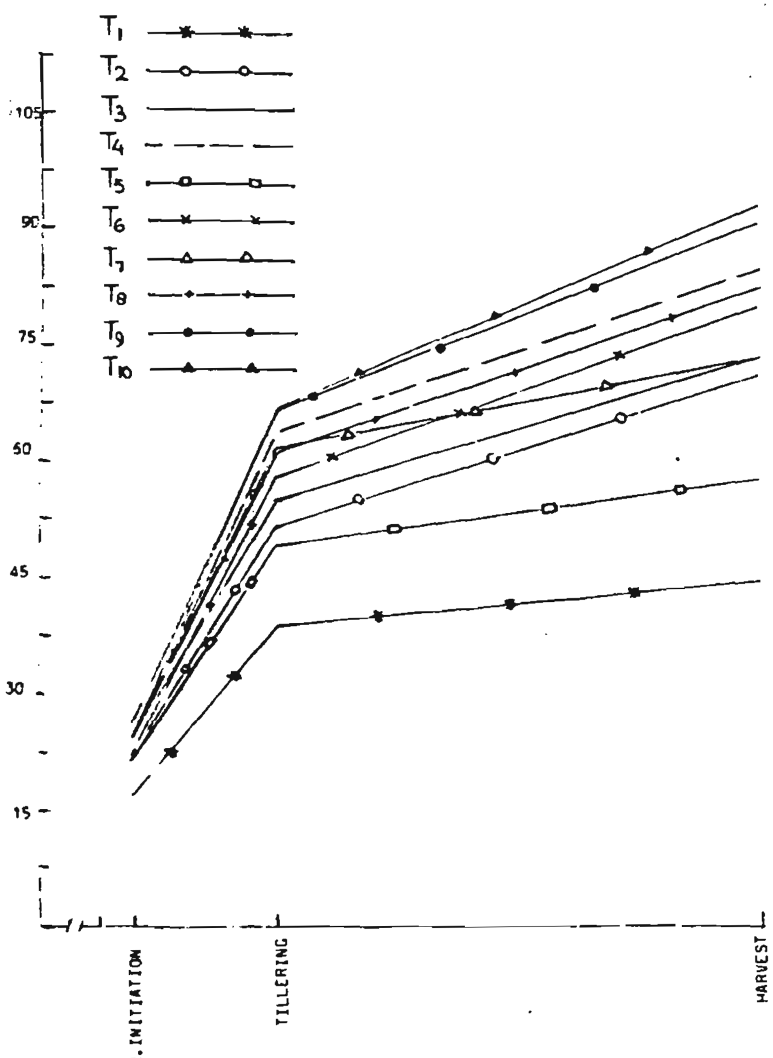

Fig.12 TOTAL B UPTAKE (g ha^{-1})

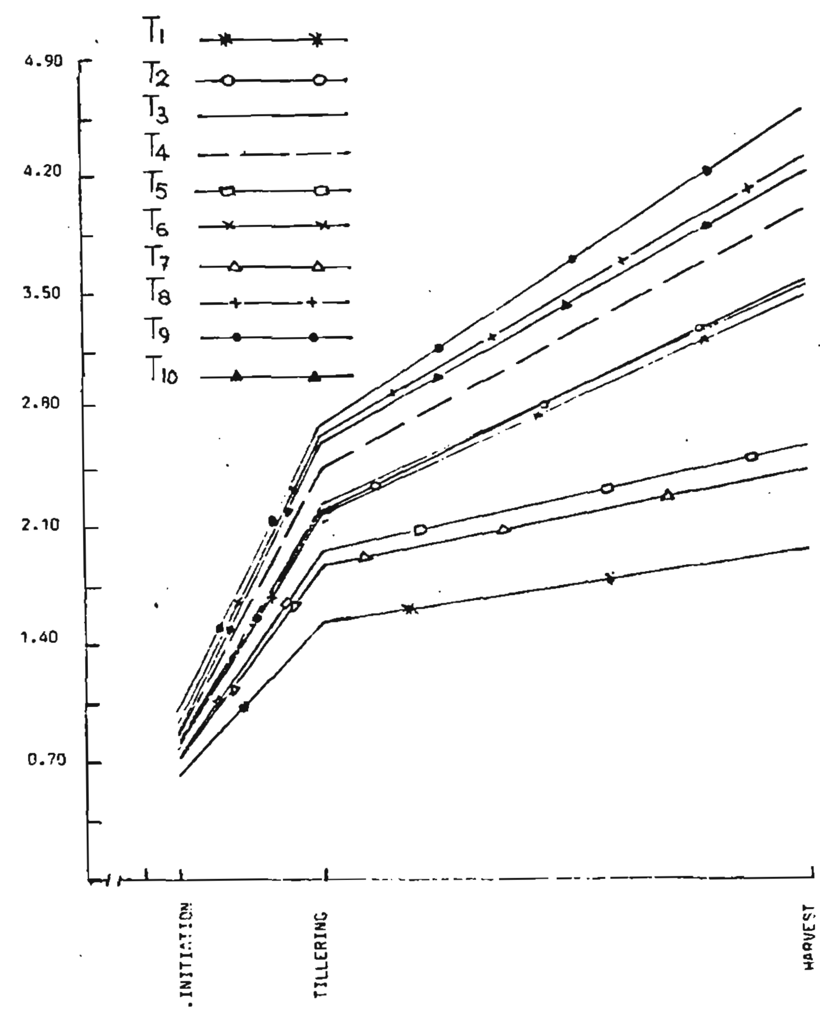

Fig.13. TOTAL Mo UPTAKE (g ha^{-1})

Lowest B uptake at harvest stage by the ginger plant was recorded in treatment T_1, which was statistically not different from T_5. In case of tops, maximum removal of B was found to be in treatment T_{10}, which was statistically similar to T_{10}, T_7, T_9 and T_8. Lowest B removal in the tops was found in T_1, which was at par with T_2 and T_5 at the harvest stage. The uptake of B by the rhizomes was found to be highest in treatment T_9 (56.93 g ha^{-1}), which was statistically at par with T_{10}, T_4, T_8, T_6 and T_3. T_1 accounted for lowest B removal by the rhizomes at the harvest stage and was statistically at par with treatment T_5.

4.3.2.8 Molybdenum uptake

The effect of various fertiliser treatments on the uptake of Mo by different plant parts at different stages of growth of ginger has been shown in the Table 4.20. Total Mo uptake at different stages of growth by ginger was also been depicted graphically in Fig.13.

An inquisition of the data reveals a gradual increase in the Mo uptake by rhizomes and whole plant with the advancement of growth stage. Whereas in tops, Mo accumulation was found to be maximum at tillering stage and afterwards, there was a slight drop in Mo accumulation in all the treatments studied. The rhizomes accumulated a higher proportion of Mo after rhizome initiation stage than the tops in all the fertiliser treatments studied.

Table 4.20 Molybdenum uptake (g ha^{-1}) by different plant parts of ginger at different stages of growth

Treatments	STAGES								
	Rhizome initiation			Tillering			Harvest		
	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
T_1	0.165	0.465	0.630	0.782	0.756	1.538	1.325	0.650	1.975
T_2	0.276	0.553	0.829	1.246	0.967	2.213	2.649	0.948	3.597
T_3	0.267	0.549	0.816	1.242	1.002	2.244	2.554	1.001	3.555
T_4	0.289	0.579	0.868	1.382	1.072	2.454	3.023	0.990	4.013
T_5	0.213	0.520	0.733	1.063	0.901	1.964	1.734	0.856	2.590
T_6	0.263	0.543	0.806	1.222	0.960	2.182	2.574	0.926	3.500
T_7	0.203	0.520	0.723	0.967	0.900	1.867	1.703	0.767	2.470
T_8	0.329	0.594	0.923	1.496	1.155	2.651	3.182	1.130	4.312
T_9	0.385	0.638	1.023	1.522	1.191	2.713	3.443	1.161	4.604
T_{10}	0.299	0.579	0.878	1.459	1.151	2.610	3.424	1.153	4.577
S.Ed.	0.037	0.057	0.057	0.143	0.087	0.177	0.334	0.109	0.335
C.D.at 5%	0.077	NS	0.119	0.299	0.183	0.373	0.702	0.229	0.704

Treatment T_9, behaving statistically similar to T_8, was found to be significantly best in respect of Mo uptake by whole plant (1.023 g ha^{-1}) and rhizomes (0.385 g ha^{-1}) at rhizome initiation stage. Lowest uptake of Mo by whole plant and rhizomes at rhizome initiation stage was recorded in T_1, which was statistically at par with T_5 and T_7, and all other treatments were superior to it. Fertiliser treatments failed to affect the Mo uptake by the tops at rhizome initiation stage. However, highest and lowest uptake of Mo tops at rhizome initiation stage was recorded in T_9 and T_1, respectively.

At tillering stage, treatment T_9 statistically comparable with T_8, T_{10} and T_4 registered significantly higher Mo accumulation as compared to rest of the treatments studied in the whole plant (2.713 g ha^{-1}) and tops (1.191 g ha^{-1}). In case of rhizomes at tillering stage, T_9 being statistically at par with T_8, T_{10}, T_4, T_2 and T_3, removed significantly higher amount of Mo than rest of the treatments. Lowest removal of Mo was recorded in T_1 which was statistically at par with T_5, T_7 in case of rhizomes and tops and with T_7 in case of whole plant at tillering stage.

At harvest stage also, T_9 removed highest amount of Mo in the whole plant (4.605 g ha^{-1}), rhizomes (3.443 g ha^{-1}) and tops (1.161 g ha^{-1}); though statistically at par with T_{10}, T_8, T_4 in case of former two and with T_{10},

T_8, T_4, T_3 and T_2 in the latter case. Treatment T_1 accumulated lowest amount of Mo in rhizomes, tops and in the whole plant; however, statistically similar to T_5, T_7 in all the three cases at the harvest stage. Out of the total Mo removed by the whole plant, rhizomes contained 67.09 per cent, 73.64 per cent, 71.84 per cent, 75.33 per cent, 73.79 per cent, 74.78 per cent, 74.81 per cent of Mo accumulation in case of treatments T_1, T_2, T_3, T_4, T_8, T_9, T_{10} at the end of the season.

4.3.3 Soil chemical studies

Data on available nutrients content have been summarised in Table 4.21 with their corresponding analysis of variance appended in Appendix-F.

