NUTRIENT REMOVAL IN RELATION TO CROP PRODUCTION IN BLACK PEPPER

By

P. G. MATHEW

THESIS

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Department of Plantation Crops and Spices
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DECLARATION

I hereby declare that this thesis entitled 'Nutrient removal in relation to crop production in black pepper' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

P.G. MATHEW

Vellanikkara,

30.10.1993.

Dr. G. Sreekandan Nair
Professor and Head
Department of Plantation Crops & Spices
Kerala Agricultural University

Vellanikkara

30 .10.1993

CERTIFICATE

Certified that this thesis entitled **Nutrient removal in relation to crop production in black pepper** is a record of research work done independently by **Mr. P.G. Mathew** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

G. Sreekandan Nair 30/10/93

G. Sreekandan Nair
Chairman, Advisory Committee

We the undersigned, members of the Advisory Committee of **Mr. P.G. Mathew**, a candidate for the degree of Master of Science in Horticulture, agree that the thesis entitled **'nutrient removal in relation to crop production in black pepper'** may be submitted by Mr. P.G. Mathew in partial fulfilment of the requirements for the degree.

Chairman : **Dr. G. Sreekandan Nair**
Professor and Head
Department of Plantation
Crops & Spices

Members : **Dr. P.A. Wahid**
Professor (Radiotracer)
College of Horticulture
Vellanikkara

Dr. K. Kumaran
Associate Director
Regional Agricultural Research Station
Kerala Agricultural University

Dr. (Mrs) Alice Kurien
Associate Professor
Department of Plantation Crops & Spices
College of Horticulture
Vellanikkara

External Examiner

17.11.97.

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P.G. MATHEW

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Black pepper (*Piper nigrum* L.) commonly known by the synonyms the 'golden vine' and the 'king of spices' is an important spice crop originated in the Western Ghats of India. Among the spices cultivated in India, black pepper has a unique position as the largest exporting crop both in quantity and value. The export earning from black pepper during 1992-93 was Rs.83.17 crores which was about 22 per cent of the total export earnings from spices (Anon. 1993). By virtue of its position as the largest foreign exchange earner among spices, black pepper enjoys a strategic position in our national economy.

Among the pepper producing countries in the world, India was holding a near monopoly both in production and export of the crop. Of late, her predominance in world trade diminished consequent to rapid pace of growth of this plantation industry on a commercial scale in the competing countries like Indonesia, Malaysia and Brazil. Moreover, our production remained more or less static without matching increase with world demand. Besides India, pepper is now grown in Indonesia, Malaysia, Brazil, Medagascar, Sri Lanka, Thailand etc. The global area under black pepper cultivation is estimated to be around 3.49 lakh ha with an annual production of 2.26 lakh tonnes (Anon. 1991).

India accounts for about 19 per cent of world production, while our share in area is 50 per cent. Pepper production in India during 1991-92 was 42,690 tonnes from a total cultivated area of 1,74, 870 ha. Kerala accounts for nearly 97 per cent of the total area (1,69,670 ha) with a production of 41,560 tonnes. The crop is cultivated on a limited scale in the neighbouring states, Karnataka, Tamil Nadu, Andhra Pradesh, Union Territory of Pondicherry etc. (Anon. 1992).

The world demand for black pepper by 2000 AD is estimated around 1,85,000 tonnes. In order to maintain about 40 per cent market share and to meet the internal demand, we need produce about one lakh tonnes of black pepper by the turn of this century as against our present average annual production of 40 to 45 thousand tonnes (Anon. 1990). Eventhough India is the native home of this crop and we are the pioneers in its cultivation, our productivity is only 300 kg ha^{-1} as against 2500, 1500 and 500 kg ha^{-1} in Malyasia, Brazil and Indonesia, respectively (Anon. 1991).

Though several reasons like senile vines, uneconomic and poor varieties, incidence of pests and diseases, etc. are attributed to the low productivity of pepper vines in our country, the nutritional factors - inadequate/imbalanced manuring are significantly contributing for poor productivity. It is observed that even under uniform managerial level the vines exhibit variation in yield and there are vines yielding 10 to 15 kg dried pepper per vine when our national average productivity is around one kg per vine. Therefore there is an imperative need to study the nutrient uptake by vines of different productivity range. The information generated would enable us to assess the extent of nutrients removed by the vines in relation to productivity as well as the impacts of foliar nutrient level and soil nutrient status on yield. It would also help in arriving at more realistic nutritional requirement for vines at different productivity level and thereby monitoring judicious fertilizer management in the crop.

The present study on 'nutrient removal in relation to crop production in black pepper' is therefore designed with the objective to investigate the extent of nutrient removal in relation to productivity. The study would also throw light on the relationships between foliar nutrient level and yield and between available nutrients in soil and yield of black pepper.

REVIEW OF LITERATURE

Black pepper is a typical tropical crop predominantly cultivated in humus rich virgin forest soils with adequate drainage facilities. The plant is recognised as being highly demanding of fertile soil. However, information about the nutrients required by this crop, their uptake and effect on plant growth and nutrition, nutritional disorders, nutritional deficiency and other related aspects is very limited. The available information relates to that of Indian, Malaysian and Indonesian workers. Though black pepper is an important commercial crop of India having very great export potential from time immemorial as well as internal demand, work relating to its inorganic nutrition is of recent origin in our country. Results of the investigations conducted elsewhere, in this direction were greatly made use of till the first half of this century. Of late, emphasis is being given to investigate the nutritional requirements of the crop.

Literature on aspects pertaining to the study on nutrient removal in relation to crop production in black pepper is reviewed under the captions:-

1. Nutrient uptake and fertilizer requirement
2. Nutritional disorders
3. Foliar diagnosis of nutritional deficiencies.

2.1 Nutrient uptake and fertilizer requirement

In Kerala, manurial experiments were conducted as early as in 1920 (Nambiar et al., 1965) at Panniyur by the Department of Agriculture, Madras. But, details of many of these experiments are not available as there has not been any published report.

According to Purseglove et al. (1981) organic manures were extensively used in Sarawak, for growing black pepper and this include prawn and fish waste, soyabean cake etc. The use of sterameal, a potassium fortified sterilised animal meat and bone meal was popular among the farmers there. They found the necessity for micro nutrients application to black pepper in Sarawak and recommended 28 g trace elements per vine. Response of black pepper to lime application was also reported by them.

In Sarawak, the systems and methods of application of fertilizers were developed largely through experience and tradition. The jungle land, which was cleared for pepper planting, provided the raw material for the preparation of burnt earth (Harden and White, 1934; Bergman, 1940), which served as a fertilizer for the pepper vine and applied at the rate of 18 kg vine^{-1} yr^{-1}. The burnt earth had a pH of 7.8, compared to 4 to 5 for fresh soil and a CaO content of 0.3 per cent. The addition of burnt earth had several effects, viz., (i) it altered the physical characteristics of the rooting medium, (ii) it increased the soil pH and (iii) it supplied the nutrients. The actual quantities of nutrients added to soil by this process was small, but these were offered in a form ideally suited for uptake by the roots.

Chancy (1951) established the phosphatic source of nutrients for black pepper grown in red soils of Vietnam. The necessity of liming acid soils for pepper cultivation was reported by Marinet (1953). However no definite pH limits were recommended.

De Waard and Sutton (1960) found that the use of fertilizers by the farmers of Sarawak, lowered the pH in the soil, reduced the uptake of calcium and magnesium and increased the K/Ca + Mg ratio in the leaf.

According to De Waard (1964) the nutrient removal of the variety Kutching with a plant population of 1729 vines ha^{-1} was 252.04 kg N, 31.75 kg P_2O_5 and 224.04 kg K_2O per hectare. De Waard (1969) also worked out the critical levels of N, P, K, Ca and Mg as 2.70, 0.10, 2.00, 1.00 and 0.20

per cent, respectively, on dry weight basis, below which deficiencies of the concerned elements were expected to develop. From a study by Sim (1971) it was found that 233 kg N, 39 kg P_2O_5, 207 kg K_2O, 30 kg MgO and 105 kg CaO hectare^{-1} were removed from the soil by seventeen year old vine.

Raj (1972) in an experiment to study the effect of organic and inorganic fertilizers on the yield of pepper observed that there was significant difference between NPK mixture with trace elements and organic manure. In 1973 he further observed that 12 oz of urea and 16 oz of muriate of potash plant^{-1} year^{-1} gave the highest economic yield in sandy soils of Sarawak.

Sim (1973) estimated the trace element content of the reproductive tissues in mature vines varying in age from below one year to above one year in Sarawak. The amount of micronutrients removal per vine was calculated as 365 mg Fe, 281 mg Mn, 104 mg Zn, 89 mg Cu and 60 mg B.

It is reported by Nagarajan and Pillai (1975) that Panniyur-1 is more nutrient exhaustive than Kalluvally for N, P, K, Ca and Mg. The order of contents of nutrients removed was N>K>Ca>Mg>P. Pillai and Sasikumaran (1976) observed that one hectare of pepper garden having a plant population of 1200 vines yielding on an average 1 kg dry pepper per vine removed 34.0 kg N, 3.5 kg P_2O_5 and 32.0 kg K_2O for the production of berries at Panniyur, Kerala. Based on this, they had recommended a manurial schedule of 100 g N, 40 g P_2O_5 and 140 g K_2O $vine^{-1}$. They also studied the N, P, K, Ca and Mg levels in root, stem, leaf and spike of four year old vines of Panniyur-1 and reported that N and K were the highest and P the lowest in the leaves.

The foliar concentration of N, P and K in different seasons was studied by Bataglia et al. (1976) and observed that N was the maximum in autumn, but declined in winter, phosphorus was the highest in summer and declined thereafter whereas K was high in summer, reached a peak in autumn and declined in winter.

De Waard (1978) observed that addition of alkaline compounds to mounds prior to planting resulted in an increase in growth and earlier establishment of vines in Sarawak.

Raj (1978) suggested a sound fertilizer policy, based on the nutrient removal by crop, crop size, yield from unit area and nutrient status of leaf as indicated by foliar analysis.

It has generally been conceived that pepper responds well to N application. It is observed by Pillai et al. (1979)

that higher levels of N encourages luxuriant vegetative growth in variety Panniyur-1, but adversely affected the yield. They therefore recommended 60 g N $vine^{-1}$ $year^{-1}$ as the maximum limit for proper growth and production of crop.

Kumar and Cheeran (____, studied the nutrient requirement of pepper vines trained both on live and dead standards. They observed that the interaction effect of N and P with standards was statistically significant. With dead standards, 75 g N and 50 g P_2O_5 $vine^{-1}$ $year^{-1}$ were found to produce the highest yield of green berries per vine. As regards the growth of vine, dead standards were found superior to live ones.

Geetha (1981) found that the flowering laterals of black pepper contain comparatively higher quantity of N, P and K during flowering and spike development stage (from June to November) and decreased from November to December. The Ca content was more in non flowering shoots from July to December. The low level of N and K content of flowering shoots during November to December is reported to be one of the reasons for spike shedding in pepper.

Growth and yield of black pepper is very much influenced by the support used for trailing the vines. Studies indicated that the growth and yield of the vines were much better when the vines trailed on dead standards like teak poles than on live standards (live trees) (Menon et al., 1982, Kurien et al., 1985; Anon, 1987).

Wahid et al. (1982) in their study on the mineral nutrition of slow wilt affected pepper had not found any difference in micronutrient level in the leaves of pepper, although the healthy leaves contain more of K than the unhealthy.

Kurien (1982) reported that there was no significant difference in levels of N, P and Mg in pepper leaves from July to September. Concentration of K was the highest during the above period. The N and P content gradually decreased from July and the berries matured in November whereas the K content slightly increased in September, followed by a decrease in November.

Sushama et al. (1984) observed significant positive correlation of yield with P and K of leaf whereas N content failed to establish significant positive correlation with yield.

Sankar (1985) studied the distribution of nutrients in various parts of the plant as well as the total nutrients removed by the plant. She observed that the annual nutrient removal by a five year old vine through harvest of 1.284 kg dry pepper was 38.5 g N, 36.7 g K, 14.9 g Ca, 13.7 g Mg, 2.2 g P, 1.37 g S, 218 mg Fe, 155 mg Mn, 48 mg Cu and 28 mg Zn. Her investigation on the root activity pattern revealed that the active root zone of black pepper was in a soil column of 30 cm radius around the vine.

Studies by Chepote et al. (1986) on the effect of NPK fertilization on the production of Piper nigrum in Southern Bahia indicated that the mean yield of dry pepper ranged from 2883 kg ha^{-1} in the unfertilised plot to 7413 kg ha^{-1} in plots receiving N:P:K at 200:240:160 kg ha^{-1} + Dolomite limestone at 1 t ha^{-1} + fritted micronutrients at 4.8 kg ha^{-1}.

According to Pillai et al. (1987) the optimum levels of N, P and K for pepper variety Panniyur-1 was 50 g N, 100 g P_2O_5 and 150 g K_2O $vine^{-1}$ $year^{-1}$.

Wahid (1987) studied the effect of fertilizing and pruning the live supports on pepper plant yield under Indonesian conditions and the best results were obtained with pruning the support trees three times a year, and application of 400 g of fertilizer (12 N: 12P: 17K: 2 Mg) $vine^{-1}$ four times a year.

According to Mathai and Sastry (1988) the support tress should be pruned during the pre-flowering stage of the vines which helps in increasing the light availability and produced greater leaf area and more compact canopy with shorter laterals. This allowed the vines to accumulate more metabolites leading to increased production of laterals, more flower spikes, greater number of berries per spike and higher dry weight of berries.

It was observed by Sankar et al. (1988) that the nutrient uptake decreased when the vines were trailed on live standards. According to them the two plant species viz., the vine and the standard are competing for nutrients and water as they share the same soil resources. They also suggested that besides competitive interaction, there was also evidence of support tree exerting an inhibitory effect on the vine.

Nybe et al. (1989) studied the direct and indirect effect of foliar nutrients and found that the foliar levels of N, K, Ca and Mg increased with the addition of fertilizers during rainy season. The nutrient elements P, K, Ca, Mg and S were found to exert direct and indirect effect on yield of green pepper. Of these P and K were found to be of greater importance in enhancing the yield.

Sadanandan and Rajagopal (1989) found that the P indices of both the youngest matured and the next matured leaves gave significant correlation with yield. In the case of youngest matured leaf, highly significant correlation in the order of r = 0.81** was obtained. The study also revealed that P index (P index = $\frac{P}{N+P+K+Ca}$) value of 0.042 gave the highest yield of dry pepper and hence they suggested that the P index can be used as an effective tool to find out the probable yield from any particular garden.

