FOLIAR DIAGNOSIS, YIELD AND QUALITY OF PEPPER (*Piper nigrum* L.) IN RELATION TO NITROGEN, PHOSPHORUS AND POTASSIUM

BY

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DECLARATION

I hereby declare that this thesis entitled "Foliar diagnosis, yield and quality of pepper in relation to nitrogen, phospherus and potassium" 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.

Vellanikkara,
May, 1982.

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CERTIFICATE

Certified that this thesis entitled "Foliar diagnosis, yield and quality of pepper in relation to nitrogen, phosphorus and potassium" is a record of research work done by Smt.Sushama, P.K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Pepper, the king of spices, is the dried matured berry of the evergreen climbing vine *Piper nigrum* L. (Piperaceae) a native of Malabar Coast of India. Pepper contributes notably to the foreign exchange earnings of the country. In 1980-81, India exported pepper and pepper products worth about rupees 50 crores.

The major pepper producing countries of the world are Malaysia, Indonesia, Brasil and India. India has the highest area under cultivation with about 1.11 lakh hectares which cover nearly half of the total area under pepper in the world. However, India stands only fourth in production contributing 27,700 tonnes of black pepper in 1980-81. About 96% of the total area under pepper in India is confined to Kerala state which shows the importance of the crop in state economy.

The average yield of pepper in Kerala is estimated to be 279 kg/ha where as it is said to be as high as 4067 kg/ha in Malaysia. Manuring of pepper in Kerala is seldom practised since originally pepper plantations were established in virgin soils. But the continuous cropping over a number of years in these soils without the addition of manures has resulted in the depletion of soil fertility and consequent decline in yield.

Experiments to work out the optimum doses of nitrogen, phosphorus and potassium in pepper have been initiated at the Pepper Research Station, Panniyoor. The general fertilizer recommendations have been brought out from such fertilizer experiments. These recommendations are to be further specifically modified based on specific soil and plant conditions for which soil and tissue testing methods are to be followed. Tissue testing, especially foliar diagnosis, can better reflect the fertiliser requirements of crops since this method gives an accurate appraisal of the nutrient already taken by the plant and the deficiency assessed. Standardization of tissue for assessing the nutrient status of the crop and the determination of critical values of nutrients in pepper have been carried out by DeWaard (1969) in Sarawak. Such basic studies for practising foliar diagnosis in pepper have not been undertaken in this country. The pattern of distribution of rain in the phases of vegetative growth and flowering of pepper in the state are entirely different from that in Sarawak and therefore the critical values and type of tissue recommended for foliar diagnostic technique by DeWaard (1969) in Sarawak cannot be adopted as such without examining the suitability of these techniques under the agroclimatic conditions of the state. The present study was therefore undertaken making use of the experimental plants of a NPK trial at Pepper Research Station, Panniyoor in order to standardise

(i) the best tissue for detecting the NPK status of the plant; and

(ii) the most suitable period for the collection of tissue samples;

and also to study the quality of pepper as influenced by the application of fertilizer nutrients at different stages of maturity.

The results of this investigation are presented and described in the following pages.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

1. Foliar diagnosis

Foliar diagnosis can be employed as a suitable guide to assess the nutritional status of the crops.

Foliar diagnosis, at a given moment is the chemical condition, at that time, of a properly chosen leaf taken from a prescribed position and annual foliar diagnosis is the series of chemical status of that leaf as shown by analysis at different times during the whole vegetative cycle (Forestier, 1968).

Lagatu and Maume (1926) in France were among the first to develop foliar diagnostic techniques for a perennial and an annual crop respectively. Since these early developments, great variety of crops has been tested nutritionally by foliar diagnosis. It was Loue (1951) in the Ivory Coast who first used the method for Robusta coffee.

Singh *et al*. (1973) stressed the necessity of a detailed examination of the differences in foliar analytical procedures in the different laboratories. To arrive at this conclusion, they carried out two cross checks during 1972 in oil palm and rubber leaf samples at 13 laboratories. The results showed that very good inter-laboratory agreement was obtained in the determination of leaf nitrogen (coefficient of variation below 3 per cent). In the case of phosphorus, potassium, calcium and magnesium (coefficient of variation about 10 per cent) the inter-laboratory agreement was not satisfactory.

During the conference on chemistry and fertility of tropical soil, Kanapathy (1973) reported that foliar analysis was being used extensively for oil palm and rubber. He also suggested that it could be extended to pineapple, coconut, maize, sorghum, rice and other crops.

As well as increasing the levels of nutrients supplied, fertilisers also affected levels of other leaf nutrients. In a particular environment, maximum yield could be obtained at only one specific combination of leaf nutrient levels. In practise, it was first necessary to determine leaf levels which corresponded to maximum yields in a particular environment and then to deduce those which corresponded to the most economic yield (Foster and Goh, 1977).

1.1 Foliar diagnosis vs.soil analysis

Prevot and Ollagnier (1957) compared the efficiency of foliar diagnosis and soil analysis for determining nutritional requirements of groundnut and reported that analysis of plant's nutrition on the spot could be done through foliar diagnosis. Foliar nutrient levels were more closely correlated with yield than that of soil nutrient levels (Ollagnier and Giller, 1965).

Leverington *et al.* (1962) suggested that potassium content in leaf blade was dependent on the age of the crop and the rate of potassium application in sugarcane. No consistent relationship was found between leaf potassium and the amount of potassium needed for yield. It was concluded that unless potassium was very deficient, soil analysis was more reliable than plant analysis for assessing potassium requirements.

According to Jons (1963) soil and leaf analysis from long term field experiments and surveys on the nutritional status in commercial fruit crops showed, in general, a relationship between the macronutrients in the top soil and those in the leaves.

Soil and tissue tests for predicting olive yields in Turkey were examined by Fox *et al.* (1964). Leaf composition was better correlated with yield than soil tests. There was a relationship between soil tests for phospherus and potassium and leaf composition.

In a study about the mineral nutrition of grape vines, Hernado and Mendiola (1965) found that the amount of nitrogen, phospherus, potassium, calcium, magnesium and sulphur in vine leaves at different stages of the vegetative cycle correlated with content of these elements in soil.

Champion (1966) opined that foliar diagnosis and soil analysis were both necessary in judging the fertiliser requirements of banana.

Brar *et al.* (1980) pointed out that if diagnosis of nutrient dificiency and its correction were not made well in time, crop yields were likely to be declained.

1.2. The organ to be sampled

It is impracticable to analyse the entire plant. Hence a smaller part or a separate organ of the plant is selected for the purpose. Leaf is considered as the plant part where the mineral nutrients are converted into plant food along with the products of photosynthesis. For all practical purposes, the leaf or a selected portion of the leaf appears to be suitable for representing the over all nutrient status of the plant.

Vandecavey (1947) analysed the leaf blades and petioles of spinach and raspberry for nitrogen, phosphorus potassium, calcium and magnesium. The results revealed that the chemical composition of the leaf petioles was more indicative of the nutritional status of the plant.

Rogers *et al.* (1955) compared different plant parts of straberry for foliar diagnosis. It was showed that leaf was as sensitive or even more sensitive than any other plant part as an index of nutritional status of crop.

For specific investigations other parts of the plant may be preferred. There are indications that sodium and heavy metals are more concentrated in the rootlets than in other parts, if these elements are present in the soil in excess amounts (Smith, 1962).

1.3. Sampling technique

A standardised sampling procedure should be worked out to select a leaf sample which represents the nutritional condition of a crop. By employing standardised methods, all factors that cause variation in leaf nutrient levels can be eliminated.

Evans (1979) cited the following ten sources of variation, affecting foliar diagnosis, viz., climate, season time of day, age of the plant, age of foliage, variation between trees, position in crown, nutrient balance, effects of diseases and other factors.

1.3.1 Climate and concentration of nutrient in plant

The climatic variations reflect the integrated effect of influences such as rainfall and sunshine on the chemical concentration of the leaves. The study conducted by Malik (1966) on the nutrient content in the leaves of apricot revealed that the nitrogen content of leaf was high during periods of low temperature and high moisture content.

Robinson (1961) studied the effect of rainfall and season on the chemical composition of coffee leaves. Reasonably consistent trends could be established by partially eliminating these factors by introducing ratios between nutrients.

The influence of sunshine and shade was noted by Sherrocks (1961) in rubber and by Murray (1961) in banana as a direct relationship between the potassium concentration in the leaves and the number of sunhours two years earlier.

DeWaard (1969) reported that significant reduction in leaf potassium concentration can be noticed in leaves of pepper from deep shade.

Ulrich (1952) opined that the best time for taking sample was from 8 a.m. to 12 noon. Lin (1966) showed that leaf samples should be taken before noon to avoid diurnal variation in leaf nitrogen.

According to DeWaard (1969) concentration of potassium remained unchanged in leaves of pepper from 7 a.m. to 1 p.m. The results of nitrogen reflected a gradual decrease from early morning to late afternoon which was not significant from 7 a.m. to 10 a.m. Gosnell _et al_. (1972) reported that in the morning, foliar nitrogen, phosphorus and potassium were not affected, but there was a decline in nitrogen and rise in potassium when sampling was in afternoon.

1.3.2. Effect of size and thickness of the leaves

Steyn (1961) reported that there was no appreciable effect of leaf size on the nutrient concentration in the tissue in citrus. Twyford and Coulster (1964) reported a substantial gradient in nutrient content over the length of banana leaf. Lin (1963) suggested that two leaves of average size could be selected for sampling in tea. The study on foliar diagnosis of pepper by DeWaard (1969) revealed that concentrations of nitrogen and potassium were high in leaves of average size as compared to small leaves. He also found that increasing thickness of leaf depressed nitrogen and potassium concentration.

1.3.3. The effect of age and position of leaf

Physiological age is considered to be a source of variation. Preveh et al. (1966) confirmed that leaf composition of citrus was affected by orientation, canopy height and distance from the outside of the canopy. According to Ballinger (1966) the optimum time to sample blue berry leaves appeared to be a 2 to 3 week period immediately after harvest.

In pear, considering the variation in leaf age, Marro (1967) recommended the selection of basal leaves from shoots less than 35 cm long which were terminal or subterminal on main or secondary branches.

DeWaard (1969) studied the differences in nutrient levels between the youngest mature, first mature and second mature leaf of the same branch in pepper. Leaf nitrogen was significantly higher in second leaf and there was no influence on potassium. The data indicated a mild depressive effect of aging on phosphorus.

Guha et al. (1969) reported that interpretation of leaf analytical data for determining nutritional status of trees, required correction of leaf nutrient contents for leaf age variation.

Preliminary foliar sampling and analysis on coconut carried out by Kanapathy (1976) revealed that nitrogen content increased with the age up to about frond 6 and then slowly declined to frond 16.

Devrani (1980) made an attempt to study the effect of age and flush on the mineral content of mango leaves. Leaf nitrogen accumulated during the period of slow growth in shoots whereas phosphorus and potassium levels decreased slightly.

1.3.4. Seasonal variation

DeWaard (1969) identified the physiologically important months for pepper as Janury, April and July in

Sarawak which coincided with periods of fruit initiation, berry enlargement and harvest. Over the period from January to May the nitrogen concentration fell by 17 per-cent whereas in the month of May, the content remained approximately constant, followed by a small rise in June to July. Significant rise in phosphorus content from January to July was also recorded. Potassium concentration was also found to be decreased with time after an initial rise in January.

Champlin (1979) initiated a study to determine the seasonal changes in plant nutrient composition so as to identify the optimum time to collect leaf samples for nutritional diagnosis. It was revealed that before critical leaf values could be established for a crop, a specific tissue must be identified for sampling which had an extended period of minimal internal flux.

1.3.5. Sampling procedure for pepper

The following procedure was recommended by DeWaard (1969).

i. Apparently homogenous blocks should be selected with respect to environment and physiological condition of vines.

ii. Each sample should be subdivided into compact sub-blocks equivalent to 70 sample vines in order to ensure even contribution of each portion of the area.

iii. With in each sub-block, the sample unit should be selected at random.

iv. Vines should be first sampled in January and subsequently as frequent as necessary.

v. From each plant, 4 leaves should be collected from a sampling population meeting the following standards:

(a) The first older mature leaf from fruit bearing lateral exposed to sunlight and located on the lower 2/3 of the canopy.

(b) Leaves of average size and thickness with the petiole retained.

(c) Leaves representing north, east, south and west quarter aspects of the vine equally.

vi. The leaves so collected should be mixed to form a single composite sample representing a plant.

vii. Sampling should be carried out between 7 a.m.to 1 p.m.

1.4. <u>Interpretation of foliar analytical data</u>

Correct interpretation of data obtained by the analysis of leaves is the most essential and the most complex stage of this diagnostic method. Foliar diagnosis is based on the assumption that the application of a limiting nutrient element causes on increase of its concentration in a suitable standard leaf with a concurrent response in growth or yield.

Tyner (1946) while presenting the relationship between corn yield and leaf nitrogen, phosphorus and potassium in the sixth leaf at the bloom stage, established the validity of the term 'critical concentration of a nutrient' above which response to further increments was doubtful or occurred at rapidly diminishing rates.

According to Shear *et al.* (1948), the optimum nutritional status of each crop as reflected by leaf analysis differed and hence the standards of comparison must be set up for each crop.

Lepoldevin (1964) suggested that before making any recommendation on the basis of analysis, the results must be interpreted with due consideration of the conditions causing any particular nutrient balance. These were climate, previous field performance and results of experiments carried out in a particular field.

The interpretation of chemical plant analysis should be based on the total curves as a composite function of the absorbed nutrient applied and growth factor (Fries-Nielson, 1966).

1.5. Foliar diagnosis as applied to specific crops

Foliar diagnosis as applied to different crops has been suggested by several research workers. Some of the important references are given here-under.

Pepper: DeWaard (1969) designated the first mature leaf with petiole from fruit bearing high order branches as the best reflect in the case of pepper. The leaf status of deficient to healthy leaves varied from 2.7 to 3.1 per cent for nitrogen, 0.10 to 0.16 per cent to phosphorus and 2.62 to 3.40 per cent for potassium.

Tea: Lin (1963) in his work entitled, 'leaf analysis as a guide to nitrogen fertilisation of the tea bushes,' remarked that the third leaf from the apex on the young shoot of tea reflected nitrogen status of the plant most sensitively. The critical nitrogen, phosphorus and potassium concentrations in leaf were approximately 4.0, 0.26 and 1.5 per cent respectively. Akhmetov and Bairamov (1968) suggested the optimal nitrogen, phosphorus and potassium contents for best harvest as 4.5 to 4.8 per cent, 0.5 to 0.6 per cent and 2.2 to 2.4 per cent respectively.

Coffee: Baker et al. (1963) showed that samples of leaves from bearing nodes would provide the most suitable index for the supply of nitrogen, phosphorus and potassium. Malavolta et al. (1964) recommended the third and fourth pair of leaves of coffee for use in foliar diagnosis.

Cocoa: From a study conducted in New Guinea, Schroe (1960) found that second and third leaves fully green from near apex of fan shoots taken in July were the best for detecting phosphorus status of the crop. The values for intermediate range for nitrogen, phosphorus and potassium were 2.32, 0.22 and 2.19 per cent respectively on dry matter basis as given by McDonald (1934).

Citrus: Chapman (1950) reported that the status of potassium of orange trees could be deduced from the potassium content of three to seven month old spring cycle leaves. It has been reported that top three leaves of fruit bearing citrus plant (6 to 7 month old leaves) are the best for foliar diagnosis (Nadir, 1967).

Sugarcane: The detection of nitrogen, phosphorus and potassium deficiency trends in sugarcane by means of foliar diagnosis was undertaken in Mauritius by Halais (1963). He observed that the major nutrients in sugarcane could be ascertained by analysis of third leaf sampled before flowering. He recorded that optimum levels of 1.95 per cent N, 0.48 per cent P_2O_5 and 1.5 per cent K_2O as critical levels in the central part of the third leaf omitting the midrib for ratoon crops of five months age.

Oilpalm: In the determination of nutrient status of oilpalm by leaf sampling, Smilde et al. (1963) found that first, seventeenth and twenty fifth leaves were best suited for foliar diagnosis. Ruer (1966) could observe visual deficiency symptoms in below three month old palms at a level 2.6 to 2.7 per cent nitrogen and 0.6 to 0.1 per cent magnesium in the ninth leaf.

Rubber: Foliar diagnosis of rubber for nitrogen, phosphorus and potassium was done by Sherrocks (1964). He selected four leaves each from two mature whorls exposed to full sunlight on outside of the canopy. Only the leaf laminae without petioles and midrib were used for analysis. The critical levels varied from 3.07 to 3.34 per cent for nitrogen, less than 0.27 per cent for phosphorus and 1.11 per cent for potassium.