4.3.3.1 Available nitrogen

A reference to the data in Table 4.21 indicates that T_9 (NPK+Zn+Mg+Mo) behaving statistically similar to T_5, T_6, T_4, T_{10}, T_2, significantly increased the available nitrogen (residual) status of soil over T_8, T_7, T_3, T_1, which were statistically comparable with each other, while the former three treatments being again statistically at par with T_{10}, T_2, T_4 and T_6. Application of N, NP, NPK, NPK+Zn, NPK+Mg, NPK+B, NPK+Mo, NPK+B+Zn+Mg+Mo, NPK+Jagromin accounted for 8.63 per cent, 5.04 per cent, 9.35 per cent, 12.59 per cent, 11.15 per cent, 5.4 per cent, 6.11 per cent, 13.67 per cent, 8.99 per cent increase in available N status of soil over control, respectively.

4.3.3.2 Available phosphorus

An examination of the data in Table 4.21 reveals that the application of N (T_2) and NPK+Zn (T_5) significantly decreased the available P status of the soil as compared to T_{10}, T_4, T_8, T_6 and comparable with T_9, T_3, T_7 and T_1; while all the former and latter treatments were at par with each other. Application of NPK accompanied with Two foliar sprays of Jayromin (T_{10}) accounted for highest available P in the soil. The decrease in available P of soil with application of NPK+Zn (T_5) over T_1, T_2, T_3 and T_4 was 4.93 per cent, 1.07 per cent, 7.41 per cent, 12.86 per cent, respectively.

4.3.3.3 Available potassium

Application of NPK (T_4), statistically indistinguishable from T_{10}, T_5, T_9, T_7 and T_6, significantly increased available potassium status of soil over rest of the treatments. Lowest available potassium in soil was recorded in case of unfertilised control (T_1), which was statistically at par with T_3, T_8, T_2 and T_6 (Table 4.21). An increase of 2.42 per cent, 1.03 per cent and 7.61 per cent in available K was recorded with the application of N, NP and NPK, respectively over control.

4.3.3.4 Available calcium

It is evident from the data in Table 4.21 that the available calcium status of soil after harvest was increased

Table 4.21 Effect of various treatments on the available N, P, K, Ca, Mg, Zn, B and Mo in the surface soil (0-15 cm) after harvest

Treatments	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Available calcium (ppm)	Available magnesium (ppm)	Available zinc (ppm)	Available Boron (ppm)	Available Molybdenum (ppm)
T_1	290.60	46.99	335.82	1027.00	643.80	1.273	1.123	0.190
T_2	315.69	45.26	343.95	1085.50	638.70	1.480	1.103	0.208
T_3	305.24	48.10	339.30	1079.00	636.50	1.227	1.133	0.198
T_4	317.78	50.54	361.38	1072.50	602.60	1.347	1.077	0.246
T_5	327.19	44.78	359.06	1033.50	629.90	1.927	1.007	0.202
T_6	323.01	49.68	349.76	1001.00	669.40	1.313	1.040	0.211
T_7	306.28	47.46	353.25	1007.50	655.50	1.333	1.263	0.238
T_8	308.37	50.27	340.46	1001.00	649.60	1.433	1.093	0.289
T_9	330.33	48.57	355.57	1027.00	653.80	1.793	1.207	0.278
T_{10}	316.73	50.82	360.22	1059.50	614.40	1.367	1.083	0.244
S.Ed.	8.48	1.92	8.11	26.52	12.98	0.061	0.054	0.015
C.D.at 5%	17.81	4.03	17.04	55.72	27.27	0.129	0.113	0.032

with the application of N (T_2), closely followed by T_3, T_4, T_{10} and T_5 which were at par with T_1 and T_9. The availability of Ca was found to be lowest with the application of NPK+Mg (T_6), being at par with T_7, T_8, T_{10}, T_1 and T_5, the former one again at par with T_{10}. Application of N, NP and NPK accounted for 5.69 per cent, 5.06 per cent, 4.43 per cent increase in the available Ca status of soil over the control.

4.3.3.5 Available magnesium

Observations on the available Mg status of the soil as affected by various fertiliser treatments are presented in the Table 4.21. Application of NPK+Mg (T_6) accounted for the highest availability of Mg in the surface soil. Available Mg was found to be lowest with the application of NPK (T_4), followed by T_{10}. No appreciable differences were observed among treatment T_7, T_9, T_8, T_1, T_2, T_3 and T_5, the former four being statistically at par with T_6 and the latter three with T_{10}. With the application of NPK+Mg (T_6), an increase of 3.97 per cent, 4.80 per cent, 5.17 per cent and 11.08 per cent in available Mg status of the soil was observed over T_1, T_2, T_3 and T_4, respectively.

4.3.3.6 Available zinc

Application of zinc significantly increased the available zinc status of the soil (Table 4.21). Treatment T_5 (NPK+Zn) accounted for the maximum available zinc in the soil and was superior to the rest of the treatments. Treatment T_9 was also superior to all the treatments except T_5. Lowest availability of zinc in the soil was observed with the application of NP (T_3), closely followed by T_1, T_6, T_7 and T_4. A decrease of 3.61 per cent over control was observed with the application of NP in the available Zn status of the soil. T_5 accounted for 43.06 per cent increase in zn status of soil as compared to T_4.

4.3.3.7 Available Boron

A reference to the data in Table 4.21 indicates that the application of B in combination of NPK (T_7), followed by T_9, significantly increased the boron status of the soil as compared to all other treatments. This increase was 17.27 per cent, 21.47 per cent, 14.51 per cent of 11.08 per cent over T_4, T_3, T_2 and T_1, respectively. Application of NPK+Zn (T_5), though at par with T_6, T_4, T_{10}, T_8, T_2, accounted for lowest availability of Zn in surface soil at harvest time.

4.3.3.8 Available Molybdenum

Treatment T_8 (NPK+Mo), while remaining at par with T_9 ,accounted for significantly higher availability of Mo in soil than rest of the treatments (Table 4.21). An increase of 17.48 per cent, 45.96 per cent, 38.94 per cent, 52.1 per cent, 3.95 per cent was observed in the available Mo with the application of NPK+Mo (T_8) over T_4, T_3, T_2, T_1 and T_9, respectively. Lowest availability of Mo was recorded in unfertilised control (T_1), closely followed by T_3, T_5, T_2, T_6. No significant differences were observed among treatments T_4, T_{10} and T_7, the latter one again at par with T_6 and T_2.

4.4 CORRELATION STUDIES AND ECONOMIC ANALYSIS

4.4.1 Correlation studies

The yield of a crop is affected considerably by plant characters. A knowledge of inter-relationship, if any, that may exist between different characters provides the explanation for the type of effect produced by a treatment on the ultimate yield. Accordingly, the correlation studies were carried out among the following characters.

1) Pseudo-stem length (cm)
2) Number of tillers plant^{-1}
3) Number of leaves plant^{-1}
4) Leaf area (cm^2)
5) Rhizome length (cm)
6) Rhizome breadth (cm)
7) Yield plant^{-1} (g)
8) Yield ha^{-1} (q)

Simple correlations between all possible combinations of the eight characters listed above were worked out and the same are presented in Table 4.22.

The correlation coefficient's (r) between rhizome yield ha^{-1} (q) and various growth and yield contributing characters viz. yield plant^{-1} (g), pseudo-stem length (cm), number of tillers plant^{-1}, number of leaves plant^{-1}, rhizome

Table 4.22 Correlation coefficients

	Rhizome yield ha^{-1}	Yield $plant^{-1}$	Pseudo-stem length	Leaf area	Number of tillers $plant^{-1}$	Number of leaves $plant^{-1}$	Rhizome length	Rhizome breadth
Rhizome yield ha^{-1}	-	0.98**	0.89**	0.87**	0.99**	0.97**	0.94**	0.92**
Yield $plant^{-1}$		-	0.82**	0.83**	0.98**	0.99**	0.89**	0.89**
Pseudo stem length			-	0.85**	0.91**	0.78**	0.97**	0.89**
Leaf area				-	0.85**	0.80**	0.91**	0.87**
Number of tillers $plant^{-1}$					-	0.95**	0.94**	0.89**
Number of leaves $plant^{-1}$						-	0.86**	0.87**
Rhizome length							-	0.89**
Rhizome breadth								-

** Significant at 1 per cent level of significance length and rhizome breadth were found to be 0.98, 0.89, 0.99, 0.97, 0.87, 0.94 and 0.92, respectively which were highly significant. Similarly, yield plant^{-1} was highly correlated with pseudo-stem length (r=0.82), number of tillers plant^{-1}, (r=0.98), number of leaves plant^{-1} (r=0.99), rhizome length (r=0.89) and rhizome breadth (r=0.89). Number of tillers plant^{-1}, number of leaves plant^{-1}, leaf area, rhizome length, rhizome breadth and pseudo-stem length were also highly correlated with each other.

4.4.2 Economic analysis

Gross and net income (Rs ha^{-1}), as affected by various treatments of this study are given in Table 4.23, depicted graphically in Fig.14 and their corresponding analysis of variance have been given in Appendix-C. The details of cost of cultivation under each treatment have been given in Appendix-G.

