FOLIAR DIAGNOSIS AND YIELD PREDICTION IN SUGARCANE IN RELATION TO N, P AND K

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Foliar diagnosis and yield prediction in sugarcane in relation to N, P and K"** is a bonafide record of research work done independently 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, fellowship, associateship or other similar title, of any other University or Society.

Vellanikkara,

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Certified that this thesis "Foliar diagnosis and yield prediction in sugarcane in relation to N, P and K" is a record of research work done independently by Mr. V. Ramesh under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

Sumam Susan Varghese,
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CERTIFICATE

We, the undersigned members of the Advisory Committee of Mr. V. Ramesh, a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled "Foliar diagnosis and yield prediction in sugarcane in relation to N, P and K" may be submitted by Mr. V. Ramesh, in partial fulfilment of the requirement for the degree.

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Dedicated to My Mother

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ABBREVIATIONS

N-3	---	Nitrogen content in the third leaf
N-4	---	Nitrogen content in the fourth leaf
N-5	---	Nitrogen content in the fifth leaf
N-6	---	Nitrogen content in the sixth leaf
P-3	---	Phosphorus content in the third leaf
P-4	---	Phosphorus content in the fourth leaf
P-5	---	Phosphorus content in the fifth leaf
P-6	---	Phosphorus content in the sixth leaf
K-3	---	Potassium content in the third leaf
K-4	---	Potassium content in the fourth leaf
K-5	---	Potassium content in the fifth leaf
K-6	---	Potassium content in the sixth leaf

Introduction

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.), the nutritional house of sugar, is an important cash cum commercial crop, and the second largest agro-based industry of the country, next to cotton and textile. India ranks first among sugarcane growing countries of the world for both extent and production of cane. It is grown in 3.78 million hectares producing 13.4 million tonnes.

To attain self-sufficiency through increased sugar production, bringing more area under sugarcane cultivation is not possible. However, attempts can be made to increase the productivity of cane by adopting latest genetical, chemical and proper management practices. Considerable amount of improvements have been done in genetics in improving cane yield and hence the chemical method as a means of increasing cane yield deserves attention in this work.

Among the crop production techniques, fertiliser is a potential means of improving cane yield. Fertiliser recommendations to various crops including sugarcane have been based on over-all soil analysis. But when a combined analysis of soil and particular tissue of the plant at appropriate stage is carried out, to make up the deficiency of any particular nutrient,the yield can be increased considerably. This forms the practical utility of foliar diagnosis.

The application of foliar diagnosis has been particularly successful in sugarcane as compared to many other crops because it is a rapidly growing crop capable of producing dry matter at a fast annual rate and hence the tissue composition is more likely to reflect the slight inadequacy in the rate of supply of nutrients.

The foliar diagnosis in relation to yield prediction, juice quality and sugar recovery have been carried out in India (Perumal 1983,1993). But attempts are not made so far in India to standardise the leaf position and stage of sampling in relation to yield and hence this study is formulated with the following objectives:

(i) To standardise leaf position and the period of sampling for the foliar diagnosis in sugarcane in relation to N, P and K

(ii) To predict the yield of sugarcane based on N, P and K status of the plant

(iii) To find out the influence of different leaf positions at various stages of sampling on nutrient uptake of sugarcane; and

(iv) To find out the influence of N, P and K on juice quality of sugarcane.

Review of Literature

REVIEW OF LITERATURE

1. NUTRITIONAL STUDIES IN SUGARCANE

Among the fertiliser need of sugarcane crop NPK fertilisers stand fore-most, which influence output of sugar per unit area and also cost of production per tonne. Consideration is given to this topic as balanced fertilisation improves not only yield, but also cane quality.

1.1. Nutrient sources in relation to yield of sugarcane

Application of organic matter as green manure (Pandit, 1978) and FYM @ 20 t/ha (Dhillon *et al.*, 1993) have been reported as a nutrient source to get higher yield and better purity of cane juice. The nitrogen need of sugarcane varied from 112 to 400 kg/ha depending upon the soil type, duration of the crop and yield levels (Yadav *et al.*, 1988). Chougule and Patil (1989) recorded an yield of 79.4 t/ha for an N dose of 247 kg N/ha in coastal Andhra soils. Kathiresan and Narayanasamy (1991) obtained a maximum cane yield of 91.1 t/ha corresponding to a N level of 325 kg N/ha, whereas Sharma and Gupta (1991) reported an yield of 107 t/ha with the application of 200 kg N/ha.

The quantity of phosphorus required to produce high yield varies mainly with the soil factors, important being the texture of soil. Singh (1989) recommended an application of 65 kg P_2O_5/ha to get optimum yield in soils, containing low phosphorus. Jayabal and Chockalingam (1990) recorded a maximum yield of 98.4 t/ha at a P level of 32 kg P_2O_5/ha whereas the yield was 91 t/ha for 60 kg P_2O_5/ha (Kumaraswamy *et al.*, 1992). Higher level of K increases the synthesis of food reserves due to high net assimilation which causes high yields. Application of an optimum dose of 100 kg K_2O/ha (Raja, 1988) was found to increase the qualitative and quantitative output of sugarcane. Chandy *et al.* (1989) recorded an yield of 88.1 t/ha for an K dose of 60 kg K_2O/ha in the acidic alluvial soils of Kerala. Patil and Shingte (1992) recorded an yield of 109.2 t/ha corresponding to a K level of 165 kg K_2O/ha.

Broadcasting the fertilisers at the rate of 165 kg N, 82.5 kg P_2O_5 and 82.5 kg K_2O per ha has been recommended in Kerala (KAU, 1993).

Kumaraswamy *et al.* (1992) recommended a basal application of 8 kg phosphobacterin biofertilizer with 65 kg P_2O_5 /ha for increased cane yield and phosphorus content of leaf sheath and cane stalk.

Jafri *et al.* (1985) observed increased uptake of macronutrients (N, P, K, Ca and S) by sugarcane plant when processed pressmud was used. Application of saturated lime solution (Paneerselvam *et al.*, 1991) and pressmud @ 3 t/ha (Singh *et al.*, 1991) were also done to increase the cane yield.