Cassava: From the nutritional studies on tapioca Pushpadas et al. (1974) suggested a sampling technique for foliar diagnosis. The petioles from middle one third of total leaves would serve as the best tissue for nitrogen, phosphorus and potassium. The petioles from middle one third of total leaves collected 4.5 months after planting correlated well with yield.

Coconut: Prevot and Ollagnier (1957) studied the nitrogen, phosphorus, potassium and calcium and magnesium status of coconut leaves. They recommended that the critical levels nitrogen, phosphorus, potassium, calcium and magnesium were 1.7, 0.1, 0.5 and 0.35 per cent respectively. Ziller and Prevot (1966) reported that the 14th leaf of mature palms could be selected for foliar diagnosis of major nutrients. Gopi (1981) recommended the second leaf as the best reflect for the foliar diagnosis of nitrogen, phosphorus and potassium.

Rice: Velasco *et al.* (1953) studied nitrogen relation in rice plant by foliar diagnosis and recorded that most recently matured leaves were the best indicator of the nitrogen needs of the plant. Intermediate values were 6.43, 0.046 and 0.036 per cent for nitrogen, phosphorus and potassium respectively.

Sweet potato: Leonard *et al.* (1949) reported that the application of available phosphorus and available potassium was definitely associated with the content of nitrogen and potassium in leaf blade of sweet potato. Plants with leaf blades varying from 4.75 to 5 per cent nitrogen in early summer and from 3 to 3.9 per cent nitrogen at harvest and with 2 per cent potassium during all stages of growth produced higher yields.

Ginger: Johnson (1978) reported that the group of fifth to twelveth leaves appeared to be the best suited for foliar diagnosis in ginger. The period between 90^{th} to 120^{th} day after planting was recommended as the optimum period for the detection and amendment of the nutrient status of the crop.

Turmeric: According to Saifudeen (1981) the third leaf is the best suited for foliar diagnosis of nitrogen, phosphorus and potassium status of the crop. The period between 90^{th} to 120^{th} day after planting was recommended as the optimum period for the detection and amendment of the nutrient status of the crop.

Banana: Leaf analysis of banana plant was first originated with the sampling of the lamina of the third youngest leaf in the succession of leaves from the top of plant since it had the highest concentration of nutrients (Hewitt, 1955). The critical values of nutrients were 3.6 per cent for nitrogen, 0.45 per cent for phosphorus and 3.3 per cent for potassium. Later, the concentrations of nitrogen, phosphorus and potassium of third, fifth and seventh leaves were determined by Simmonds (1959) and he recommended third leaf as the standard for foliar diagnosis.

Groundnut: Prevot (1953) suggested that the first stage of flowering was the most suitable time for leaf sampling in groundnut. Based on the results of fertilizer experiments, the critical levels in leaves were tentatively given as 4 per cent for nitrogen, 0.2 per cent for phosphorus and 1 per cent for potassium.

2. Nutrient requirements for pepper

DeWaard (1960) reported that the use of artificial manures by the farmers of Sarawak lowered the pH of soil, reduced uptake of calcium and mangesium and increased K/Ca + Mg ratio in the leaf.

The nutrient removal of variety Kuching (1,729 vines/ha) was 252.04 kg/ha N, 31.37 kg/ha P_2O_5 and 224.04 kg/ha K_2O (DeWaard, 1964).

Based on the results, Department of Agriculture, Sarawak recommended that compound fertilizers should contain 11 to 13 per cent N, 5 to 7 per cent P_2O_5, 16 to 18 per cent K_2O and trace elements.

DeWaard (1969) outlined the history of black pepper growing in Sarawak. In a field trial on mature vines, it was established that systematic consideration of leaf concentrations and ratios derived from foliar analysis was a satisfactory basis for fertilizer applications. This was confirmed in a further trial in which physiological exhaustion and yield instability were prevented by maintaining leaf nutrients at fair to normal levels.

A study was carried out by Sim (1971) on the dry matter production and major nutrients of both reproductive tissues in mature vines and vegetative tissues in vines varying in age from less than one year to seventeen years in pepper. He established that 233 kg/ha N, 39 kg/ha P_2O_5 and 207 kg/ha K_2O were removed by vines of 3.5 to 17 years of age.

A comparison of the effects of organic and inorganic fertilizers on the yield of pepper was done by Raj (1972). A field trial was also conducted by Raj (1973) to study the response of black pepper to inorganic fertilizers in Sarawak. A fertilizer including 340.2 g urea, 113.4 g superphosphate and 453.6 g muriate of potash per vine per year produced the highest yield of sandy soil and a fertiliser composed of same amounts of urea and muriate of potash, but a higher amount of superphosphate produced the highest yield on a clayey soil.

Sim (1974) conducted a nutrient survey of black pepper in small holdings of Sarawak. It is revealed that leaf nutrients gave a better correlation with yield data than soil nutrients.

DeWaard (1975) conducted field trials with black pepper which showed that addition of alkaline compounds to mounds prior to planting resulted in an increase in growth and earlier establishment.

According to Bataglia et al.(1976) the nitrogen levels in the leaves of black pepper rose in the autumn, but declined in the winter, phosphorus was highest in the summer and declined thereafter and potassium was high in the summer, reached,a peak in the autumn and declined in the winter.

Nitrogen, phosphorus, potassium, calcium and magnesium in root, stem, leaf and spike were determined by Pillay and Sasikumaran (1977) with 4 year old plants of variety, Panniyoor-1. Nitrogen was highest in leaves followed by spikes and lowest in roots; potassium showed a similar tend except it was lowest in the stem; and phosphorus was less in leaves than roots, stem and spikes. They have estimated that one hectare of pepper (1200 vines) with an average yield of 1 kg dry pepper/vine removes 34.0 kg N, 3.5 kg P_2O_5 and 32.0 kg K_2O for the production of berries alone. Based on this observation, a manurial schedule of 100 g N, 40 g P_2O_5 and 140 g K_2O per vine was recommended.

Belger (1977) opined that the basis of higher yields of pepper was the application of compound fertilisers at the rate of 1.32 to 1.80 kg per vine. Raj (1978) suggested a sound fertiliser policy based on the nutrient removal by crop, crop size, yield per unit area and nutrient composition of leaf as indicated by foliar analysis.

Pillay _et al_.(1979) studied the response of Panniyoor-1 variety of pepper to nitrogen and lime application and pointed out that higher levels of nitrogen adversely affected the yield. It is not necessary to increase the nitrogen level above 60 g/vine/year.

Recent research on yellow disease complex of black pepper on the Island of Bangka had shown that application of complete fertilisers containing nitrogen, phosphorus, potassium, calcium, magnesium trace elements and dolomite given in association with a dense layer of mulch increased the yields and apparently controlled the symptoms (DeWaard, 1979).

3. <u>Pepper oleoresin</u>

As a spice, the quality of pepper has to be judged on its characteristic pungency and flavour due to the presence of alkaloids and volatile oil content respectively (Jose and Nambiar, 1972 a).

To obtain the pungent principles of pepper in a concentrated form, ground black pepper is extracted repeatedly with volatile solvents. The extract containing the alkaloids and essential oils after the removal of the solvent is the oleoresin of pepper. The quantitative composition of it depends in the nature of the solvent and variety of pepper used (Jose, 1978).

Namboodhiri <u>et al</u>.(1970) reported that acetone was the best solvent for the extraction of pepper oleoresin. A coarse powder of about 0.3 mm size allowed easy draining of solvent and gave satisfactory yield of oleoresin.

Jose and Nambiar (1972 b) studied the quality of hybrid pepper, Panniyoor-1 and reported that it was high in volatile ether extract and medium in crude piperine.

The change in quality of pepper with the varying age of the berry has been examined (Anon, 1975). It is reported that pungency decreased with maturation. Volatile oil also decreased slightly with increasing maturity. The oleoresin content increased from 3.5 to 5.5 months and then decreased at 8.5 months (Anon, 1975).

MATERIALS AND METHODS

MATERIALS AND METHODS

Pepper plants of variety Panniyoor-1 of the NPK fertilizer trial established in 1972 at the Pepper Research Station, Panniyoor, Cannanore District were made use of for the present study. The details of the field experimant maintained at the Pepper Research Station, Panniyoor are as follows:

1.1. Site, climate and soil

The experimental field is located on a moderately slopping terrain. The area enjoys a typical humid tropical climate. The average altitude of the site is 95 m above mean sea level. The data on the meteorological parameters of the experimental site are presented in Appendix I.

The soil of the experimental field is acid laterite (pH 5.0) of clay loam texture (coarse sand 20 per cent, fine sand 14.4 per cent, silt 17.6 per cent and clay 48.0 per cent). The nutrient status of the soil is given Appendix II.

1.2. Experimental design

The NPK fertilizer trial was started in 1975 as a 3^3 factorial experiment totally confounding $N P^2 K^2$, in a randomised block design with two replications.

The details of the layout (Fig.I) are

Number of treatments	-	27
Number of replications	-	2
Total number of blocks	-	6
Total number of plots	-	54
Number of plants per plot	-	5
Spacing	-	2 m x 3.5 m

<u>Treatments</u>:

<u>Levels of nitrogen</u>

1. n_0 50 g N/vine/year
2. n_1 100 g N/vine/year
3. n_2 150 g N/vine/year

<u>Levels of phosphorus</u>

1. p_0 50 g P_2O_5/vine/year
2. p_1 100 g P_2O_5/vine/year
3. p_2 150 g P_2O_5/vine/year

<u>Levels of potassium</u>

1. k_0 50 g K_2O/vine/year
2. k_1 100 g K_2O/vine/year
3. k_2 150 g K_2O/vine/year

1.3. <u>Field culture</u>

The plants were established in 1971 on standards of <u>Erythrina indica</u> though the treatments were effected only in 1975.

The plants were supplied with fertilizers in the form of urea, superphosphate and muriate of potash in accordance with the treatments as a single dose in August-September. Over and above the fertilizer treatments, a uniform dose of 10 kg green leaves and 500 g lime per plant were given with the onset of South West monsoon. The cultural operations and plant protection measures were carried out uniformally irrespective of the fertiliser treatments.

2. Collection of samples for the present study

2.1. Selection of plants

Out of the five plants receiving a single treatment, only two plants were selected at random for the chemical analysis of soil and plant materials. Thus samples were collected separately from 108 plants i.e., 2 plants per plot x 27 treatments x 2 replications. Again to reduce the number of samples involved in chemical analysis, samples from plants of the same treatment of the two replications were pooled together to give rise to a composite sample representing a single treatment. In other words, the effects of replication were completely pooled and there were only 27 composite samples each representing a single treatment, though they were separately collected from 108 plants.

2.2. Collection of soil

Soil samples at a depth of 0 to 15 cm were collected from different aspects of the basin of the plant at random and composited to give a sample representing a single plant.

Samples of the four plants receiving the same treatment as detailed above were pooled into a composite sample and thus there were 27 soil samples representing the treatments. Soils were collected in March 1980 and also in January 1981.

2.3. Collection of plant samples

Leaves were sampled for chemical analysis. The following procedure for collection was followed. Samples were collected separately from the 108 plants selected for the study. Samples of the plants receiving the same treatment were then pooled to give rise to composite samples of the treatment. Sampling was carried out between 7 a.m. to 12 noon.

2.3.1. Standardisation of leaf position

For this purpose, four fruit bearing laterals exposed to sunlight and located on the lower 2/3 of the canopy representing the north, east, south and west quarter aspect of the vine were selected at random during the third month after flushing (Date of sampling 9th September 1980). The leaves of each laterals were numbered and the first older mature leaf, the second, the third and the fourth were collected separately, taking the youngest fully matured leaf as leaf No.1. The four leaves of the same position drawn from the four laterals of the same plant were pooled to represent a composite leaf positional sample of the plant.

2.3.2. <u>Standardisation of season or period of sampling</u>

In order to standardise the optimum season for the collection of leaf intended for foliar diagnosis, sampling of leaf was carried out at different periods as follows:

Periods		Date of sampling
1. After the harvest of berries	-	11^{th} March 1980
2. Prior to flushing	-	29^{th} May 1980
3. One month after flushing	-	9^{th} July 1980
4. Two months after flushing	-	9^{th} August 1980
5. Three months after flushing	-	9^{th} September 1980
6. Four months after flushing	-	9^{th} October 1980
7. Five months after flushing	-	9^{th} November 1980
8. Six months after flushing	-	9^{th} December 1980
9. Seven months after flushing	-	9^{th} January 1981

For this purpose, the first older mature leaf of laterals exposed to sunlight and located on the lower 2/3 portion of the canopy was selected. Four such leaves possessing average thickness and size, representing the north, east, south and west quarter aspects of the vine were collected along with the petioles. These four leaves constituted the composite sample of a plant.

2.4. Collection of stem for analysis

In order to examine the suitability of stem portion of the plant for tissue analysis, the following types of stems were sampled during the fourth month after flushing (Date of sampling - 9th October 1980).

1. Fruit bearing laterals (Plagiotropes)
2. Hanging shoots (Geotropes)
3. Runner shoots
4. Top shoots (Orthotropes)

Samples of stems of length one foot from the point of first mature leaf were collected from the four quarter aspects of the plant and sampled separately. The samples were finally pooled in order to obtain composite samples of the four types of stems for each treatment separately.

2.5. Collection of berries

For studying the variation in the quality of pepper with respect to increasing periods of maturity, pepper berries were collected from fruit bearing laterals at random from different quarter aspect of the plant, located on the lower 2/3 of the canopy, during the following stages.

1. Four months after flowering (9th October 1980)
2. Six months after flowering (9th December 1980)
3. Seven months after flowering (9th January 1981)

3. Analytical methods

3.1. Soil

The mechanical analysis of the soil was conducted using the hydrometer method (Piper, 1942). The pH the soil water suspension (1 : 2.5) was determined using a pH meter. Total organic carbon of the soil was estimated by Walkley and Black method described by Piper (1942). The Kjeldahl digestion and distillation method (Jackson, 1958) was followed for the determination of total nitrogen. Available phosphorus was determined in the Bray No.1 and triple acid (Mathew, 1979) extracts of soil by the chloro-stannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1958). The exchangeable potassium extracted by 1 N neutral ammonium acetate was determined flamephotometrically and reported as available potassium (Jackson, 1958).

3.2. Plant material

The total nitrogen content of the plant sample was determined using Kjeldahl method (Jackson, 1958). For the determination of phosphorus and potassium, the plant material was digested in a mixture of perchloric, sulphuric and nitric acids (1:2:9). In the triple acid extract, phosphorus was determined by the vanadomolybdate yellow colour method and potassium using a flamephotometer (Jackson, 1958).

The counter-current extraction with acetone using a soxhlet apparatus was carried out for the determination of oleoresin in freshly ground dry pepper (A.S.T.A. 1960).

4. Statistical analysis

The data relating to growth and yield characters were analysed by applying the analysis of variance technique, suggested by Panse and Sukatme (1967) for confounded factorial experiments.

The degree of relationship between yield and N, P and K contents of leaf at different leaf positions was estimated by calculating the simple linear correlation coefficients. Apart from the simple linear correlation coefficients, the partial linear correlation coefficients were also calculated in order to find out the degree of association of any two variables, eliminating the effects of other variables acting in the casual mechanism. The multiple correlation coefficients were also calculated in order to know the joint relationship between the dependent variable and a set of independent variables as per the methods suggested by Snedecor and Cochran (1967). The same methods were also used to find the relationship between yield and nitrogen, phospherus and potassium contents of first mature leaf at different periods of sampling.

The distribution pattern of the nitrogen, phospherus and potassium at different periods of sampling was depicited graphically by using moving average method so as to smooth the sharp variations present in the data and to give a statisfactory representation of the general trend of variation in the concentration of nutrients (Monga, 1975).

RESULTS

RESULTS

1. Effect of NPK treatment on yield of black pepper

Data on the yield of black pepper as influenced by NPK treatment are furnished in Table 1. The mean values are presented in Table 2 and the analysis of variance in Appendix III. As already pointed out the yield data presented in Table 2 form a part of the NPK experiment maintained at Pepper Research Station, Panniyoor. However, it is presented here to provide the back ground information on the effect of NPK treatment on yield, which is necessary in interpreting the results of tissue analysis undertaken.

The yield of experimental plants were grouped under three categories.

i) The cumulative yield of pepper during the five years from 1976-77 to 1980-81.

ii) The yield of pepper during the year 1979-80.

iii) The yield of pepper during the year 1980-81.

The cumulative yield was taken in order to reduce the influence of year-wise variation on the effects of NPK treatments employed. The yields of 1979-80 and 1980-81 were however examined separately since tissue samples were collected for chemical analysis after the 1979-80 harvest.

Observations revealed that the varying levels of nitrogen, phosphorus and potassium employed in the experiment could not influence the total yield of pepper for the period

Table 1 Effect of NPK treatment on yield of black pepper.