Sangakkara (1989) investigated on the effect of pH of the propagating medium on root and shoot growth of black pepper found that substrates with pH 7.8 and 8.1 gave greater root and shoot weights after 70 days of planting.

Studies by Geetha (1990) revealed that application of N, P, K, Ca, Mg and S had influence on one or more growth parameters of both bush pepper and vine pepper. The application of Ca improved the root characters markedly. Among the nutrients applied, it was found that only N and S increased their concentration in the stem and leaf. Treatments devoid of N produced typical N deficiency symptoms. She observed considerable variability among black pepper varieties with respect to growth, fertilizer P utilization, nutrient uptake and nutrient concentration. Nutrients N, K, Ca, S, Fe and Mn were found more accumulated in the leaf whereas P and Mg were more in the stem. The order of contents of nutrients removed was K>N>Ca>Mg>P>S>Fe>Mn>Zn.

Sadanandan et al. (1991) obtained significant positive correlation between yield and leaf N in Panniyur-1 variety of black pepper. Sadanandan (1992) observed that application of organic amendments like neem cake at the rate of 1 t ha^{-1} besides the scheduled dose of fertilizers resulted in significant increase in the availability of nutrients in the soil and increased the yield. It also restricted the incidence of foot rot and slow decline of pepper.

Cheeran et al. (1992) in their study on the effect of variety, spacing and support material on nutrition and yield of black pepper observed that the variety Karimunda accumulated more K, Ca and Mn in the leaf compared to Panniyur-1. Three to four fold increases in yield were obtained by trailing the vines on teak poles than on trees. A depressing effect on foliar Ca level was noticed in vines trailed on Garuga pinnata. They found that closer spacing of 2 m x 2 m did not affect the yield adversely.

Sivakumar (1992) observed that the biomass production in black pepper was greatly influenced by addition of organic materials into the soil. Significant increases were noticed in the N, P, K and S concentrations of leaf and stem, Mg and Mn concentrations of leaf, and Fe content of stem following application of organic matter. The vines removed significantly higher quantities of N, P, K, Ca, Mg, S, Fe and

Mn following the addition of leaf materials to the soil. He observed an average nutrient removal of 200.19 mg N, 18.92 mg P, 432.53 mg K, 155.89 mg Ca, 19.44 mg Mg, 12.33 mg S, 1517 μg Fe and 3546 μg Mn by 6 month old black pepper vine to produce 11.19 g total (shoot) dry matter. Significant increase in major and micronutrient availability was also observed in the soil following the addition of leaf material.

Reddy et al. (1992) observed 258 per cent yield increase in black pepper grown at a spacing of 2 x 1 m over the normal spacing of 3 x 3 m. They found that there was a corresponding depletion of nutrients in the soil as the plant population of pepper increased from 1100 to 5000 ha^{-1}. So also there was a decreasing trend of nutrient concentrations in plant tissue with the increase in population, warranting judicious application of nutrients for optimum productivity.

2.2 Nutritional disorders

Malnutrition is one of the major causes responsible for diseases/disorders in all biological species. In black pepper not much investigations have been done in this direction. Some attempts were made in this regard in India and abroad.

De Waard and Sutton (1960) attributed the dropping and yellowing of pepper growing in highly acid soils of Sarawak to Al toxicity.

Sim (1972) suspected toxicity of Mn to black pepper and identified the symptoms. Severe Mg deficiency and Al and Mn toxicity were reported in Sarawak pepper gardens by Sim (1974).

De Waard (1979) referred the significance of nutrients, especially K, in checking yellow leaf disease complex in black pepper in the islands of Bangka, Indonesia. It was reported that application of fertilizers having 400 kg N, 180 kg P_2O_5, 480 kg K, 425 kg Ca and 112 kg Mg per ha with proper mulching controlled the disease efficiently and produced an average yield of 2.0 to 2.5 kg dried berries per vine.

Mustica _et al_. (1988) observed that application of N:P:K 15:15:15 fertilizer at 250 g $vine^{-1}$ $year^{-1}$ and either aldicarb at 50 g $vine^{-1}$ or manozeb at 12 g $vine^{-1}$ or both could reduce the severity of yellow disease in black pepper.

Nambiar _et al_. (1965) worked out tentative ratios of $\frac{K_2O}{N}$ (total) $\frac{K_2O}{N}$ (available) and $\frac{CaO + K_2O + MgO}{N}$ in soil and found that slow wilt of black pepper occurred when these ratios were below 14.10, 0.15 and 3.80, respectively.

Wahid *et al*. (1982) in a study on the mineral nutrition of slow wilt affected black pepper observed that the K content of leaves from healthy vines was considerably higher than that of diseased ones. Foliar yellowing and tip necrosis of laminae were noticed in diseased vines which were attributed to N and K deficiencies, respectively. The pot culture studies conducted by them revealed N deficiency as a cause for the 'yellow leaf disease' in pepper.

Sivaprasad *et al*. (1993) observed that artificial inoculation of pepper cuttings with VAM fungus improved the growth and general condition of the vines and its colonization induced resistance to root-knot nematode infestation and multiplication.

2.3 Foliar diagnosis of nutritional deficiencies

A productive soil should contain all the essential plant nutrients in sufficient quantity and balanced proportion. The nutrients should also be present in an available form before plants can use them. Each of the essential nutrients has a definite and specific function to perform in the growth and development of plants. Inadequacy of any one of these elements will inhibit the plant growth to its full potential and cause some abnormal condition that upsets the growth and production of plants.

Foliar diagnosis through analysis of leaf tissue is regarded as an effective tool for assessing the nutrient status of the plants in detecting the 'hidden hunger' or visual deficiency of one or more elements.

According to De Waard (1969), who was one of the pioneers to introduce foliar diagnosis in pepper, the first mature leaf with petiole, from fruit bearing high order branches, could be designated as the best reflex of nutrients. The nutrient content of leaves varied from 2.7 to 3.1 per cent for N and from 0.10 to 0.16 per cent for P and 2.62 to 3.40 per cent for K. The concentration of K remained unchanged in leaves from 7 am to 1 pm whereas N content decreased from early morning to late afternoon, which was not significant from 7 am to 10 am. Employing pot culture experiments he could induce visual deficiency symptoms associated with five major nutrient elements such as N, P, K, Ca and Mg in black pepper and reported the critical levels as 2.7, 0.1, 2.0, 1.0 and 0.2 per cent respectively on dry weight basis, below which deficiencies of the concerned elements could be expected to occur. He also studied the deficiency symptoms of the aforesaid nutrients under field condition and reported that the symptoms resembled to that observed in pot culture studies. However, no pattern of symptoms associated with P deficiency have been observed under field condition.

Similarly, Ca deficiency symptoms were not common under field condition.

Sim (1974) also reported that the leaf nutrients gave a better correlation with yield than soil nutrients.

Pillai and Sasikumaran (1976) studied the N, P, K, Ca and Mg levels in root, stem, leaf and spike of four year old pepper vines of variety Panniyur-1 and found that N and K we-- the highest and P the lowest in leaves.

Sushama et al. (1982) observed that the first mature leaf counting from the tip of the lateral shoot, better reflected the variation in the content of N, P and K in pepper leaf corresponding to the variation in the levels of these nutrients applied and considered those leaves as the best for the foliar diagnosis of N, P and K in pepper. Sushama et al. (1984) further reported that the period just prior to flushing of pepper was the best suited for collection of leaf samples for foliar diagnosis.

Nybe and Nair (1986, 1987a, 1987b, 1987c) and Nybe et al. (1988) could induce deficiency symptoms of macro and micro nutrients by sand culture experiments in Kerala. Deficiency symptoms of macro nutrients except Ca and S were first manifested on the older leaves. Symptoms of N deficiency was expressed as uniform yellowing followed by necrosis, whereas purple to bronze yellow colour and ash coloured necrotic areas were the symptoms of P deficiency. K deficiency was characterised by tip and marginal necrosis which later progressed to the distal 2/3 portion of the lamina. Vegetative growth was considerably reduced due to deficiency of macro and micronutrients. Ca, P, N and S showed profound influence on shoot growth. Visual symptoms of deficiencies were concurred with a marked reduction in the foliar level of concerned element. The deficiency symptoms could also be recovered by the application of the deficient nutrient element and thus the deficiency of the element was confirmed.

Nybe et al. (1989) observed fairly good correlation for foliar contents of P, K, Ca, Mg and S in April and June with the yield of black pepper, the said period, ie. the period just prior to flushing was suggested as the most suitable period for leaf sampling in pepper.

Materials and Methods

MATERIALS AND METHODS

The present investigation on the nutrient removal in relation to crop production in black pepper, was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 1992-93. For this study a standing crop of black pepper variety Panniyur-1 at the Regional Agricultural Research Station, Ambalavayal was used.

3.1 Location

The Regional Agricultural Research Station is located at Ambalavayal in Sultan Bathery Taluk of Wynadu district, Kerala State. This is one of the hill stations in the Western Ghats of Kerala. The research station is situated at an altitude of 974 m above M.S.L. It lies between 10° 26' and 11° 59' North latitudes and 76° 26' and 75° 46' East latitudes.

The climate prevailing in the area is by and large mild sub-tropical which is conducive for growing both subtropical and tropical crops. Data on meteorological observations collected from the research station are presented in Appendix-I and II. The average annual rainfall of the area is around 2300 mm with an average relative humidity of 73 per cent. The area is experiencing a minimum temperature of about 14.5°C and a maximum of 32.1°C.

located on a moderately sloping terrain. The total extent of the block is 1.8 ha fully under black pepper. The vines are in the age group of 12 years. Silver oak (*Grevilea robusta*) trees are mainly used as standard for trailing the vines. The vines are raised by adopting all the cultural practices including fertilizer and plant protection applications as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1989).

3.3 Selection of plants

One hundred and fifteen vines having different productivity levels were selected from this block for the study. While selecting the vines, 3 border rows on all sides were discarded and only inner vines were selected. The vines were planted during 1980 planting season. All the selected vines were from the variety Panniyur-1 and trailed on silver oak (*Grevilea robusta*) trees.

3.4 Collection of samples

3.4.1 Collection of soil

The soil samples were collected in May 1992, just prior to the flushing of the vines. Soil samples from 0 to 25 cm depth were collected from four points in the basin 15 cm away from the vine and composited to give a sample. Soils from all the selected 115 vines were collected separately.

3.4.2 Collection of leaf samples

The leaf samples were collected from the 115 selected vines, following the procedure prescribed by De Waard (1969). The sampling was done on 15th May 1992, just prior to flushing of the vines. The first mature older leaf from the fruit bearing laterals, exposed to sunlight and located on the lower two-thirds of the canopy was selected as sampling leaf.

From each plant, eight leaves with petiole intact were collected at the rate of two each from north, south, east and west quarter aspects of the vine. The time of sampling was between 8 am and 12 noon.

3.4.3 Collection of spike samples

Spike samples from all the selected 115 vines were collected during March 1993, at the time of harvesting of the crop. Spikes were collected at random from the harvested produce of each vine.

3.5 Yield of pepper

Yield of spikes from the selected vines for the year 1993 was recorded and expressed as green yield per vine (kg of green spikes).

Representative samples of 100 g green spikes from each vine were drawn from all the selected vines and noted its sun-dried weight and oven dried weight to ascertain the loss of moisture on drying. This data was used for arriving at the sundried and oven dried weight of the total produce from the vines.

3.6 Laboratory studies

3.6.1 Soil samples

The soil samples collected were air dried, powdered gently and passed through a 2 mm sieve. The samples were kept in labelled plastic containers for further analysis.

3.6.1.1 Chemical analysis of soil samples

The pH of the soil was determined at a soil-water ratio of 1:2.5 using a pH meter. For the determination of organic carbon content of soil, Walkley-Black's method was followed (Jackson, 1958).

Available P in the soil was extracted by Bray No.1 extractant and the P content determined colorimetrically by the ascorbic acid blue colour method (Watanabe and Olsen, 1965).

Exchangeable K in the soil was extracted using neutral normal ammonium acetate and the K content read in EEL flame photometer (Jackson, 1958).

Determination of exchangeable Ca and Mg was made using ammonium acetate leachate in an atomic absorption spectrophotometer. Available S content in the soil was estimated by turbidimetric method (Fox _et al._, 1964 and Hesse, 1971).

For determination of available micronutrients Fe, Mn and Zn, the soil samples were extracted with 0.05 N HCl + 0.025 N H_2SO_4 in the ratio 1:4 for 15 min. The Fe content in the extract was determined colorimetrically using KSCN (Jackson, 1958). The Mn and Zn contents were read in an atomic absorption spectrophotometer (Page, 1982).

3.6.2 Plant samples

The leaf samples were cleaned with moist cotton immediately on collection and dried in a hot air oven at 70°C. The spike samples collected were also dried in a hot air oven at 70°C. The dried leaf and spike samples were ground in a Wiley mill fitted with stainless steel blades and passed through 40 mesh sieve. The samples were kept in labelled plastic containers for further analysis.

3.6.2.1 Chemical analysis of plant samples

The plant samples viz., leaf and spike samples were analysed for macro and micro nutrients such as N, P, K, Ca, Mg, S, Fe, Mn and Zn as detailed below.

The total N in the samples was estimated by Kjeldahl method (Jackson, 1958). For the analysis of other elements, diacid extracts were prepared by digesting 1 g of the sample in 15 ml of 2:1 concentrated nitric-perchloric acid mixture (Johnson and Ulrich, 1959). Aliquots of the digest were used for the analysis and estimation of total P, K, Ca, Mg, S, Fe, Mn and Zn.

Phosphorus was determined colorimetrically by vanadomolybdo-phosphoric yellow colour method (Jackson, 1958). The yellow colour was read in a spectrophotometer (Spectronic-20) at a wavelength of 470 nm. Potassium was estimated using flame photometer (EEL make).

Total Ca, Mg, Mn and Zn were determined using an atomic absorption spectrophotometer.

Sulphur in the diacid mixture was determined turbidimetrically following barium chloride method (Hart, 1961). The turbidity was read using a spectrophotometer (Spectronic-20) at a wavelength of 490 nm. Fe was estimated by KSCN method (Jackson, 1958) and the colour read at a wavelength of 490 nm using spectrophotometer (Spectronic-20).

3.7 Statistical analysis

The results obtained were subjected to correlation and regression analysis between various factors and r values and regression equations were worked out as described by Snedecor and Cochran (1967).