1.2. Nutrient uptake studies

1.2.1. *Uptake of nitrogen*

Uptake of nitrogen by the crop decreases as the maturity of the crop advances and falls suddenly at the time of harvest of crop. The total uptake of nitrogen increased as a result of increased dry matter production. Cruz and Puyaoan (1970) estimated that the nitrogen uptake of common varieties varied from 62.4 to 94.5 kg/ha. Uptake of nitrogen by sugarcane varies with the methods of planting and earthing up (Yadav, 1983), and different levels of irrigation (Sharma and Gupta, 1991). Zende (1991) reported that on an average, a tonne of the crop removes 1.5 kg N, 0.6 kg P_2O_5 and 3.5 kg K_2O from the soil.

1.2.2. *Uptake of phosphorus*

Uptake of phosphorus depends upon variety and age of the crop. Fogliata (1973) found that stools left out in the field after harvest of cane amounted to 10.63 t/ha and it contained 35 kg P_2O_5. Uptake of phosphorus under Hawaiian conditions was reported to be in the range of 8.2 to 32.0 kg/ha whereas under Indian conditions, it was found to be 37.3 kg/ha (Parthasarathy *et al.*, 1979).

1.2.3. *Uptake of potassium*

Uptake of potassium goes often to the extent of luxury consumption, when it is available in the soil freely. The estimated uptake of potassium per tonne of cane produced varied from 1.0 to 2.5 kg K_2O (Humbert, 1963). Dagade and Ranadive (1983) noted that the phosphate application increased the uptake of potash. Perumal (1993) reported that under ideal condition, the uptake of P will be hardly 15 per cent of the total nutrients applied through fertilisers and stressed that irrigation and drainage played an important role in P and K uptake.

1.3. Influence of leaf nutrient content on yield

1.3.1. *Nitrogen*

The yield of sugarcane can be increased by maintaining higher levels of leaf nitrogen at grand growth and maturity phases (Perumal, 1979). Also, Perumal (1983) found a positive influence of cane yield with leaf nitrogen at the fourth month of crop and to get a higher yield of 119.0 t/ha, the N should be maintained at 2.0 per cent while the K content should be around 3.0 per cent in early growth phase of the crop. The leaf N content also increases more with the application of nitrogen (Rao *et al.*, 1989).

1.3.2. *Phosphorus*

Perumal (1987) reported an sheath P content of 0.12 per cent in early growth phase of the crop to obtain maximum sugar yield per hectare. Sreenivas *et al*. (1990) found that the sheath phosphorus content was negatively correlated with cane yield and sugar yield at maturity phase of the crop.

1.3.3. *Potassium*

Potassium is particularly important in the later stages of growth to ensure the use of remaining nitrogen. Sreenivas *et al*. (1990) found a positive correlation between sheath K content and final sugar yield at grand growth and maturity phases of the crop.

2. FOLIAR DIAGNOSIS PURPOSE AND DEFINITION

Foliar diagnosis is based on the principle that the ability of a plant to take up and utilise mineral nutrients is reflected in the concentration of each nutrient in its tissues and in the relationship between these concentrations. The application and further development of *diagnostic foliare* were done on grapes by Lagatu and Maume (1932) who defined foliar diagnosis as "the succession of chemical conditions in different phases of vegetative cycle, established through analysis of leaves or other organs".

Ulrich (1952) has proposed the basic concept that the nutrient concentration with in a specific plant part is related to plant growth. Therefore, foliar analysis as a method for assessing the nutrient requirement of a given crop, makes use of the fact that with in certain limits there are positive relationships among doses of nutrient supplied, leaf nutrient content and yield. Chemical analysis of selected tissues provides valuable information on soil fertility, nutrient availability to plants and the critical level of plant nutrients. Thus, for leaf analysis to serve as a guide to crop fertilization, it is essential to standardise the sampling procedures with respect to each nutrient.

2.1. Index tissue

Index tissue can be defined as the tissue that can be used to follow the levels of each factor as the crop grows (Clements, 1980). Such a tissue must reflect in a high degree of correlation, the levels within the whole plant, for as the absorption and utilization of any factor vary, such variations should be reflected by the index tissue.

The index tissues are standardised for a large number of crops. Reddy *et al.* (1988) carried out studies to identify and select N, P and K index tissue in papaya by determining their concentrations in petioles at different stages of maturity. Mathew (1990) identified the first group of leaves (leaf no 1 and 2 near to inflorescence) as ideal for diagnostic purpose in relation to N and K in cashew. Rathore and Manohar (1990) considered the second and third leaf at 60 days as the best plant part and stage for foliar analysis of mustard. Jose *et al*. (1991) suggested regression models to predict the yield in coconut with an accuracy of 86.2 per cent utilising N, P and K content of the leaf lamina of tenth leaf.

2.2. Critical nutrient concentration (CNC)

Critical nutrient concentration is the level of a nutrient below which crop yield, quality and performance are unsatisfactory. But the traditional method for establishing standard reference values for nutrient diagnosis is the critical nutrient level which is defined as that concentration which is at the mid point of the transitional zone between deficiency and sufficiency levels (Ulrich and Hills, 1973). Since greater nutrient utilization generally occurs as the crop approaches maturity, critical nutrient levels are often developed for mature crops and response to most corrective treatment are unlikely.

2.3. Factors affecting CNC

2.3.1. *Selection of tissue*

Several research workers reported that leaves are usually the most satisfactory plant part. Leaves are called as "Chemical laboratory of the plant" because it is the site where mineral nutrients are converted into structurally and metabolically active components along with the products of photosynthesis. Ulrich *et al.* (1959) compared leaves and petioles for a number of elements in sugar beet and concluded that leaves and petioles are equally satisfactory. Reuter *et al.* (1982) reported that the concentration in leaf of defined physiological age in subterranean clover was much superior to whole shoot for diagnosing zinc deficiency. In papaya, petioles were selected for nutritional diagnosis (Reddy *et al* ., 1988).

2.3.2. *Climate*

Weather conditions may affect the nutrient concentration at the time plant samples are taken, and later they may affect the response to applied nutrients. Jones *et al.* (1980) reported that following heavy rainfall, there was reduction in the N, B, Mn and Zn content of leaves. An increase in percentages of macronutrients in the third leaf of sugarcane due to 200 mm rainfall, two months prior to sampling was noted by Malavolta and Carvalho (1984). The decline in leaf N content with the onset of monsoon in coconut was reported by

Wahid *et al.* (1981). He also found that the leaf P increased slightly in rainy season whereas leaf K increased until December and there after declined.

2.3.3. *Soil factors*

Soil temperature and soil reaction can have a direct effect on nutrient composition of leaves. Power *et al.* (1963) observed that soil or solution temperature and light intensity affected the concentration of nutrient in plant. Chabra *et al.* (1979) reported that the zinc content of sunflower decreased with increase in ESP (alkalinity) while the iron content increased. Duncan *et al.* (1980) investigated the effect of acidity on leaf elemental concentration and grain yield of sorghum.