Highest gross and net incomes were obtained with the application of Jagromin in combination with NPK (T_{10}), though being at par with T_4 and T_9. Lowest gross income was observed in case of control (T_1), which was statistically comparable with T_5. As expected, the lowest net income was recorded in control (T_1), which was statistically at par with T_5 and T_7. No significant differences were observed between treatments T_3, T_8, T_6 and T_2. Treatment T_9 was found to be statistically at par with T_4 and T_3, in which

Table 4.23 Gross and net income (Rs ha^{-1}) as affected by various treatments

Treatments	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	Net returns per Re investment
T_1	34986.11	2706.69	1.08
T_2	54026.11	20587.19	1.61
T_3	56986.11	23030.91	1.68
T_4	64472.21	30409.76	1.89
T_5	39493.07	5317.18	1.16
T_6	54923.61	20675.06	1.61
T_7	42395.33	8127.13	1.24
T_8	56374.99	21328.72	1.61
T_9	63937.50	28535.45	1.81
T_{10}	66763.90	32240.54	1.95
S.Ed.	3340.50	3354.30	-
C.D.at 5%	7018.39	7047.38	-

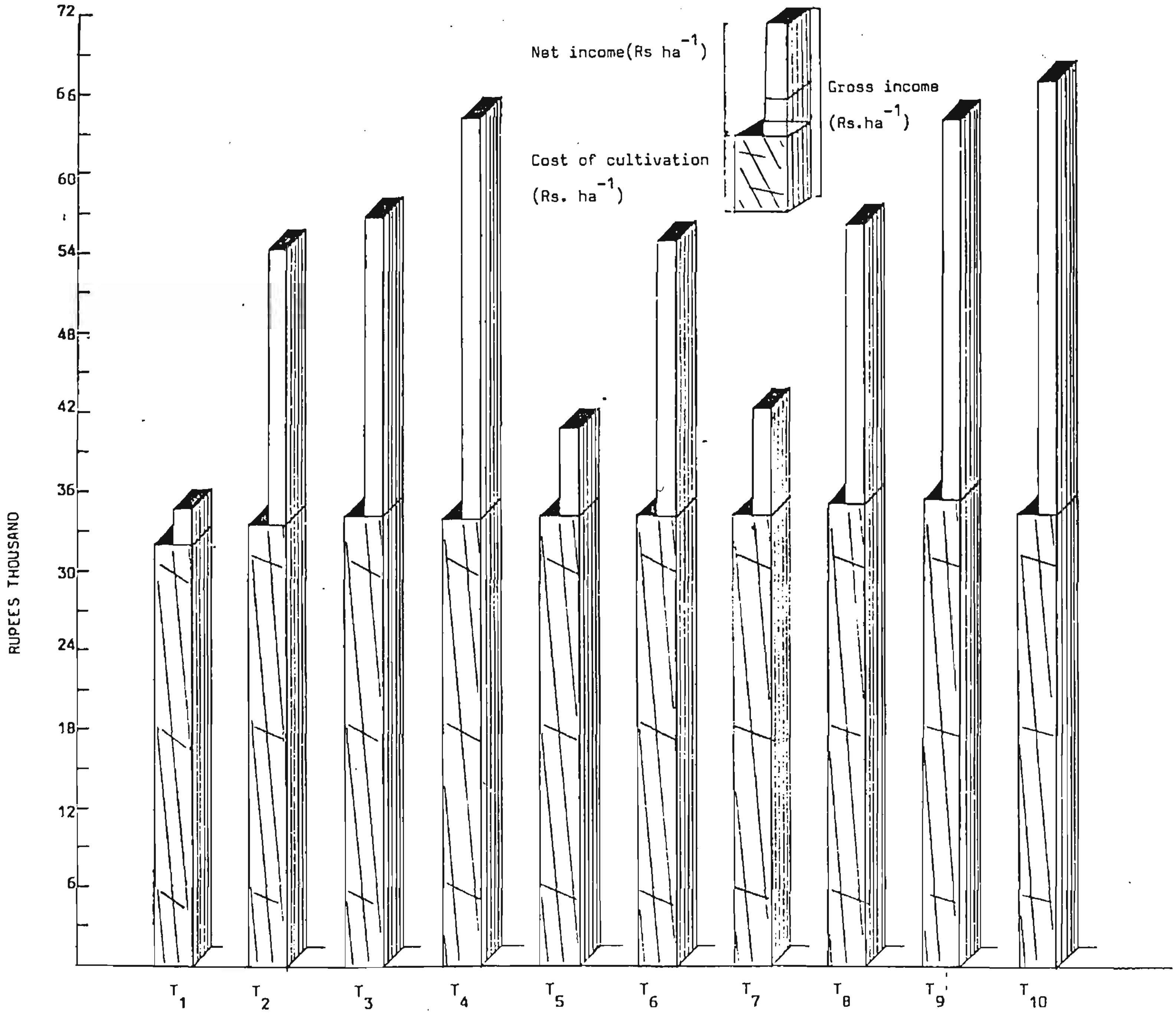

Fig.14 GROSS AND NET INCOME (Rs ha^{-1})

the former one being statistically superior to the latter one in respect of gross and net returns.

Net returns per Re investment were found to be highest in case of treatment T_{10} (1.95), followed by T_4 (1.89) and T_9 (1.81). Lowest net returns per Re investment were recorded in case of control (T_1).

CHAPTER – V

DISCUSSION

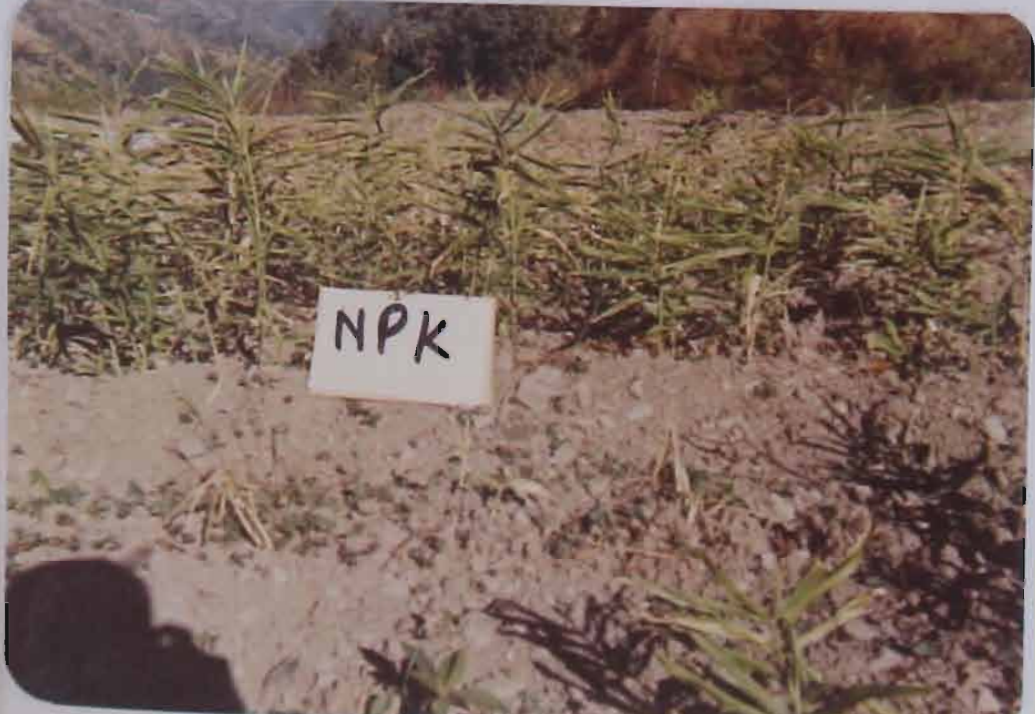

PLATE II

5. DISCUSSION

The results obtained from the present field investigation entitled "Nutritional studies on ginger (Zingiber officinale Rosc.)", conducted during Kharif, 1989 to assess the effects of NPK with micro-elements (Zn, B, Mo and Mg) on the growth (pseudo-stem length (cm), number of tillers per plant, number of leaves per plant, leaf area (cm^2), development (dry matter accumulation), yield contributing attributes (rhizome length, rhizome breadth and yield $plant^{-1}$), yield and quality (oleoresin, oil and crude fibre contents) of ginger in addition to its effect on the soil chemical properties have been described in the preceding chapter. An attempt has been made in this chapter to interpret the important observations recorded during this study on scientific basis to establish cause and effect relationship in the light of available evidences. The photographs of the ginger crop treatment wise are shown in Plates I to IV.

5.1 Effect of treatments on crop growth and yield

The rhizome yield of ginger crop being the resultant of the rate and duration of rhizome bulking is related primarily to the time of rhizome initiation and persistence of tops (foliage). Each management practice influences yield by relative effect of all treatments usually explain yield differences detected in field trials.

Plates I to IV. Treatmentwise photographs of ginger at an advanced stage of growth

General View

PLATE I

The application of NPK @ 100:50:50 kg ha^{-1} followed by two sprays of Jagromin-99 (T_{10}) produced the highest ginger rhizome yield than rest of the treatments excepting T_4 and T_9 with which it was at par (Table 4.2). Jagromin containing various micro-nutrient elements in chelated form (providing maximum absorption) along with the major NPK nutrients (T_{10}) resulted in higher pseudo-stem length, number of leaves $plant^{-1}$, number of tillers $plant^{-1}$ and rhizome length (Table 4.1 and 4.2) owing to better nutrition of the crop which were reflected in higher uptakes of N, P, Ca and B (Tables 4.13, 4.14, 4.16, 4.19). Wallace and Wallace (1983) and Alexander and Schroeder (1987) also reported the beneficial effects of the application of micro-nutrients through chelated form because of their easy penetration, less scrotching and improved translocation in the crop plants as compared to inorganic forms.

Dry matter accumulation by ginger plants, which to a large extent is a function of plant density per unit area was significantly influenced by various treatments of this investigation. The dry matter of ginger tops and rhizomes increased upto harvest stage. Among various treatments T_{10} (NPK+Jagromin) produced highest dry matter through tops and rhizomes at tillering and harvest stages, however, remaining at par with T_9 and T_4 in case of former stage and with T_9, T_4 and T_8 in the latter stage (Table 4.3). Better promotion of the growth factors of ginger plant in these treatments (T_{10}, T_4 and T_9) favourably reflected