RESULTS

The soil and plant samples viz., leaf and spike collected from the pepper garden at the Regional Agricultural Research Station, Ambalavayal were analysed for various nutrient elements. The yield from the selected 115 vines from which the samples were taken was also recorded. The data generated from the experiments to assess the nutrient removal in relation to crop production in black pepper are described as follows:

4.1 Soil characteristics and variability in soil fertility level

The 115 soil samples collected from the basin of the selected vines were analysed for soil pH, organic carbon, available P, K, Ca, Mg, S, Fe, Mn and Zn. The data relating to the mean, range, standard deviation and coefficient of variation are furnished in Table 1.

The pH of the soil samples ranged between 4.5 to 6.5 with a mean of 5.23. There was not much variation in the pH range of the samples and the coefficient of variation observed was only 8.0 per cent.

The organic carbon content in the samples ranged

Table 1. Chemical characteristics of the root zone soils of the vines

Soil characteristic	Mean	Range		S.D	C.V (%)
		Minimum	Maximum		
pH	5.23	4.5	6.50	0.42	8.0
Organic Carbon (%)	1.39	1.1	2.28	0.22	15.8
Available P (ppm)	7.47	2.0	22.70	5.31	71.1
Exchangeable K (ppm)	270.61	105.0	610.00	104.70	38.7
Exchangeable Ca (ppm)	339.37	83.0	997.00	206.97	61.0
Exchangeable Mg (ppm)	40.43	17.0	137.00	27.13	67.1
Available S (ppm)	38.38	4.0	97.00	26.76	69.7
Available Fe (ppm)	31.23	16.0	46.00	7.37	23.6
Available Mn (ppm)	54.35	21.0	94.00	14.52	26.7
Available Zn (ppm)	1.54	0.7	4.00	0.63	40.9

between 1.1 to 2.28 per cent. The mean, standard deviation and coefficient of variation were 1.39, 0.22 and 15.8 per cent respectively.

The available P content in the soil samples ranged between 2 to 22.7 ppm with 7.47 ppm as the mean value. The coefficient of variation between the samples was 71.1 per cent.

The content of exchangeable K varied between 105 to 610 ppm (0.27 to 1.56 cmol (+) kg^{-1}) with a mean value of 270.61 ppm (0.69 cmol (+) kg^{-1}). The coefficient of variation between the samples was 38.7 per cent.

Exchangeable Ca content in the soil ranged from 83 ppm (0.415 cmol (+) kg^{-1}) to 997 ppm (4.985 cmol (+) kg^{-1}). The average Ca content in the soil samples was 339.37 ppm (1.697 cmol (+) kg^{-1}) with standard deviation of 206.97 and 61 per cent coefficient of variation.

Like soil Ca, the exchangeable Mg content in the samples showed great variation. The coefficient of variation was 67.1 per cent with a Mg content ranging from 17 to 137 ppm (0.142 to 1.142 cmol (+) kg^{-1}).

Available S also showed great variation between the samples. The sulphur content in the soil ranged from 4 to

97 ppm with a mean of 38.38 ppm and a coefficient of variation of 69.7 per cent.

Among the micronutrients analysed soil Fe showed the minimum variation of 23.6 per cent. The Fe content in the soil ranged between 16 to 46 ppm with a mean of 31.23 ppm.

The available Mn content in the soil ranged from 21 to 94 ppm with a mean value of 54.35 ppm. The variation of Mn content in the soil was in the order of 26.7 per cent.

Unlike the other two micronutrients, soil Zn showed maximum variation of 40.9 per cent. The available Zn content in the soil was ranging from 0.7 ppm to 4 ppm with an average of 1.54 ppm.

4.2 Leaf nutrient composition

The leaf samples were analysed for N, P, K, Ca, Mg, S, Fe, Mn and Zn. On dry matter basis the concentration of K was the highest and Zn the lowest in the leaves. The nutrient concentration in the leaves was in the descending order of K, N, Ca, S, Mg, P, Mn, Fe and Zn. The data on the mean, range, standard deviation and coefficient of variation of different leaf nutrients are furnished in Table 2.

Among the leaf nutrients, N showed least variation of

Table 2. Foliar nutrient composition of the vines

Nutrient		Mean	Range		S.D	C.V (%)
			Minimum	Maximum		
N	(%)	2.47	1.96	2.94	0.17	6.9
P	(%)	0.14	0.106	0.185	0.02	14.3
K	(%)	2.61	1.80	3.20	0.27	10.3
Ca	(%)	1.73	1.14	2.32	0.24	13.9
Mg	(%)	0.20	0.10	0.40	0.06	30.0
S	(%)	0.27	0.178	0.377	0.05	18.5
Fe	(ppm)	434.30	250.00	800.00	139.71	32.2
Mn	(ppm)	617.79	447.00	815.00	81.76	13.2
Zn	(ppm)	25.27	19.00	35.00	3.36	13.3

6.9 per cent. The leaf N concentration varied between 1.96 to 2.94 per cent with mean 2.47 and standard deviation 0.17.

The leaf P content in the samples ranged from 0.106 to 0.185 per cent. The coefficient of variation between the samples was 14.3 per cent.

The content of K concentration was the highest among the leaf nutrients. The K content in the samples ranged from 1.80 to 3.20 per cent. The mean was 2.61 and there was 10.3 per cent variation among the samples.

The foliar concentration of Ca ranged from 1.14 to 2.32 per cent with a mean 1.73 and coefficient of variation 13.9 per cent.

The foliar concentration of Mg was between 0.10 to 0.40 per cent. The samples showed a variation of 30 per cent in the level of Mg.

The S content in the leaves ranged from 0.178 to 0.377 per cent with 18.5 per cent coefficient of variation. The mean was 0.27 per cent.

Among the foliar nutrients analysed, leaf Fe showed maximum variation. The content ranged from 250-800 ppm with a mean value of 434.30 ppm and 32.2 per cent coefficient of variation.

The content of foliar Mn varied between 447 and 815 ppm with 617.79 ppm as the mean value and 13.2 per cent coefficient of variation.

The foliar level of Zn was the lowest among the elements analysed. Its content ranged from 19 to 35 ppm with a mean of 25.27 ppm and 13.3 per cent coefficient of variation.

4.3 Nutrient composition of the spike

The spikes were analysed for nutrient elements, N, P, K, Ca, Mg, S, Fe, Mn and Zn. Data on the mean, range, standard deviation and coefficient of variation are furnished in Table 3.

The N content in the spike samples ranged between 1.96 to 2.66 per cent. There was not much variation in the N content between the samples, the coefficient of variation being 6.6 per cent.

The P content of the samples varied from 0.109 to 0.190 per cent with a coefficient of variation of 6.3 per cent.

The spike samples showed a coefficient of variation of 9.2 per cent in K concentration. The minimum content of K was 1.65 per cent and the maximum 2.60 per cent.

Table 3. Nutrient composition and green yield of the spikes

Nutrient	Mean	Range		S.D	C.V (%)
		Minimum	Maximum		
N (%)	2.43	1.96	2.66	0.16	6.6
P (%)	0.16	0.109	0.19	0.01	6.3
K (%)	2.17	1.65	2.60	0.20	9.2
Ca (%)	0.40	0.20	0.53	0.05	12.5
Mg (%)	0.16	0.12	0.28	0.03	18.8
S (%)	0.11	0.078	0.139	0.01	9.1
Fe (ppm)	214.46	100.00	438.00	79.43	37.0
Mn (ppm)	111.61	71.00	178.00	19.78	17.7
Zn (ppm)	15.50	11.00	29.00	2.56	16.5
Green yield (kg)	16.56	0.70	54.30	12.27	74.1

The Ca content in the spike samples varied from 0.20 per cent to 0.53 per cent. The coefficient of variation was 12.5 per cent.

The spikes contained 0.12 to 0.28 per cent Mg with a mean value of 0.16 and 18.8 per cent coefficient of variation.

The S content in the spike samples ranged between 0.078 and 0.139 per cent. The coefficient of variation was 9.1 per cent.

Among the spike nutrients studied, Fe showed maximum variation of 37 per cent coefficient of variation. The Fe content in the samples ranged from 100 to 438 ppm.

The content of Mn in the spike samples varied from 71 to 178 ppm with 17.7 per cent coefficient of variation.

Zn content was the lowest among the nutrients studied. The content ranged between 11 to 29 ppm with 16.5 per cent coefficient of variation.

4.4 Green yield

The highest yield obtained was 54.30 kg and the lowest 0.70 kg. The mean yield was 16.56 kg. The coefficient of variation was 74.1 per cent with a standard deviation of 12.27

(Table 3). On sun drying, the recovery was 32.09 per cent, on an average.

4.5 Relationships between soil characteristics and yield

Significant correlations between soil characteristics and the green yield and their regression equations are presented in Table 4. Significant positive correlations were obtained between green yield and soil pH (r = 0.430**), green yield and soil organic carbon (r = 0.545**), green yield and available Ca (r = 0.596**) and green yield and available Mg (r = 0.584**). Scatter diagrams of these relationships showing linear regression are depicted in Figs.1, 2, 3 and 4 respectively.

The correlations between green yield and available S and green yield and available Fe were negative (r values -0.391** and -0.318**) respectively. The relationships of green yield with available P, K, Mn and Zn were not significant.

4.6 Relationships between leaf nutrient composition and yield

The correlation matrix among leaf nutrients and green yield is presented in Table 5. Except in the case of K, all other leaf nutrient concentrations showed significant correlation with green yield. Positive correlations were

Table 4. Correlations (r values) and regression equations for significant relationships between soil characteristics and green yield in black pepper

Soil characteristic	r	R^2	Regression equation
pH	0.430**	0.185	y = -49.634 + 12.663 x
Organic Carbon (%)	0.545**	0.297	y = -26.694 + 31.116 x
Exchangeable Ca (ppm)	0.596**	0.355	y = 4.559 + 0.0354 x
Exchangeable Mg (ppm)	0.584**	0.341	y = 5.877 + 0.2641 x
Available S (ppm)	-0.391**	0.153	y = 23.434 - 0.1792 x
Available Fe (ppm)	-0.318**	0.101	y = 33.118 - 0.5304 x

** Significant at 1 per cent level

y = Green yield (kg $standard^{-1}$)