2.3.4. *Interaction among nutrients*

The complicating problem of plant analysis is that one nutrient may effect not only the concentration of another nutrient in plants but also its critical concentration. Sharma *et al.* (1968) studied the interaction of phosphorus and zinc in different plant parts of corn and tomato. Singh and Tripathi (1974) studied the effect of N, P and K fertilization on zinc concentration of wheat plant. In cashew, a slight increase in leaf N content due to increase in P and K treatment was observed by Ghosh and Bose (1986).

2.4. Interpretation of the data

Correct interpretation of the data obtained by the analysis of leaves is the most useful and most complex stage of diagnostic technique. Generally, three methods have been used in sugarcane for the interpretation of the nutrient status after the plant analysis. These are critical nutrient concentration (CNC) or critical nutrient range (CNR), sufficiency range and balance of the nutrient or diagnosis and recommendation integrated system (DRIS). Meyer (1981) opined that DRIS could be used as a fairly reliable system to indicate N, P and K deficiencies in the order of decreasing importance. The DRIS was designed to assess the relative nutrient imbalances or deficiency or both in plant tissue (Sumner, 1982). In coconut, DRIS gave more accurate diagnosis of nutrient imbalance or deficiency than critical level of nutrient (CLN) approach (Khan *et al* ., 1988).

2.5. Foliar analysis of some important crops

2.5.1. *Rice*

Gilmour (1977) measured plant micronutrient content of top, middle and bottom leaves as well as whole plant. Braden *et al*. (1981) reported that grain yield could be predicted based on the N content of most recent matured leaf (Y-leaf). Garcia and Treto (1986) reported active tillering stage as the best stage than the tiller initiation stage for plant N status estimation.

2.5.2. *Tapioca*

Pushpadas (1968) attempted foliar diagnostic studies in tapioca in relation to potassium and calcium. Vijayan (1968) evolved a suitable diagnostic technique for the nutritional status of nitrogen and phosphorus in two varieties by foliar analysis and their interaction in relation to uptake, yield and quality of tubers. He also observed that the middle one third of the total petiole would be the best reflect for nitrogen and phosphorus. Spear *et al.* (1979) found out the relationship between shoot dry matter and the concentration of potassium in the youngest fully expanded leaf (YFEL) of cassava (*Manihot esculenta* (Crantz)).

2.5.3. *Mango*

Pathak and Pandey (1976) evaluated the leaf sampling technique in mango. Kumar (1979) reported the variation in N content between fruit, leaf blade and petiole. Chadha *et al.* (1980) suggested matured leaf taken from the mid-point of shoot whose growth has ceased whereas Thakur *et al.* (1981) recommended leaf samples from nonfruiting branches. He also reported that leaf age was the critical factor responsible for variation in mineral composition of mango leaves with particular reference to P, K, Ca, S, Cu and Mn.

2.5.4. *Coconut*

The critical level for leaf N, P and K was first proposed in 1956 by Prevot and Ollagnier for Tall West African coconut. Indirakutty and Pandalai (1968) recorded increased foliar content of N, P and K with increase in yield, but Ca and Mg did not show this trend. The absence of a positive correlation between yield and foliar levels of Na, Ca and Mg was reported by Wahid *et al.* (1974) and Krishnakumar (1983). Jose *et al.* (1991) suggested regression models to predict the yield with an accuracy of 86.2 per cent utilizing N, P and K content of the leaf lamina of 10th leaf in coconut.

3. FOLIAR DIAGNOSIS IN SUGARCANE

Sugarcane is cultivated in a wide variety of climate and soil, throughout the world. So it is difficult to assess its nutritional requirement with certainty. Foliar analysis could be of much use in such situations. Foliar analysis as a method in planning and evaluation of the fertiliser programmes and in planning of harvest schedules was reported by various workers. (Meyer, 1981; Perumal, 1983).

3.1. Index tissue

Selection of index tissue for plant analysis varied. Different sugar growing countries have adopted different indicator tissues for analysis. Also, the 8-10 leaves (Humbert, 1963), TVD (top visible dewlap) leaf (Beaufils, 1973) can also be used as index tissues. Clements (1980) had chosen (3,4,5 and 6) leaf sheath for P, K, Ca and minor elements and leaf blade for nitrogen analysis. Studies relating NPK content of index tissue with macro as well as micronutrient composition of soils were reported from Andhra Pradesh (Rao *et al.*, 1983).

3.2. Time and size of sampling

Plant nutrients especially nitrogen was synthesised most rapidly at night and during early hours. Alvarez (1971) stated that time of sampling influenced the leaf nutrient composition and suggested 6 to 8 a.m. as the best time for sampling. Filho and Decampos (1975) conducted a trial to find out the optimum number of leaves required for foliar diagnosis and concluded that number of leaves analysed did not affect the analytical result for N, P and K.

3.3. Leaf nutrient composition

Leaf nutrient composition is affected not only by the difference in environment but also by the age of crop. Studies on phosphorus nutrition of cane revealed that the P content in the leaf sheath in complete nutrient solution was 0.32 per cent whereas in P deficient solution, it was 0.12

per cent (Anon., 1961-62). Srinivasan and Mariakulandai (1969) reported that the increase in leaf nitrogen was linear up to 288 kg N/ha after which there was no appreciable increase. Perumal (1981) registered higher potassium content between four and six months of crop age and decreased thereafter. The concentration of nutrients in the leaf was reduced with age of the crop (Shukla and Kamalabai, 1990).

3.4. Nutrient interaction

Experiments revealed that the different levels of nitrogen had no influence on phosphorus content of index tissue (Anon., 1961-1962). Naidu *et al.* (1982) reported that application of P_2O_5 and K_2O resulted in a slight increase in sheath phosphorus and potassium with no effect on leaf nitrogen. Desai *et al.* (1988) found a significant positive correlation with nitrogen in third leaf with that of phosphorus at all stages except at grand growth stage. Increase in nitrogen and phosphorus content of leaf blade due to foliar application of micronutrients (Fe, Cu, Mn, Zn) has been reported (Kapur and Kanwar, 1988).

3.5. Critical level of nutrients

Critical level of nutrient is defined as the concentration of the element in the leaf above which a yield response from the element in the fertiliser is unlikely to occur (Prevot and Ollagnier, 1957).