Sl. No.	Treatment NPK	Yield, kg/ha		
		1976-77 to 1980-81	1979-80	1980-81
1	000	2996	563	73
2	001	4410	1223	106
3	002	5113	1050	239
4	010	6072	1239	127
5	011	4378	1599	45
6	012	7458	2326	220
7	020	3244	683	86
8	021	4519	1183	42
9	022	8690	2826	76
10	100	3614	632	70
11	101	3995	1113	65
12	102	3397	1059	122
13	110	3909	1047	102
14	111	6407	1929	129
15	112	4029	1490	82
16	120	6167	1423	167
17	121	5334	1113	122
18	122	2905	875	102
19	200	4310	713	105
20	201	4010	1079	76
21	202	4576	1067	153
22	210	3557	1137	10
23	211	5538	1487	142
24	212	5449	1023	175
25	220	2311	462	85
26	221	5450	895	147
27	222	3972	1220	6

Table 2 Effect of NPK treatment on yield of black pepper.

Summary

Treatment groups	yield, kg/ha		
	1976-77 to 1980-81	1979-80	1980-81
n_0	5195	1409	113
n_1	4416	1187	107
n_2	4352	1009	100
F test	NS	Sig	NS
p_0	4034	944	112
p_1	5199	1475	115
p_2	4731	1186	93
F test	NS	Sig	NS
k_0	4007	878	92
k_1	4892	1291	97
k_2	5070	1436	131
F test	NS	Sig	NS
CD (0.05) for comparing levels of N, P and K	NS	74	NS

from 1976-77 to 1980-81. However, when the yield of 1979-80 was examined, the levels of N, P & K significantly influenced the yield. The mean yields of pepper during this year corresponding to n_0, n_1 & n_2 levels of nitrogen application were 1409, 1187 and 1009 kg/ha were respectively which showed that further increase in the levels of nitrogen from the n_0 level of 50 g N/vine/year resulted in a significant and continuous decrease in the yield and hence the n_0 level was found to be the best. However it is not possible to infer from this result whether further decrease in the nitrogen application from the n_0 level is possible to get the maximum yield. In the case of levels of phosphorus employed, the yield increased from p_0 to p_1, but declined from p_1 to p_2, the increase and decrease being statistically significant. The p_1 level (100 g P_2O_5/vine/year) was therefore superior to p_0 (50 g P_2O_5/vine/year) and p_2(100 g P_2O_5/vine/year). The optimum dose of P_2O_5 for maximum yield was worked out to be 107.38 g P_2O_5/gine/year. As regards the effect of levels of potassium, the yield continued to increase significantly with increasing levels of potassium applied. The mean yield of pepper corresponding to k_0, k_1 and k_2 levels were 878, 1291 and 1436 kg/ha respectively showing that the k_2 level (150 g K_2O/vine/year) was superior to k_0 (50 g K_2O/vine/year) and k_1 (100 g K_2O/vine/year) levels. However the k_2 level cannot be considered optimum since the yield continued to increase with increasing levels of potassium tried.

Of the interactions between the levels of nitrogen and phosphorus, the combination $n_0 p_1$ found to be significantly superior to other nitrogen and phosphorus combinations. Interaction between the levels of nitrogen and potassium was also significant with the highest yield at $n_0 k_2$ combination. Among the combinations of phosphorus and potassium levels, the yields at $p_1 k_1$ and $p_1 k_2$ were on par which were significantly superior to other combinations of phosphorus and potassium levels. The highest yield was however recorded as 2826 kg/ha at $n_0 p_2 k_2$ level which was significantly superior to the yield obtained at other combinations.

When the yield of 1980-81 was examined, it was seen that the levels of nitrogen, phosphorus and potassium tried, could not influence the yield significantly.

It was observed that though the levels of application of nitrogen, phosphorus and potassium could not significantly influence the cumulative yield of 1976-77 to 1980-81 and also the yield of 1980-81, the pattern of variation in yield with the levels of nitrogen, phosphorus and potassium was exactly similar with that of the result obtained for the 1979-80 yield, clearly showing the supremacy of the levels of n_0, p_1 and k_2.

2. Standardisation of leaf position for foliar diagnosis

(1) Nitrogen

Data on the effect of NPK treatment and leaf position on nitrogen content of leaf are presented in Table 3. The mean values are furnished in Table 6 and the analysis of variance in Appendix IV.

The content of nitrogen in leaf ranged from 1.0 to 5.0% with a mean value of 3.19, when all the treatments and positions were pooled.

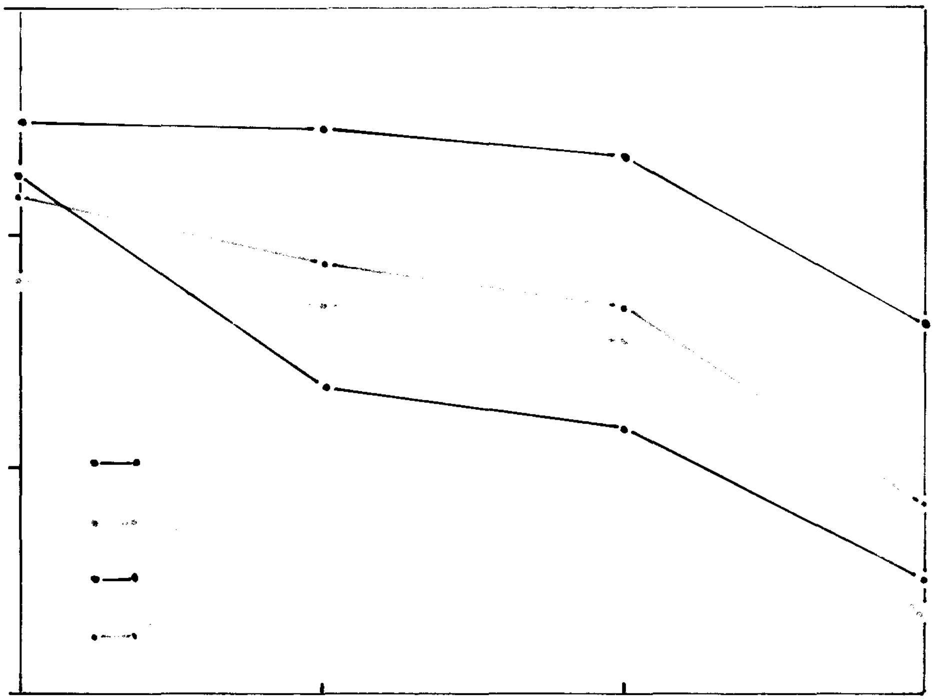
When the distribution of nitrogen in leaf over the different leaf positions were examined, it was seen that the nitrogen content of leaf continuously decreased with increasing number of leaf position (Fig.2). The first older mature leaf recorded the highest value for nitrogen and the fourth leaf contained the least. The differences in nitrogen content between adjacent leaf positions were statistically significant. The mean values in percentage for nitrogen in leaf corresponding to 1st, 2nd, 3rd and 4th position were 3.51, 3.33, 3.21 and 2.69 respectively.

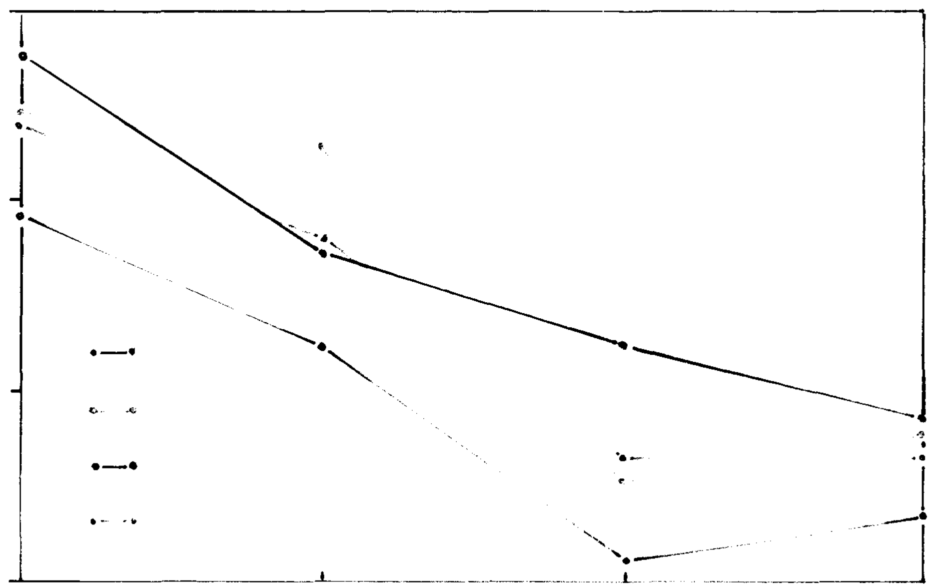
The varying levels of nitrogen application influenced the nitrogen percentage of leaves from different leaf positions. The value of nitrogen percentage in leaf did not vary significantly for n_0 and n_1 levels. However, the mean value for n_2 treatment (3.54%) was significantly higher as compared to values corresponding to n_0 and n_1 levels (3.01%).

Table 3 Effect of NPK treatment and leaf position on nitrogen content of leaf.

Nitrogen % on moisture free basis

Sl. No.	Treatment NPK	Leaf position 1	2	3	4
1	000	2.80	3.40	3.00	1.10
2	001	3.95	3.50	2.70	3.50
3	002	4.00	2.60	2.90	2.60
4	010	2.80	3.20	2.80	3.20
5	011	4.00	3.00	3.10	3.00
6	012	3.70	2.90	2.70	1.50
7	020	4.10	2.70	3.10	3.20
8	021	4.10	3.30	3.00	3.00
9	022	2.50	3.00	2.80	1.40
10	100	2.90	3.00	3.00	3.20
11	101	2.55	3.50	2.50	3.00
12	102	3.70	3.00	3.20	2.50
13	110	4.00	3.00	3.65	1.10
14	111	2.80	3.40	2.95	1.70
15	112	2.70	3.05	3.40	3.00
16	120	4.10	3.75	3.50	2.80
17	121	4.00	3.00	3.30	2.80
18	122	2.80	4.00	2.70	1.50
19	200	3.80	3.40	3.90	3.10
20	201	3.30	4.00	5.00	3.10
21	202	2.60	4.00	4.20	3.30
22	210	3.80	4.50	3.00	3.20
23	211	3.80	4.70	2.60	3.40
24	212	3.70	4.75	2.40	3.10
25	220	5.00	3.00	3.50	2.90
26	221	3.30	2.90	4.10	3.20
27	222	4.00	2.00	3.80	3.20
	n_0	3.55	3.07	2.90	2.50
	n_1	3.28	3.22	3.13	2.40
	n_2	3.70	3.69	3.61	3.16





As regards the coefficients of correlation between the nitrogen content of leaf from different positions and the yield of pepper, it was seen that the content of nitrogen failed to establish significant positive correlation with yield irrespective of leaf positions.

(ii) Phosphorus

Data on the effect of NPK treatment and leaf position on phosphorus content of leaf are presented in Table 4. The mean values are presented in Table 6 and the analysis of variance in Appendix IV.

The content of phosphorus in leaf ranged from 0.085 to 0.165% with mean value of 0.128% when all the values were pooled together.

The pattern of variation in the phosphorus content of leaf was similar to that of nitrogen though the total contents of phosphorus in the third and fourth leaf positions were on par (Fig.3). But the phosphorus content of first older mature leaf was significantly higher as compared to that in the second position which differed significantly with the third and fourth positions.

The levels of phosphorus application significantly influenced the phosphorus content of leaf at different positions. In general, phosphorus percentage of leaf increased with increasing levels of phosphorus application.

It was seen that the phosphorus content of leaf also increased with increasing levels of nitrogen application.

Table 4 Effect of NPK treatment and leaf position on phosphorus content of leaf.

Phosphorus % on moisture free basis

Sl. No.	Treatment NPK	Leaf position 1	2	3	4
1	000	0.160	0.135	0.120	0.120
2	001	0.135	0.110	0.100	0.115
3	002	0.135	0.110	0.095	0.105
4	010	0.145	0.150	0.090	0.100
5	011	0.135	0.130	0.110	0.115
6	012	0.165	0.140	0.115	0.110
7	020	0.155	0.135	0.145	0.125
8	021	0.130	0.125	0.105	0.110
9	022	0.160	0.115	0.105	0.120
10	100	0.130	0.145	0.090	0.115
11	101	0.135	0.110	0.115	0.125
12	102	0.130	0.110	0.085	0.100
13	110	0.155	0.140	0.090	0.120
14.	111	0.140	0.160	0.115	0.105
15	112	0.135	0.150	0.115	0.135
16	120	0.165	0.145	0.120	0.110
17	121	0.170	0.145	0.120	0.125
18	122	0.140	0.135	0.125	0.135
19	200	0.125	0.145	0.095	0.095
20	201	0.145	0.130	0.130	0.115
21	202	0.140	0.140	0.095	0.130
22	210	0.140	0.145	0.110	0.135
23	211	0.145	0.135	0.100	0.125
24	212	0.150	0.140	0.135	0.125
25	220	0.135	0.135	0.160	0.110
26	221	0.160	0.150	0.125	0.110
27	222	0.145	0.125	0.120	0.130
	P_0	0.137	0.126	0.107	0.111
	P_1	0.146	0.143	0.114	0.118
	P_2	0.151	0.134	0.126	0.119

Results showed that NK and PK interactions were significant with respect to content of phosphorus in leaf. The highest phosphorus content was observed at $n_2 k_2$ among NK combinations and at $p_2 k_0$ among PK combinations.

The coefficient of simple linear correlation between the cumulative yield of pepper and phosphorus content of first mature leaf was found to be significant at 5% level (Table 20).

(iii) Potassium

Data on the effect of NPK treatment and leaf position on potassium content of leaf are presented in Table 5. The mean values are presented in Table 6 and the analysis of variance in Appendix IV.

The potassium content of leaf ranged from 0.85 to 2.25% with a mean value of 1.54% when leaf positions and treatments were pooled.

The pattern of variation of potassium content of leaf at different leaf positions was almost similar to that of nitrogen and phosphorus as the potassium percent decreased with increasing age of the leaf (Fig.4). However, the third and fourth positions of leaf were on par with respect to potassium content of leaf. The highest percentage of potassium was recorded in the first older mature leaf which was significantly higher than that of other leaf positions.

Table 5 Effect of NPK treatment and leaf position on potassium content of leaf.