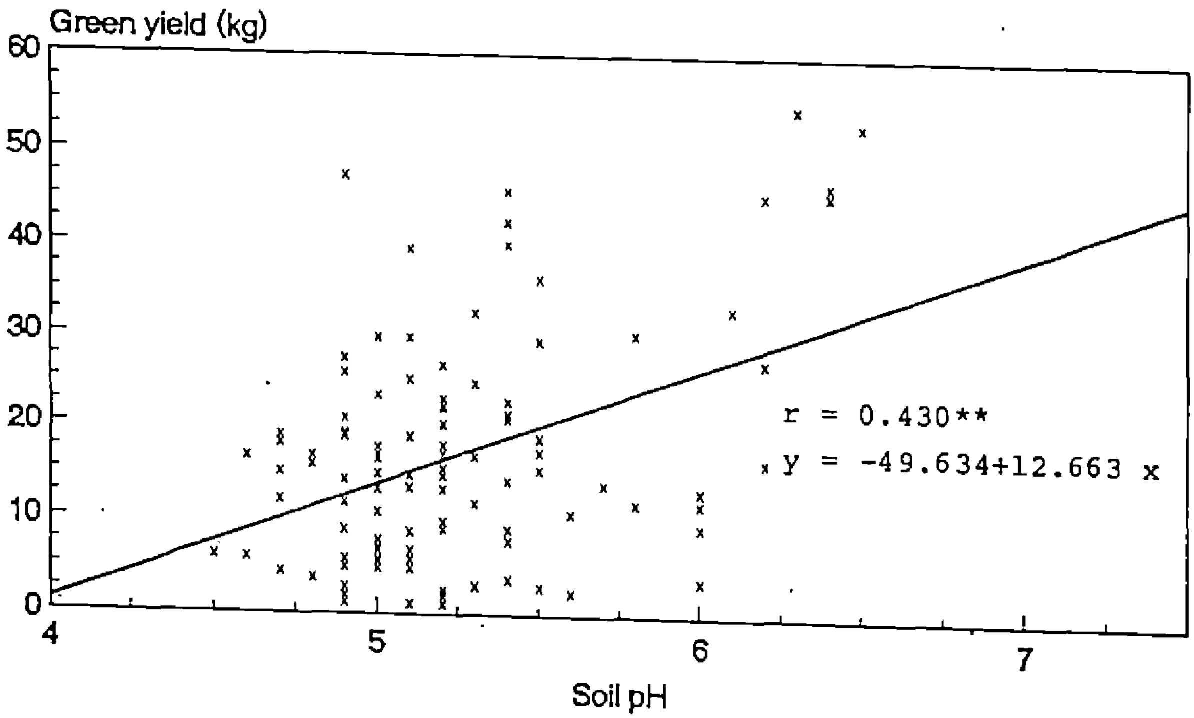

Fig.1 Pepper green yield in relation to soil pH

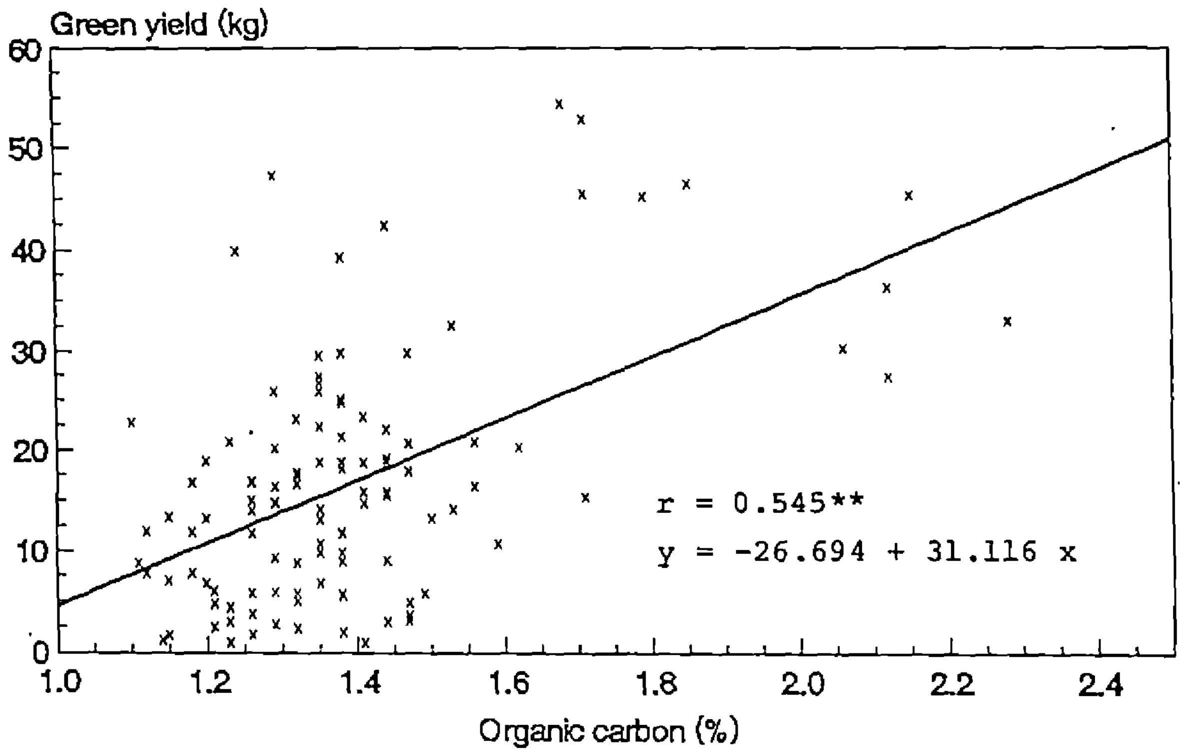

Fig.2 Pepper green yield in relation to soil organic carbon

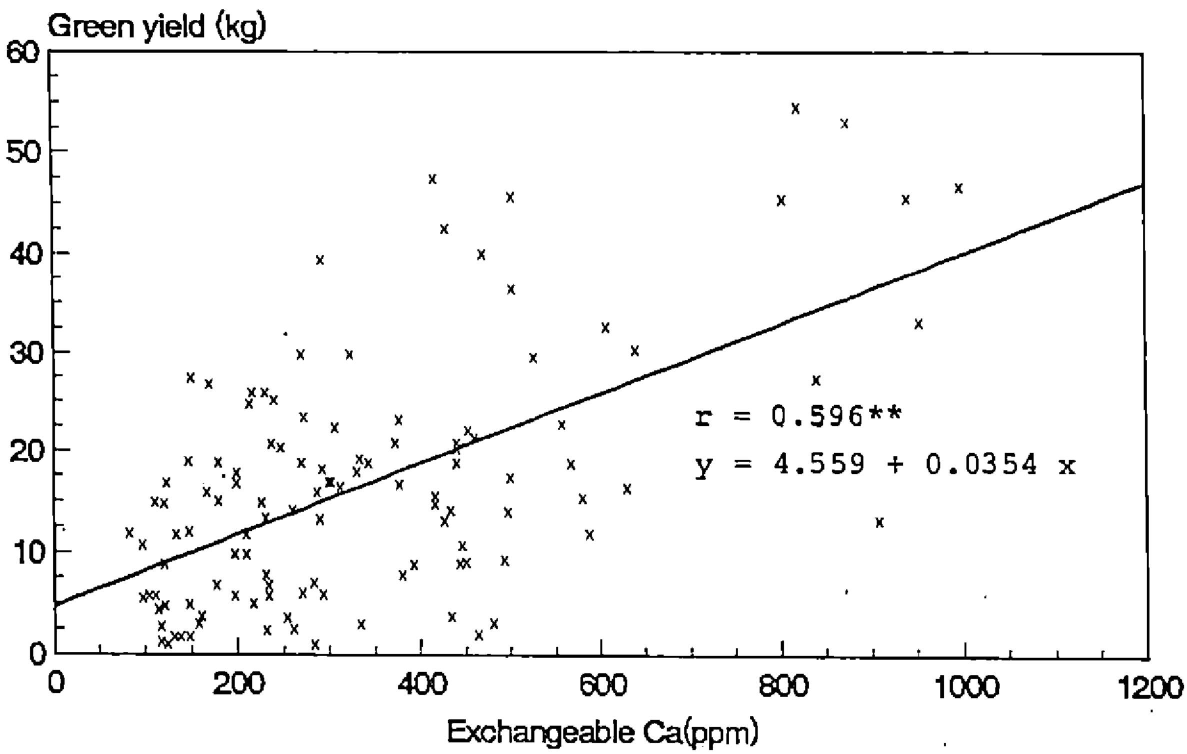

Fig.3 Pepper green yield in relation to Ca availability in soil

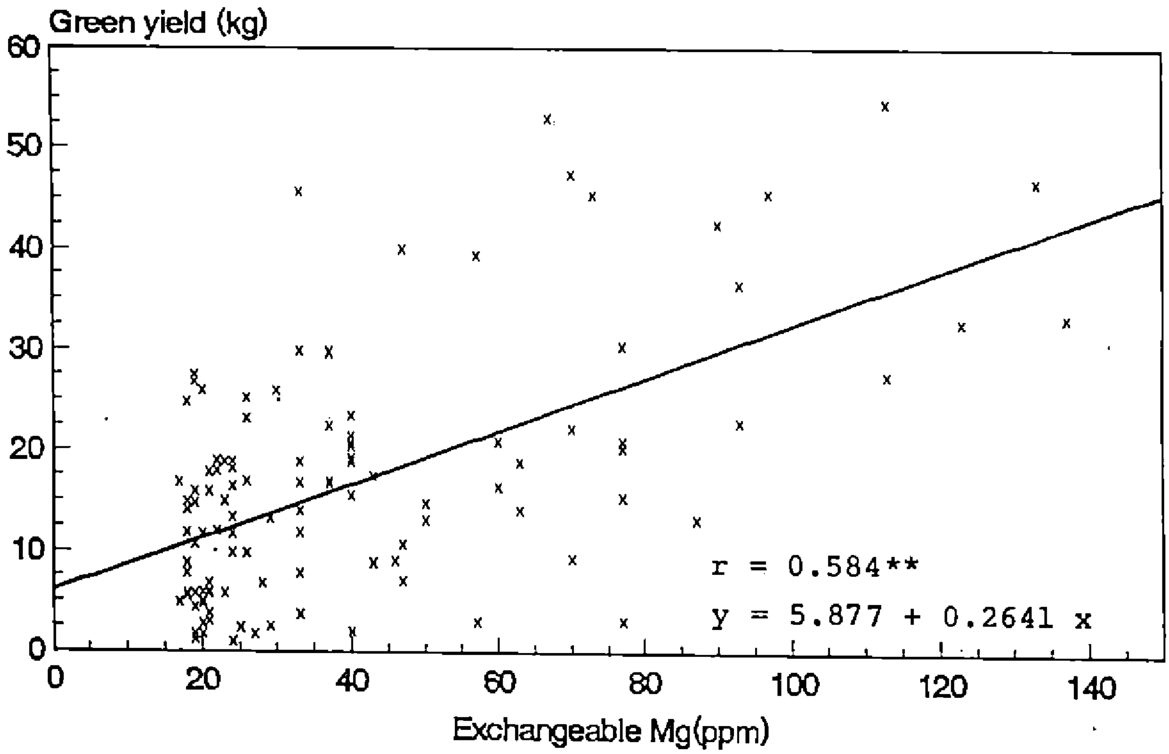

Fig.4 Pepper green yield in relation to Mg availability in soil

ble 5. Correlation matrix for green yield and leaf nutrients (r values)

	Green yield	Leaf nutrients							
		N	P	K	Ca	Mg	S	Fe	Mn
.f N	0.589**								
P	-0.335**	-0.270*							
K	-0.137	0.108	0.104						
Ca	0.536**	0.253*	-0.241*	-0.380**					
Mg	0.446**	0.215	-0.381**	-0.518**	0.575**				
S	-0.477**	-0.316**	0.415**	0.025	-0.148	-0.228**			
Fe	0.400**	0.235*	0.025	-0.046	0.095	-0.041	-0.202		
Mn	0.311**	0.211	0.097	-0.082	0.326**	-0.025	-0.012	0.329**	
Zn	0.294**	0.297**	-0.039	0.127	0.159	0.090	-0.026	0.116	0.205

Significant at 5 per cent level

Significant at 1 per cent level

obtained with N (r = 0.589**), Ca (r = 0.536**), Mg (r = 0.446**), Fe (r = 0.400**), Mn (r = 0.311**) and Zn (r = 0.294**). Both P and S showed negative correlations with yield (r = -0.335** and -0.477** respectively).

Linear regression equations were worked out for leaf nutrients showing significant correlation with green yield and given in Table 6.

4.7 Relationships between spike nutrient composition and yield

The correlation matrix between green yield and spike nutrient concentrations is given in Table 7. Negative correlation was observed between the green yield and spike N (r = 0.535**) and P (r = 0.221*). For others, the r values were not significant.

4.8 Interrelationship among soil characteristics

The existence of significant interrelationships among the concentrations of some of the soil characteristics are also evident. The correlations between these soil characteristics and their regression equations are furnished in Table 8.

Significant positive correlations were obtained between pH and organic carbon (r = 0.532**), pH and Ca (r = 0.781**), pH and Mg (r = 0.641**) organic carbon and Ca (r =

Table 6. Regression equations for significant relationships between green yield and leaf nutrients

Leaf nutrient	r	R^2	Regression equation
N	0.589**	0.346	y = -86.59 + 41.84 x
P	-0.335**	0.112	y = 47.79 - 224.77 x
Ca	0.536**	0.287	y = 31.79 + 27.92 x
Mg	0.446**	0.199	y = -2.92 + 96.30 x
S	-0.477**	0.228	y = 48.15 - 118.62 x
Fe	0.400**	0.160	y = 1.29 + 0.035 x
Mn	0.311**	0.097	y = -12.32 + 0.047 x
Zn	0.294**	0.086	y = -10.65 + 1.08 x

** Significant at 1 per cent level

y Green yield (kg $standard^{-1}$)

x Leaf nutrients (N, P, Ca, Mg and S expressed in per cent and Fe, Mn and Zn in ppm)

Table 7. Correlation matrix for green yield and spike nutrients

Spike	r
N	-0.535**
P	-0.221*
K	0.191
Ca	0.026
Mg	0.101
S	-0.138
Fe	-0.169
Mn	0.148
Zn	-0.025

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 8. Correlations (r values) and regression equations for significant relationships between soil characteristics

y	x	r	R^2	Regression equation
pH	Organic carbon	0.532**	0.283	y = 3.793 + 1.031 x
pH	Exchangeable Ca	0.781**	0.610	y = 4.693 + 0.0016 x
pH	Exchangeable Mg	0.641**	0.411	y = 4.829 + 0.0098 x
pH	Available S	-0.226*	0.051	y = 5.362 - 0.0035 x
pH	Available Fe	-0.442**	0.195	y = 6.009 - 0.025 x
Org. carbon	Exchangeable Ca	0.647**	0.419	y = 1.162 + 0.00067x
Org. carbon	Exchangeable Mg	0.640**	0.410	y = 1.185 + 0.0051 x
Org. carbon	Available S	-0.286**	0.082	y = 1.478 - 0.0023 x
Org. carbon	Available Fe	-0.321**	0.103	y = 1.682 - 0.0094 x
Exchangeable Ca	Exchangeable Mg	0.856**	0.733	y = 75.274 + 6.531 x

* Significant at 5 per cent level

** Significant at 1 per cent level

Organic carbon expressed in per cent and nutrient concentrations in ppm and S, pH and Fe, organic carbon and S and organic carbon and Fe were -0.226*, -0.442**, -0.286** and -0.321** respectively.

4.9 Relationships among leaf nutrients

The correlations (r values) and regression equation presented in Table 9 show the significant relationships among leaf nutrients. It was observed that positive correlation existed between foliar N and Ca, N and Fe, N and Zn, P and S, Ca and Mg, Ca and Mn and between foliar Fe and Mn. The r values being 0.253*, 0.235*, 0.297**, 0.415**, 0.575**, 0.326** and 0.329** respectively. The scatter diagrams showing the relationships between foliar P and S and foliar Ca and Mg in view of the high r values are given in Fig.5 and 6.

Negative correlations existed between foliar N and P, N and S, P and Ca, P and Mg, K and Ca, K and Mg and between foliar Mg and S. Scatter diagram showing the negative relationship between foliar K and Mg (r = -0.518**) is presented in Fig.7.

Table 9. Correlations and regression equations for the significant relationships among leaf nutrients

y	x	r	R^2	Regression equation
N	P	-0.270*	0.073	y = 2.820 - 2.552 x
N	Ca	0.253*	0.064	y = 2.144 + 0.186 x
N	S	-0.316**	0.100	y = 2.760 - 1.105 x
N	Fe	0.235*	0.055	y = 2.339 + 0.00029 x
N	Zn	0.297**	0.088	y = 2.079 + 0.015 x
P	Ca	-0.241*	0.058	y = 0.171 - 0.0187 x
P	Mg	-0.381**	0.145	y = 0.164 - 0.122 x
P	S	0.415**	0.172	y = 0.098 + 0.154 x
K	Ca	-0.380**	0.144	y = 3.352 - 0.429 x
K	Mg	-0.518**	0.268	y = 3.098 - 2.420 x
Ca	Mg	0.575**	0.331	y = 1.250 + 2.379 x
Ca	Mn	0.326**	0.106	y = 1.151 + 0.00094 x
Mg	S	-0.228*	0.052	y = 0.272 - 0.263 x
Fe	Mn	0.329**	0.108	y = 86.948 + 0.562 x

* Significant at 5 per cent level

** Significant at 1 per cent level

y and x are leaf nutrients (N, P, K, Ca, Mg and S are expressed in per cent and Fe, Mn and Zn in ppm)