Fogliata and Dip (1971) regarded the leaf nitrogen level of 1.76 to 1.82 per cent as critical values whereas Gonsell and Long (1971) reported that in sugarcane the third leaf blade at 4 - 6 month age should contain 1.80 per cent N, 0.18 per cent P and 1.10 per cent K. Orlando *et al.* (1977) reported that critical level for one variety and soil type may differ for other varieties or soils.

3.6. Review on yield prediction models

The application of foliar diagnosis technology in predicting the final yield of various crops employing NPK content of different diagnostic leaf positions have been reported by many workers. Gopi (1981) predicted the yield in coconut with an accuracy of 84 per cent by taking the percentage of nitrogen in the lamina of second leaf and the number of leaves retained by the palm. Mathew (1990) identified the preflushing sampling as the best stage for N and the stage just before fruit set was found to be the best for K and predicted the yield with an accuracy of 55 per cent employing P and K content of leaf, as well as N/P and N/K ratio of the first group of leaves at the above critical stages.

4. INFLUENCE OF NPK ON JUICE QUALITY OF SUGARCANE

4.1. Influence of nitrogen

Nitrogen has a favourable effect on juice quality only when it is applied in optimum amount, as too much of this nutrient results in poor juice quality whereas too little of the same gives poor yield (Humbert, 1963). By maintaining lower levels of leaf nitrogen at harvest, the sugar content can be increased (Parthasarathy and Perumal, 1976). Rao and Parashar (1988) found no influence with the graded levels of nitrogen on juice quality parameters like brix, sucrose per cent, CCS per cent, and CCS yield. Negative correlation between leaf nitrogen and juice sucrose at grand growth phase was reported by Sreenivas *et al.* (1990).

4.2. Influence of phosphorus

The influence of phosphorus on juice quality parameters was not significant as reported by Kadian *et al.* (1981) whereas Pannu *et al.* (1985) observed that the cane quality and sugar production was increased significantly by the application of phosphorus fertilisers on a phosphorus deficient sandy loam soil. Maintaining phosphorus in the leaf sheath at 0.12 per cent in early growth phase of the crop to achieve maximum sugar yield per ha was reported by Perumal (1987). Sreenivas *et al.* (1990) found that the sheath phosphorus content was positively correlated with sucrose at maturity phase only.

4.3. Influence of potassium

Application of potassic fertilizers to sugarcane will immensely increase the sucrose content (Samuels and Landrau,1956). Potassium influences the juice quality by reducing the gum and starch content (Gupta and Shukla,1970) and by increasing the brix, purity and sugar recovery (Sharma and Sharma,1981). Yadav and Prasad(1991) found no relation between juice quality and various potassium fertilization treatments. Reddy *et al.* (1992) reported that the availability of potassium in soil was inversely correlated with sucrose in juice in all the test varieties of Chitoor region.

Materials and Methods

MATERIALS AND METHODS

A fertiliser trial of sugarcane was conducted at the Sugarcane Research Station, Tiruvalla in order to standardise the stage of sampling and leaf position in relation to yield and to predict the yield with the nutrient content of leaf positions. The field experiment was started in 1992 with the variety Madhuri. The details of the experiments and analytical techniques followed during the course of investigation are presented .

1.1. Site characteristics of the field experiment

The station is situated at 9°5' N latitude at an elevation of 25.14 metre above MSL, on the banks of Manimala river in Pathanamthitta District.

The soil of the experimental site is clay loam, with a pH of 5.2. The data on the physico-chemical characteristics of the experimental site are given in Table 1. and the weather parameters during the crop period are furnished in Appendix I.

1.2. Design, lay out and treatments (Fig.1)

Design : Randomised block design

No of replications: 2

Plot size : 32.4 m^2

Total number of treatments : 27

Table 1. Physico-chemical characteristics of the soil

Parameter	Analytical value
1. Particle size analysis:(Singh,1980)	
Sand (%)	40.8
Silt (%)	22.8
Clay (%)	36.4
Texture	Clay loam
2. pH	5.2
3. Specific conductivity (dS/m)	0.04
4. Organic carbon (%)	2.10
5. Available N (ppm)	217.0
6. Available P (ppm)	1.8
7. Available K (ppm)	37.5

The treatments were the factorial combinations of N, P and K each at 3 levels as given below.

Levels of nitrogen, kg N/ha

1	n_0	0.0
2	n_1	165.0
3	n_2	330.0

Levels of phosphorus, kg P_2O_5/ha

1	p_0	0.0
2	p_1	82.5
3	p_2	165.0

Levels of potassium, kg K_2O/ha

1	k_0	0.0
2	k_1	82.5
3	k_2	165.0

The different combinations of nitrogen, phosphorus and potassium levels tried in the experiment and their respective treatment notations are given below.

Sl.No.	NPK Treatment	NPK Treatment notation
1	$n_0p_0k_0$	000
2	$n_0p_0k_1$	001
3	$n_0p_0k_2$	002
4	$n_0p_1k_0$	010
5	$n_0p_1k_1$	011
6	$n_0p_1k_2$	012
7	$n_0p_2k_0$	020

Contd...

Sl.No.	NPK Treatment	NPK Treatment notation
8	$n_0p_2k_1$	021
9	$n_0p_2k_2$	022
10	$n_1p_0k_0$	100
11	$n_1p_0k_1$	101
12	$n_1p_0k_2$	102
13	$n_1p_1k_0$	110
14	$n_1p_1k_1$	111
15	$n_1p_1k_2$	112
16	$n_1p_2k_0$	120
17	$n_1p_2k_1$	121
18	$n_1p_2k_2$	122
19	$n_2p_0k_0$	200
20	$n_2p_0k_1$	201
21	$n_2p_0k_2$	202
22	$n_2p_1k_0$	210
23	$n_2p_1k_1$	211
24	$n_2p_1k_2$	212
25	$n_2p_2k_0$	220
26	$n_2p_2k_1$	221
27	$n_2p_2k_2$	222

200	111	000	020	011	012	021	101	002	Replication I
121	010	001	022	112	102	201	122	120	
202	110	100	221	211	220	210	222	212	
010	211	220	122	112	101	020	000	221	Replication II
022	110	121	210	212	222	200	111	120	
202	201	102	011	001	012	002	021	100	

Fig. 1 Layout of the field experiment

Nitrogen, phosphorus and potassium as per treatments were applied in the form of urea, mussooriephos and muriate of potash respectively. The entire quantity of P_2O_5 was applied as basal, whereas N and K_2O were applied in two splits on the 45th and 90th day after planting. The cultural operations were carried out uniformly irrespective of the fertiliser treatments.