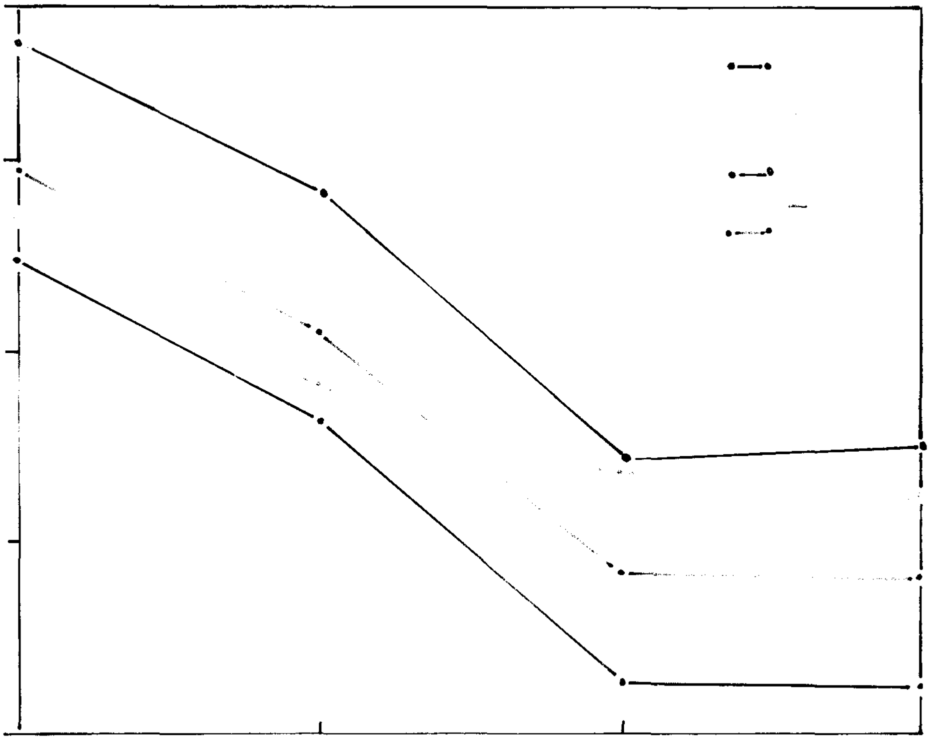
Potassium % on moisture free basis

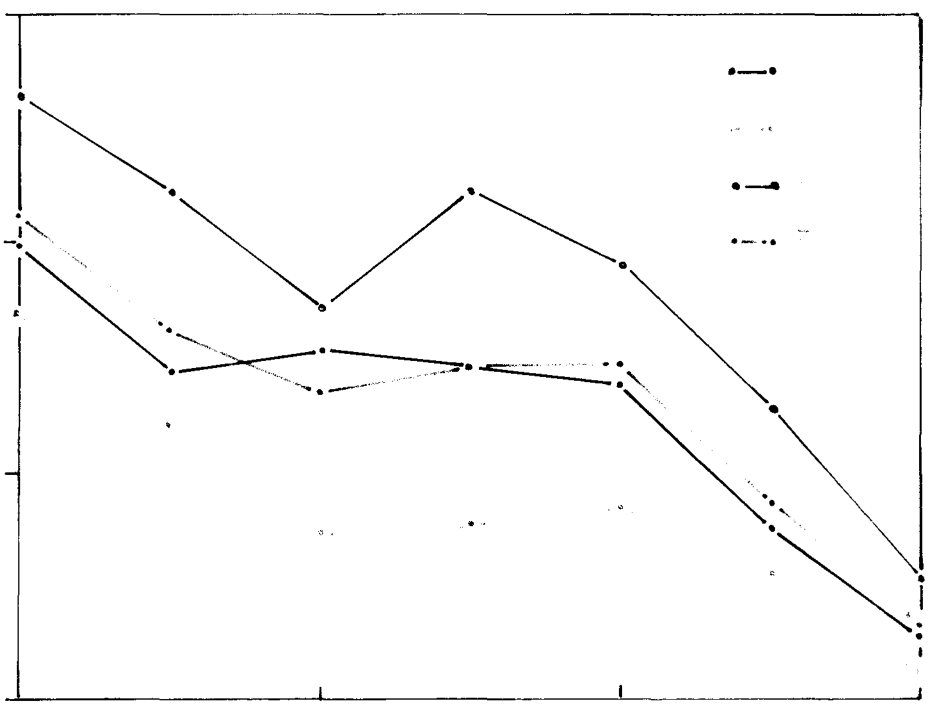
Sl. No.	Treatment NPK	Leaf position			
		1	2	3	4
1	000	1.85	1.55	1.30	1.18
2	001	1.83	1.75	1.40	1.48
3	002	2.18	1.78	1.55	1.33
4	010	2.00	1.53	1.10	1.45
5	011	1.63	1.40	1.13	1.15
6	012	2.13	1.75	1.13	1.30
7	020	1.58	0.95	0.98	0.88
8	021	1.58	1.58	1.28	1.35
9	022	2.25	1.50	1.23	1.68
10	100	1.40	1.95	0.85	0.93
11	101	1.55	1.05	1.65	1.58
12	102	1.88	1.48	1.30	1.35
13	110	1.70	1.58	1.33	1.35
14	111	1.75	1.78	1.50	1.28
15	122	2.20	2.18	1.70	1.73
16	120	1.95	1.48	1.30	1.05
17	121	2.23	1.73	1.83	1.70
18	122	1.53	1.80	1.60	1.53
19	200	1.45	1.68	1.08	1.00
20	201	1.70	1.50	1.30	1.13
21	202	2.00	2.00	1.50	1.30
22	210	1.80	1.63	1.35	1.38
23	211	1.55	1.68	1.23	1.33
24	212	1.95	2.05	1.68	1.33
25	220	1.75	1.28	1.20	1.18
26	221	2.20	1.53	1.63	1.73
27	222	2.00	1.73	1.48	1.65
	k_0	1.72	1.51	1.17	1.16
	k_1	1.78	1.56	1.44	1.41
	k_2	2.01	1.81	1.46	1.47

Table 6 Effect of NPK treatment and leaf position on nutrient content of leaf.

Summary

Treatment group	Percentage on moisture free basis		
	N	P	K
n_0	3.01	0.124	1.49
n_1	3.01	0.129	1.58
n_2	3.54	0.130	1.55
F test	Sig	Sig	NS
p_0	3.24	0.120	1.49
p_1	2.94	0.130	1.58
p_2	3.21	0.133	1.56
F test	NS	Sig	NS
k_0	3.24	0.129	1.39
k_1	3.32	0.127	1.55
k_2	3.03	0.127	1.69
F test	NS	NS	Sig
C.D.(0.05) for comparing levels of N, P and K	0.293	0.004	0.106
Positions			
1	3.51	0.145	1.84
2	3.33	0.135	1.63
3	3.21	0.116	1.36
4	2.69	0.116	1.35
C.D.(0.05) for comparing positions	0.338	0.006	0.120





The percentage of potassium in leaf increased with increasing levels of potassium application irrespective of the leaf positions. The interaction between levels of phosphorus and potassium was also found to be significant with the highest content of potassium in leaf being recorded at $p_1 k_2$ level (1.76%).

The coefficient of correlation (simple linear) between potassium content of first mature leaf and yield of pepper during 1979-80 is presented in Table 20. Results showed that the coefficient of simple linear correlation between yield and potassium content of the first mature leaf was significant at 5% level. The simple linear coefficient of correlation between the cumulative yield (1976-77 to 1980-81) and potassium content of first mature leaf was also significant at 1% level (Table 20).

3. Standardisation of season or period for sampling of tissue.

In order to standardise the optimum season or period for the sampling of leaf intended for foliar diagnosis, leaf samples were collected from experimental plants at the following stages.

1. After the harvest of berries
2. Prior to flushing
3. One month after flushing
4. Two months after flushing

5. Three months after flushing
6. Four months after flushing
7. Five months after flushing
8. Six months after flushing
9. Seven months after flushing

These periods of sampling were referred to as period 1 to 9.

(i) Nitrogen

Data on the effect of NPK treatment and period of sampling on nitrogen are presented in Table 7. The mean values are furnished in Table 13 and the analysis of variance in Appendix V.

The content of nitrogen in leaf ranged from 1.0 to 5.1% with a mean value of 3.15%, when the values for all the treatments and periods were considered. The variation in the nitrogen content of leaf at different periods of sampling is graphically represented in Fig. 5. When the distribution of nitrogen in leaf over different periods of sampling was examined, it was seen that the nitrogen content of leaf remained high before flushing and sharply declined till the period of two month after flushing. Thereafter the nitrogen content increased at the 5^{th} and 6^{th} periods corresponding to third and fourth month after flushing, but again declined at the 7^{th} period. After the 7^{th} period, the nitrogen content slightly increased and then decreased at the 9^{th} period.

Table 7 Effect of NPK treatment and period of sampling on nitrogen content of leaf.

Nitrogen % on moisture free basis

Sl. No.	Treatment NPK	Period of sampling								
		1	2	3	4	5	6	7	8	9
1	000	4.68	3.57	3.50	3.30	2.80	3.50	3.10	3.00	2.90
2	001	4.42	3.23	3.50	2.75	3.95	3.10	3.00	3.25	2.80
3	002	3.23	3.06	3.50	2.70	4.00	3.15	2.90	3.20	1.90
4	010	2.38	3.40	3.70	2.90	2.80	3.40	2.95	3.10	2.90
5	011	3.74	4.25	3.10	3.10	4.00	3.70	2.80	3.05	2.80
6	012	4.25	3.23	3.00	1.90	3.70	3.75	2.10	2.95	2.85
7	020	2.72	2.38	3.50	1.80	4.10	3.80	2.90	3.10	2.50
8	021	1.70	4.25	3.15	2.80	4.10	1.85	1.00	1.20	3.00
9	022	3.40	3.40	3.55	3.30	2.50	3.25	2.70	2.75	2.60
10	100	1.70	3.57	1.30	2.85	2.90	3.30	3.00	2.95	2.80
11	101	2.38	3.40	3.30	1.40	2.55	3.20	3.00	3.00	3.10
12	102	1.87	3.49	3.20	1.75	3.70	3.10	1.60	2.90	3.20
13	110	2.89	3.23	3.50	3.10	4.00	3.60	2.95	2.60	3.20
14	111	2.89	3.40	3.20	3.20	2.80	3.25	3.05	3.00	3.20
15	112	3.40	4.93	3.40	1.40	2.70	3.05	1.00	2.40	2.90
16	120	3.40	3.40	3.70	3.20	4.10	2.60	3.00	1.40	1.60
17	121	3.57	4.34	3.60	1.80	4.00	3.30	2.90	3.25	2.90
18	122	3.57	4.59	3.30	1.70	2.80	3.25	2.70	3.00	2.80
19	200	3.57	4.51	2.55	2.00	3.80	3.50	2.40	2.80	2.05
20	201	4.42	4.42	3.90	3.40	3.30	3.70	3.10	3.00	2.95
21	202	3.23	4.17	3.35	3.20	2.60	3.70	2.90	2.50	2.70
22	210	2.81	3.83	3.40	2.80	3.80	3.85	2.90	3.30	3.15
23	211	3.66	4.25	1.40	3.30	3.80	4.00	1.00	3.25	2.70
24	212	3.40	4.08	3.70	3.20	3.70	3.20	3.00	3.05	2.80
25	220	3.91	4.42	3.45	3.00	5.00	3.50	2.30	3.10	3.10
26	211	3.40	5.10	3.50	3.20	3.30	4.05	3.00	3.00	2.90
27	222	3.23	4.25	2.90	3.00	4.40	3.85	3.00	3.10	3.05

Table 8 Effect of NPK treatment and period of sampling on nitrogen content of leaf (Average and 3 position moving average of N% on moisture free basis)

Period of sampling	Treatment							
	n_0		n_1		n_2		M	
	Average	Moving average	Average	moving average	Average	Moving average	Average	Moving average
1	3.39		2.85		3.51		3.26	
2	3.42	3.40	3.82	3.28	4.14	3.66	3.86	3.45
3	3.39	3.18	3.17	3.09	3.13	3.49	3.23	3.25
4	2.73	3.22	2.37	2.90	3.01	3.29	2.67	3.14
5	3.55	3.19	3.28	2.91	3.74	3.49	3.53	3.19
6	3.28	3.15	3.18	3.01	3.71	3.36	3.37	3.19
7	2.61	2.91	2.58	2.83	2.62	3.11	2.60	2.94
8	2.84	2.71	2.73	2.65	3.00	2.81	2.86	2.72
9	2.69		2.63		2.82		2.72	

The nitrogen content of leaves also differed with respect to the levels of nitrogen application. The value of nitrogen percentage in leaf did not vary significantly for n_0 and n_1 levels. However, the mean value for n_2 treatments was significantly higher as compared to values corresponding to n_0 and n_1 levels. The pattern of variation in the nitrogen content of leaf over different periods of sampling was separately examined for n_0, n_1 and n_2 levels. It was seen that the nitrogen content of leaf increased with increasing levels of nitrogen application. This was observed only at the second period of sampling corresponding to the preflushing stage where the percentage of nitrogen in the leaf for n_0, n_1 and n_2 were 3.42, 3.82 and 4.34% respectively. At all other periods, nitrogen content of leaf corresponding to n_1 level of application was lower than the nitrogen content of n_0 level.

Results showed that interaction between the levels of nitrogen and phosphorus was significant with respect to content of nitrogen in the leaf. The highest nitrogen content in leaf was obtained at the n_2 p_2 combination.

As regards the coefficients of correlation between nitrogen content of leaf at different periods and yield of black pepper, it was seen that the content of nitrogen retained in the leaf failed to establish significant positive correlation with yield irrespective of periods of sampling.

(ii) Phosphorus

Table 9 presents the data on the effect of NPK treatment and period of sampling on phosphorus. The mean values are furnished in Table 13 and the analysis of variance in Appendix V.

The content of phosphorus in leaf ranged from 0.053 to 0.253% with a mean value of 0.167%. The three position moving average of phosphorus content of leaf at different periods of sampling are graphically represented in Fig.6.

The pattern of variation in the phosphorus content of leaf at different periods of sampling was almost similar to that of nitrogen during the periods after flushing though the total content of phosphorus retained in the leaf at any period of sampling was considerably lower as compared to that of nitrogen. In sharp contrast with the pattern of variation of nitrogen, phosphorus content of leaf during the first two periods prior to flushing was relatively lower as compared to the phosphorus content of leaf after flushing. The phosphorus content of leaf increased with flushing but declined at the 5th period corresponding to 3rd month after flushing, again increased at the 6th and 7th periods and then declined. The phosphorus content again increased at the last period of sampling.

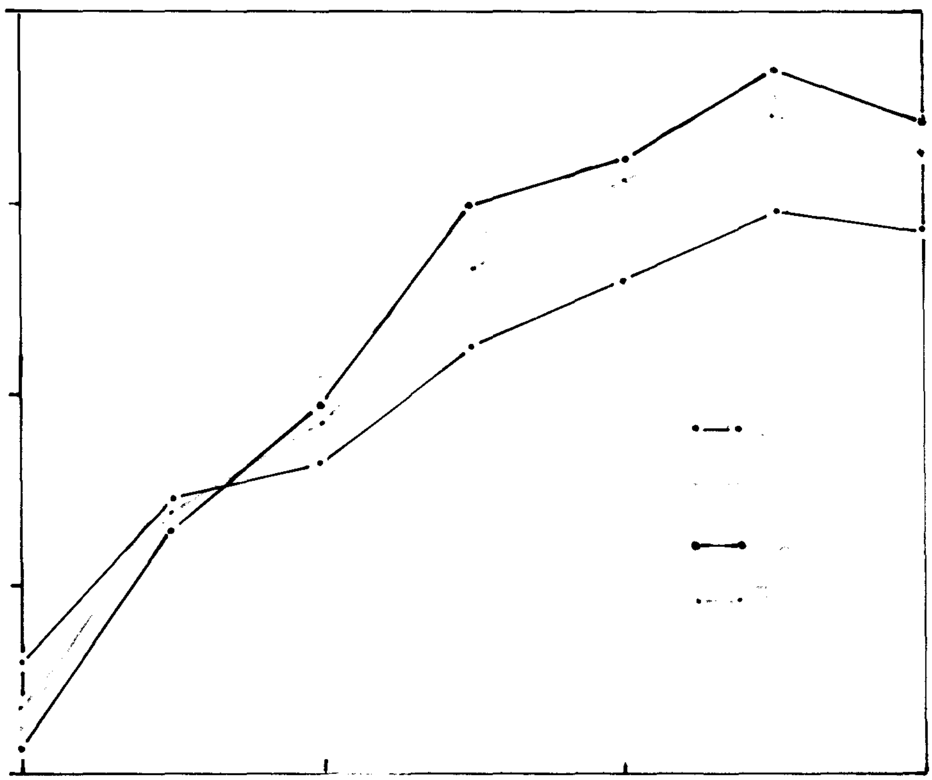
Table 9 Effect of NPK treatment and period of sampling on phosphorus content of leaf.