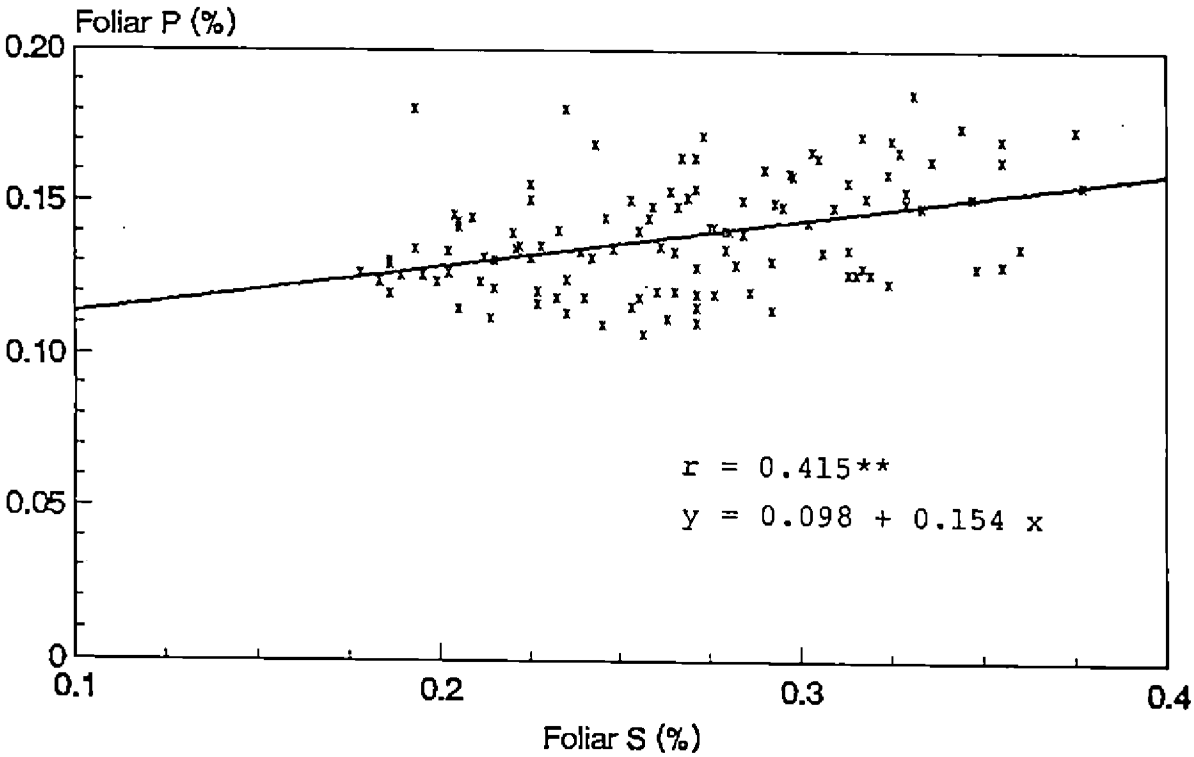

Fig.5 Relationship between foliar P and S concentrations

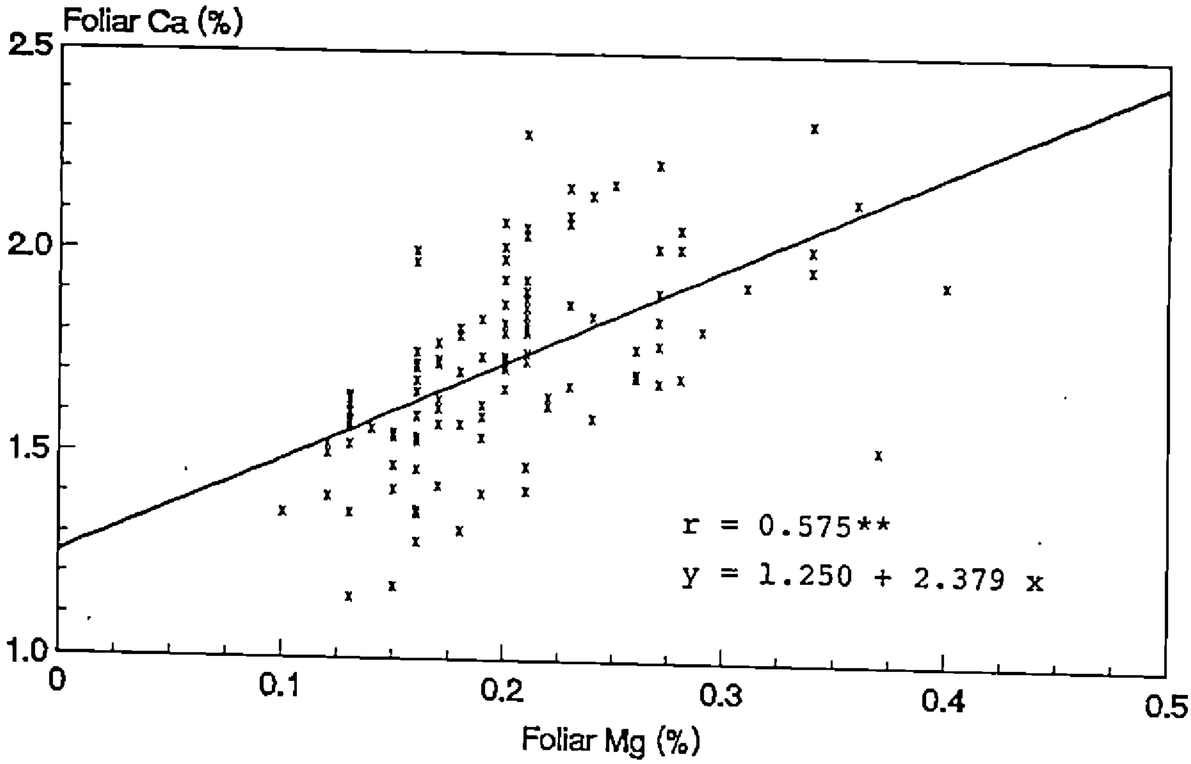

Fig.6 Relationship between foliar Ca and Mg concentrations

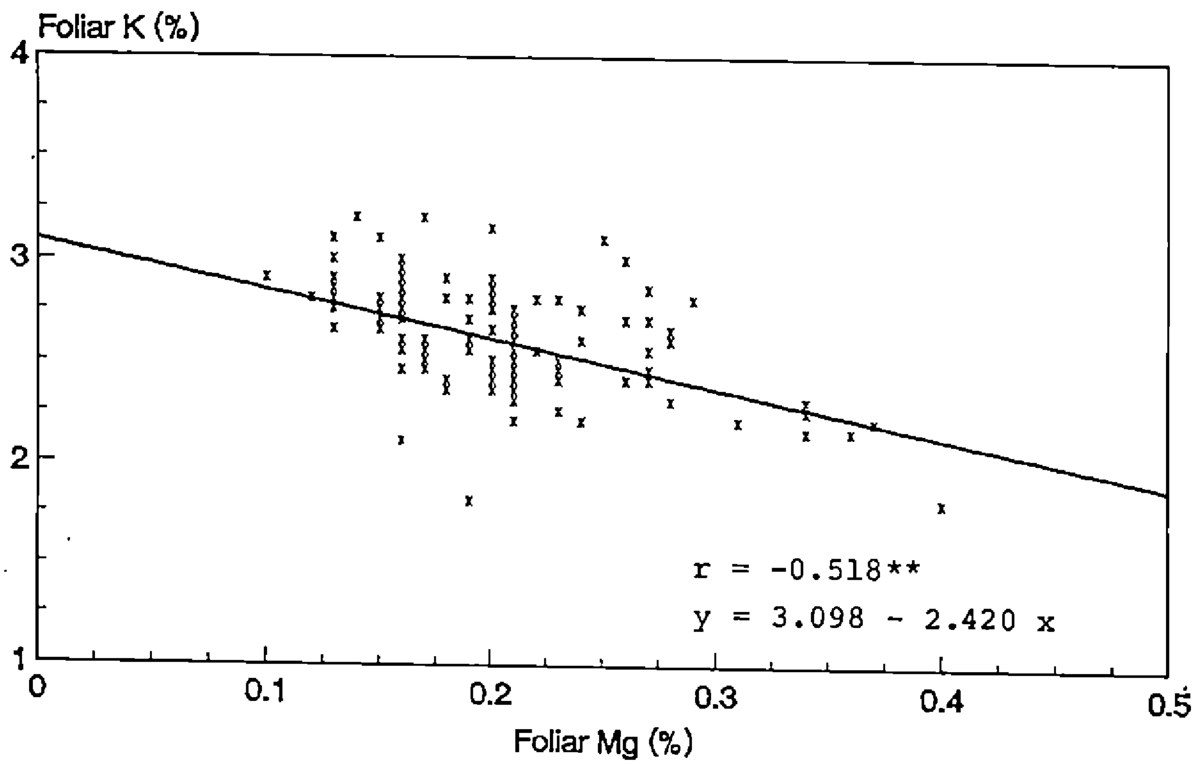

Fig.7 Relationship between foliar K and Mg concentrations

4.10 Relationships between available soil nutrients and foliar nutrient composition

The correlations between available soil nutrients and foliar nutrients along with the regression equation for significant correlations are given in Table 10.

It was observed that soil pH had significant positive correlation with foliar N (r = 0.318**), foliar Ca (r = 0.426**), foliar Mg (r = 0.308**) and foliar Fe (r = 0.279*). The soil pH maintained ignificant negative correlation with foliar K (r = -0.247*) and foliar S (r = -0.231*). The correlations between soil pH and foliar Mn, P and Zn were not significant.

The soil organic carbon had significant positive correlation with leaf N, (r = 0.461**), leaf Ca (r = 0.270*) and leaf Fe (r = 0.339**) and significant negative correlation with leaf S (r = -0.373**). The relationships of soil organic carbon with leaf nutrients P, K, Mg, Mn and Zn were not significant.

The correlation between available P and foliar P was not significant. On the other hand exchangeable K had positive correlation with foliar K (r = 0.231*).

able 10. Correlations (r values) and regression equations for the significant relationships between soil characteristics and leaf nutrients

Leaf utrient (y)	Soil characteristics (x)	r	R^2	Regression equation
N	pH	0.318**	0.101	$y = 1.178 + 0.132\ x$
N	Organic carbon	0.461**	0.213	$y = 1.950 + 0.370\ x$
K	pH	-0.247*	0.061	$y = 3.432 - 0.158\ x$
K	Exchangeable K	0.231*	0.053	$y = 2.449 + 0.00059\ x$
Ca	pH	0.426**	0.181	$y = 0.474 + 0.241\ x$
Ca	Organic carbon	0.270*	0.073	$y = 1.320 + 0.296\ x$
Ca	Exchangeable Ca	0.436**	0.190	$y = 1.563 + 0.0005\ x$
Mg	pH	0.308**	0.095	$y = -0.017 + 0.042\ x$
S	pH	-0.231*	0.053	$y = 0.409 - 0.027\ x$
S	Organic carbon	-0.373**	0.139	$y = 0.385 - 0.085\ x$
Fe	pH	0.279*	0.078	$y = -53.760 + 93.37\ x$
Fe	Organic carbon	0.339**	0.115	$y = 128.607 + 219.92\ x$
Zn	Available Zn	0.231*	0.053	$y = 23.365 + 1.240\ x$

Significant at 5 per cent level

Significant at 1 per cent level

NS Not significant

The exchangeable Ca maintained significant positive correlation with leaf Ca (r = 0.436**), but the correlation between exchangeable Mg and leaf Mg was not significant.

It was observed that no significant correlation existed between available S and leaf S, available Fe and leaf Fe and between available Mn and leaf Mn. However, there was significant positive correlation between available Zn and foliar Zn.

4.11 Relationships between yield and nutrients removed through spikes

Correlation studies revealed that there existed strong positive correlations between the yield and quantities of nutrient elements removed by way of harvest of the spikes. The correlations (r values) and regression equations worked out for the different relationships are furnished in Table 11. It was observed that barring Fe, over 95 per cent of the variability could be accounted for by the regression equations. The plots of these relationships between yield and quantities of N, P, K, Ca, Mg, S, Fe, Mn and Zn removed through harvest are presented in Figs.8 to 16 respectively. The r values for these correlations were 0.987**, 0.989**, 0.984**, 0.972**, 0.962**, 0.976**, 0.763**, 0.976** and 0.975** respectively.

Table 11. Correlations and regression equations between quantity of various nutrients removed by way of harvest and green yield

y	x	r	R^2	Regression equation
N	Green yield	0.987**	0.974	y = 13.54 + 6.35 x
P	"	0.989**	0.978	y = 0.68 + 0.44 x
K	"	0.984**	0.968	y = 5.27 + 6.33 x
Ca	"	0.972**	0.945	y = 1.75 + 1.11 x
Mg	"	0.962**	0.925	y = 0.47 + 0.47 x
S	"	0.976**	0.953	y = 0.38 + 0.29 x
Fe	"	0.763**	0.582	y = 318.17+42.89 x
Mn	"	0.976**	0.953	y = -2.73 +34.45 x
Zn	"	0.975**	0.951	y = 6.44 +4.28 x

** Significant at 1 per cent level

x Green yield (kg $standard^{-1}$)

y Quantity of nutrient removed through spikes by way of harvest (N, P, K, Ca, Mg and S in g and Fe, Mn and Zn in mg)

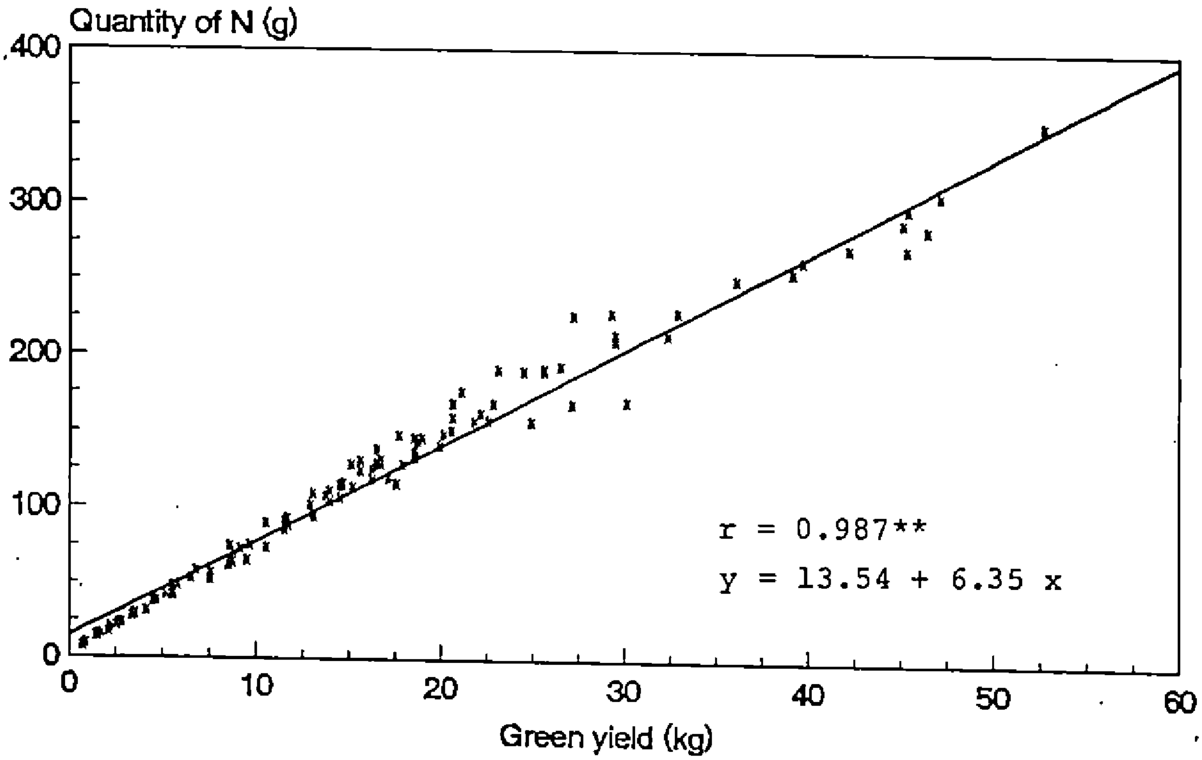

Fig.8 Quantity of N removed through harvested spikes in relation to pepper green yield