Varietal description

Madhuri (CoTl 88322) is the first hybrid derivative of the cross Co 740 x Co 775, released by the Kerala Agricultural University. This is a high sugared mid-late maturing (10-12 months) variety, suitable for flood prone and garden land situations. Its millable cane yield is 125 t/ha and the commercial cane sugar (CCS) yield is 12.6 t/ha. Madhuri is tolerant to red rot disease.

2. COLLECTION OF SAMPLES FOR THE STUDY

2.1. Collection of soil samples

Three soil samples (0-15cm depth) from each plot were collected at random before planting and after harvest of the crop. The three samples were composited and analysed.

2.2. Collection of plant samples

Sugarcane leaf at the tip of the actively growing primary stem i.e., the leaf that just began to unroll was counted as leaf No.1 (plate I). Leaf blades, with and without sheath of leaves 3 to 6 were collected separately. The middle 20 cm length of the leaf blade (10 cm on either side of centre) was taken after removing the midrib for analysis. Out of the two plots receiving the same treatment, two plants were taken, one from each plot selected at random, for chemical analysis.

3. STANDARDISATION OF PERIOD OF SAMPLING

In order to standardise the critical stage for the collection of leaf intended for foliar diagnosis, sampling was carried out at six different stages of plant growth as follows:

	Period	Date of sampling
1.	Prior to tillering and before first top dressing (Germination phase)	30th April, 1992 (45 DAP)
2.	After germination but before second top dressing (Tillering phase)	15th June, 1992 (90 DAP)
3.	At the beginning of grand growth phase	15th July, 1992 (120 DAP)
4.	After grand growth phase but before flower formation	15th September, 1992 (180 DAP)
5.	After flower formation but before maturity phase	16th November, 1992 (240 DAP)
6.	Harvesting stage	15th January, 1993 (300 DAP)

Plate I The well-developed cane top showing the spindle leaf (+1) i.e., the leaf that just begins to unroll from the unrolling edge of +2. The number beside each blade applies not only to it, but also to the sheath and the internode below the node to which the sheath is attached

4. ANALYTICAL METHODS

4.1. Soil

Parameters	Method	Reference
Particle size analysis	International pipette method	Piper (1942)
soil reaction	1:2.5 soil:water suspension, using pH meter	Jackson (1958)
Electrical conductivity	Supernatent of 1:2.5 soil:water suspension using EC bridge	Jackson (1958)
Organic carbon	Chromic acid wet digestion (Walkley & Black)	Piper (1942)
Available nitrogen	Alkaline permanganate distillation	Subbiah & Asija (1956)
Available phosphorus	Bray 1 extractant chloromolybdo blue color in HCl system	Jackson (1958)
Available potassium	Neutral 1N Ammonium acetate extract, flame photometer method	Jackson (1958)

4.2. Plant material

Total nitrogen	Kjeldahl digestion and distillation method	Jackson (1958)
Total phosphorus	Colorimetric,triacid extract vanadomolybdo phosphoric yellow color method in HNO_3 medium	Jackson (1958)
Total potassium	Flame photometric method, triacid extract	Jackson (1958)

4.3. Juice characteristics

Brix	Brix hydrometer spindle	Meade & Chen (1977)
Pol percentage (sucrose)	Clarification of the juice with lead sub acetate and reading in a polariscope	Meade & Chen (1977)
Commercial Cane Sugar (CCS) percentage	Sucrose % - 0.4 (Brix - sucrose) X 0.73	Meade (1953)

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5. DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM (DRIS)

Data base for this study was derived from NPK factorial experiment. As it is more meaningful to find out the nutrient imbalance, especially at the early stages which falls within the fertiliser application period, the second stage of sampling was selected for the study. Sugarcane plants which yielded less than 60 t/ha were considered as low yielding population and those yielded more than 60 t/ha were considered as high yielding population. Irrespective of fertiliser treatments, 216 leaf samples were taken for the study of which 24 was coming under high yielding population.

Leaf samples were collected from 3rd, 4th, 5th and 6th leaf positions, washed with a wet cloth, rinsed with distilled water, oven dried at 65°C to a constant weight, powdered in a wiley mill with steel blades and analysed for N, P and K.

The general procedure given by Walworth and Sumner (1987) was followed for developing the preliminary norms. The N, P and K indices were calculated, supplementing the nutrient ratios in the following formula.

$$\text{N index} = \frac{f(N/K) - f(P/N)}{2}$$

$$\text{P index} = \frac{f(P/K) + f(P/N)}{2}$$

$$\text{K index} = \frac{-f(P/K) - f(N/K)}{2}$$

$$\text{Where:} \quad f(N/K) = \left(\frac{N/K}{n/k} - 1\right)\frac{1000}{CV}, \text{ when } N/K > n/k$$

$$= \left(1 - \frac{n/k}{N/K}\right)\frac{1000}{CV}, \text{ when } N/K < n/k$$

Where :

N/K = actual value of ratio in the leaf of a test sample

n/k = the mean value of the ratio for the high yielding population

CV = Coefficient of variation of high yielding population

f = function of nutrient ratios comprising the nutrient index .

6. STATISTICAL ANALYSIS

The data relating different NPK treatments on yield of cane and brix, pol and CCS per cent of cane juice were analysed by applying the analysis of variance technique (Panse and Sukatme, 1967).

The degree of relationship between yield and N, P and K content of leaf at different leaf positions and stages of sampling was estimated by calculating the simple correlation coefficients (Snedecor and Cochran, 1967). The direct effect and indirect effects of different independent variables on yield was estimated using path analysis (Dewey and Lu, 1959). Step-wise regression analysis was applied to relate the leaf nutrients with cane yield at different stages of sampling (Draper and Smith, 1967).

Results and Discussion

RESULTS AND DISCUSSION

In order to study the relationship of cane yield and nutrient status through foliar diagnosis, samples were drawn from sugarcane plants of a NPK trial, laid out in 1992 using the variety Madhuri at the Sugarcane Research Station, Tiruvalla. The yield as well as the nutrient content of leaves were analysed to standardise the leaf position and stage of sampling and for the yield prediction based on plant nutrient levels. The nutrient uptake of sugarcane in relation to N, P and K at harvest stage was correlated with different leaf positions collected during different stages of sampling. The quality of cane juice was analysed for brix, pol and CCS per cent to know the influence of different NPK treatments.