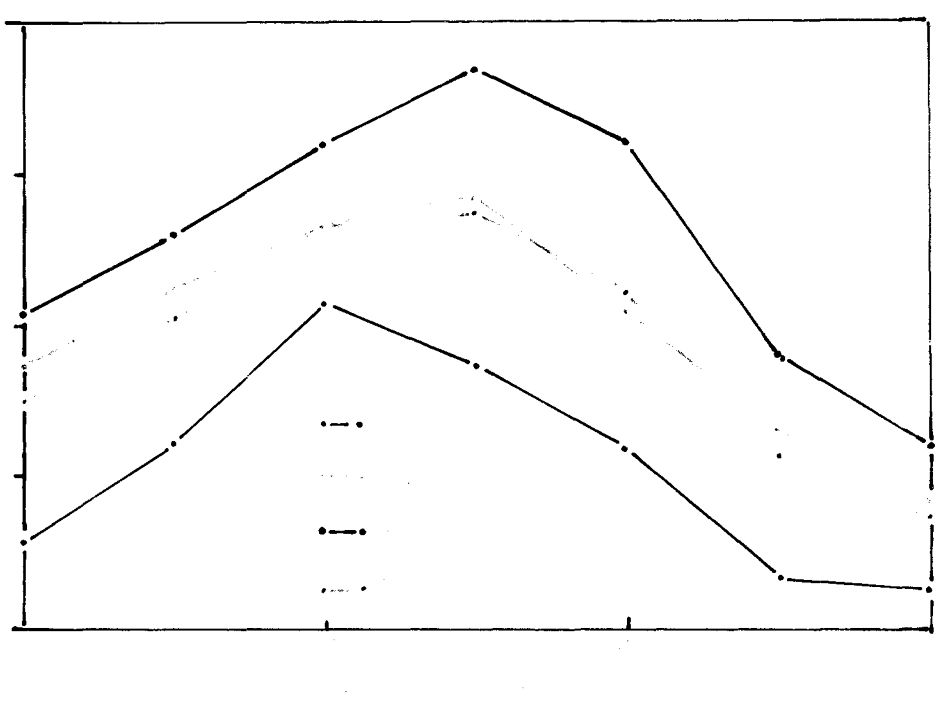
Phosphorus % on moisture free basis

Sl. No.	Treatment NPK	Period of sampling								
		1	2	3	4	5	6	7	8	9
1	000	0.118	0.136	0.164	0.208	0.160	0.230	0.210	0.153	0.153
2	001	0.130	0.128	0.158	0.170	0.135	0.180	0.200	0.166	0.179
3	002	0.128	0.126	0.168	0.174	0.135	0.180	0.200	0.166	0.173
4	010	0.120	0.122	0.194	0.208	0.145	0.170	0.240	0.153	0.146
5	011	0.118	0.160	0.144	0.186	0.135	0.200	0.200	0.139	0.173
6	012	0.122	0.108	0.144	0.218	0.165	0.240	0.230	0.153	0.146
7	020	0.112	0.198	0.148	0.178	0.155	0.220	0.190	0.146	0.166
8	021	0.120	0.138	0.154	0.178	0.130	0.190	0.210	0.153	0.173
9	022	0.126	0.118	0.154	0.220	0.160	0.250	0.210	0.153	0.179
10	100	0.118	0.138	0.160	0.178	0.130	0.210	0.190	0.159	0.186
11	101	0.118	0.118	0.144	0.162	0.135	0.230	0.190	0.139	0.193
12	102	0.108	0.108	0.156	0.160	0.130	0.210	0.160	0.159	0.193
13	110	0.132	0.098	0.160	0.204	0.155	0.190	0.210	0.159	0.193
14	111	0.104	0.108	0.142	0.166	0.140	0.200	0.240	0.139	0.179
15	112	0.124	0.148	0.178	0.176	0.135	0.240	0.240	0.173	0.153
16	120	0.148	0.108	0.150	0.202	0.165	0.200	0.220	0.166	0.219
17	121	0.128	0.106	0.176	0.178	0.170	0.230	0.200	0.186	0.226
18	122	0.124	0.148	0.158	0.188	0.140	0.220	0.200	0.166	0.219
19	200	0.122	0.096	0.160	0.232	0.125	0.210	0.210	0.093	0.239
20	201	0.124	0.134	0.174	0.180	0.145	0.190	0.180	0.226	0.233
21	202	0.126	0.152	0.184	0.100	0.140	0.180	0.200	0.159	0.199
22	210	0.082	0.152	0.168	0.182	0.140	0.180	0.200	0.193	0.226
23	211	0.108	0.059	0.164	0.198	0.145	0.190	0.200	0.179	0.253
24	212	0.126	0.065	0.160	0.196	0.150	0.230	0.220	0.179	0.239
25	220	0.110	0.053	0.160	0.174	0.135	0.210	0.210	0.186	0.210
26	221	0.116	0.061	0.150	0.194	0.160	0.250	0.210	0.213	0.253
27	222	0.124	0.055	0.146	0.190	0.145	0.210	0.190	0.193	0.226

Table 10 Effect of NPK treatment and period of sampling on phosphorus content of leaf (Average and 3 position moving average of P% on moisture free basis)

Period of sampling	Treatment							
	P_0		P_1		P_2		$\bar{P}$	
	Average	Moving average	Average	Moving average	Average	Moving average	Average	Moving average
1	0.121		0.115		0.122		0.119	
2	0.126	0.137	0.113	0.130	0.109	0.128	0.116	0.132
3	0.163	0.154	0.162	0.156	0.155	0.151	0.160	0.153
4	0.173	0.158	0.193	0.167	0.189	0.164	0.182	0.162
5	0.137	0.170	0.146	0.181	0.148	0.185	0.144	0.178
6	0.202	0.177	0.204	0.191	0.219	0.190	0.209	0.187
7	0.193	0.184	0.222	0.196	0.204	0.199	0.207	0.194
8	0.158	0.182	0.163	0.192	0.174	0.193	0.165	0.190
9	0.194		0.190		0.208		0.198	





When the influence of varying levels of phosphorus application on phosphorus content of leaf was examined, it was seen that phosphorus percentage of leaf for different periods, of sampling varied significantly with the varying levels of phosphorus application. The mean values for phosphorus percentage in leaf corresponding to p_0, p_1 and p_2 levels of application were 0.163, 0.167 and 0.174 respectively when the effect of periods were pooled. This showed that in general, the content of phosphorus in leaf increased with increasing levels of phosphorus application, the differences being statistically significant. However, this increase in the phosphorus application was not found uniformly reflected at all the periods of sampling especially during early periods. It was seen that the phosphorus content of leaf was also influenced by levels of nitrogen application. Phosphorus content of leaf increased with increasing levels of nitrogen application though mean values for n_1 and n_2 were statistically on par. Also the effects of NP, NK and PK interaction were significant in influencing the content of phosphorus in leaf.

Coefficients of simple linear correlation between the cumulative yield of pepper and the phosphorus content of leaf (Table 14) were found to be significant for the 5^{th} period (r = 0.462*) and 7^{th} period (r = 0.405*) of sampling at 5% level of significance.

(iii) Potassium

Data on the effect of NPK treatment and period of sampling on the potassium content of leaf are presented in Table 11. The mean values are furnished in Table 13 and the analysis of variance in Appendix V.

The potassium content of leaf ranged from 0.53 to 2.68% with a mean value of 1.48. When the values for treatments and periods were pooled, the pattern of variation in the potassium content of leaf over the different periods of sampling varied significantly as represented graphically in Fig.7. In general the potassium content of leaf increased with the increasing periods of sampling upto 5th period and declined thereafter.

The percentage of potassium in the first period was 1.44 which increased to a value of 1.84 at 5th period and then declined to 1.26 in the last period.

Potassium content of leaf irrespective of period of sampling increased with the increasing levels of potassium application. When the effect of period of sampling is pooled, the percentage of potassium in leaves corresponded to k_0, k_1 and k_2 levels of application were 1.31, 1.51 and 1.64 respectively. Though, the levels of potassium application influenced the content of this element in leaf, the pattern of variation over different periods of sampling remained the same for all the levels of potassium application. With the increase in levels of potassium

Table 11 Effect of NPK treatment and period of sampling on potassium content of leaf.

Potassium % on moisture free basis

Sl. No.	Treatment NPK	Period of sampling 1	2	3	4	5	6	7	8	9
1	000	1.43	1.25	1.45	1.93	1.85	1.23	1.10	1.50	0.95
2	001	1.53	1.03	1.53	1.93	1.83	1.60	1.15	1.63	0.93
3	002	1.38	1.15	1.58	2.18	2.18	1.95	1.60	1.50	1.78
4	010	1.38	1.30	1.43	2.33	2.00	0.85	1.35	1.25	1.75
5	011	1.35	1.53	1.65	1.93	1.63	1.45	1.18	1.55	1.43
6	012	2.13	1.58	1.23	2.10	2.13	1.53	1.88	0.63	1.15
7	020	0.85	0.85	1.25	1.40	1.58	0.95	1.10	1.10	1.10
8	021	1.23	1.65	1.33	1.53	1.58	1.48	1.50	0.90	0.83
9	022	2.03	2.00	1.33	2.60	2.25	2.18	1.50	0.70	1.18
10	100	1.33	1.15	1.30	1.53	1.40	1.20	0.88	1.45	1.03
11	101	1.70	1.73	1.50	2.25	1.55	1.85	1.58	1.50	1.70
12	102	1.70	1.18	1.48	2.08	1.88	1.10	1.33	0.85	1.75
13	110	1.65	1.08	1.13	1.80	1.70	1.25	1.48	0.90	0.75
14	111	1.53	1.45	1.48	0.95	1.75	1.70	1.60	0.75	1.50
15	112	1.53	2.23	1.48	1.33	2.20	2.05	1.75	0.85	0.60
16	120	1.56	1.23	1.45	1.65	1.95	1.28	1.60	0.83	0.63
17	121	2.03	1.58	1.75	2.03	2.23	1.85	0.73	1.20	1.85
18	122	1.70	1.75	1.53	1.68	1.53	1.70	1.65	1.05	1.75
19	200	1.18	0.98	1.48	1.70	1.45	0.85	1.45	0.58	0.95
20	201	1.38	1.63	1.48	1.18	1.70	1.40	0.90	1.55	1.28
21	202	1.23	1.93	1.95	1.23	2.00	1.78	1.45	1.90	1.40
22	210	1.03	1.48	1.28	0.53	1.80	1.40	1.45	1.50	1.33
23	211	0.80	1.40	1.43	1.48	1.55	1.10	1.43	1.63	1.35
24	212	1.13	1.85	1.30	1.65	1.95	1.45	1.68	1.35	1.25
25	220	0.95	1.15	1.58	1.88	1.75	1.18	1.45	1.85	1.03
26	221	1.58	1.90	1.33	2.68	2.20	2.05	1.85	1.10	1.20
27	222	1.43	1.28	1.33	2.15	2.00	2.10	1.68	1.73	1.63

Table 12 Effect of NPK treatment and period of sampling on potassium content of leaf (Average and 3 position moving average of K% on moisture free basis)

Period of sampling	Treatment							
	k_0		k_1		k_2		$\bar{k}$	
	Average	Moving average	Average	Moving average	Average	Moving average	Average	Moving average
1	1.26		1.46		1.58		1.44	
2	1.16	1.26	1.54	1.50	1.66	1.57	1.46	1.45
3	1.37	1.39	1.50	1.60	1.47	1.67	1.44	1.56
4	1.64	1.58	1.77	1.68	1.89	1.79	1.77	1.68
5	1.72	1.50	1.78	1.72	2.01	1.89	1.84	1.70
6	1.13	1.39	1.61	1.57	1.76	1.79	1.50	1.59
7	1.32	1.22	1.32	1.41	1.61	1.51	1.42	1.38
8	1.22	1.20	1.31	1.32	1.17	1.39	1.23	1.30
9	1.06		1.34		1.39		1.26	

application, the potassium content of leaf increased invariably at all sampling periods and variation due to levels of application was found to be maximum at the 6^{th} period. Values for the percentage of potassium in leaf in the 6^{th} period were 1.13, 1.61 and 1.76 corresponding to k_0, k_1 and k_2 levels respectively.

It is also seen that the level of potassium in leaf was also influenced by interaction between levels of nitrogen and phosphorus applied. The potassium content of leaf of plant receiving n_0 p_2 treatment was only 1.30% while the corresponding value for n_2 p_2 combination was 1.62%.

The coefficients of correlation (simple linear) between the potassium content of leaf and yield of pepper during 1979-80 are presented in Table 14. Results showed that the coefficients of simple linear correlation between yield and potassium content of leaf were significant for the 1^{st}, 2^{nd}, 6^{th}, 7^{th} and 8^{th} period of sampling at 5% level of significance and between yield (1979-80) and the first period of sampling at 1% level of significance. Values for the partial linear correlation between the yield (1979-80) and potassium content of leaf were significant for the sampling periods, 1^{st}, 2^{nd} and 8^{th} at 1% level of significance. Simple linear coefficients of correlation

Table 13 Effect of NPK treatment and period of sampling on nutrient content of leaf.

Summary

Treatment group	Percentage on moisture free basis		
	N	P	K
n_0	3.09	0.164	1.48
n_1	2.95	0.167	1.50
n_2	3.32	0.168	1.48
F test	Sig	Sig	NS
p_0	3.09	0.160	1.47
p_1	3.23	0.167	1.47
p_2	3.15	0.174	1.52
F test	NS	Sig	NS
k_0	3.13	0.167	1.31
k_1	3.16	0.167	1.51
k_2	3.08	0.166	1.64
F test	NS	NS	Sig
C.D.(0.05) for comparing levels of N, P and K	0.182	0.003	0.092
Periods			
1	3.26	0.119	1.44
2	3.86	0.116	1.46
3	3.23	0.160	1.44
4	2.67	0.182	1.77
5	3.53	0.144	1.84
6	3.37	0.209	1.50
7	2.60	0.207	1.42
8	2.86	0.165	1.23
9	2.72	0.198	1.26
F test	Sig	Sig	Sig
C.D.(0.05) for comparing periods	0.316	0.006	0.160

Table 14 Coefficients of correlation (simple linear) between yield and nitrogen, phosphorus and potassium % of first mature leaf in relation to period of sampling.

Period of sampling	Coefficients of correlation (r)		
	Nitrogen	Phosphorus	Potassium
<u>Yield of 1976-77 to 1980-81</u>			
Prior to flushing	-0.178	-0.204	0.336
Three months after flushing	-0.232	0.462*	0.523**
Five months after flushing	-0.006	0.405*	0.307
Six months after flushing	-0.664**	0.093	0.178
Seven months after flushing	-0.407*	-0.101	0.045
<u>Yield of 1979-80</u>			
After the harvest of berries	0.107	0.047	0.522**
Prior to flushing	-0.170	-0.218	0.423*
Three months after flushing	-0.262	0.295	0.422*
Four months after flushing	-0.065	0.192	0.413*
Five months after flushing	-0.169	0.393*	0.327
Six months after flushing	-0.106	0.112	0.421
<u>Yield of 1980-81</u>			
Three months after flushing	-0.027	0.292	0.409*
Seven months after flushing	-0.437*	-0.031	0.108

* Significant at 5% level.
** Significant at 1% level.

Table 15 Coefficients of correlation (partial and multiple) between yield and nitrogen, phosphorus and potassium % of first mature leaf in relation to period of sampling.

Period of sampling	Coefficients of correlation, partial			Multiple correlation coreficient
	Nitrogen	Phosphorus	Potassium	
Yield of 1976-77 to 1980-81				
Prior to flushing	-0.381	-0.400	0.571**	0.469*
Three months after flushing	-0.275	0.299	0.358	0.368
Five months after flushing	-0.055	0.347	0.348	0.209
Six months after flushing	-0.661**	0.028	0.120	0.449
Seven months after flushing	-0.404	0.268	0.075	0.250
Yield of 1979-80				
After the harvest of berries	0.061	0.006	0.516**	0.276
Prior to flushing	-0.282	-0.673**	0.734**	0.456*
Three months after flushing	-0.229	0.038	0.347	0.238
Four months after flushing	-0.053	0.051	0.374	0.175
Five months after flushing	-0.079	0.228	0.353	0.198
Six months after flushing	-0.065	0.071	0.568**	0.186
Yield of 1980-81				
Three months after flushing	-0.042	0.106	0.313	0.179
Seven months after flushing	-0.447*	-0.028	0.145	0.210

* Significant at 5% level.
** Significant at 1% level.

between the cumulative yield (1976-77 to 1980-81) and potassium content of leaf were significant for the 1st, 2nd, 5th, 6th and 8th period of sampling while the coefficients of partial linear correlation between the same set of variables were significant only for the 1st and 2nd periods at 1% level of significance.

4. Distribution of nitrogen, phosphorus and potassium in different types of shoots as influenced by period of sampling and NPK treatment.

Data on the distribution of nitrogen in different kinds of shoots as influenced by NPK treatment are presented in Table 16. The mean values are furnished in Table 19 and the analysis of variance in Appendix VI.

(i) Nitrogen

The content of nitrogen in stem ranged from 1.00 to 4.40% with a mean value of 2.95% when the values for all the treatments and shoots were pooled.

When the distribution of nitrogen in different types of shoots was examined, it was seen that the hanging shoots of the upper canopy recorded the highest nitrogen content and the top shoot the least. The differences in nitrogen content between different types of shoots were statistically significant. The mean values for percentage of nitrogen in hanging shoot, runner shoot, fruit bearing lateral and top shoot were 3.60, 3.14, 2.98 and 2.17 respectively.

Table 16 Effect of NPK treatment and type of shoot on nitrogen content of stem.

Nitrogen % on moisture free basis

Sl. No.	Treatment NPK	Type of shoot			
		Runner shoot	Top shoot	Hanging shoot	Fruit bearing lateral
1	000	2.70	2.50	4.40	3.00
2	001	2.90	1.10	3.80	3.10
3	002	2.50	2.65	4.00	2.50
4	010	3.10	2.70	1.80	3.40
5	011	3.50	2.60	3.80	3.10
6	012	1.10	2.35	3.20	2.85
7	020	2.50	2.40	3.90	3.40
8	021	3.00	2.70	1.60	2.80
9	022	3.10	1.00	3.80	2.80
10	100	3.30	2.80	3.60	3.40
11	101	2.90	1.90	2.00	2.70
12	102	2.80	2.60	5.20	2.85
13	110	3.70	1.00	3.20	2.90
14	111	3.50	3.00	4.20	2.90
15	112	3.50	2.70	3.30	3.10
16	120	3.60	1.40	4.40	2.55
17	121	3.90	2.20	4.10	3.15
18	122	4.20	1.50	4.00	3.30
19	200	2.85	2.70	3.80	2.95
20	201	3.40	1.00	4.60	3.15
21	202	3.60	1.00	3.40	3.00
22	210	1.00	1.00	4.40	2.80
23	211	3.30	2.60	3.00	2.90
24	212	3.60	2.80	2.20	3.30
25	220	3.70	2.90	3.20	2.95
26	221	3.60	2.80	4.00	3.00
27	222	4.00	2.60	4.20	2.60

The varying levels of nitrogen, phosphorus and potassium applied did not influence the nitrogen percentage of shoot of different types. The interactions between the fertilizer levels were not significant. The nitrogen percentage of stem failed to establish significant correlation with yield irrespective of type of shoot examined.