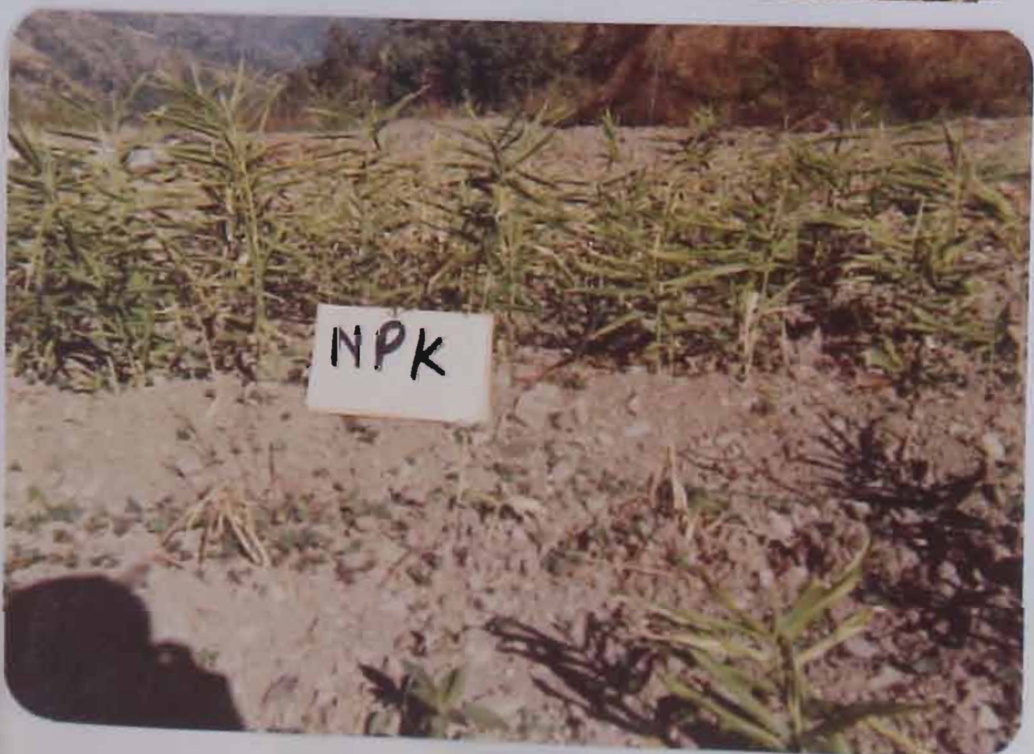

PLATE II

in the plant photosynthetic surface viz. pseudo-stem length, number of tillers plant^{-1}, number of leaves plant^{-1} and thus might have attributed towards higher dry matter production by ginger plant and its accumulation in the sink (rhizome). Similar results were obtained by Randhawa and Nandpuri (1969) and Kingra and Gupta (1977). Neopaney (1988), while working under the similar conditions of Himachal Pradesh, also reported that the application of NPK @ 150:60:40 kg ha^{-1} increased plant height, number of leaves plant^{-1} and yield ha^{-1}.

The rhizome yield in ginger is a function of rhizome size (length and breadth) and yield plant^{-1}. The maximum rhizome length and yield plant^{-1} were recorded in T_{10}, followed by T_4 and T_9 which were at par with each other. Whereas, maximum rhizome breadth was found in T_4 followed by T_9, T_{10} and T_8. The differences in the related treatments were, however, non-significant). Thus, the superiority of these treatments (T_{10}, T_4 and T_9) over rest of the treatments was reflected in the final rhizome yield due to cumulative effects of better nutrition on the yield contributing characters. These results are in conformity to the findings of Neopaney (1988).

The leaf area was significantly influenced by the combined application of NPK in conjunction with minor elements viz. Zn, Mg, B and Mo (T_9) over rest of the treatments (Table 4.1). It was found that under the conditions of this investigation ginger rhizome yield per unit area (q ha^{-1}) was also found to be positively correlated with pseudo-stem length (r=0.89), number of tillers $plant^{-1}$ (r=0.99), number of leaves $plant^{-1}$ (r=0.97), leaf area (r=0.87), rhizome length (r=0.94) and rhizome breadth (r=0.92), respectively, which were highly significant. The correlation coefficients among different parameters were also highly positively significant (Table 4.22). Similar results were obtained by Marwaha (1984) and Rattan et al.(1988).

The individual application of Zn or Mg or B or Mo with NPK through soil, however, significantly decreased leaf area, rhizome length and rhizome yield ha^{-1} over NPK application alone (Tables 4.1 and 4.2). It may be due to poor growth as evident from the dry matter yield through tops and rhizomes at rhizome initiation stage (Table 4.3). The yield $plant^{-1}$ was also significantly decreased with the application of Zn or B with NPK. Rhizome length, number of leaves per plant, pseudo-stem length and number of tillers $plant^{-1}$ significantly decreased with the application of every minor element in combination with NPK. Various workers like Sreedharan and George (1969), Dang et al.(1990) and Roberts and Rhee (1990) have reported reduction in yield of crops like paddy, onion and potato due to application of micro-nutrients through their higher concentration/accumulation and interference with other elements in the plant metabolism and toxicity.

PLATE
IV

5.2 Ginger quality and disease incidence

The quality of ginger is decided by high oleoresin and oil and low crude fibre content and disease free rhizomes. The ginger oil content was not significantly affected by various treatments. However, T_6 (NPK+Mg) and T_9 (NPK+Zn+Mg+B+Mo) produced rhizomes with highest oil content. Nitrogen application (T_2) lowered the oil content as compared to control (T_1) (Table 4.4). Saraswat (1972) also reported that the ginger oil content was adversely affected by N applications. Application of B, Mg or Zn with NPK (T_7, T_6 or T_5) significantly increased the oleoresin content as compared to NPK (T_4). Application of Mo (T_8) also increased the oleoresin content as compared to NPK (T_4), though non-significantly. It was found that the K application improved the oleoresin and oil contents of ginger rhizomes (Table 4.4). The crude fibre content was found to be highest in the rhizomes obtained from plots treated with N (T_2), closely followed by T_1, T_4, T_{10}, T_8, T_3 and T_5 (Table 4.4). Neopaney (1988) reported highest crude fibre content in ginger rhizomes when 100 kg N was applied in combination with 40 kg P_2O_5 and 20 kg K_2O ha^{-1}.

None of the treatments could significantly influence the incidence of rhizome rot. However, it ranged from 14.06 to 26.03 per cent in general.

5.3 Nutrient content and uptake

The concentrations of N, P, K, Zn and Mo both in ginger tops and rhizomes and of B in tops and Mg in the rhizomes, in general, decreased with the advancement of growth stage. Whereas, the Ca content both in tops and rhizomes, B in rhizomes and Mg content in tops increased upto tillering stage and, thereafter, a decline was observed. The ultimate decrease in nutrient concentration with the advancement in age of the plant may be due to the dilution effect caused by more dry matter accumulation (Smith,1962; Sharma et al.,1978; Sharma and Verma,1988). Tops in general, contained higher N, P, K, Ca, Mg, Zn, B and Mo contents than rhizomes at all stages of growth (Tables 4.5 to 4.12). Application of Mo, Zn or Mg individually in combination with NPK increased the N content in tops and rhizomes as compared to NPK at all stages of growth, though the increase was not significant in most cases. The results are in line with Mondy and Munshi (1988), Klein et al.(1982) in case of potato and Medhi (1987) in cauliflower. It was found that the B application in combination with NPK (T_7) reduced the N content as compared to NPK (T_4). With the application of B, the N content in cauliflower was found to decrease (Randhawa and Bhail,1976). When $ZnSO_4$ was incorporated as a fertiliser to the soil as in treatments T_5 (NPK+Zn) and T_9 (NPK+Zn+B+Mg+Mo), it significantly decreased the P content in tops and rhizomes at tillering stage as compared to NPK (T_4). Zn application also marginally decreased the P content in the tops and rhizomes at other growth stages also. The P content was found to be highest in

NP administered plots (T_3). The K content was significantly influenced by the various treatments in the tops at tillering stage and in rhizomes at rhizome initiation and harvest stages. K content in tops was found to be highest in NPK + Jagromin (T_{10}), closely followed by NPK+Zn (T_5), NPK+B (T_7) and NPK (T_4) at tillering stage. T_5 (NPK+Zn) accounted for highest content of K in rhizomes at rhizome initiation and harvest stages. Application of Mg in combination with NPK (T_6) decreased the K content as compared to NPK (T_4), which may be probably due to the antagonistic effects between K and Mg as reported by Smith(1962). The Ca content was significantly influenced by various treatments at all stages of growth except at tillering stage in the tops. It was found that the application of B in conjunction with NPK (T_7) produced tops and rhizomes with highest Ca content. It may be due to the primary role played by B in the Ca metabolism (Yawalkar et al.,1984). Application of Mg in combination with NPK (T_6) significantly increased the Mg content in tops at rhizome initiation and tillering stage as compared to NPK. Merchand and Schenk (1985) reported an increase in Mg concentration with the soil application of Mg. Incorporation of Zn to the soil, as in treatments T_5 (NPK+Zn) and T_9 (NPK+Zn+B+Mg+Mo) significantly incrased the Zn content in both tops and rhizomes at all stages of growth when compared with T_4 (NPK). Gupta and Potallia (1987) reported that the Zn concentration in peanut tissue increased with its application. Application of B in combination with NPK (T_7) significantly affected the B content in tops at all stages of growth when compared to other treatments, but could not significantly affect the B content in the rhizomes. Roberts and Rhee (1990) reported that 2.2 kg B ha^{-1} applied broadcast or side placed in band significantly increased the B concentration in both vines and tubers of potato. None of the treatments in the present study could significantly affect the Mo content in the tops and rhizomes at all crop growth stages. However, Mo content was highest in tops and rhizomes when Mo was included in a treatment viz. T_8 (NPK+Mo) and T_9 (NPK+Zn+B+Mg+Mo).

Nutrient uptake is a product of dry matter yield and concentration of particular nutrient element in question. Hence, it is dependent on both dry matter yield and nutrient content. Treatment T_9 (NPK+Zn+Mg+Mo+B) resulted in highest removal of N, Ca, Mg, Zn, B and Mo at the rhizome initiation stage through ginger plant (tops + rhizomes). The Mg, Zn and Mo removals through ginger plant (tops and rhizomes) were found highest in the same treatment i.e., T_9 at all stages of growth. The P accumulation throughout the growth period and N accumulation after rhizome initiation stage were highest in treatment T_{10} (NPK+Jagromin) which may be due to the highest dry matter production. Highest K accumulation in the ginger plant was recorded in treatment T_4 (NPK) at rhizome initiation and harvest stage. It may be due to the highest K content in the rhizomes and tops in case of treatment T_4 (NPK) (Tables 4.13 to 4.20). It was found that the application of N, NP and NPK increased the uptake of P, K, Ca, Mg and B over control, N and NP, respectively. Similar results were obtained by Krishnappa and Gowda (1988), Krishnappa(1988) and Sharma et al.(1978).