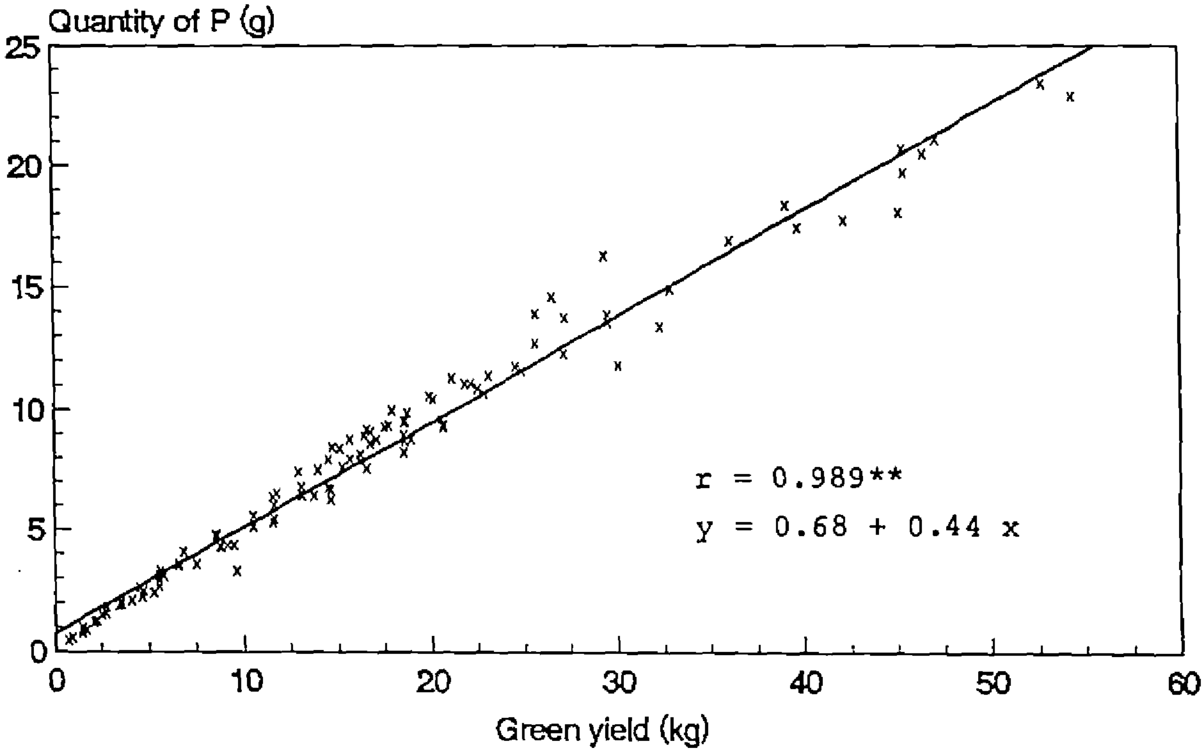

Fig.9 Quantity of P removed through harvested spikes in relation to pepper green yield

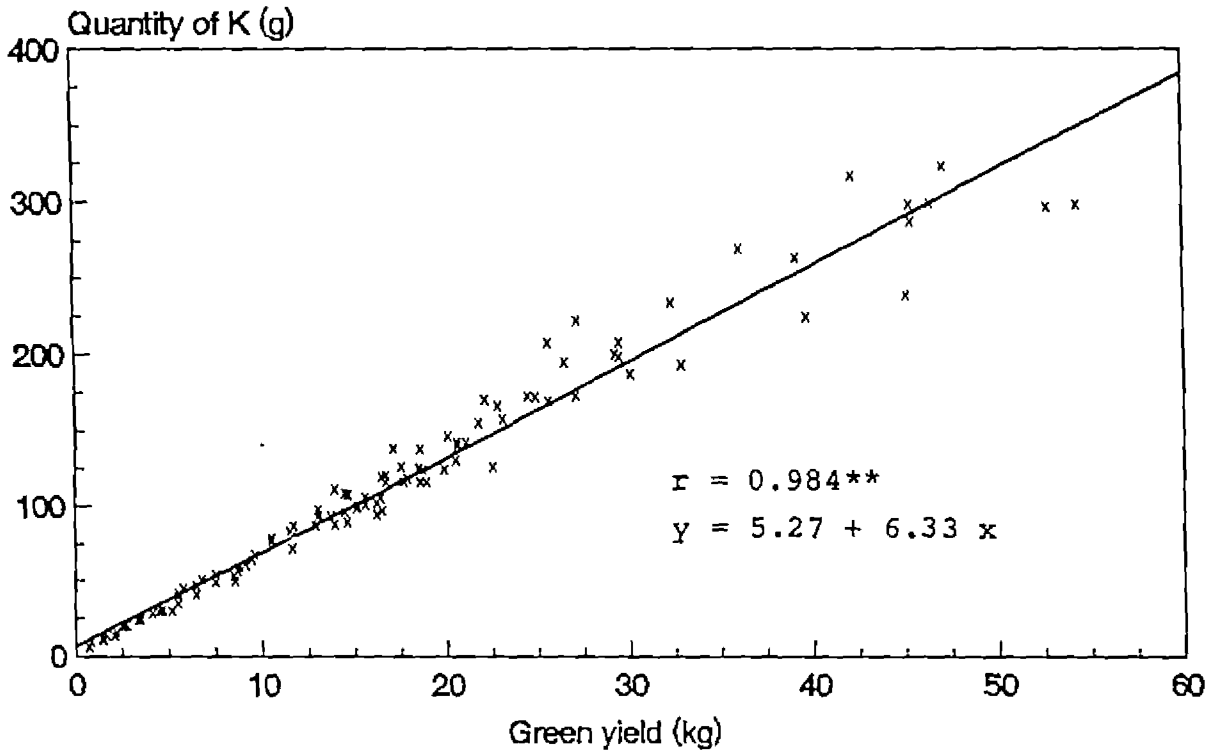

Fig.10 Quantity of K removed through harvested spikes in relation to pepper green yield

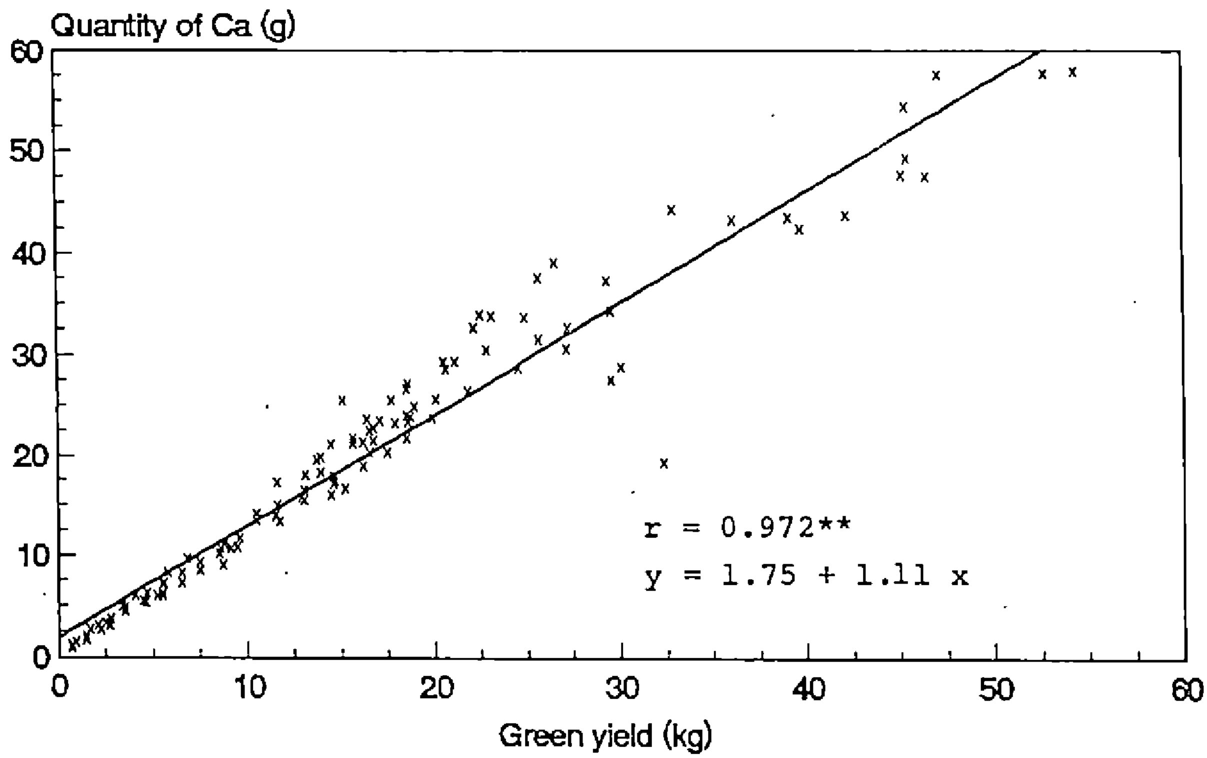

Fig.11 Quantity of Ca removed through harvested spikes in relation to pepper green yield

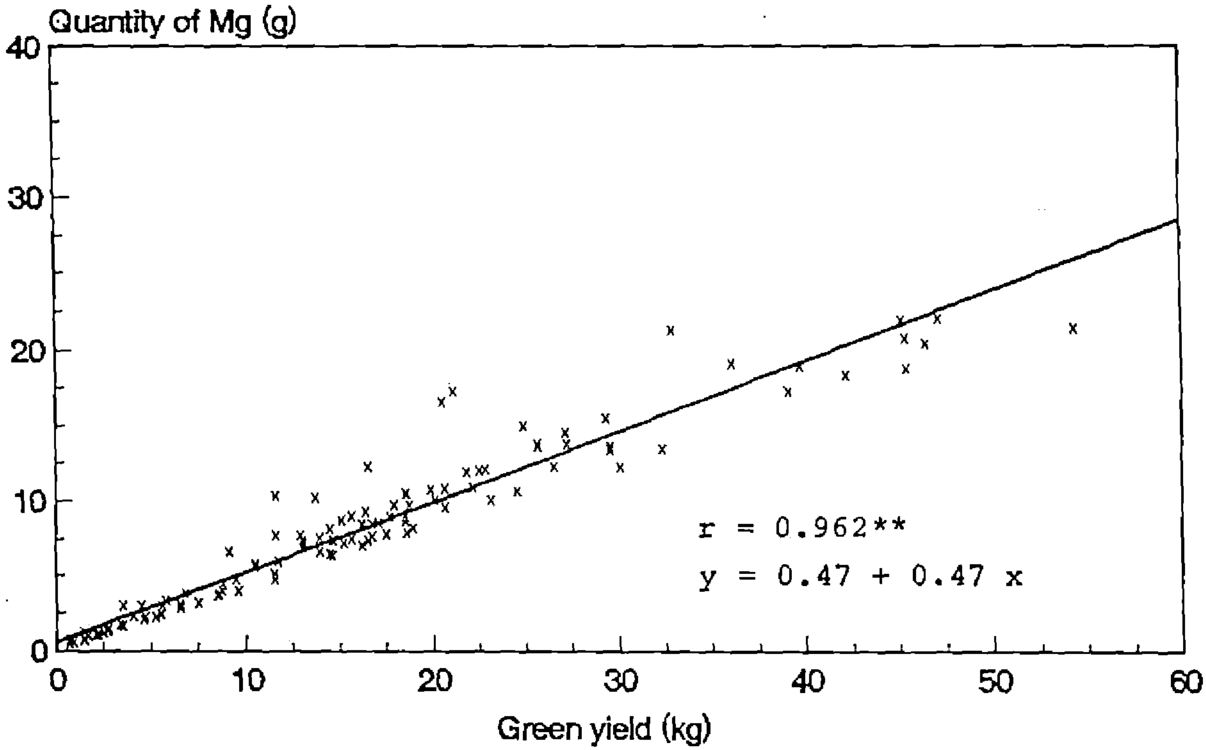

Fig.12 Quantity of Mg removed through harvested spikes in relation to pepper green yield

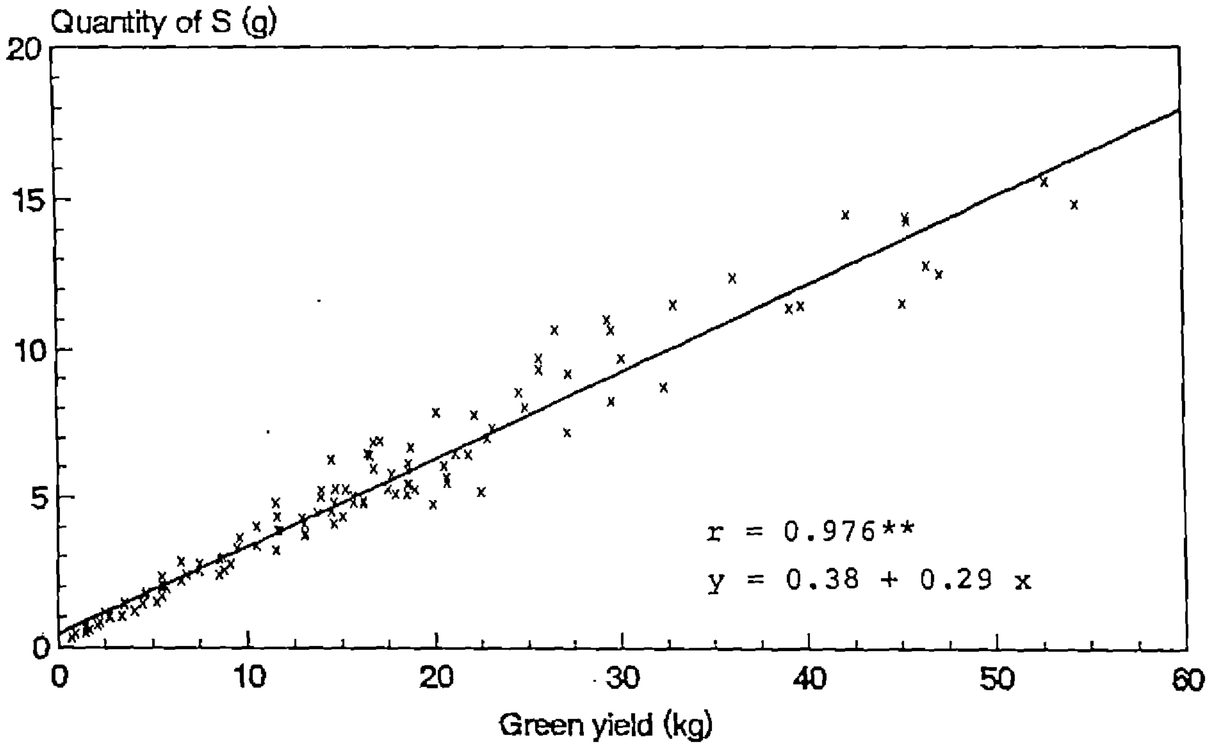

Fig.13 Quantity of S removed through harvested spikes in relation to pepper green yield