(ii) Phosphorus

Data on effect of NPK treatment and type of shoot on phosphorus content of stem are presented in Table 17. The mean values are furnished in Table 19 and the analysis of variance in Appendix VI.

The percentage of phosphorus in stem ranged from 0.14 to 0.49 with a mean value of 0.264 when treatments and type of shoots were pooled.

When the distribution of phosphorus in shoots of different types was examined, it was observed that the percentage of phosphorus was 0.321 in runner shoot, 0.273 in top shoot, 0.269 in hanging shoot and 0.194 in fruit bearing lateral. Statistical analysis of the data revealed that runner shoot, top shoot and hanging shoot were on par with respect to phosphorus content of shoot. There was no significant difference in phosphorus content between the hanging shoot and fruit bearing lateral and they contained

Table 17 Effect of NPK treatment and type of shoot on phosphorus content of stem.

Phosphorus % on moisture free basis

Sl. No.	Treatment NPK	Type of shoot			
		Runner shoot	Top shoot	Hanging shoot	Fruit bearing lateral
1	000	0.310	0.270	0.270	0.170
2	001	0.300	0.260	0.260	0.210
3	002	0.290	0.260	0.300	0.150
4	010	0.330	0.250	0.280	0.240
5	011	0.320	0.220	0.260	0.210
6	012	0.390	0.340	0.240	0.230
7	020	0.300	0.250	0.240	0.190
8	021	0.260	0.230	0.180	0.170
9	022	0.360	0.280	0.290	0.190
10	100	0.280	0.250	0.250	0.230
11	101	0.310	0.260	0.270	0.210
12	102	0.310	0.310	0.230	0.180
13	110	0.340	0.260	0.220	0.230
14	111	0.270	0.300	0.240	0.140
15	112	0.350	0.300	0.250	0.240
16	120	0.400	0.310	0.300	0.200
17	121	0.340	0.270	0.490	0.210
18	122	0.340	0.330	0.290	0.160
19	200	0.230	0.280	0.200	0.210
20	201	0.280	0.270	0.300	0.180
21	202	0.350	0.250	0.210	0.160
22	210	0.290	0.220	0.250	0.180
23	211	0.320	0.280	0.250	0.170
24	212	0.320	0.330	0.310	0.220
25	220	0.370	0.270	0.240	0.180
26	221	0.360	0.290	0.330	0.190
27	222	0.340	0.240	0.270	0.190

significantly less amount of phosphorus as compared the other types of shoots. The levels of phosphorus failed to influence the phosphorus content of all the types of shoot. Results also showed that the different combinations of fertiliser levels were not significant with respect to content of phosphorus in shoot.

The coefficient of simple linear correlation between the phosphorus content of runner shoot and yield of pepper during 1980-81 was found to be significant at 5% level (Table 20). The coefficients of partial linear correlation for the same set of variables was also significant at the 5% level.

(iii) Potassium

Data on the distribution of potassium in stem as influenced by the type of shoot and NPK treatment are presented in Table 18. The Table 19 presents the mean values and Appendix VI, the analysis of variance.

The potassium content of shoot ranged from 0.58 to 3.70 with a mean value of 1.72% when types of shoots and treatments were considered.

The potassium content of stem varied significantly with types of shoot. The highest potassium content (2.78%) was recorded for fruit bearing lateral and the lowest value of 1.25% was obtained in the case of hanging shoot. The content of potassium in top shoot and runner

Table 18 Effect of NPK treatment and type of shoot on potassium content of stem.

Potassium % on moisture free basis

Sl. No.	Treatment NPK	Type of shoots			
		Runner shoot	Top shoot	Hanging shoot	Fruit bearing lateral
1	000	1.48	1.25	1.18	2.60
2	001	1.45	1.23	1.25	2.90
3	002	1.00	1.40	1.20	2.70
4	010	0.58	1.50	1.28	2.65
5	011	1.30	1.18	1.13	3.15
6	012	0.78	1.93	1.63	2.35
7	020	1.18	1.15	0.80	2.70
8	021	0.95	1.48	1.23	2.10
9	022	1.35	1.55	1.40	3.40
10	100	1.10	0.95	1.08	2.90
11	101	1.15	1.35	1.30	3.00
12	102	1.58	2.03	1.15	2.70
13	110	1.75	0.98	1.40	2.30
14	111	0.80	1.73	0.98	3.05
15	112	1.53	1.70	1.45	2.65
16	120	1.53	1.80	1.18	3.40
17	121	1.60	1.45	1.45	2.00
18	122	1.70	1.45	1.40	3.30
19	200	1.75	1.25	1.00	2.00
20	201	1.40	1.20	1.10	3.00
21	202	1.95	1.15	1.35	2.50
22	210	1.25	0.83	1.50	2.05
23	211	1.83	1.48	1.05	2.90
24	212	1.63	1.75	1.70	3.45
25	220	1.70	1.15	1.10	2.55
26	221	1.80	1.90	1.35	3.70
27	222	1.60	1.33	1.10	3.05

Table 19 Effect of NPK treatment and type of shoot on nutrient content of shoot.

Summary

Treatment group	Percentage on moisture free basis		
	N	P	K
n_0	2.82	0.258	1.62
n_1	3.09	0.274	1.75
n_2	3.00	0.260	1.76
F test	NS	NS	NS
p_0	2.97	0.252	1.62
p_1	2.87	0.267	1.70
p_2	3.08	0.274	1.80
F test	NS	NS	NS
k_0	2.94	0.258	1.58
k_1	2.92	0.262	1.72
k_2	3.05	0.272	1.83
F test	NS	NS	NS
<u>Type of shoot</u>			
Runner shoot	3.14	0.321	1.39
Top shoot	2.17	0.273	1.41
Hanging shoot	3.60	0.269	1.25
Fruit bearing lateral	2.98	0.194	2.78
F test	Sig	Sig	Sig
C.D. (0.05) for comparing type of shoots	0.098	0.082	0.255

Table 20 Coefficients of correlation (simple linear) between yield and nitrogen, phosphorus and potassium % of different tissues of black pepper.

Tissues sampled	Coefficients of correlation (r)		
	Nitrogen	Phosphorus	Potassium
<u>Yield of 1976-77 to 1980-81</u>			
First mature leaf	-0.232	0.462*	0.523**
<u>Yield of 1979-80</u>			
First mature leaf	-0.262	0.295	0.422*
<u>Yield of 1980-81</u>			
First mature leaf	-0.027	0.292	0.409*
Runner shoot	0.129	0.602**	0.349

* Significant at 5% level.
** Significant at 1% level.

Table 21 Coefficients of correlation (partial and multiple) between yield and nitrogen, phosphorus and potassium % of different tissues of black pepper.

Correlation with yield for tissues sampled	Coefficients of correlation, partial			Multiple correlation coefficient
	Nitrogen	Phosphorus	Potassium	
Yield of 1976-77 to 1980-81				
First mature leaf	-0.275	0.299	0.358	0.368
Yield of 1979-80				
First mature leaf	-0.229	0.038	0.347	0.238
Yield of 1980-81				
First mature leaf	-0.042	0.106	0.313	0.179
Runner shoot	0.083	0.530**	0.014	0.366

* Significant at 5% level.
** Significant at 1% level.

shoot were 1.41% and 1.39% respectively. Statistically, the potassium percentage of fruit bearing lateral was significantly higher while other types of shoots were on par.

The potassium percentage of stem did not correlate significantly with yield irrespective of types of shoot examined.

5. <u>Distribution of nitrogen, phosphorus and potassium in berry as influenced by period of sampling and NPK treatment</u>.

(1) <u>Nitrogen</u>

Data on the effect of NPK treatment and period of sampling on nitrogen content of berry are presented in Table 22 and their mean values in Table 26. The Appendix VII furnishes the analysis of variance.

The content of nitrogen in berry varied from 1.00 to 3.25% with a mean value of 2.49%, when values for all treatments and periods were considered. The influence of different periods on nitrogen percentage of berry was not statistically significant.

The varied levels of nitrogen, phosphorus and potassium application did not influence the content of nitrogen in berry significantly. However, the combination between phosphorus and potassium levels significantly influenced the nitrogen content of berry. The highest

Table 22 Effect of NPK treatment and period of sampling on nitrogen content of berry.

Nitrogen % on moisture free basis

Sl. No.	Treatment NPK	Periods, months after flowering 4	6	7
1	000	3.00	2.50	2.50
2	001	3.00	3.25	2.45
3	002	2.50	1.10	2.40
4	010	3.10	1.20	1.00
5	011	1.00	3.35	1.10
6	012	3.10	3.50	2.50
7	020	2.80	3.05	2.60
8	021	2.60	2.25	2.60
9	022	2.90	2.85	2.50
10	100	2.95	2.85	2.60
11	101	2.60	3.70	2.60
12	102	2.80	1.70	2.80
13	110	2.80	2.65	3.15
14	111	2.50	3.50	1.00
15	112	1.00	1.75	1.30
16	120	2.50	2.60	2.20
17	121	3.10	2.00	3.00
18	122	3.00	3.20	2.60
19	200	2.60	2.85	2.70
20	201	3.00	1.80	2.60
21	202	3.30	1.40	2.05
22	210	2.90	3.35	3.20
23	211	3.30	1.00	2.85
24	212	1.00	3.00	2.60
25	220	3.10	3.20	2.50
26	221	2.95	2.15	2.40
27	222	2.70	1.20	1.00

nitrogen content in berry was obtained at the p_0 k_1 combination. The interactions between the level of fertilizer application and period of sampling were not statistically significant.

(ii) Phosphorus

Table 23 presents the distribution of phosphorus in berry as influenced by period of sampling and NPK treatment. The mean values are presented in Table 26 and the analysis of variance in Appendix VII.

The content of phosphorus in berry ranged from 0.113% to 0.439% with a mean value of 0.251%.

The period of sampling significantly influenced the phosphorus content of berry. The pattern of variation in phosphorus content of berry at different periods showed that phosphorus content of berry increased with increasing periods of sampling to register the maximum value at 6th month after flowering and thereafter decreased.

(iii) Potassium

Data on the potassium content of berry at varying periods of sampling are presented in Table 24. The mean values are furnished in Table 26 and the analysis of variance in Appendix VII.

Table 23 Effect of NPK treatment and period of sampling on phosphorus content of berry.

Phosphorus % on moisture free basis

Sl. No.	Treatment NPK	Period, months after flowering		
		4	6	7
1	000	0.219	0.266	0.206
2	001	0.219	0.253	0.413
3	002	0.246	0.253	0.146
4	010	0.233	0.253	0.206
5	011	0.253	0.273	0.193
6	012	0.219	0.273	0.173
7	020	0.253	0.266	0.193
8	021	0.233	0.439	0.433
9	022	0.226	0.279	0.199
10	100	0.259	0.286	0.199
11	101	0.246	0.259	0.213
12	102	0.239	0.239	0.113
13	110	0.279	0.273	0.226
14	111	0.226	0.293	0.226
15	112	0.226	0.299	0.186
16	120	0.226	0.273	0.173
17	121	0.226	0.266	0.186
18	122	0.239	0.313	0.213
19	200	0.239	0.273	0.239
20	201	0.259	0.266	0.206
21	202	0.273	0.339	0.193
22	210	0.273	0.319	0.116
23	211	0.286	0.299	0.206
24	212	0.233	0.299	0.253
25	220	0.226	0.319	0.199
26	221	0.219	0.279	0.206
27	222	0.266	0.293	0.346

Table 24 Effect of NPK treatment and period of sampling on potassium content of berry.

Potassium % on moisture free basis

Sl. No.	Treatment NPK	Period, months after flowering		
		4	6	7
1	000	1.85	1.90	0.48
2	001	2.00	1.90	0.90
3	002	1.70	1.85	0.92
4	010	1.95	1.35	1.30
5	011	1.85	2.10	0.95
6	012	0.95	2.05	1.25
7	020	1.65	1.80	1.55
8	021	1.70	2.08	1.00
9	022	1.40	2.05	0.55
10	100	1.45	2.03	1.28
11	101	1.93	1.80	1.30
12	102	1.85	2.00	1.05
13	110	1.65	1.98	1.25
14	111	1.85	1.60	0.63
15	112	0.90	2.25	0.50
16	120	1.85	1.20	1.45
17	121	1.38	2.50	1.65
18	122	1.75	2.03	1.40
19	200	1.80	0.88	0.50
20	201	1.65	0.90	0.98
21	202	1.70	2.25	0.90
22	210	1.88	2.15	0.75
23	211	1.83	1.95	0.58
24	212	1.95	2.05	1.95
25	220	1.90	1.75	1.35
26	221	2.25	1.80	0.78
27	222	2.10	2.15	1.73

The potassium content of berry ranged from 0.50 to 2.5% with a mean value of 1.60% when treatments and periods were pooled.

The potassium content of berry over different periods of sampling varied significantly. This pattern of variation was similar to that observed in the case of phosphorus. The potassium content first increased with periods of sampling, attained a maximum value of 1.86% at 6 months after flowering and thereafter declined.

The different levels of potassium application could not significantly influence the potassium content of berry. However, the levels of phosphorus application influenced the potassium content of berries. The percentage of potassium corresponding to p_0, p_1 and p_2 levels were 1.47, 1.53 and 1.66 respectively.

6. Oleoresin content of pepper as influenced by period of sampling and NPK treatment.

Data on the effect of NPK treatment and period of sampling on the oleoresin content of berry are presented in Table 25. The mean values are furnished in Table 26 and analysis of variance in Appendix VIII.

The oleoresin content of berry ranged from 10.20 to 19.34% with a mean value of 14.59%. Variation in the oleoresin content of berry at different periods of sampling

Table 25 Effect of NPK treatment and period of sampling on oleoresin content of berry.

Oleoresin % on moisture free basis

Sl. No.	Treatment NPK	Period, months after flowering		
		4	6	7
1	000	15.50	17.53	13.31
2	001	13.29	12.50	14.05
3	002	12.98	11.41	12.32
4	010	12.31	18.91	13.74
5	011	12.98	19.03	14.71
6	012	12.57	19.07	13.86
7	020	12.92	19.30	14.07
8	021	14.27	18.14	14.05
9	022	12.93	16.17	11.76
10	100	17.00	17.96	10.55
11	101	14.88	18.25	12.96
12	102	16.69	18.87	11.01
13	110	15.81	19.34	11.27
14	111	17.00	11.70	12.59
15	112	17.25	10.84	10.30
16	120	17.15	11.57	14.38
17	121	14.47	10.20	10.03
18	122	15.40	17.20	16.74
19	200	13.90	17.65	13.06
20	201	16.38	15.64	13.06
21	202	17.30	17.32	14.38
22	210	11.59	17.55	11.70
23	211	15.24	18.03	11.23
24	212	15.19	15.53	11.74
25	220	17.25	11.99	11.49
26	221	16.94	17.04	10.92
27	222	16.84	15.78	12.34

Table 26 Effect of NPK treatment and period of sampling on nutrient and oleoresin content of berry.

Summary

Treatment group	Percentage of moisture free basis			
	N	P	K	Oleoresin
n_0	2.47	0.253	1.52	14.58
n_1	2.54	0.242	1.55	14.49
n_2	2.47	0.258	1.57	14.71
F test	NS	NS	NS	NS
p_0	2.46	0.243	1.47	14.81
p_1	2.32	0.251	1.53	14.48
p_2	2.58	0.260	1.66	14.50
F test	NS	NS	Sig	NS
k_0	2.68	0.242	1.52	14.77
k_1	2.51	0.265	1.55	14.43
k_2	2.50	0.246	1.60	14.58
F test	NS	NS	NS	NS
C.D.(0.05) for comparing levels of N,P,K.	NS	NS	0.095	NS
<u>Periods</u>				
4 months after flowering	2.67	0.244	1.73	15.04
6 months after flowering	2.48	0.289	1.86	16.09
7 months after flowering	2.33	0.220	1.07	12.65
F test	NS	Sig	Sig	Sig
C.D.(0.05) for comparing periods	NS	0.038	0.095	1.16

was statistically significant. In general, the oleoresin content increased with increasing periods of sampling upto six months after flowering.

The varying levels of nitrogen, phosphorus and potassium did not significantly influence the oleoresin content of pepper. The interactions between the levels of nitrogen, phospherus and potassium and periods of sampling were not significant.

DISCUSSION

DISCUSSION

In the present study, pepper plants of a NPK fertiliser trial laid out at Pepper Research Station, Panniyoor are made use for the collection of tissue samples. The samples were analysed with a view to select the tissue most suitable for foliar diagnosis and to standardise the period of sampling. Since the standardisation is to be carried out based on the degree of relationship between the yield and nutrient content of the tissue at different periods, the yield data collected and maintained by the Pepper Research Station, Panniyoor have been presented in the foregoing chapter.