5.4 Soil chemical studies

Application of N, P, K, Mg, Zn, B and Mo in various treatment combinations increased their respective availabilities in the soil after the crop harvest (Table 4.21), which may be due to the additional supply of nutrients to the soil. Subba Rao and Ghosh (1981) also reported that the addition of Zn improved its availability by 128 per cent. Application of minor elements viz. Zn, Mg, B and Mo along with NPK (T_9) increased the available N status of the soil after the harvest of the crop. Incorporation of Zn (T_5) decreased available P content of the soil, which may be due to antagonistic effects between Zn and P. Katyal and Rattan(1990) also reported that there is widely known antagonism between phosphorus and zinc and phosphorus and iron in soils and hinders Zn and Fe uptake. Plots administered with N contained highest available Ca content, which may be attributed to the additional supply of Ca by the use of CAN.

5.5 Economics

Economic analysis of various fertiliser treatments worked out with a view to evaluate their profitability under the conditions of present investigation indicated that the maximum gross and net incomes and net returns per rupee invested were obtained with the application of NPK+Jagromin (T_{10}). However, no significant differences were observed between treatment T_{10}, T_4 and T_9 in respect of gross and net incomes (Table 4.23 and Fig.14).

CHAPTER – VI

SUMMARY

6. SUMMARY AND CONCLUSION

The study entitled "Nutritional studies on ginger (<u>Zingiber officinale</u> Rosc.)", was conducted at Regional Research Station, Kandaghat of Dr Y S Parmar University of Horticulture and Forestry, Solan (HP) during the <u>Kharif</u> (1989). The experiment was laid out in Randomized Block Design with three replications. There were ten treatments, namely, control (T_1), N @ 100 kg ha^{-1} (T_2), N:P @ 100 kg N : 50 kg P_2O_5 ha^{-1} (T_3), N:P:K @ 100 kg N:50 kg P_2O_5: 50 kg K_2O ha^{-1} (T_4), N:P:K+Zn @ 100:50:50+$ZnSO_4$ 20 kg ha^{-1} (T_5), N:P:K+Mg @ 100:50:50+$MgSO_4$ 10 kg ha^{-1} (T_6), N:P:K+B @ 100:50:50+Borex 10 kg ha^{-1} (T_7), N:P:K+Mo @ 100:50:50+ ammonium molybdate 1 kg ha^{-1} (T_8), N:P:K+Zn+Mg+B+Mo @ 100:50:50+$ZnSO_4$ 20 kg+$MgSO_4$ 10 kg+Borax 10 kg+ Ammonium molybdate 1 kg ha^{-1} (T_9) and N:P:K+2 foliar sprays of Jagromin @ 100:50:50 kg ha^{-1}+ 0.7% in each spray (T_{10}).

Full dose of P, K and Zn, B, Mg and Mo and ½ N was applied at the time of sowing and FYM @ 30 t ha^{-1} was applied in each plot. Remaining dose of N was applied in two splits viz., ¼ at rhizome initiation stage and ¼ at tillering stage. The crop season was normal for the growth of ginger crop.

Observations on growth and development of ginger plants (pseudo-stem length, number of tillers $plant^{-1}$, number of leaves $plant^{-1}$, leaf area and dry matter accumulation in tops and rhizomes at three stages viz.

rhizome initiation, tillering and harvest stage), yield attributes, content and uptake of N, P, K, Ca, Mg, Zn, B and Mo in rhizomes and tops at different stages were recorded to explain the effects of treatments on rhizome yield and quality of ginger.

The important results of the study have been summarised as follows:

6.1 Effect on growth and yield of ginger

1. Highest pseudo-stem length (cm), number of tillers plant^{-1}, number of leaves plant^{-1} and rhizome length (cm) were found in treatment T_{10} (NPK+Jagromin).

2. Leaf area (cm^{2}) was significantly influenced by the treatment T_9 (NPK+Zn+B+Mg+Mo).

3. Maximum rhizome breadth (cm) was recorded in treatment T_4) (NPK).

4. Rhizome yield plant^{-1} (g) and rhizome yield (q ha^{-1}) were recorded highest in treatment T_{10} (NPK+Jagromin).

5. Soil application of minor elements viz., Zn or Mg or B or Mo with NPK (T_5 or T_6 or T_7 or T_8) decreased the growth and yield of ginger.

6. Different growth and yield traits viz., stem length (cm), number of tillers plant^{-1}, number of leaves plant^{-1}, leaf area (cm^{2}), rhizome length (cm), rhizome

breadth (cm), yield plant^{-1} and rhizome yield (q ha^{-1}) were found positively correlated with each other.

Dry matter accumulation (kg ha^{-1}) by tops was highest in treatment T_{10} at tillering and harvest stages. Treatment T_4 produced higher dry matter yield through tops at rhizome initiation stage. T_{10} accounted for the highest dry matter production through rhizomes at all the three stages of growth studied viz., rhizome initiation stage, tillering stage and harvest stage.

6.2 Effect on quality and incidence of rhizome rot

1. Oil content in ginger was not significantly influenced by various treatments.

2. K applications improved the oleoresin content of ginger. Incorporation of B or Mg or Zn to the soil with NPK (T_7 or T_6 or T_5) significantly increased oleoresin content as compared to NPK (T_4).

3. Crude fibre content was found to be highest in treatment T_2 (N).

4. None of the treatments could significantly affect the incidence of rhizome rot ginger. However, it was minimum in case of treatment T_5 (NPK+Zn).

6.3 Plant and soil chemical studies

6.3.1 Nutrient content in ginger

1. N, P, K, Zn and Mo content both in tops and rhizomes, B content in tops and Mg content in rhizomes, in general, decreased with the advancement of growth; whereas, the Ca content both in tops and rhizomes, B content in rhizomes and Mg content in tops increased upto tillering stage and afterward a decline was observed.

2. Application of Mo or Zn or Mg with NPK (T_8 or T_5 or T_6) increased N content, while B application with NPK (T_7) decreased it in both tops and rhizomes at all stages of growth as compared to NPK (T_4).

3. Highest P content was found in T_3 in both tops and rhizomes and it decreased with the application of Zn at all stages of growth.

4. K content in the tops at rhizome initiation and harvest stages and in rhizomes at tillering stage was not significantly affected by various treatments. It was observed to be highest in treatment T_{10} in case of tops at tillering and in treatment T_5 in case of rhizomes at rhizome initiation and harvest stages.

5. Ca content in tops and rhizomes was significa influenced by various treatments at all stages growth except in the plant tops of tillering stage.

Treatment T_7 (NPK+B) produced rhizomes with highest Ca content.

6. Treatment T_6 (NPK+Mg) significantly influenced the Mg content in tops at rhizome initiation and tillering stages and in rhizomes at harvest stage when compared with T_4 (NPK).

7. Application of Zn as in treatments T_5 and T_9 significantly increased the Zn content in rhizomes and tops at all stages of growth.

8. Incorporation of B to soil with NPK (T_7) significantly increased its content in the tops at all stages of growth.

9. None of the treatments could significantly affect the Mo content in tops and rhizomes at all stages of growth.

6.3.2 Nutrient uptake by ginger

1. Application of NPK+Zn+B+Mo (T_9) resulted in highest removal of N, Ca, Mg, Zn, B and Mo at rhizome initiation stage through whole ginger plant (tops and rhizomes). K accumulation in tops and whole plant was recorded to be highest in case of treatment T_4 stage, while T_{10} accounted for highest accumulation of K in the rhizomes.

P accumulation in tops and

rhizomes was highest in T_{10}.

2. N, P, K and Ca accumulation by tops and rhizomes, B accumulation by tops and, thereby, whole plant were found to be highest in T_{10} at tillering stage. T_4 accumulated highest B in the rhizomes at the same stage. Removals of Mg, Zn and Mo through tops and rhizomes and thereby, whole plant were highest in case of treatment T_9.

3. B and Ca accumulation in tops, N accumulation in rhizomes and P accumulation both in tops and rhizomes were found to be maximum in case of treatment T_{10} at harvest stage. T_4 accounted for highest removal of K (tops and rhizomes) and N through tops. Mg, Zn and Mo uptake by tops and rhizomes and Ca and B uptake by rhizomes were highest in case of treatment T_9 at the harvest stage.

6.3.3 Soil chemical studies

1. Available N status (kg ha^{-1}) of the soil after harvesting of ginger was found to be highest in case of treatment T_9 (NPK+Zn+Mg+B+Mo); whereas, T_{10} (NPK+Jagromin) accounted for the highest available P content (kg ha^{-1}) of the soil after the harvesting of ginger.

2. Application of NPK (T_4) increased the available K status of the soil after harvesting of ginger.

3. Available Ca content (ppm) of the soil after harvesting of ginger was observed to be highest in treatment T_2 (N).

4. Application of Mg in combination with NPK (T_6) significantly improved the available Mg content of the soil after harvesting of ginger.

5. Available Zn, B and Mo contents (ppm) of the soil after harvesting of ginger were significantly influenced with their respective applications to the soil as in treatments T_5, T_7, T_8 and T_9.

6.4 Economic analysis

Highest gross and net income of Rs.66763.90 and 32240.54 ha^{-1}, respectively was obtained in T_{10}. The net returns per rupee investment were also highest in treatment T_{10}.

CONCLUSION

Soil application of NPK @ 100:50:50 kg ha^{-1} accompanied with two foliar sprays (0.7% in each spray) of Jagromin-99 was the best treatment for getting higher yields of good quality ginger. Since the results are based on one year experimentation, thus further testing is necessary.

REFERENCES

REFERENCES

*Aclan, F. and E.C. Quisumbing (1976).Fertiliser requirement, mulch and light attenuation on the yield and quality of ginger. Phillipine Agriculturist. 60(5/6):183-191.

Alexander, A. and M. Schroeder (1987). Modern trends in foliar fertilisation. J . Plant Nutr. 10(9-16): 1391-1399.

Anonymous (1953). Investigation 1950-51: Cultivated trees, shrubs and vines. Ginger Bull. Dept. Agric., Jamaica. 49: 118-119.

Anonymous (1989). Statistical outlines of Himachal Pradesh. Economics and Statistical Department, H.P., Shimla-1.

Anonymous (1990). Special Tables. Agric. Situation in India. 45(1): 48-49.

Baethgen, W.E. and M.M. Alley (1989). A manual colorimetric procedure for measuring ammonium nitrogen in soil and plant Kjeldahl digests. Communications in Soil Sci and Plant Analysis. 20: 961-969.

*Chew, Wee Yong (1969). The performance of tapioca, sweet potato and ginger on peat at the Federal Experiment Station, Jalan Kebun, Selangor. Planter Kuala Lumpur. 45: 445-451.