The experimental variety, Madhuri is a mid-late crop commencing flowering from sixth to seventh month onwards, by which time the nutrients especially NPK are used mostly for the production and accumulation of sugars. So from sixth month onwards, possibilities of having a significant and positive correlation with yield and NPK content of leaves with and without sheath are very low. However, the relationship between NPK content of leaf, both with and without sheath at various stages was examined separately through path analysis and attempts were made to standardise the best stage as well as leaf position with respect to NPK to give maximum yield prediction.

1. EFFECT OF NPK ON THE YIELD OF SUGARCANE

The yield of sugarcane as influenced by NPK treatments are presented in Table 2. The mean values and the analysis of variance relating to yield data has been furnished in Table 3.

1.1. Nitrogen

Results revealed that the application of nitrogen from 0 to 165 kg/ha significantly increased the yield of sugarcane (Table 3). The mean yields at n_0, n_1 and n_2 levels were 34.6, 53.2 and 56.6 t/ha respectively. The percentage increase in yield between n_0 and n_1 level was 54.0 while that of n_1 and n_2 was negligible. The per cent increase in yield at n_2 level as compared to n_0 level was 63.0. In other words the sugarcane responded to increasing levels of nitrogen only up to 165.0 kg/ha. Dhillon *et al.* (1993) found that application of nitrogen beyond 150.0 kg/ha did not prove significant effect in increasing the cane yield.

1.2. Phosphorus

Unlike in the case of N, increasing levels of phosphorus application had no impact on increasing cane yield. The mean yields at p_0, p_1 and p_2 levels were 47.0, 46.9 and 50.4 t/ha respectively. The per cent increase at p_2 level as

Table 2. Yield of sugarcane as influenced by NPK treatments

Sl. No.	NPK Treatment notation	Yield, t/ha		
		R_1	R_2	Mean
1	000	35.1	32.6	33.8
2	001	28.5	31.8	30.3
3	002	45.2	44.8	45.0
4	010	28.8	26.4	27.6
5	011	32.7	24.2	28.4
6	012	34.3	32.6	33.4
7	020	41.0	35.7	38.4
8	021	38.6	56.3	47.5
9	022	28.5	25.4	26.9
10	100	49.1	54.7	51.9
11	101	55.6	51.5	53.6
12	102	53.7	43.6	48.6
13	110	50.3	43.1	46.7
14	111	52.5	63.6	58.1
15	112	53.9	55.5	54.7
16	120	51.1	52.6	51.9
17	121	44.5	52.8	48.6
18	122	69.3	60.7	65.0
19	200	42.5	60.6	51.5
20	201	72.0	46.0	58.9
21	202	45.2	53.8	49.5
22	210	60.9	49.8	55.3
23	211	55.4	55.4	55.4
24	212	65.1	59.9	62.5
25	220	50.1	53.1	51.6
26	221	57.1	58.1	57.6
27	222	75.8	57.4	66.0

Table 3. Effect of NPK treatment on yield of sugarcane

Summary

Treatment groups	Yield, t/ha
n_0	34.6
n_1	53.2
n_2	56.6
CD (0.05)	4.7
p_0	47.0
p_1	46.9
p_2	50.4
CD (0.05)	NS
k_0	45.4
k_1	48.7
k_2	50.2
CD (0.05)	NS
Interaction	
NP	NS
NK	NS
PK	NS
NPK CD (0.05)	14.1

NS - Not significant

compared to p_0 was only 7.29 whereas it was negative in case of p_1 as compared to p_0 level. Also, the analysis of variance of the yield data furnished in Table 3 revealed that effect of different phosphorus levels was not at all significant. This might be due to the adequate content of available P in the soil and hence the added P did not help in increasing the yield of sugarcane. The result is in conformity with the findings of Patil and Shingte (1990).

1.3. Potassium

Like P, the effect of different levels of potassium application on yield was not significant. The mean annual yields at k_0, k_1 and k_2 levels were 45.4, 48.7 and 50.2 t/ha respectively. The per cent increases in yield at k_1 and k_2 level over k_0 level were 7.24 and 10.64 respectively. The increase in yield due to increasing K levels was not significant. Yadav and Prasad (1991) reported that the various treatments of potassium application did not influence the cane yield and the yield attributes significantly.

1.4. NPK interaction

The analysis of variance relating the different NPK treatments with yield showed that the NPK interaction was significant (Table 3). The mean yields at n_0p_0, n_1p_1 and n_2p_2 levels were 36.3, 53.1 and 58.6 t/ha respectively. At high levels of NP combination (n_2p_2), a corresponding increase in yield was observed, which is in conformity with the findings of Thakur *et al.* (1982).

2. STANDARDISATION OF STAGE OF SAMPLING AND LEAF POSITION IN SUGARCANE

2.1. Nitrogen

Data on the percentage of N in leaf with sheath and without sheath during the different stages of sampling as influenced by varying in levels of nutrients applied in the soil are presented in Tables 4 to 9 and the mean values in Tables 10 and 11.

The nitrogen content of leaf with sheath varied from 0.35 to 1.41 per cent. The mean values of N in the first, second, third, fourth, fifth and sixth stages of sampling were 1.31, 1.27, 1.19, 0.76, 0.62 and 0.39 per cent respectively. It was revealed that the N content of leaves exhibited some variation with respect to different leaf positions and stages of sampling. The decrease in content of N with the age of crop clearly showed the dilution effect of the nutrient in sugarcane in which the rate of growth was more than the uptake of N. A sudden decrease in the content of N