Since the effect of fertiliser application on the yield of pepper is the main aspect covered under the experiment maintained at Pepper Research Station, Panniyoor, this aspect is not within the purview of the present investigation and hence not discussed.

Standardisation of leaf positions for foliar diagnosis

One of the objectives of the present investigation was to select an index leaf for foliar diagnosis in relation to nitrogen, phosphorus and potassium. For this purpose, the leaves of fruiting laterals were numbered and the first second, third and fourth leaves were collected separately taking the youngest fully matured leaf as leaf number 1.

For the selection of the index leaf, the following atributes of an ideal reflect are kept in mind.

(1) As far as possible the nutrient percentage of the leaf should correlate with the yield of the crop.

(2) The reflect should contain sufficient amount of the nutrient element for its easy determination.

(3) The reflect should respond to varying levels of the nutrient element supplied.

(4) The sampling error should be minimum, that is, the index leaf should belong to the plateau of the curve when the nutrient percentage of the leaf is plotted against leaf positions.

However, it is rather difficult to meet all the above requirements of an ideal reflect at a particular set of conditions and hence it becomes necessary to compromise between the ideal atributes described.

It was observed that increasing dressings of nitrogen, phosphorus and potassium were directly reflected in rising concentrations of leaf nitrogen, leaf phosphorus and leaf potassium.

The nitrogen percentage in leaf decreased with increasing age of leaf with the mean values being varied from 3.51 to 2.69 corresponding to the first and last leaf respectively. The differences in nitrogen percentage of leaf with respect to positions were found to be statistically significant. DeWaard (1969) also reported significant positional differences with respect to nitrogen content, the highest being in the youngest mature leaf. But the nitrogen content of the leaf failed to establish significant positive correlation with yield irrespective of the leaf positions. As regards the influence of levels of nitrogen on the nitrogen percentage at different leaf positions, it was seen that the differences between leaf positions were statistically significant. The mean value for n_2 treatment (3.54% N) was significantly higher as compared to values corresponding to n_0 and n_1 levels (3.01% N).

As in the case of nitrogen, maximum percentage of phosphorus was noticed in the first mature leaf which progressively decreased with increasing number of leaf positions. The phosphorus content of the first mature leaf was significantly higher with a mean value of 0.145% than the second leaf with 0.135%. There is no significant difference in the percentage of phosphorus between the third and fourth leaves. DeWaard (1969) could not notice much differences in the content of phosphorus in leaves of different positions, though the phosphorus content was found to be more in the youngest mature leaf. The phosphorus percentage of leaves increased with increasing levels of phosphorus application. The phosphorus content of the first mature leaf established significant positive correlation with cumulative yield of pepper ($r = 0.462^{**}$).

Similar to nitrogen and phosphorus, the highest percentage of potassium (1.84%) was observed in the first mature leaf which significantly dropped at the second (1.63%) thereafter maintaining almost a constant level. The percentage of potassium in leaf increased with increasing levels of potassium application irrespective of leaf positions. According to DeWaard (1969) there was no apparent influence of leaf age on potassium in leaf. The potassium content of the first mature leaf established significant positive correlation with cumulative yimld of pepper (r = 0.523**).

These observations tend to conclude that the first mature leaf is superior to other leaves as an index for foliar diagnosis in pepper in relation to nitrogen, phosphorus and potassium status of the plant.

Standardisation of season or period of sampling for foliar diagnosis.

Results presented in the Table 7,9,11 & 13 and Appendix V showed that the period of sampling significantly influenced the nitrogen percentage of leaf. Leaf samples collected during the first period of sampling contained relatively high amount of nitrogen which further increased to attain the maximum value at the second period. The nitrogen content thereafter declined till two month after flushing (4th period) and then increased at the 5th period and then again decreased till harvest. The accumulation of nitrogen in leaves prior to sampling is quite understandable since the rate of growth and leaf production of the vine during this period is considerably low. With the onset of flushing, rapid increase in the total dry matter production of vine takes place with a consequent decrease or dilution in the concentration of this nutrient in the leaf tissue. An increase in the nitrogen content of the leaf at three month after flushing is quite expected since the experimental plants received the nitrogen fertiliser application in between the second and third month after flushing. However, the trend of variation in the nitrogen content of leaf during different periods indicates that the increased uptake and accumulation of nitrogen during the fifth period consequent to nitrogen fertiliser application is counteracted by the increasing demand of this element due to fast rate of growth in leaf tissue as well as the development of berries. Consequently, the nitrogen percentage gradually declines from the fifth period to final harvest (9^{th} period).

Application of increasing levels of nitrogen resulted in the increasing content of this element in leaves at different periods of sampling followed in this study. However, leaf nitrogen values for the n_1 level of application overlapped with the nitrogen values for n_0 level of application. Still, the superiority of the n_1 level of application over n_0 was reflected in the first mature leaf collected during the second period of sampling namely prior to flushing. As a result, the nitrogen content of leaf at this period of sampling was well separated in accordance with the levels of application.

No significant correlation was observed between the yield and nitrogen content of leaf of different periods of sampling.

Since no significant correlation was established between the nitrogen content of leaf during different periods of yield it is not possible to select the best period based on this criterion. However, the second period appears to be a better season for sampling since at this period the response to level of application of nitrogen was found to be in order as compared to that at other periods. Moreover, the maximum requirement of nitrogen takes place at the onset of flushing. It will be ideal to diagnose the nitrogen status of the plant before flushing so that the application of fertilisers can be effected as soon as flushing is initiated with the receipt of early monsoon showers.

The results presented in Table 13 showed that the phosphorus content of first mature leaf at the first and second periods was relatively low and then increased gradually and steadily, with the increase in period to record the maximum at 5 month after flushing (7^{th} period) and thereafter the phosphorus content slightly declined in subsequent periods. It is likely that the increase in the content of phosphorus with the onset of flushing is due to the increased uptake of phosphorus from soil after the receipt of monsoon showers since flushing usually commences after the receipt of rains. The continuous increase in the phosphorus content of leaf after the flushing is therefore indicative of a period of active phosphorus absorption synchronizing with the distribution of rain over the different periods of sampling tried. In the case of nitrogen content of leaf, an increased uptake of nitrogen was noticed at 5^{th} period since it was the sampling period succeeding the period of fertiliser application. But, in the case of phosphorus, the increase with the increasing periods of sampling after flushing was gradual and continuous till the 7^{th} period probably due to the fact that soils were able to provide a steady supply to plant irrespective of the period of fertilizer application. DeWaard (1969) also observed a gradual increase in the content of phosphorus from the period of flowering to harvest.

In general, the phosphorus content of the leaf at varying periods of sampling increased with the level of application.

The phosphorus content of leaf did not correlate with the current yield of pepper irrespective of the period of sampling employed. When the relationship between the aggregate yield and phosphorus content of leaf over different periods is examined, it is seen that the coefficients of correlation for 5^{th} period and 7^{th} period were statistically significant at 5% level.

Data presented in Table 13 revealed that in general, potassium content of leaf increases with increasing period of sampling upto 5^{th} period and declined thereafter. The high accumulation of potassium at 5^{th} period may be due to the increased uptake of potassium applied to the soil during the period between 4^{th} and 5^{th} sampling. As in the case of phosphorus, the increased accumulation of potassium with advancing periods of sampling after flushing may be attributed to the increased rate of absorption of this nutrient from the soil consequent to the onset of monsoon. Potassium content of leaf of initial samplings remains almost stable, probably due to the fact that growth of the plant during this period is very limited since the period corresponds to the dry spell of the year. Plants receiving high levels of potassium application retained high content of this nutrient in the leaves.

The decline in the content of potassium in leaves from the 5^{th} period onwards may be due to withdrawal of the element from the leaf tissue to the developing berries. The present observation is in conformity with the report of DeWaard (1969) who observed that potassium concentration significantly decrease with time after a rise at the time of full flowering.

The foregoing observation tends to suggest that the period just prior to flushing is the most suitable one for the collection of leaf sample for foliar diagnosis, on the grounds that,

(1) Leaf sample collected during this period is the most sensitive to application for different levels of nitrogen.

(2) The potassium content of the leaf collected during this period significantly correlated with yield.

(3) Only if the nutrient status is diagnoised during this period, it will be possible to supply the fertilizers in time, synchronising with the onset on South West monsoon.

(4) It is essential that the supply of nutrients to the vine should be made at a time when the tissue elaboration is taking place at a faster rate simultaneous with the spike initiation. This will be possible, based on foliar diagnosis, only if the nutrient level of the vine is assessed prior to spike initiation.

Distribution of nitrogen, phosphorus and potassium in different types of shoots as influenced by period of sampling and NPK treatment.

Based on growth habits, morphological characters and biological functions, five distinct types of stem portions can be identified in the shoot of pepper vine. They are termed as the main stem, top shoot, fruiting branches (laterals), runner shoots and hanging shoots (Chandy and Pillai 1980). Except the main stem, all the different shoots are examined for their suitability in tissue testing in the present study.

The distribution of nitrogen in shoots ranges from 1.00 to 4.40% with a mean value of 2.95%. Highest values for nitrogen were observed in hanging shoots while the fruit bearing laterals contained the least. The hanging shoots that found at the top portion of the vine are lanky in appearence. As they do not produce fruiting branches or spikes, they retained the nitrogen content in excess amounts unlike the fruiting branches which produce spikes in the axil of every new leaf. In the latter case, the translocation of nitrogen into spikes might have readily took place as the berry development coincided with the period of sampling. Runner shoots that readily produce roots into the soil from every node that touches the ground, contain comparatively more amounts of nitrogen as compared to fruiting branches. The top shoots contained lesser amounts of nitrogen as compared to other stem portions except fruiting laterals, since it almost attained a bushy appearance with profuse branches thus diluting the contents of nitrogen in its tissue.

The different levels of fertilisers could not influence the percentage of nitrogen in the different stem portions studied. Thus they failed to serve as a reflect of nutrient levels of the plant. Also no significant correlation was observed between yield and nitrogen content of different types of shoot studied.

Fairly high values of phosphorus content are found in the different stem portions of pepper vine as compared to its leaves and spikes. As already explained in the case of nitrogen, the runner shoot that strikes roots into the ground contained the highest percentage of phosphorus. The top shoot that profusly branches records the next highest value of phosphorus in the tissues followed by the hanging shoot. The fruit bearing lateral registered the least in phosphorus content.

As in the case of nitrogen, the different levels of phosphorus could not influence the phosphorus content of stem portions examined. A high degree of correlation ($r = 0.602$) was established between the phosphorus content in runner shoot and the yield obtained during 1980-81. Thus the runner shoot appeared to be the best tissue for assessing the phosphorus status of the vine.

Fruit bearing lateral recorded the highest content of potassium and significantly differed with top shoot, runner shoot and hanging shoot which registered comparatively lower values.

The sampling of shoot was done at four month after flushing of the vine which coincided with the enlargement of berries in spikes produced in the axil of every new leaf of lateral branches. As a result during this period, the potassium content of other plant parts would have been mobilised to the fruit bearing laterals in order to supply this element to the developing spikes.

Application of different levels of potassium has no influence in determining the potassium content of different types of shoot studied. Significant correlation could not established between the potassium content of stem and yield. Thus the stem portions failed to serve as good index of nutrient levels of the plant.

<u>Distribution of nitrogen, phospherus and potassium in berry as influenced by period of sampling and NPK treatment</u>.

The results revealed that the nitrogen percentage was high in the berries with a mean value of 2.49%. Though the nitrogen content found to decrease with the increasing periods of sampling, it was not statistically significant. The different levels of nitrogen employed in the fertiliser trial could not influence the nitrogen content of berries.

No significant correlation was established between yield and nitrogen content of berry.

The periods of sampling significantly influenced the phosphorus content of the berry which increased from 4 months after flowering to 6 months after flowering and then decreased. This trend of variation is almost similar to that of potassium and oleoresin content of the berry. As in the case of nitrogen, the different levels of phosphorus could not influence the phosphorus content of the berry.

The period of maturity exerted significant influence on the potassium content of berry at six months after flowering. The berry attained the maximum content of potassium and then decreased at the final harvest. The different levels of phosphorus significantly influenced the potassium content of berry. The relatively high content of potassium at six month after flowering may be due to the high demand for this nutrient during berry enlargement which is maximum at this period.

<u>Oleoresin content of pepper as influenced by period of sampling and NPK treatment</u>.

The results presented in Table 25 & 26 and the analysis of variance in Appendix VIII revealed that the quality of pepper is influenced by periods of sampling. It is found that the percentage of oleoresin was maximum at six month after flowering which did not differ significantly with that at four month after flowering. But, the percentage of oleoresin at harvest was significantly low as compared to that of 4^{th} and 6^{th} month after flowering.

The results also revealed that the levels of nitrogen, phosphorus and potassium and their interaction had no significant influence on the oleoresin content of pepper. It is probable that the synthesis of the components of oleoresin is not significantly governed by the levels of these nutrients available in the plant tissue.

SUMMARY

SUMMARY

Pepper vines of a NPK fertiliser trial maintained at the Pepper Research Station, Panniyoor (Cannanore Dt.) were selected for the collection of tissue samples under this study. The field experiment commenced from 1975 and laid out in a 3^3 factorial design totally confounding NP^2K^2 consisted of 3 levels each of nitrogen (50,100 and 150 g N/vine/year), phosphorus (50,100, 150 g P_2O_5/vine/year) and potassium (50,100, 150 g K_2O/vine/year).

In order to standardise the best leaf in relation to leaf position for foliar diagnosis, the mature leaves of fruit bearing laterals were numbered, counting the youngest fully mature leaf as the first and they were collected separately. For the purpose of suggesting the most suitable season for the collection of tissue samples intended for foliar diagnosis, samples of first mature leaf were drawn for chemical analysis at different stages of plant growth which coincided with the different seasons. The suitability of different types of stems of the plant for tissue analysis was studied making use of runner shoot, top shoot, hanging shoot and fruit bearing lateral of the plant sampled at three months after flushing. Attempt was also made to find out variations in the oleoresin content of berry as influenced by stages of maturity. The important observations are summarised below.

(1) The first mature leaf of fruit bearing laterals better reflected the variation in the content of nitrogen, phosphorus and potassium in leaf corresponding to variations in the levels of these nutrients applied.

(2) Nitrogen content of leaf failed to establish significant positive correlation with yield irrespective of leaf positions.

(3) Significant positive correlation ($r = 0.462^{**}$) was observed between the cumulative yield and phosphorus content of first mature leaf.

(4) Potassium content of first mature leaf established significant positive correlation ($r = 0.523^{**}$) with the cumulative yield of pepper.

(5) Based on the above findings the first mature leaf is considered as the best leaf for the foliar diagnosis of nitrogen, phosphorus and potassium in pepper.

(6) The period just prior to flushing of vine was found to better reflect variations in the nitrogen content of leaf corresponding to variations in the level of nitrogen applied as compared to that of other periods.

(7) Potassium content of leaf collected just before flushing of vine significantly correlated with the yield.

(8) The period just before flushing of vine thus appeared to be more suitable for the collection of samples intended for foliar diagnosis of nitrogen, phosphorus and potassium.

(9) The variations in the level of application of nitrogen were not found reflected in terms of the concentration of this element in the different types of stems examined.

(10) A high degree of correlation ($r = 0.602^{**}$) was observed between the yield and phosphorus content of runner shoot.

(11) The highest content of potassium was observed in fruit bearing lateral as compared to other types of stem.

(12) The different levels of nitrogen, phosphorus and potassium applied could not influence the concentration of these elements in the berry.

(13) The period of maturity significantly influenced the concentration of phosphorus, potassium and oleoresin in the berry. These components in the berry increased from fourth to sixth month after flowering and then decreased.

(14) The levels of nitrogen, phosphorus and potassium and their interaction had no significant influence on the oleoresin content of pepper.