*Cho, G.H.; C.H. Yoo; J.W. Choi; K.H. Park; S.S. Han and S.J. Kim (1987). Studies on soil characteristics and yield in main ginger producing districts. Research Reports of the Rural Development Administration, Plant Environment, Mycology and Farm Products Utilization, Korea Republic. 29(2): 30-42.

Cochran, G.C. and G.M. Cox (1963). Experimental Designs. Asia Pub. House, Bombay.

Dang, Y.P.; R. Chhabra and K.S. Verma (1990). Effects of Cd, Ni, Pb and Zn on Growth and Chemical Composition of onion and fenugreek. Communications in Soil Sci. and plant analysis. 21(9 & 10): 717-735.

*Dasaradhi, T.B.; R. Sriramamurthy and V.V.R. Rao (1971). Ginger - different photophases - Climatic requirements. Paper presented at the plantation crops research workshop, Kaseragod (Mimeographed).

Dohroo, N.P. (1990). Management practices against diseases of ginger. Summer Institute on production technology of off-season vegetables and seed crops. June 15-July 4. Dr YS Parmar Univ of Hort & Fort., Solan. 214-217.

George, C.K. and E. Vellapan (1980). The proceedings of the National Seminar on Ginger and Turmeric. C.P.C.R.I., Calicut.

Grewal, T.S. and S.P. Trehan (1979). Micronutrients for potatoes. Fert. News. 24(8): 27-30.

Grigg, G.L. (1953). Determination of available Molybdenum in soils. Jr. Sc. Technol. 34: 405-414.

*Groszman, H.M. 1954. Ginger production. Qd. Agric. Jr. 78: 259-262.

Gupta, V.K.; B.S. Potallia (1987). Effect of molybdenum and zinc on yield, Mo and Zn concentration in peanut. Jr. Ind. Soc. Soil Sci. 35(1): 82-84.

Hatcher, J.T. and L.V. Wilcox (1950). Colorimetric determination of boron using carmine. Analyt. Chem. 22: 567-569.

Horwitz, W. (1980). Official methods of analysis of the Association of Official Analytical Chemists,Washington.

Jackson, M.L. (1967). Soil Chemical Analysis. Prentice Hall, New Delhi.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall, New Delhi.

Kanwar, J.S. and S.L. Chopra (1976). Analytical Agricultural Chemistry. Kalyani Pub. Ludhiana, India.

Katyal, J.C. and R.K. Rattan (1990). Micro-nutrient use in the 90's. Soil fertility and fertiliser use. Vol.IV. Indian farmers fertiliser Co. Ltd., New Delhi.

Kingra, I.S. and M.L. Gupta (1977). Ginger cultivation in Himachal. Kurukshetra. 25(19): 14-15.

Klein, L.B.; S. Chandra and N.I. Mondy (1982). Effect of magnesium fertilisation on the quality of potatoes, total nitrogen, nonprotein nitrogen, protein, amino acids, minerals and firmness. Jr. of Agric. and Food Chem. 30(4): 754-757.

Krishnappa, K.S. 1988. Uptake of S, Ca and Mg by Kufri Chandramukhi potato (Solanum tuberosum L.) at different stages of growth. J. Indian Potato Assoc. 15(3&4): 134-138.

Krishnappa, K.S. and M. Chandre Gowda (1988). NPK uptake by Kufri Jyoti potato (Solanum tuberosum L.) in sandy loam soil. J. Indian Potato Assoc. 15(3&4): 153-158.

Kumar, V. and P.S. Marwaha (1984). Micronutrient nutrition of crops and problems associated with the availability of micronutrient products with particular reference to northern India Industry's view. In Balanced fertilisation programme with special reference to secondary and micronutrients nutrition of crop under intensive cropping. Proc. of FAI-NR Seminar, Jaipur, March 30-31, 1984. 125-134.

Lee, M.T. and C.J. Asher (1981). Nitrogen nutrition of ginger (Zingiber officinale). Effect of sources, rates and times of nitrogen application. Plant and Soil. 62(1): 23-24.

*Lee, M.T.; D.G. Edwards and C.J. Asher (1981). Nitrogen nutrition of ginger (Zingiber officinale). II. Establishment of a leaf analysis test. Field Crops. Res. 4(1): 69-81.

Lindsay, W.L. and W.A. Norvell (1969). A micronutrient soil test for zinc, iron, manganese and copper. Agron. Abstr. pp.84.

Loknath, M. and N.K. Dash (1964). Determination of optimum spacing, fertilisation and method of planting for ginger (Zingiber officinale Rosc.). Indian J. Agron. 9: 281-285.

Maity, T.K.; D. Sengupta; M.G. Som; P.K. Jaua and T.K. Bose (1988). Growth and yield of Zingiber officinale Rosc. as influenced by some agronomic practices in the plains of West Bengal. Acta Horticulturae. No.18A: 117-122.

Marwaha, S. (1984). Propagation studies in ginger (Zingiber officinale Rosc.). M.Sc.(Ag.) Thesis. H.P.K.V.V., C.O.A., Solan.

Medhi, R.P. (1987). Effect of Macro and micronutrients on curd yield, quality, seed yield and disease incidence in cauliflower. Ph.D. Thesis. Dr YS Parmar Univ. of Hort & Fort., Solan, HP, India.

*Merchand, P.; R. Schenk (1985). Applying Molybdenum and magnesium to the foliage of potatoes. Wissenschaftlicha Zeitschrift der Humboldt - Universitat Zu zerlin. Mathematisch - Naturwissenchaftliche Reihe.34 (6):554-58.

Mohanty, D.C. and Y.N. Sharma (1979). Genetic variability and correlation for yield and other variables in ginger germplasm. Indian J. of Agric. Sci. 49(4): 250-253.

*Mohanty, D.C.; Y.N. Sharma; B.S. Naik and B.S. Panda (1988). Influence of fertiliser-cum-seed rates on yield and performance of the selected ginger clones in the Eastern Ghats Highland Zone of Orissa. Indian Cocoa, Arecanut and Spices J. 12(1): 1-3.

Mondy, N.I. and C.B. Munshi (1988). Effect of molybdenum fertilisation on the nitrogenous constituents of potatoes. J. of Food Sci. 53(6): 1909-10.

Muralidharan, A. (1973). Effect of graded doses of NPK on the yield of ginger (Zingiber officinale R.) var. Rio-de-Janeiro. Madras Agric. J. 60(8): 664-666.

Muralidharan, A.; A.S. Verma and E.V.G. Nair (1974). Effect of nitrogen, phosphorus and potash on growth and yield of ginger (Zingiber officinale Rosc.). Ind. J. Agron. 19(2): 103-104.

Muralidharan, A.; E.V.G. Nair and S. Bala Krishnan (1973). Studies on the fertiliser requirement of ginger (Zingiber officinale Roscoe.). Agric. Res. J. Kerala. 11(2): 135-137.

Muralidharan, A. and N.N. Ramankutty (1975). Relative performance of some selected clones of ginger (Zingiber officinale Roscoe.) with reference to rate and time of application of nitrogen. Madras Agric. J. 62(6): 357-359.

Muralidharan, A. and N.N. Ramankutty (1977). A note on the effect of potash and boron on the growth and yield of ginger (Zingiber officinale Rosc.) cv. Maran. Madras Agric. J. 64(11): 760-762.

Nagarajan, M. and N.G. Pillai (1979). A note on the nutrient removal by ginger and turmeric rhizomes. Madras Agric. J. 66(1): 56-59.

Nair, G.S. and R.C. Das (1980). Effect of foliar application of urea and Planofix (NAA) on the oleoresin and fibre content of Ginger (Zingiber officinale Rosc .). Proceedings of the National Seminar on Ginger and Turmeric - Calicut. pp.86-89.

Nair, P.C.S. and A.S. Varma (1970). Ginger in Kerala: Steps towards increased production. Indian Fmg. 20(3): 37-39.

Neopaney, Bhanu (1988). Effect of different levels of (NPK) essential elements and spacing on growth and yield of ginger (Zingiber officinale Rosc.). M.Sc. (VCF) Thesis, Dr YS Parmar Univ. of Hort & Fort, Solan.

Panigrahi, U.C. and G.K. Patro (1985). Ginger cultivation in Orissa. Indian Fmg. 35(5): 3-4.

Pawar, H.K. and B.R. Patil (1988). Studies on some quality aspects of ginger as influenced by manuring and time of harvesting. Proceedings of the National Seminar on Chillies, ginger and turmeric, Hyderabad. pp.200-206.

Piper, C.S. (1966). Soil and Plant Analysis. Hans Pub. Bombay.

Prakasam, V.; Peter, G.B. Vedamathu; Md. Abdul-Khader and R. Jeyarajan (1988). Salient features of work done in the management of diseases of turmeric and chillies at Tamil Nadu Agricultural University. Proceedings of the National Seminar on chillies, ginger and turmeric, Hyderabad. pp.168-182.

Purseglove, J.W.; E.G. Brown; C.L. Green and S.R.J. Robbins (1981). Spices Vol.2 Longman Inc., New York.

Rajan, K.M. and R.S. Singh (1972). Effect of organic amendments of soil on plant growth, yield and incidence of soft rot of ginger. J. Plant Crops. 1(Suppl): 102-106.

Rajan, K.M. and R.S. Singh (1974). Effect of organic amendments of soil on plant growth, yield and incidence of soft rot of ginger. J. Plant Crops. 1 (Supplement): 102-106.

Randhawa, K.S. and A.S. Bhail (1976). Growth, yield and quality of cauliflower as influenced by N, P and B. Ind. J. Hort. 33(1): 83-91.

Randhawa, K.S. and K.s. Nandpuri (1969). Response of ginger (Zingiber officinale Rosc.) to nitrogen, phosphorus and potash fertilisation. J. Res. Punjab Agric. Univ., Ludhiana. 6(1): 212-214.

Rattan, R.S.; B.N. Korla and N.P. Dohroo (1988). Performance of ginger varieties under Solan condition of Himachal Pradesh. Proc. of the National Seminar on chillies, ginger and turmeric, Hyderabad. pp.71-73.

Richard, L.A. (1954). Diagnosis and improvement of saline and alkaline soils. USDA. Hand Book No.60. Washington, D.C.