Table 4. Nitrogen per cent in leaf at the first stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath			Leaf position without sheath		
	3	4	5	3	4	5
000	1.27	1.11	1.11	1.11	1.43	1.59
001	1.43	1.27	1.27	1.27	1.27	1.11
002	1.43	1.11	0.95	1.11	1.43	1.11
010	1.11	0.95	1.11	0.95	1.11	1.43
011	1.43	1.27	1.11	1.11	1.11	1.11
012	1.27	1.75	0.95	0.95	1.43	1.27
020	1.11	1.11	1.27	1.27	1.27	1.43
021	1.43	1.27	1.59	0.95	1.11	1.59
022	0.95	1.11	1.11	1.27	1.27	1.27
100	1.11	1.11	1.11	1.27	0.95	1.27
101	1.11	1.27	1.27	1.11	1.11	0.79
102	1.59	1.59	1.27	1.27	1.11	1.75
110	1.59	1.43	1.43	1.11	1.27	1.91
111	1.27	1.43	1.11	2.71	1.59	1.11
112	1.43	1.11	1.11	1.11	1.11	1.43
120	1.27	1.43	1.11	1.43	1.43	1.75
121	1.27	1.43	1.27	1.27	1.11	1.75
122	1.11	1.11	1.43	1.27	1.43	1.59
200	1.59	3.83	1.43	1.59	1.59	1.91
201	1.43	1.75	1.43	1.43	1.11	1.59
202	1.43	1.91	1.59	1.43	1.43	1.43
210	1.59	1.27	1.27	1.27	2.23	1.27
211	1.11	1.43	1.43	0.95	1.27	1.27
212	1.43	1.43	1.11	1.11	1.27	1.27
220	1.11	1.11	1.27	1.27	0.95	1.27
221	0.95	1.11	1.43	1.27	1.27	1.27
222	1.27	1.27	0.95	1.11	1.43	0.95
n_0	1.27	1.22	1.16	1.11	1.27	1.32
n_1	1.30	1.32	1.23	1.39	1.23	1.48
n_2	1.32	1.68	1.32	1.27	1.39	1.35

Table 5. Nitrogen per cent in leaf at the second stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	1.27	1.75	1.11	1.59	1.59	1.75	1.75	1.43
001	0.95	0.95	0.79	0.95	1.11	0.95	0.11	0.95
002	1.27	1.43	1.27	0.95	1.11	1.43	1.43	1.27
010	1.27	1.43	1.27	1.11	1.27	1.27	1.27	1.11
011	1.59	1.43	1.59	1.27	1.11	1.27	1.59	1.11
012	1.27	1.43	1.27	0.95	1.11	1.11	1.27	1.11
020	1.43	1.11	0.95	1.27	1.43	1.27	1.11	1.43
021	1.11	1.11	0.79	1.11	1.27	1.11	1.11	1.11
022	1.27	0.47	0.79	0.79	1.11	1.59	0.95	1.27
100	1.11	1.43	1.43	1.27	1.43	1.43	1.59	1.27
101	1.43	1.27	1.27	1.11	1.43	1.11	1.75	1.27
102	1.11	1.43	1.27	1.27	1.59	1.27	1.43	1.43
110	1.27	1.43	1.27	1.27	1.75	1.59	1.59	1.27
111	1.27	1.59	1.27	1.27	1.43	1.43	1.27	1.59
112	1.27	1.27	1.27	1.27	1.75	1.59	1.75	1.27
120	1.27	1.27	1.11	1.59	1.27	1.11	1.27	1.43
121	1.27	1.27	1.11	1.11	1.59	1.59	1.27	1.27
122	1.43	1.11	1.11	1.27	1.43	1.43	1.27	1.27
200	1.75	1.27	1.27	1.43	1.59	1.59	1.43	1.43
201	1.11	1.27	1.27	1.27	1.27	1.43	1.91	1.43
202	1.27	1.59	1.27	1.11	1.43	1.27	1.43	1.43
210	1.43	1.75	1.43	1.43	1.59	1.27	1.75	1.91
211	1.75	1.43	1.27	1.43	1.59	1.91	2.07	1.75
212	1.27	1.43	1.27	1.27	1.75	1.43	1.59	2.07
220	1.43	1.43	1.59	1.11	1.91	1.75	1.59	1.75
221	1.59	1.27	1.27	0.95	1.27	1.59	1.59	1.27
222	1.43	1.27	1.43	1.59	1.75	1.27	1.59	1.59
n_0	1.27	1.23	1.09	1.11	1.23	1.31	1.18	1.20
n_1	1.27	1.34	1.23	1.27	1.52	1.39	1.47	1.34
n_2	1.41	1.41	1.34	1.29	1.57	1.50	1.66	1.63

Table 6. Nitrogen per cent in leaf at the third stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	1.11	1.11	0.79	0.63	1.59	1.43	1.27	1.27
001	1.27	1.27	1.27	0.79	1.75	1.27	1.59	1.27
002	1.11	1.27	1.27	1.27	1.43	1.75	1.75	1.43
010	1.27	1.43	1.27	2.23	1.43	1.59	1.75	1.75
011	0.79	0.95	0.95	0.79	1.59	1.59	1.43	0.95
012	1.11	0.79	0.95	0.79	1.59	1.11	1.11	1.11
020	0.95	1.59	1.27	1.11	1.43	1.59	1.59	1.27
021	1.11	1.27	1.59	1.11	1.43	1.75	1.59	1.27
022	1.27	1.27	0.95	0.79	1.27	1.59	1.11	1.43
100	1.11	1.59	1.43	1.11	1.59	1.75	1.75	2.39
101	0.95	1.27	1.11	0.95	1.43	1.43	1.43	1.27
102	1.11	0.95	0.79	0.95	1.43	1.43	1.27	1.11
110	1.27	1.11	0.79	0.95	1.91	1.59	1.59	1.27
111	1.27	0.95	0.95	0.95	1.27	1.43	1.27	1.11
112	1.59	1.27	1.27	1.27	1.75	1.75	1.59	1.91
120	1.91	1.59	1.43	1.11	2.23	1.59	1.75	1.43
121	1.27	1.27	1.43	0.95	1.59	1.75	1.27	1.11
122	1.27	1.27	0.95	0.79	1.43	1.43	1.27	1.59
200	1.75	1.43	1.27	1.27	1.75	1.73	1.43	1.27
201	1.59	1.59	1.43	1.91	1.91	2.07	0.95	2.07
202	1.11	1.27	1.43	1.11	1.59	1.43	2.07	1.27
210	1.59	1.27	1.11	1.11	1.75	1.59	1.59	1.11
211	1.11	1.43	1.11	0.79	1.27	1.59	1.27	0.95
212	1.27	1.11	0.95	1.91	1.75	1.59	1.27	0.95
220	1.11	1.11	1.27	0.79	1.59	1.43	1.59	1.43
221	1.11	1.11	1.11	0.95	1.43	1.43	2.07	1.43
222	1.11	1.11	1.43	1.27	1.59	1.43	1.27	1.27
n_0	1.11	1.22	1.15	1.06	1.50	1.52	1.47	1.31
n_1	1.31	1.25	1.13	1.00	1.63	1.57	1.47	1.47
n_2	1.31	1.27	1.23	1.23	1.63	1.59	1.50	1.31