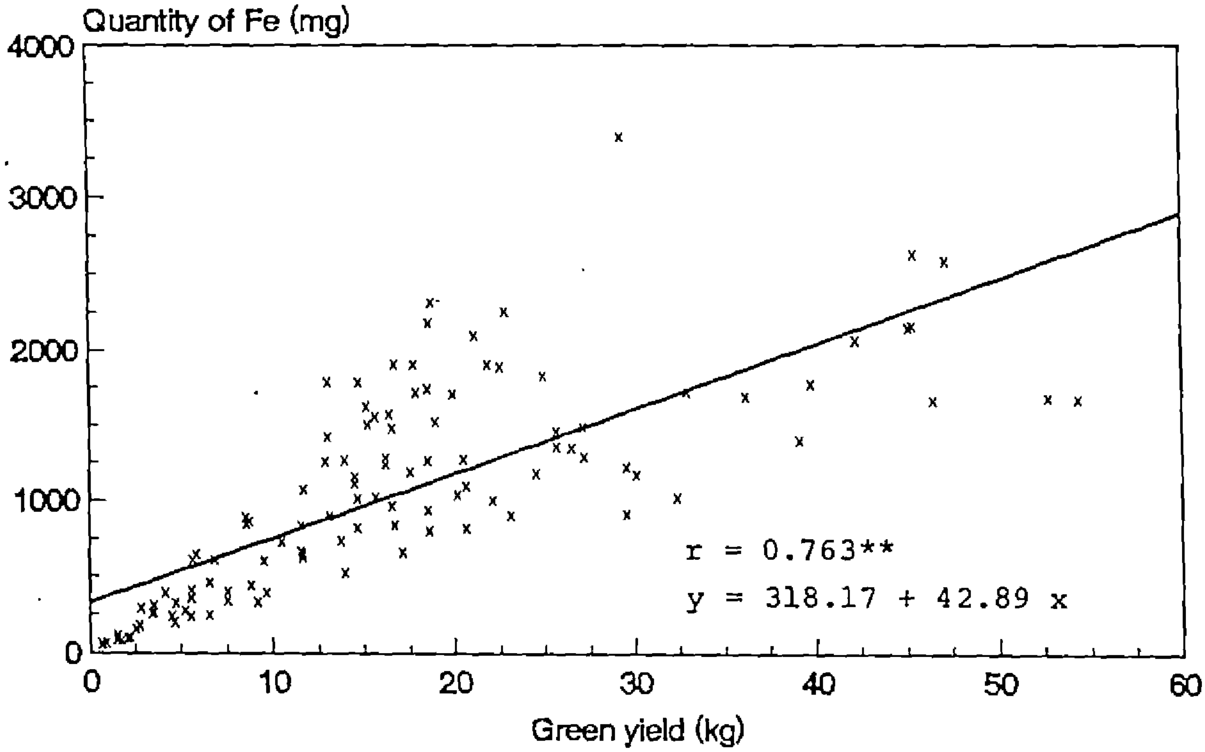

Fig.14 Quantity of Fe removed through harvested spikes in relation to pepper green yield

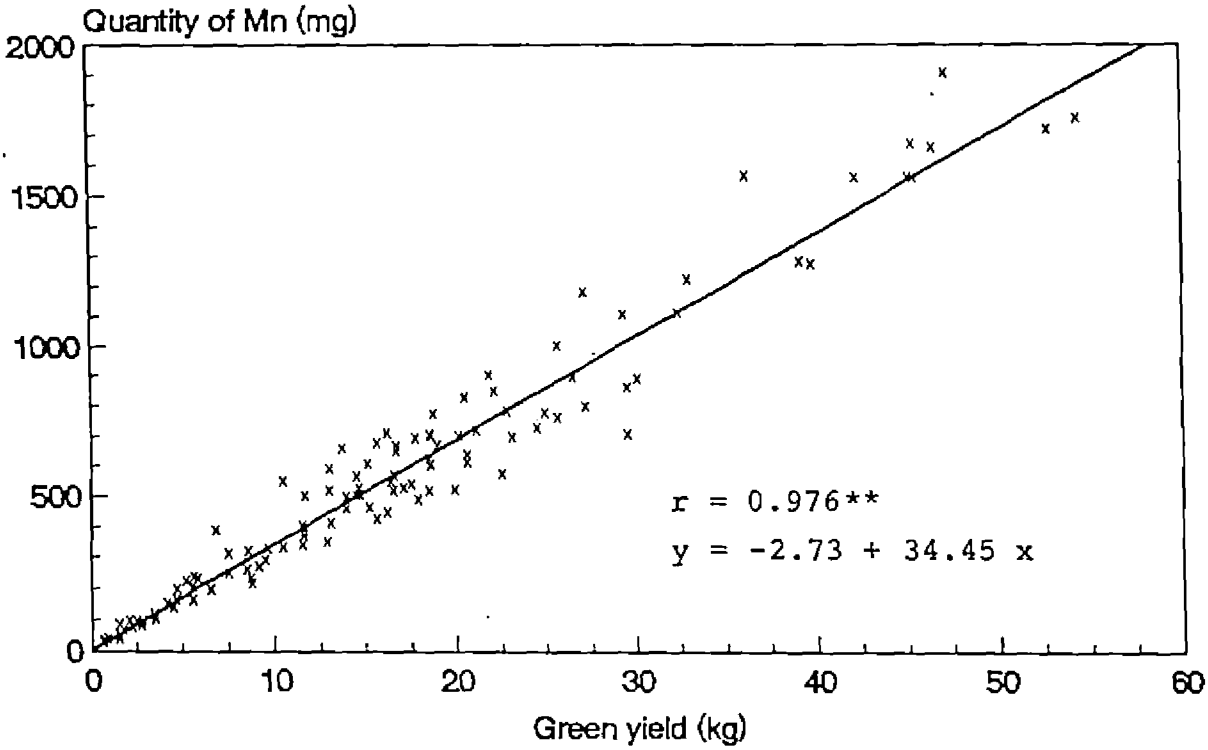

Fig.15 Quantity of Mn removed through harvested spikes in relation to pepper green yield

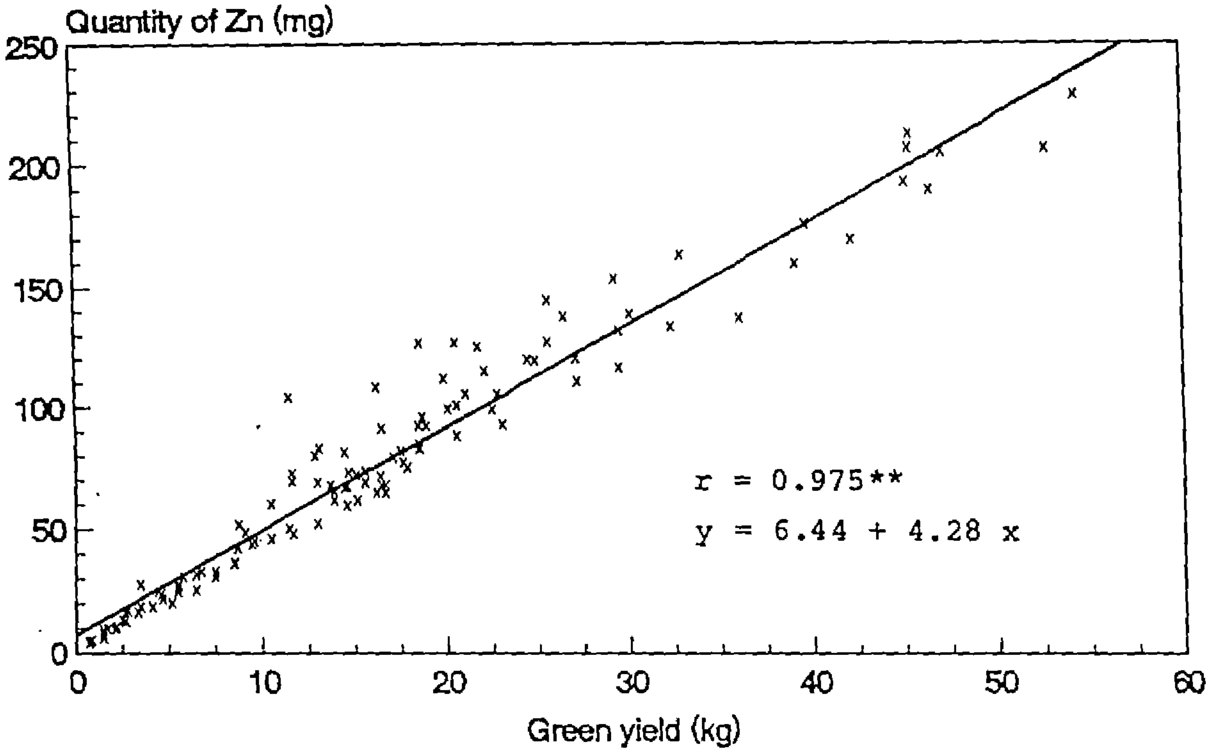

Fig.16 Quantity of Zn removed through harvested spikes in relation to pepper green yield

Discussion

DISCUSSION

The experiment was conducted with a standing crop of black pepper at the Regional Agricultural Research Station, Ambalavayal. A total of 115 vines of variety Panniyur-1, trailed on silver oak, were selected for the study. The vines were 12 years old planted in 1980 and were receiving fertilizers and other management practices as per the package of practices recommendation of the Kerala Agricultural University.

It may be generally expected that black pepper, being a vegetatively propagated crop, plant to plant variability in vegetative growth and yield characteristics, within a small compact piece of land would be insignificant. Nevertheless, the yield of the vines indicated considerable variation of the order of 74.1 per cent. This variation could possibly be due to the differences in soil fertility in the root zone of the vines. The results obtained in this study are examined from this point of view.

5.1 Soil factors in relation to yield of vines

Among the soil characteristics studied, pH, organic carbon, available Ca and available Mg were found to be positively correlated with yield (Table 4 and Figs. 1, 2, 3 and 4). On the other hand, available S and Fe contents were negatively correlated with yield. The negative correlation of S and Fe with yield could be due to the nature of their relationships with soil pH and organic carbon (Table 8). With increasing soil pH and organic carbon, soil available S and Fe decreased. In other words, the availability of these two nutrients in the soil is mainly governed by soil pH and organic carbon. The role of pH and organ[illegible] n enhancing the availability of S and Fe is well documented in literature (Tisdale et al., 1985).

The positive correlations observed between yield and soil characteristics like pH, organic carbon, exchangeable Ca and exchangeable Mg are indicative of the very strong influence of these characteristics in increasing the yield of black pepper vines. It was seen from Table 8 that pH in the soil was greatly influenced by the Ca and Mg saturation of the exchange sites as evidenced from the very high positive correlation values among Ca, Mg and pH. The positive correlation of organic carbon with pH indicates that the effect would be through improvement of the exchangeable Ca and Mg in the soil with increasing organic matter. These interrelationships among the soil characteristics might have been responsible for the positive correlations obtained between the individual characteristics and yield. Thus it can be said that black pepper prefers high pH, higher organic matter content and high exchangeable Ca and Mg contents in the soil for successful growth and production. It can be seen from Fig.1 and 2 that the highest yields were obtained when the soil pH was around 6.5 and organic carbon content was more than 2 per cent. The common observation that the pepper production is generally higher in vines grown on virgin soils may be due to the higher organic matter content of the soil.

The result of a NPK fertiliser trial conducted at the Pepper Research Station, Panniyur indicated that with increasing level of applied N, the yield of the vines decreased (Pillai et al., 1987). Accordingly, it was suggested to reduce the recommended dose of N from 100 g to 50 g per standard. The results obtained from the present study provide an explanation for the adverse effect of applied N on black pepper yield. It was demonstrated that regular application of nitrogenous fertilisers decreased the soil pH in coconut soil basins (Anilkumar and Wahid, 1989). Perhaps, the yield decline observed by Pillai et al. (1987) in the fertiliser trial with increasing level of N could be due to the decline in soil pH following annual application of nitrogenous fertilisers. Further, the results of the present study also indicate that N nutrition of the vine can be improved at higher soil pH, perhaps due to greater microbial activity and N mineralisation.

5.2 Foliar nutrient composition and yield

Significant correlations were obtained between leaf nutrient levels and yield (Tables 5 and 6). While the correlations between yield and the concentrations of S, P and K were negative, for other nutrients it was positive. The highest positive correlation was found between leaf N and yield (r = 0.589). Although the r values were statistically significant, in terms of predictability the parameters do not explain much of the variations obtained in the yield.

5.3 Soil-leaf nutrient relationships

Considering the foliar nutrient composition as an index of nutrient absorption by the vines, an attempt to identify the probable soil factors determining the uptake of various nutrients was made. Absorption of N was directly related to the organic matter content of the soil (Table 10). A positive correlation between soil pH and leaf N content was also obtained. These results indicate that organic matter content of the soil plays a dominant role in the absorption of N by the vine. It is a well established fact that pH around 7 is the most favourable soil pH for the mineralisation of organic N. The significant positive correlation existing between soil pH and leaf N may be due to the favourable effect of higher pH on the mineralisation of N and consequent enhancement of its absorption by the vines.

Although, organic matter and higher soil pH may be expected to enhance absorption of soil P by the vines from this lateritic soil, such a trend could not be observed (Table 10). The r values were not significant in this case. More importantly, the available P determined by using Bray 1 reagent (the most generally used extractant for soil P testing in acid soils) also did not yield significant correlation with leaf P. This would mean that Bray 1 reagent (0.025 N HCl + 0.03 N NH_4F is not a suitable extractant for testing available soil P in the pepper gardens of this area. It is, therefore, desirable that further work in this direction is to be initiated for developing a more precise method for soil P test for black pepper soils.