Roberts, S. and J.K. Rhee (1990). Boron utilization by potato in nutrient cultures and in field plantings. Communications in soil Sci. and Plant Analysis. 21 (11&12):921-932.

*Sadanandan, A.K. and R. Iyer (1986). Effect of organic amendments on rhizome rot of ginger. Indian Cocoa, Arecanut and Spices J. 9(4): 94-95.

Sadanandan, N. and V.K. Sasidharan (1979). A note on the performance of ginger (Zingiber officinale Rosc.) under graded doses of nitrogen. Agric. Res. J. Kerala. 17(1): 103-104.

Sankaram, A. (1966). A laboratory manual for agricultural chemistry. Asia Pub. House, Madras.

*Saraswat, K.B. (1972). Effect of N, P and K on yield and oil content of ginger. Agric. Agro. Ind. J. 5(5): 37-38.

Sharma, I.P. and U.K. Verma (1988). Effect of planting and harvesting dates on mineral composition of potatoes. J. Indian Potato Assoc. 15(1&2): 74-79.

Sharma, R.C.; J.S. Grewal and A.K. Sharma (1978). Dry matter and nutrient accumulation in the potato as affected by flertiliser application. J. Indian Potato. Assoc. 5(2): 56-69.

*Sivaraman, K. (1985). Spices. Proceedings of VIIth Workshop on All Indian Coordinated Coconut and Arecanut, Spices and Cashewnut Improvement Project. 146-147.

Smith, P.F. (1962). Mineral analysis of plant tissues. Ann. Rev. Plant Physiol. 13: 81-108.

Sood, Ghanshyam and Om Parkash Sharma (1976). Highlights of ginger research in Himachal Pradesh. Haryana J. Hort. Sci. 5(1&2): 102-103.

Sreedharan, C. and C.M. George (1969). Effect of micro-nutrients on paddy in a red loam soil of Kerala. Agric. Res. J. Kerala. 7(2): 61-66.

Sreekumar, V.; G. Indrasenan and M.K. Mammen (1980). Studies on the quantitative and qualitative attributes of ginger cultivars. Proc. of National Seminar on Ginger and Turmeric. C.P.C.R.I. Calicut. pp.47-49.

Subba Rao, A. and A.B. Ghosh (1981). Effect of intensive cropping and fertiliser use on the crop removal of sulphur and zinc and their availability in soil. Fert. Research. 2(4): 303-308.

Subbiah, B.V. and G.S. Asija (1956). A rapid procedure for the estimation of available nitrogen in soil. Curr. Sc. 25: 259-260.

Wallace, A. and G.A. Wallace (1983). Foliar fertilisation with metalosates. J. Plant Nutr. 6(6): 551-559.

Wear, J.I. (1965). Boron. In C.A. Black et al.(ed.). Methods of "Soil analysis", Part II. Agron. Monograph. 9: 1059-63.

Yawalkar, K.S.; J.P. Agarwal and S. Bokde (1984). Manures and Fertilizers (6th ed.). Agri-Horticultural Pub. House, Nagpur, India.

* Original not seen

APPENDIX-A

MEAN WEEKLY METEOROLOGICAL DATA OF THE VEGETABLE RESEARCH STATION, SOLAN FOR THE YEAR 1989

Standard week	Week ending	Temperature (°C)		Mean Relative Humidity (%)	Total Rainfall (mm)
		Maximum	Minimum		
19	13 May	29.86	13.86	46.36	-
20	20 May	33.86	17.14	48.49	-
21	27 May	32.43	16.71	54.46	15.20
22	3 June	29.86	17.28	67.14	27.3
23	10 June	29.29	16.71	72.93	23.20
24	17 June	27.57	15.71	67.36	49.60
25	24 June	28.00	16.71	78.64	3.40
26	1 July	29.29	19.43	78.43	3.20
27	8 July	29.57	17.00	69.50	-
28	15 July	32.29	19.43	70.93	32.40
29	22 July	29.57	18.14	76.46	6.20
30	29 July	26.14	20.14	79.36	124.60
31	5 August	23.14	16.79	90.21	95.80
32	12 August	28.14	18.28	84.07	2.40
33	17 August	25.43	18.43	90.36	39.00
34	26 August	26.29	18.00	92.00	122.00
35	2 September	24.43	16.86	90.00	17.80
36	9 September	26.00	16.57	89.93	2.20
37	16 September	25.36	16.00	76.36	16.20
38	23 September	25.00	17.00	76.86	8.40
39	30 September	25.43	13.86	76.29	0.20
40	7 October	28.00	14.29	80.86	-
41	14 October	26.71	12.86	76.43	-
42	21 October	25.29	9.79	67.36	-
43	28 October	23.43	9.57	76.71	-
44	4 November	20.29	8.86	73.57	-
45	11 November	19.57	6.07	73.86	3.60
46	18 November	20.29	7.21	67.43	-

APPENDIX-B

ANALYSIS OF VARIANCE FOR DIFFERENT OBSERVATIONS UNDER STUDY IN GINGER (*Zingiber officinale* Rosc.)

	Mean sum of square		
	Replication	Treatment	Error
Degree of freedom	(2)	(9)	(18)
OBSERVATIONS			
GROWTH PARAMETERS			
Pseudo Stem length (cm)	0.4650	33.3308	0.9727
Number of tillers per plant	0.0360	3.6083	0.0790
Number of leaves per plant	0.0280	137.9912	1.3405
Leaf area (cm^2)	0.0054	0.2312	0.0040
YIELD PARAMETERS			
Rhizome length (cm)	0.0595	8.0428	0.8570
Rhizome breadth (cm)	0.0130	2.9374	0.0433
Yield per plant (g)	106.6295	1689.1167	64.0011
Yield per ha (q)	137.2977	1201.6433	55.3336
Dry matter accumulation (kg ha^{-1})			
Rhizome initiation stage			
Tops	124.4355	3467.3207	107.5858
Rhizomes	95.9574	11207.338	94.8800
Tillering stage			
Tops	2840.1725	23124.6840	870.0924
Rhizomes	68.4615	178393.96	2628.4123
Harvest stage			
Tops	291.961	53435.746	1532.7876
Rhizomes	146952.43	2220520.6	74616.43

APPENDIX-C

ANALYSIS OF VARIANCE FOR QUALITY AND ECONOMICS OF GINGER (*Zingiber officinale* Rosc.)

	Mean sum of squares		
	Replication	Treatment	Error
Degree of freedom	(2)	(9)	(18)
Quality parameters			
Ginger oil content (%)	0.0141	0.0229	0.0349
Oleoresin content (%)	0.0017	0.0327	0.0039
Crude fibre content (%)	0.0147	0.0358	0.0138
Incidence of rhizome rot	10.9877	17.1355	18.4062
Economic studies			
Gross income (Rs ha^{-1})	41532532	363497100	16738429
Net income (Rs ha^{-1})	42587721	332888325	16876950

APPENDIX-D

ANALYSIS OF VARIANCE FOR CONCENTRATION OF NUTRIENT ELEMENTS IN GINGER (*Zingiber officinale* Rosc.)

	Mean sum of squares					
	Replication		Treatment		Error	
Degree of freedom	(2)		(9)		(18)	
Conc. of nutrient elements	Rhizomes	Tops	Rhizomes	Tops	Rhizomes	Tops
N content (%)						
Rhizome initiation stage	0.01457	0.00702	0.00898	0.04173	0.01011	0.01030
Tillering stage	0.00586	0.02182	0.02057	0.06766	0.00685	0.00392
Harvest stage	0.00322	0.01519	0.02145	0.02715	0.00383	0.00696
P content (%)						
Rhizome initiation stage	0.00017	0.00047	0.00197	0.00461	0.00020	0.00081
Tillering stage	0.00015	0.00019	0.00179	0.00447	0.00010	0.00072
Harvest stage	0.00096	0.00035	0.00058	0.00120	0.00025	0.00036
K content (%)						
Rhizome initiation stage	0.00048	0.02830	0.02986	0.02104	0.01169	0.01367
Tillering stage	0.01048	0.01438	0.00749	0.03787	0.00930	0.01378
Harvest stage	0.00117	0.00230	0.03592	0.01539	0.01139	0.00931
Ca content (%)						
Rhizome initiation stage	0.00006	0.00674	0.00029	0.01792	0.00007	0.00663
Tillering stage	0.0000072	0.00564	0.00038	0.01398	0.00011	0.01325
Harvest stage	0.000018	0.01110	0.00040	0.01909	0.00008	0.00648
Mg content (%)						
Rhizome initiation stage	0.00007	0.00232	0.00025	0.00528	0.00023	0.00145
Tillering stage	0.00026	0.00086	0.00040	0.00324	0.00019	0.00131
Harvest stage	0.00017	0.00102	0.00056	0.00157	0.00022	0.00078
B content (ppm)						
Rhizome initiation stage	1.1435	2.1420	0.7473	26.1229	1.8541	4.9300
Tillering stage	2.6080	7.2820	1.2644	39.6276	2.5255	2.2893
Harvest stage	0.7260	3.6320	0.5996	21.9265	1.5698	4.3153
Zn content (ppm)						
Rhizome initiation stage	22.5333	25.0334	29.7074	56.2220	4.7185	10.9222
Tillering stage	1.0333	21.7000	32.8926	42.0593	5.0704	6.9482
Harvest stage	3.0333	5.4333	28.3296	29.5704	3.4407	5.9148
Mo content (ppm)						
Rhizome initiation stage	0.02294	0.02073	0.01370	0.00734	0.01811	0.02581
Tillering stage	0.03026	0.02821	0.01237	0.01347	0.01195	0.01607
Harvest stage	0.01677	0.00344	0.01229	0.01660	0.01537	0.01356

APPENDIX-E

ANALYSIS OF VARIANCE FOR NUTRIENT UPTAKE BY GINGER (*Zingiber officinale* Rosc.)