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* Originals not seen

APPENDICES

APPENDIX - I

Weather data

MONTH	Total rain fall mm			Temperature C					
				Minimum			Maximum		
	1979	1980	1976-1980 Mean	1979	1980	1976-1980 Mean	1979	1980	1976-1980 Mean
January	Nil	Nil	Nil	20.92	19.00	19.18	33.60	34.54	34.23
February	Nil	Nil	Nil	20.50	21.00	21.30	34.24	36.24	35.10
March	18.00	31.00	12.20	23.05	23.00	23.21	36.44	36.02	36.69
April	10.00	135.10	61.60	24.75	23.00	23.95	36.40	36.00	36.29
May	65.50	125.00	147.50	24.56	24.00	25.31	35.95	36.11	35.61
June	958.00	1443.50	1032.40	23.72	23.00	23.34	30.90	29.17	30.41
July	1324.50	128.68	1074.80	22.48	24.76	19.25	30.20	29.27	29.09
August	843.00	884.00	660.00	22.65	24.34	22.80	29.37	28.52	29.18
September	231.50	272.40	197.50	23.57	24.37	23.19	29.84	30.60	30.29
October	121.20	336.00	249.90	23.00	24.18	23.84	33.23	31.69	32.38
November	155.20	103.30	195.10	23.00	23.98	22.20	30.76	32.72	31.90
December	8.50	23.00	13.00	21.00	22.95	21.19	34.27	33.66	33.79

APPENDIX - XX

Nutrient status of experimental field

Treatments	During March 1980					During January 1981				
	Organic carbon %	Total nitrogen %	Available phosphorus (ppm)		Available potassium (ppm)	Organic carbon %	Total nitrogen %	Available phosphorus (ppm)		Available potassium (ppm)
			Bray	Triple acid				Bray	Triple acid	
n_0	3.71	0.111	45	100	180	4.93	0.263	62	96	181
n_1	3.87	0.138	59	140	200	4.86	0.259	52	96	205
n_2	3.77	0.110	48	170	150	4.64	0.286	55	91	164
p_0	3.71	0.115	41	100	190	4.75	0.252	58	95	160
p_1	3.86	0.118	49	180	170	4.93	0.261	57	91	181
p_2	3.80	0.112	62	180	170	4.77	0.286	55	96	160
k_0	3.81	0.117	67	150	140	4.77	0.260	57	94	126
k_1	3.73	0.105	45	110	190	4.79	0.275	56	95	175
k_2	3.83	0.138	47	120	210	4.89	0.272	56	93	201

APPENDIX - III

Effect of NPK Treatment on yield of black pepper (1979-80)

Source	df	Mean squares
Block	5	17.43**
N	2	6.97**
P	2	14.87**
NP	4	1.43**
K	2	18.73**
NK	4	3.12**
PK	4	0.68**
NPK	2	5.40**
NP^2K	2	6.16
NPK^2	2	5.86**
Error	24	0.23

Comparison of levels of N, P and K
(Mean values are furnished in Table 2)

Conclusion

Yield of pepper (kg/ha) due to levels of N : n_0 n_1 n_2

Yield of pepper (kg/ha) due to levels of P : p_1 p_2 p_0

Yield of pepper (kg/ha) due to levels of K : k_2 k_1 k_0

Comparison of PK combination

	k_0	k_1	k_2
p_0	636	1141	1059
p_1	1141	1672	1613
p_2	856	1064	1637

C.D.(0.05) = 134

Comparison of NP combination

	p_0	p_1	p_2
n_0	955	1721	1561
n_1	935	1489	1137
n_2	953	1216	859

C.D.(0.05) = 134

Comparison of NK combination

	k_0	k_1	k_2
n_0	828	1335	2064
n_1	1034	1385	1141
n_2	771	1154	1103

C.D.(0.05) = 134

APPENDIX - IV

Effect of NPK treatment and leaf position on nutrient content of leaf.

Source	df	Mean squares		
		N content of leaf	P content of leaf	K content of leaf
Block	3	2.24**	0.0002	0.04
Position	3	4.38**	0.0060**	1.50**
N	2	1.76*	0.0004*	0.07
P	2	0.06	0.0015**	0.07
NP	4	0.70	0.0002	0.02
K	2	0.50	0.0001	0.81**
NK	4	0.48	0.0004**	0.04
PK	4	0.70	0.0004**	0.18**
N1	6	0.48	0.0002	0.05
P1	6	0.29	0.0003	0.06
K1	6	0.24	0.0002	0.05
Error	66	0.39	0.0001	0.05

** Significant at 1% level
* significant at 5% level

Comparison of leaf position

(Mean values are furnished in Table 6)

Conclusion

N content $\overline{1 \quad 2 \quad 3} \quad 4$

P content $1 \quad 2 \quad \overline{3 \quad 4}$

K content $1 \quad 2 \quad \underline{3 \quad 4}$

Comparison of leaf of nitrogen, phosphorus and potassium

(Mean values are furnished in Table 6)

Conclusion

N content of leaf position $n_2 \quad \overline{n_1 \quad n_0}$

P content of leaf position $\overline{n_2 \quad n_1} \quad n_0 \qquad \overline{p_2 \quad p_1} \quad p_0$

K content of leaf position $k_2 \quad k_1 \quad k_0$

Comparison of NK combination

P content of leaf

	n_0	n_1	n_2
k_0	0.131	0.127	0.128
k_1	0.118	0.130	0.131
k_2	0.123	0.125	0.131

C.D.(0.05) = 0.008

Comparison of PK combination

P content of leaf

	k_0	k_1	k_2
p_0	0.123	0.122	0.115
p_1	0.127	0.126	0.136
p_2	0.137	0.131	0.130

C.D.(0.05) = 0.008

Comparison of PK combination

K content of leaf

	k_0	k_1	k_2
p_0	1.35	1.49	1.64
p_1	1.52	1.45	1.76
p_2	1.30	1.70	1.67

C.D.(0.05) = 0.179

APPENDIX - V

Effect of NPK treatment and period of sampling on nutrient content of leaf.

SOURCE	df	MEAN SQUARES		
		N content of leaf	P content of leaf	K content of leaf
Block	2	0.73	0.0005**	0.11
Period	8	5.10**	0.0003**	1.08**
N	2	2.89**	0.0007**	0.01
P	2	0.08	0.0016**	0.06
NP	4	1.57**	0.0075**	0.37**
K	2	0.11	0.0002	2.21**
NK	4	0.26	0.0010**	0.11
PK	4	0.04	0.0015**	0.14
NT	15	0.55	0.0025**	1.08
PT	16	0.24	0.0006**	0.10
KT	16	0.21	0.0006**	0.12
Error	166	0.35	0.0001	0.09

** Significant at 1% level
* Significant at 5% level

Comparison of period of sampling
(Mean values are furnished in Table 13)

Conclusion

N content of leaf in relation to period of sampling : 2 5 6 1 3 8 9 4 7

P content of leaf in relation to period of sampling : 6 7 9 4 8 3 5 1 2

K content of leaf in relation to period of sampling : 5 4 6 2 1 3 7 9 8

Comparison of levels of nitrogen, phosphorus and potassium.

(Mean values are furnished in Table 13)

Conclusion:

N content	n_2 $\underline{n_0\ \ n_1}$	
P content	$\underline{n_2\ \ n_1}$ n_0	p_2 p_1 p_0
K content	k_2 k_1 k_0	p_2 p_1 p_0

Comparison of NP combination

N content of leaf

	n_0	n_1	n_2
p_0	3.26	2.76	3.25
p_1	3.17	3.27	3.23
p_2	2.86	3.10	3.48

C.D.(0.05) = 0.316

Comparison of NP combination

P content of leaf

	n_0	n_1	n_2
p_0	0.164	0.158	0.167
p_1	0.167	0.166	0.170
p_2	0.163	0.191	0.167

C.D.(0.05) = 0.005

Comparison of NK combination

P content of leaf

	n_0	n_1	n_2
k_0	0.168	0.168	0.165
k_1	0.162	0.165	0.174
k_2	0.163	0.167	0.166

C.D.(0.05) = 0.005

Comparison of PK combination

P content of leaf

	k_0	k_1	k_2
P_0	0.166	0.165	0.158
P_1	0.167	0.162	0.173
P_2	0.168	0.172	0.166

C.D.(0.05) = 0.005

Comparison of NP combination

K content of leaf

	n_0	n_1	n_2
P_0	1.54	1.48	1.41
P_1	1.56	1.48	1.39
P_2	1.38	1.55	1.64

C.D.(0.05) = 0.16

Comparison of NT combination

P content of leaf

	1	2	3	4	5	6	7	8	9
n_0	0.122	0.137	0.159	0.193	0.144	0.206	0.212	0.154	0.165
n_1	0.122	0.120	0.158	0.168	0.144	0.214	0.206	0.161	0.196
n_2	0.115	0.092	0.163	0.183	0.143	0.206	0.202	0.180	0.231

C.D. (0.05) = 0.009

Comparison of PT combination

P content of leaf

	1	2	3	4	5	6	7	8	9
p_0	0.121	0.126	0.163	0.173	0.137	0.202	0.193	0.158	0.194
p_1	0.115	0.113	0.162	0.193	0.146	0.204	0.222	0.163	0.190
p_2	0.122	0.109	0.155	0.189	0.148	0.219	0.204	0.174	0.208

C.D. (0.05) = 0.009

Comparison of KT combination

P content of leaf

	1	2	3	4	5	6	7	8	9
k_0	0.118	0.122	0.163	0.196	0.146	0.202	0.209	0.156	0.210
k_1	0.118	0.112	0.156	0.178	0.144	0.207	0.206	0.171	0.207
k_2	0.123	0.114	0.161	0.180	0.144	0.218	0.206	0.167	0.192

C.D. (0.05) = 0.009

APPENDIX - VI

Effect of NPK treatment and type of shoot on nutrient content of stem.

Source	df	Mean squares		
		N content of shoot	P content of shoot	K content of shoot
Block	2	0.810	0.0010	0.415
Shoot	3	9.503**	0.0750*	13.80**
N	2	0.672	0.0030	0.211
P	2	0.388	0.0040	0.131
NP	4	0.381	0.0040	0.067
K	2	0.0270	0.0020	0.571
NK	4	0.375	0.0020	0.146
PK	4	0.883	0.0030	0.0430
NS	6	0.427	0.0003	0.269
PS	6	0.620	0.0018	0.0970
KS	6	0.202	0.0025	0.592**
NPS	12	0.382	0.0017	0.0180
NKS	12	0.212	0.0011	0.0800
PKS	12	0.516	0.0256	0.0400
Error	30	0.648	0.0225	0.210

** Significant at 1% level
* Significant at 5% level

Comparison of type of shoot

(Mean values are furnished in Table 19)

Conclusion

N content	Hanging shoot	Runner shoot	Fruit bearing lateral	Top shoot
P content	Runner shoot	Top shoot	Hanging shoot	Fruit bearing lateral
K content	Fruit bearing lateral	Top shoot	Runner shoot	Hanging shoot

Comparison of NP combination

K content of shoot

	n_0	n_1	n_2
p_0	1.64	1.69	1.64
p_1	1.62	1.69	1.79
p_2	1.61	1.94	1.86

C.D.(0.05) = 0.382

Comparison of KS combination

K content of leaf

	Runner shoot	Top shoot	Hanging shoot	Fruiting lateral
k_0	1.36	1.21	1.17	2.57
k_1	1.36	1.44	1.20	2.87
k_2	1.46	1.59	1.38	2.90

C.D.(0.05) = 0.441

APPENDIX - VII

Effect of NPK treatments and periods of sampling on nutrient content of berry.

Source	df	Mean squares		
		N content of leaf	P content of leaf	K content of leaf
Block	2	0.69	0.005	0.030
Period	2	0.81	0.033**	4.87**
N	2	0.04	0.002	0.250**
P	2	0.58	0.002	0.250**
NP	4	0.45	0.008	0.890**
K	2	1.07	0.004	0.050
NK	4	0.50	0.007	0.340**
PK	4	2.31**	0.011	0.290**
NT	4	0.34	0.001	0.260**
PT	4	0.46	0.001	0.120**
KT	4	0.05	0.004	0.120**
Error	46	0.41	0.005	0.030

** Significant at 1% level
* Significant at 5% level

Comparison of period of sampling

(Mean values are furnished in Table 26)

Conclusion

P content	6 months after flowering	4 months after flowering	7 months after flowering
K content	6 months after flowering	4 months after flowering	7 months after flowering

Comparison of levels of nitrogen, phosphorus and potassium

(Mean values are furnished in Table 19)

Conclusion

K content of berry P_2 P_1 P_0

Comparison of PK combination

N content of berry

	k_0	k_1	k_2
P_0	2.73	2.78	1.87
P_1	2.59	2.18	3.19
P_2	2.73	2.56	2.44

C.D.(0.05) = 0.606

Comparison of NP combination

K content of berry

	n_0	n_1	n_2
p_0	1.50	1.63	1.28
p_1	1.53	1.40	1.68
p_2	1.53	1.69	1.76

C.D.(0.05) = 016

Comparison of NK combination

K content of berry

	n_0	n_1	n_2
k_0	1.54	1.57	1.44
k_1	1.61	1.63	1.41
k_2	1.41	1.53	1.86

C.D.(0.05) = 0.16

Comparison of PK combination

K content of berry

	k_0	k_1	k_2
p_0	1.35	1.48	1.58
p_1	1.58	1.48	1.54
p_2	1.61	1.68	1.68

C.D.(0.05) = 0.16

Comparison of NT combination

K content of berry

	4 months after flowering	6 months after flowering	7 months after flowering
n_0	1.67	1.90	0.99
n_1	1.62	1.93	1.17
n_2	1.90	2.21	1.06

(C.D.(0.05) = 0.16

Comparison of PT combination

K content of berry

	4 months after flowering	6 months after flowering	7 months after flowering
p_0	1.77	1.72	0.92
p_1	1.65	1.94	1.02
p_2	1.78	1.93	1.27

C.D.(0.05) = 0.16

Comparison of KT combination

K content of berry

	4 months after flowering	6 months after flowering	7 months after flowering
k_0	1.78	1.67	1.10
k_1	1.83	1.85	0.97
k_2	1.59	2.08	1.14

C.D.(0.05) = 0.16

Comparison of PT combination

K content of berry

	4 months after flowering	6 months after flowering	7 months after flowering
P_0	1.77	1.72	0.92
P_1	1.65	1.94	1.02
P_2	1.78	1.93	1.27

C.D.(0.05) = 0.160

Comparison of KT combination

K content of berry

	4 months after flowering	6 months after flowering	7 months after flowering
k_0	1.78	1.67	1.10
k_1	1.83	1.85	0.97
k_2	1.59	2.08	1.14

C.D.(0.05) = 0.160

APPENDIX - VIII

Effect of NPK treatment and period of sampling on oleoresin content of berry.

Source	df	Mean squares
Block	2	14.41*
Period	2	83.90**
N	2	0.29
P	2	0.08
NP	4	6.86
K	2	0.79
NK	4	7.25
PK	4	1.88
NT	4	16.73*
PT	4	3.52
KT	4	1.87
Error	46	4.51

Comparison of periods

(Mean values are furnished in Table 26)

Conclusion

6 months after flowering 4 months after flowering 7 months after flowering

Comparison of NT combination

	Oleoresin content of berry		
	4 months after flowering	6 months after flowering	7 months after flowering
n_0	13.31	16.90	13.54
n_1	16.18	15.10	12.20
n_2	15.63	16.28	12.21

C.D. (0.05) = 2.01

FOLIAR DIAGNOSIS, YIELD AND QUALITY OF PEPPER (*Piper nigrum* L.) IN RELATION TO NITROGEN, PHOSPHORUS AND POTASSIUM

BY

SUSHAMA, P. K.

ABSTRACT OF A THESIS

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ABSTRACT

Pepper vines of variety, Panniyoor-1, of the NPK fertilizer trial maintained at the Pepper Research Station, Panniyoor, Cannanore District were selected for the collection of tissue samples under the present study during 1979-81. The experiment was laid out in a 3^3 factorial design in a randomised block design, confounding the effect of NP^2K^2 totally.

In order to standardise the best leaf position for foliar diagnosis, the mature leaves of fruit bearing laterals were numbered from the youngest to the oldest, taking the youngest fully matured leaf as the first and they were collected separately. The most suitable season for the collection of leaf intended for foliar diagnosis was also standardised by drawing samples of first mature leaf at different stages of growth of the vine. The suitability of different types of stem of the plant such a runner shoot, top shoot, fruit bearing lateral and hanging shoot for tissue analysis was also examined. For studying the variations in the oleoresin content of berry as influenced by fertiliser nutrients, the berries were sampled at different stages of maturity.

The first mature leaf better reflected variation in the levels of application of nitrogen to the vine.

As the phosphorus and potassium contents of the first mature leaf established significant positive correlation with yield of pepper, it is recommended as an index for foliar diagnosis in pepper in relation to nitrogen, phosphorus and potassium status of the vine.

The period just prior to flushing is the most suitable season for the collection of leaf samples intended for foliar diagnosis. During this period, the first mature leaf is sensitive to application for different levels of nitrogen and its potassium content established significant positive correlation with yield.

For assessing the phosphorus status of the vine, the runner shoot appeared to be a better tissue as its phosphorus content established a high degree of correlation with yield. As compared to other types of stem, the highest content of potassium was found in the fruit bearing laterals.

The periods of maturity significantly influenced the phosphorus, potassium and oleoresin contents of the berry. Their contents increased from four to six months after flowering and then decreased. The graded doses of nitrogen, phosphorus and potassium and their interaction failed to influence the percentage of oleoresin content of pepper.