Ammonium acetate extractable K was positively correlated with leaf K. Similarly ammonium acetate extractable Ca also showed a positive correlation with the leaf nutrient. However for soil Mg, such a trend was not observed. These results therefore indicate that ammonium acetate can be used for determining the exchangeable K and Ca status of soil. In view of the lack of significant positive correlation between available S, available Fe, available Mn and their corresponding leaf nutrient levels, the extractants viz. KH_2PO_4 for S, and diacid (0.05 N HCl + 0.025 N H_2SO_4) for Fe and Mn are poor indicators for estimating the availability of these nutrients in the soils of black pepper gardens. On the contrary soil available Zn extracted by diacid extractant does give some indication of the nutrient availability in the soil (Table 10).

Although ammonium acetate can be suggested as a suitable extractant for determination of exchangeable K and Ca and diacid for soil available Zn in black pepper gardens, it may be reminded that the r values variability (R^2) explained by the quantities of nutrients extracted by these reagents were very less, despite their statistical significance. Hence more work in this area is necessary to evolve suitable methods for the determination of these soil nutrients.

5.4 Relationships among leaf nutrient levels

Both antagonistic and synergistic interactions do take place during nutrient uptake by black pepper vine. Although several nutrient elements may be implicated on such interactions (Table 9), very high positive correlations between leaf P and S and between leaf Ca and Mg indicate very strong synergistic relationships (Figs. 5 and 6). The synergistic effect would mean that the requirement of P and S as well as those of Ca and Mg should correspond with each other. In other words, when P is absorbed more, the demand for S is also more, so is the case with Mg when Ca is taken up more. This is also true of the reverse relationships.

Although the results indicated several cases of antagonistic effect during nutrient uptake (Table 9), the strongest antagonism was observed between K and Mg (Fig.7). In several crops, antagonistic effect between mono and divalent cations had been observed during nutrient uptake. Wahid et al. (1974) observed strong antagonism between K and Mg in coconut palm. The negative correlation between K and Mg indicates that in black pepper, at higher levels of K, Mg nutrition will be adversely affected. This warrants judicious application of K for maintaining balanced K-Mg nutrition.

5.5 Nutrient requirements

The current fertilizer recommendation for black pepper does not take into account the yield potential of the vine. Thus irrespective of the yield, the quantities of fertilizer nutrients applied to the vines are same. It is logical that a high yielding vine needs more quantity of a nutrient than a low yielding vine. In view of the perennial nature of the crop, it is difficult to conduct field experiments for developing discriminate fertilization method based on yield potential. The results obtained in the present study are made use of for generating information on the differential nutrient requirement of the vine in relation to yield. The data on the quantities of different nutrients removed through the harvested spikes can be used for this purpose, although it will be some what underestimate of the actual nutrient requirement, since vegetative growth taken place during the year is not taken into account. However, since the quantities of foliar and stem nutrients are still intact as part of the vine, the amounts of nutrients removed by way of harvested produce do give the quantities of nutrients gone out of the system.

The relationships between the yield and the quantities of nutrients removed by the spikes are highly significant. Excepting for Fe, the variability accounted by the other nutrients exceeded more than 95 per cent. This indicates that the quantity of a nutrient removed from the system is proportional to the yield (Figs. 8, 9, 10, 11, 12, 13, 14, 15 and 16). From the regression analysis of the nutrient-yield relationships it is possible to work out the quantity of each nutrient required for the production of a unit weight of green spikes. The values so worked out for different nutrients are given in Table 11. The results indicated that the quantities of N and K removed from the system through 1 kg of harvested produce are more or less the same and the highest (6.35 and 6.33 g respectively). This is followed by Ca (1.11 g), Mg (0.47 g), P (0.44 g), S (0.29 g), Fe (42.89 mg), Mn (34.45 mg) and Zn (4.28 mg) in descending order. These quantities may be considered as the additional requirement by the vine for each 1 kg increment in green yield. The most important information that can be derived from this result is that irrespective of the yield potential, the quantity of a nutrient required for the production of 1 kg of green pepper is fairly constant. This would imply that vines with high production potential require proportionately higher dose of nutrients. Thus a low yielder requires relatively less quantit f nutrients than a higher yielder. The proportionality may e expained by the lack of a negative trend in the nutr t concentrations of the spikes with increasing yield of the ye. The two exceptions in this respect are N and P whose ncentrations showed a negative relationship with the y (Table 7). These negative correlations, although sma point to the lowering of the nutrient concentrations in t ikes with increasing yield potential. However, the decr were not sufficient enough to affect the overall lineare tween yield and the spikes. The values so worked out for different nutrients are given in Table 11. The results indicated that the quantities of N and K removed from the system through 1 kg of harvested produce are more or less the same and the highest (6.35 and 6.33 g respectively). This is followed by Ca (1.11 g), Mg (0.47 g), P (0.44 g), S (0.29 g), Fe (42.89 mg), Mn (34.45 mg) and Zn (4.28 mg) in descending order. These quantities may be considered as the additional requirement by the vine for each 1 kg increment in green yield. The most important information that can be derived from this result is that irrespective of the yield potential, the quantity of a nutrient required for the production of 1 kg of green pepper is fairly constant. This would imply that vines with high production potential require proportionately higher dose of nutrients. Thus a low yielder requires relatively less quantity of nutrients than a higher yielder. The proportionality may be expained by the lack of a negative trend in the nutrient concentrations of the spikes with increasing yield of the vine. The two exceptions in this respect are N and P whose concentrations showed a negative relationship with the yield (Table 7). These negative correlations, although small, point to the lowering of the nutrient concentrations in the spikes with increasing yield potential. However, the decreases were not sufficient enough to affect the overall linearity between yield and the quantities of N and P removed by way of harvest (Figs.8 and 9). The results, thus, strongly indicate the need for amending fertilizer recommendation for black pepper based on the yield potential of the vine.

Summary

SUMMARY

An investigation on the 'nutrient removal in relation to crop production in black pepper (*Piper nigrum* L.) was conducted during 1992-93. The study was conducted with a standing crop of black pepper, variety Panniyur-1 at the Regional Agricultural Research Station, Ambalavayal in Wyanadu district. The major objectives of the investigation were to assess the extent of nutrient removal in relation to productivity in black pepper and to study the relationship between foliar nutrient level and yield and between available nutrients in the soil and yield.

Black pepper vines of variety Panniyur-1 grown under identical conditions and same managerial techniques as per the package of practices recommendations of the Kerala Agricultural University were used for the study. One hundred and fifteen pepper vines at different productivity level, but of the same age group of 12 years (1980 planting) from a compact area within a block having 2100 plants were selected for the study. The selected vines were trailed on silver oak (*Grevilea robusta*) trees. Soil samples from the basin of the vines and plant samples viz. leaf and spike were analysed for their chemical characteristics employing spectrophotometric,

flame photometric and atomic absorption spectrometric methods. The yield of pepper (both green weight and dry weight) from the selected vines was also recorded.

The important findings from these studies are summarised as follows:

Among the soil characteristics, pH, organic carbon, exchangeable Ca and exchangeable Mg were found to exert direct influence in increasing the pepper yield. There existed interrelationships between these soil characteristics. The pH of the soil was greatly influenced by the Ca and Mg saturation of the exchange sites.

It was observed that the highest yields were obtained when the organic content of the soil was more than 2 per cent and the pH around 6.5. Thus it was evidenced that black pepper prefers high pH, high organic matter content and exchangeable Ca and Mg for successful growth and production.

An increased level of soil pH and organic matter content decreased the availability of S and Fe.

Significant correlations were obtained between leaf nutrient concentrations and yield of black pepper.

The positive correlation of foliar N with soil organic carbon and soil pH indicated that the organic matter content in the soil plays a major role in the absorption of N by the vines and a higher pH activate mineralisation of N and its greater absorption by the plant.

Very high positive correlations observed between foliar P and S and foliar Ca and Mg indicated the synergistic interaction between these nutrients. The negative correlation existed between foliar K and Mg indicated the antagonistic effect of these nutrients in black pepper.

The relationships between the yield and the nutrients removed by the harvested spikes were highly significant. The nutrients removed by the spikes indicated the quantities of various nutrients gone out of the system and hence it is made use of for generating information on the differential nutrient requirement of the vines in relation to yield. The very high correlations existed between yield and various nutrients removed by the spikes (0.987** for N, 0.989** for P, 0.984** for K, 0.972** for Ca, 0.962** for Mg, 0.976** for S, 0.763** for Fe, 0.976** for Mn and 0.975** for Zn) infer that there is a linear proportionality between yield and the quantity of each nutrient removed from the system.

From the regression analysis of the nutrient-yield relationships, it is possible to work out the requirement of each nutrient for production of a unit weight of green spikes.

It was observed that the quantities of various nutrients removed from the system through 1 kg of harvested produce were in the descending order of N, K, Ca, Mg, P, S, Fe, Mn and Zn at the rate of 6.35 g, 6.33 g, 1.11 g, 0.47 g, 0.44 g, 0.29 g, 42.89 mg, 34.45 mg and 4.28 mg respectively. These quantities may be considered as the additional requirement by the vine for each 1 kg increment in yield.

It also revealed that irrespective of the yield potential, the quantity of each nutrient required for the production of 1 kg of green pepper is fairly constant. In other words vines with higher production potential requires relatively and proportionately higher dose of nutrients. The study therefore highlights the need for amending fertiliser recommendation for black pepper based on yield potential of the vine.

The results of the present study give indication of a greater role of soil pH in realising the yield potential of the black pepper vine. There is practically no work conducted so far to elucidate the effect of soil pH on pepper production. This aspect is all the more important as all the soil types on which the crop is grown are acidic in reaction. In this context there is good scope for evaluating the effect of liming on black pepper yields.

More work is also required to assess the beneficial effect of organic matter application on the yield of pepper.

The available P in the soil determined by using Bray I extractant did not yield significant correlation with foliar P; thereby the suitableness of the extractant for P determination in pepper soils is questioned. Further work for developing more precise method for soil P testing in pepper soils is warranted.

Similarly, the absence of positive correlation between available S, available Fe and available Mn with their corresponding foliar nutrient levels necessitated more works in this direction to evolve suitable methods for detection of these nutrients available in black pepper soils.

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Annexure I

Rainfall (in mm) data of Regional Agricultural Research Station Ambalavayal (From January 1991 to June 1993)

	1991		1992		1993	
	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)
Jan.	1	1.0	-	-	-	-
Feb.	1	34.0	1	0.6	1	11.6
Mar.	5	43.8	-	-	3	69.8
Apr.	9	156.2	4	44.4	12	197.8
May	11	192.6	12	234.0	10	220.6
Jun.	23	388.2	17	587.0	19	377.6
Jul.	26	719.0	26	535.2		
Aug.	17	365.0	23	315.2		
Sep.	9	83.8	16	196.0		
Oct.	13	215.2	7	181.6		
Nov.	5	102.4	11	224.8		
Dec.	-	-	-	-		

Source: RARS Ambalavayal

Annexure-2

Maximum minimum temperature (in°C) and relative humidity (in %) of Regional Agricultural Research Station, Ambalavayal (From January 1991 to June 1993)

Month	1991			1992			1993		
	Temperature (°C)		RH %	Temperature (°C)		RH %	Temperature (°C)		RH %
	Max.	Min.		Max.	Min.		Max.	Min.	
January	28.4	16.6	60.1	27.7	14.1	27.8	14.0	56.1	
February	30.0	16.4	55.2	29.1	16.8	29.3	16.8	59.0	
March	30.8	19.4	67.0	32.1	17.6	29.7	17.6	69.1	
April	30.4	19.8	73.1	31.6	19.3	30.2	19.0	75.5	
May	30.2	19.8	75.0	29.3	19.5	29.6	19.6	75.3	
June	25.0	18.6	88.0	24.9	19.0	25.9	19.1	84.7	
July	24.1	18.4	84.9	23.9	18.1				
August	24.1	18.3	84.3	23.9	18.4				
September	27.2	19.9	63.3	25.9	18.2				
October	26.5	18.2	80.0	25.9	18.4				
November	28.8	17.1	73.3	25.5	18.0				
December	26.7	15.1	66.6	26.0	14.5				

Source: RARS, Ambalavayal

NUTRIENT REMOVAL IN RELATION TO CROP PRODUCTION IN BLACK PEPPER

By

P. G. MATHEW

ABSTRACT OF A THESIS

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Faculty of Agriculture
Kerala Agricultural University

Department of Plantation Crops and Spices
COLLEGE OF HORTICULTURE
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ABSTRACT

A study on the nutrient removal in relation to crop production in black pepper (Piper nigrum L.) was conducted at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 1992-93. For the purpose of the study, a standing crop of black pepper variety Panniyur-1 managed under identical condition at the Regional Agricultural Research Station, Ambalavayal was used.

The study revealed that the soil characteristics such as pH, organic carbon exchangeable Ca and exchangeable Mg were found to exert direct influence in increasing the black pepper yield. Highest yields were obtained when the organic carbon content of the soil was more than 2 per cent and pH around 6.5

An increased level of soil pH and organic matter content decreased the availability of S and Fe in the soil.

Significant correlations were obtained between leaf nutrient concentrations and yield of black pepper.

Significant positive correlation existed between foliar N and soil organic carbon and between foliar N and soil pH.

Very high positive correlation observed between foliar P and S and foliar Ca and Mg indicated the synergestic interaction between these nutrients in black pepper. Foliar K maintained negative correlation with foliar Mg indicating the antagonistic effect between mono and divalent cations.

The relationships between the yield and the nutrients removed by the spikes by way of harvest were highly significant. The very high correlations indicated a linear proportionality between yield and the quantity of each nutrient removed from the system. The regression analysis of the nutrient-yield relationships shows that the quantities of nutrients removed from the system through 1 kg of harvested produce were in the descending order of N, K, Ca, Mg, P, S, Fe, Mn and Zn at the rate of 6.35 g, 6.33 g, 1.11 g, 0.47 g, 0.44 g, 0.29 g, 42.89 mg, 34.45 mg and 4.28 mg respectively. These quantities may be considered as the additional requirement by the vine for one kg increment in yield. It was observed that irrespective of the yield potential, the quantity of each nutrient required for production of 1 kg of green pepper is fairly constant and vines with higher production potential require relatively and proportionately higher dose of nutrients. This shows that there is need for amending the fertilizer recommendation of black pepper based on yield potential of the vine.