	Mean sum of squares								
	Replication			Treatment			Error		
Degree of freedom	(2)			(9)			(18)		
Nutrient uptake	Rhizomes	Tops	Total	Rhizomes	Tops	Total	Rhizomes	Tops	Total
N uptake (kg ha^{-1})									
Rhizome initiation stage	0.0595	0.2006	0.2860	5.3101	5.0064	20.3256	0.1669	0.4161	0.5075
Tillering stage	1.3223	3.6720	3.8275	63.2623	31.5347	180.1103	3.0086	1.4234	10.5800
Harvest stage	52.9485	2.7881	55.5745	791.5698	29.8707	1117.0010	33.4489	1.4301	33.9159
P uptake (kg ha^{-1})									
Rhizome initiation stage	0.0011	0.0020	0.0046	0.1197	0.2588	0.7204	0.0028	0.0162	0.0135
Tillering stage	0.0413	0.1381	0.2710	2.2678	1.0949	6.3977	0.0551	0.7790	0.1559
Harvest stage	0.1683	0.0731	0.1175	12.7267	0.8481	19.6418	0.5088	0.0419	0.5899
K uptake (kg ha^{-1})									
Rhizome initiation stage	0.1361	0.3038	0.2243	10.3129	7.3267	34.4397	0.3129	0.3061	0.4586
Tillering stage	2.5426	10.4928	12.3850	122.0908	47.2555	316.0760	5.0801	2.4334	5.2677
Harvest stage	119.5447	0.2711	97.9443	1244.0494	24.5930	1596.3420	65.5398	1.3486	69.9113
Ca uptake (kg ha^{-1})									
Rhizome initiation stage	0.0014	0.2458	0.2379	0.0327	1.0552	1.4396	0.0080	0.1141	0.1145
Tillering stage	0.0097	1.4389	1.3971	0.8441	7.2811	12.8061	0.0406	0.9753	0.9206
Harvest stage	0.8008	1.3771	3.4399	9.1865	13.3723	43.2919	0.4028	1.1396	1.7052
Mg uptake (kg ha^{-1})									
Rhizome initiation stage	0.0020	0.0805	0.0740	0.0397	0.2046	0.3979	0.0021	0.0309	0.0281
Tillering stage	0.0705	0.0335	0.0065	0.7282	1.0048	3.3550	0.0491	0.1294	0.1839
Harvest stage	1.0305	0.1540	1.8190	7.2061	1.0292	13.5672	0.4929	0.0927	0.5859
B uptake (g ha^{-1})									
Rhizome initiation stage	0.2137	0.4928	0.0667	2.8878	8.4496	18.6274	0.2734	0.2057	1.2109
Tillering stage	7.5193	17.6399	46.9992	56.2162	66.7275	228.8735	8.6462	2.4419	9.9883
Harvest stage	43.1773	8.6254	87.8277	363.2084	63.3824	651.0031	39.6744	8.0688	58.0018
Zn uptake (g ha^{-1})									
Rhizome initiation stage	2.1380	3.4833	8.2118	10.2924	20.6119	57.0806	0.4913	2.0471	2.3607
Tillering stage	3.4453	33.6525	43.7100	164.4867	67.9858	430.8882	15.2353	4.5017	30.3289
Harvest stage	186.2068	8.0961	270.2745	956.8649	98.7940	1648.7356	82.0997	13.0615	85.1274
Mo uptake (g ha^{-1})									
Rhizome initiation stage	0.0028	0.0052	0.0045	0.0122	0.0068	0.0369	0.0020	0.0049	0.0048
Tillering stage	0.0833	0.0099	0.0366	0.1767	0.0568	0.4298	0.0305	0.0114	0.0472
Harvest stage	0.5401	0.0027	0.4947	1.6928	0.0849	2.5039	0.1676	0.0179	0.1682

APPENDIX-F

ANALYSIS OF VARIANCE FOR AVAILABLE NUTRIENT STATUS OF THE SOIL AFTER HARVEST

	Mean sum of square (MSS)		
	Replication	Treatment	Error
Degree of freedom	(2)	(9)	(18)
Nitrogen (kg ha^{-1})	324.7458	420.5176	107.7934
Phosphorus (kg ha^{-1})	11.3087	13.7507	5.5211
Potassium (kg ha^{-1})	189.9365	266.8934	98.6147
Ca (ppm)	1406.9250	3167.3417	1054.8417
Mg (ppm)	106.7040	1189.4520	252.8640
Zn (ppm)	0.00745	0.15909	0.00566
B (ppm)	0.01359	0.01707	0.00439
Mo (ppm)	0.00029	0.00351	0.00036

APPENDIX-C

COST OF CULTIVATION OF GINGER (Rs ha^{-1})

Particulars	Unit	$Rs.unit^{-1}$	Amount($Rs.ha^{-1}$)
I. Fixed expenses			
i) Preparatory tillage			
a) Ploughing	3	150	450.00
b) Planking	3	30	90.00
c) Preparation of beds and channels	80 labour units	18	1440.00
ii) Seed and sowing			
a) Cost of seed	20 q	1100/q	22000.00
b) Seed treatment	-	-	455.00
c) Sowing	48 labour units	18	864.00
iii) Manuring			
a) Cost of FYM	30 t	85/t	2550.00
b) FYM application	24 labour units	18	432.00
iv) Three weedings followed by earthing up	80 labour units	18	1440.00
v) Three irrigations			
a) Charges of irrigation water	-	-	16.50
b) Labour required for three irrigations	6 labour units	18	108.00
vi) Harvesting and sorting	80 labour units	18	1440.00
Total:			31285.50
II. Variable expenses			
i) Cost of fertilisers			
a) N (through CAN)	100 kg	6.80/kg	680.00
b) P_2O_5 (through SSP)	50 kg	5.94/kg	297.00
c) K_2O (through MOP)	50 kg	2.08/kg	104.00
d) $ZnSO_4$	20 kg	5.50/kg	110.00
e) $MgSO_4$	10 kg	3.50/kg	35.00
f) Borax	10 kg	20.00/kg	200.00
g) Ammonium molybdate	1 kg	954.00/kg	954.00
h) Jagromin-99	2.5 l	58.00/l	145.00
i) Fertiliser application			
1) Charges at sowing time	12 labour units	18	216.00
2) Top dressing of N fertilisers in two splits splits	24 labour units	18	432.00
j) Two foliar spray of Jagromin-99	6 labour unit	18	108.00

Price of the Product

i) Ginger rhizomes	Rs.550.00/q

TREATMENTWISE COST OF CULTIVATION (Rs ha^{-1})

Treatments	Working capital	Interest on working capital @ 12.5% for 3 months(Rs ha^{-1})	Land revenue (Rs ha^{-1})	Total (Rs ha^{-1})
T_1	31285.50	977.67	16.25	32279.42
T_2	32613.50	1019.67	16.25	33648.92
T_3	32910.50	1028.45	16.25	33955.20
T_4	33014.50	1031.70	16.25	34062.45
T_5	33124.50	1035.14	16.25	34175.89
T_6	33059.50	1032.80	16.25	34098.55
T_7	33214.50	1037.95	16.25	34268.70
T_8	33968.50	1061.52	16.25	35046.27
T_9	34313.50	1072.30	16.25	35402.05
T_{10}	33267.50	1039.61	16.25	34323.36

APPENDIX-H

COMPOSITION OF JAGROMIN-99

Constituent	Concentration (ppm)
Zinc	9000
Iron	4000
Copper	5100
Manganese	3200
Cobalt	100
Boron	100
Molybdenum	180

Jagromin-99 was procured from Jai Shree Agro Industries Pvt. Ltd., Baxoli, G.T. Karnal Road, Delhi 110 036, through the courtesy of the Director of Agriculture, Himachal Pradesh, Shimla.

Title of Thesis	Nutritional studies on ginger (*Zingiber officinale* Rosc.)
Full name of the Student	Nutan Mahajan
Admission Number	H-88-12-M
Name and address of Major Advisor	Dr K K Singh, Professor Dept. Vegetable Crops, Dr Y S Parmar University of Horticulture & Forestry Nauni, Solan.
Degree awarded	M.Sc. Horticulture(Vegetable Crops)
Year of award of degree	1991
Major subject	Vegetable Crops
Minor subject(s)	i) Soil Science and Water Management
University awarding degree	Dr Y S Parmar University of Hort.& Forestry, Solan.
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No. of words in abstract	350

ABSTRACT

Studies were conducted at Regional Research Station, Kandaghat in Randomised Block Design, consisting of ten treatments, namely, T_1 (control), T_2 (N), T_3 (NP), T_4(NPK), T_5(T_4+$ZnSO_4$), T_6 (T_4+$MgSO_4$), T_7 (T_4+Borax), T_8(T_4+Ammonium molybdate), T_9 (T_4+$ZnSO_4$+$MgSO_4$+Borax + Ammonium molybdate), T_{10}(T_4+two foliar sprays of Jagromin each at 0.7%), with a view to see the effect of macro and micro-nutrient elements on growth, yield, quality and disease incidence in the ginger. The rates of N, P, K, $ZnSO_4$, $MgSO_4$, Borax & Ammonium molybdate were 100, 50, 50, 20, 10, 10 and 1 kg per ha, respectively.

Highest pseudo-stem length, number of leaves $plant^{-1}$, number of tillers plant, rhizome length and, thereby, ginger yield was obtained in T_{10}. Leaf area was significantly influenced by treatment T_9. Maximum rhizome breadth was obtained in treatment T_4. Soil application of micronutrients viz., Zn, Mg, B or Mo with NPK decreased the growth and yield. The correlation coefficients between growth and yield parameters were highly positively significant. Dry matter accumulation at tillering and harvest stages of growth was highest in treatment T_{10}, while at rhizome initiation stage it was highest in treatment T_9. Oil content and incidence of rhizome rot was not significantly influenced by various treatments. K applications improved oleorisin content. Incorporation of B or Mg or Zn with NPK significantly increased oleoresin content as compared to NPK (T_4). Crude fibre content was highest in treatment T_2.

Nutrient content decreased with advancement of growth. Mo or Zn or Mg increased N content while B decreased it. Zn application decreased P content. Application of nutrient elements increased ~~xn~~ their content in plant tissue and in the soil (available) also. T_7 produced rhizome with highest Ca content. N, P, K and Ca accumulation by tops and rhizome, B accumulation by tops and whole plant were found to be highest in T_{10} at tilleringstage. T_9 accounted for highest removal of Mg, Zn and Mo throughout growth period and N, Ca and B accumulation at rhizome initiation stage. T_4 accounted for highest removal of K at rhizome initiation and harvest stages P accumulation throughout growth was highest in T_{10}. Highest gross and net income and net returns per Rs investment were highest in treatment T_{10}.

Signature of Major Advisor

4/2/91

Signature of the Student

4/2/91

COUNTERSIGNED

4/1/91