Table 7. Nitrogen per cent in leaf at the fourth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.86	0.73	0.68	0.65	1.08	0.98	0.87	0.63
001	0.59	0.54	0.47	0.68	0.70	0.65	0.67	0.43
002	0.84	0.76	0.65	0.73	1.10	1.14	1.19	1.08
010	0.52	0.46	0.52	0.51	0.70	0.59	0.44	0.87
011	0.98	0.73	0.67	0.62	0.68	0.92	0.98	0.95
012	0.67	0.62	0.59	0.63	0.79	0.68	0.95	0.92
020	0.86	0.67	0.54	0.52	1.03	0.98	0.95	1.05
021	0.81	0.84	0.76	0.70	1.24	1.21	1.19	0.86
022	0.59	0.51	0.52	0.46	0.65	0.68	0.73	0.63
100	0.68	0.68	0.62	0.76	1.11	1.06	0.92	0.95
101	0.98	0.94	0.81	0.78	1.43	1.37	1.34	1.38
102	0.76	0.76	0.70	0.68	1.06	0.95	0.95	0.81
110	0.65	0.78	1.00	0.73	1.03	1.13	1.22	1.14
111	1.00	0.82	0.86	0.86	1.37	1.13	1.26	1.43
112	0.63	0.73	0.71	0.47	0.97	0.97	1.22	1.02
120	1.11	1.08	1.03	1.03	1.19	1.22	1.29	1.34
121	0.87	0.84	0.68	0.70	1.18	1.18	0.97	1.00
122	1.05	0.89	0.86	0.81	1.19	1.16	1.16	0.89
200	1.27	1.00	1.00	0.86	1.72	1.26	1.34	1.46
201	0.89	0.90	0.55	0.67	0.94	0.92	0.79	0.78
202	0.81	0.87	0.92	0.98	1.06	1.02	1.03	1.59
210	0.87	0.68	0.78	0.75	1.13	1.16	1.16	1.21
211	0.79	0.71	0.87	0.63	1.10	1.08	1.08	1.13
212	0.70	0.76	0.62	0.70	0.97	0.95	0.92	0.81
220	0.33	1.13	0.81	0.89	0.83	0.78	1.00	0.98
221	0.87	0.84	0.73	0.78	0.98	0.92	0.87	0.86
222	0.76	0.73	0.52	0.51	0.94	0.86	0.82	0.71
n_0	0.75	0.65	0.60	0.61	0.89	0.87	0.89	0.82
n_1	1.86	0.84	0.81	0.76	1.17	1.13	1.15	1.11
n_2	0.81	0.85	0.76	0.75	1.07	0.99	1.00	1.06

Table 8. Nitrogen per cent in leaf at the fifth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.76	0.79	0.71	0.49	1.30	1.03	1.13	1.15
001	0.54	0.47	0.47	0.44	0.73	0.60	0.65	0.59
002	0.84	0.83	0.63	0.63	1.21	1.11	0.89	0.97
010	0.36	0.57	0.67	0.31	0.70	0.49	0.47	0.65
011	0.79	0.81	0.73	0.60	1.22	0.90	1.13	1.18
012	0.98	0.75	0.86	0.73	1.32	1.08	1.34	1.21
020	0.68	0.70	0.57	0.63	1.13	1.08	1.03	0.98
021	0.97	0.83	0.75	0.70	1.38	1.21	1.24	1.21
022	0.68	0.49	0.46	0.35	0.57	0.62	0.55	0.62
100	0.54	0.54	0.38	0.35	0.68	0.67	0.59	0.59
101	0.71	0.86	0.87	0.79	1.29	1.30	1.30	1.29
102	0.78	0.89	0.84	0.81	1.30	1.37	1.27	1.18
110	0.52	0.44	0.49	0.46	0.63	0.44	0.68	0.65
111	0.81	0.89	0.71	0.73	1.18	1.10	1.05	1.34
112	0.91	0.79	0.68	0.62	1.32	0.97	1.06	0.43
120	0.79	0.87	0.65	0.71	1.16	1.10	1.05	0.87
121	0.60	0.41	0.39	0.31	0.49	0.67	0.59	0.52
122	0.73	0.73	0.84	0.68	1.11	1.06	1.19	1.19
200	0.83	0.91	0.75	0.84	1.32	1.18	0.91	1.11
201	0.76	0.94	0.78	0.71	1.53	1.26	1.29	1.18
202	0.51	0.41	0.39	0.43	0.76	0.68	0.60	0.55
210	0.49	0.65	0.49	0.41	0.68	0.91	0.63	0.68
211	0.67	0.43	0.43	0.39	0.76	0.63	0.62	0.55
212	0.52	0.51	0.49	0.36	0.67	0.67	0.63	0.62
220	0.55	0.51	0.46	0.44	0.84	0.75	0.68	0.57
221	0.47	0.54	0.43	0.36	0.71	0.78	0.60	0.89
222	0.59	0.55	0.41	0.41	0.81	0.78	0.71	0.59
n_0	0.73	0.69	0.65	0.54	1.06	0.90	0.94	0.95
n_1	0.71	0.71	0.65	0.61	1.02	0.96	0.98	0.90
n_2	0.60	0.61	0.51	0.48	0.90	0.85	0.74	0.75

Table 9. Nitrogen per cent in leaf at the sixth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.52	0.49	0.39	0.47	0.57	0.63	0.62	0.54
001	0.44	0.41	0.30	0.30	0.70	0.60	0.51	0.39
002	0.44	0.44	0.38	0.47	0.63	0.71	0.54	0.41
010	0.41	0.41	0.38	0.28	0.65	0.46	0.51	0.44
011	0.39	0.41	0.33	0.36	0.60	0.62	0.67	0.49
012	0.39	0.43	0.38	0.22	0.67	0.73	0.51	0.46
020	0.46	0.51	0.39	0.35	0.62	0.75	0.62	0.44
021	0.46	0.35	0.46	0.31	0.55	0.51	0.54	0.62
022	0.36	0.35	0.30	0.31	0.63	0.57	0.43	0.49
100	0.35	0.38	0.35	0.23	0.51	0.62	0.46	0.54
101	0.51	0.49	0.39	0.35	0.75	0.83	0.62	0.63
102	0.44	0.38	0.51	0.43	0.63	0.65	0.67	0.57
110	0.41	0.41	0.44	0.31	0.71	0.44	0.62	0.59
111	0.63	0.46	0.44	0.43	0.75	0.81	0.78	0.63
112	0.49	0.43	0.43	0.36	0.57	0.59	0.62	0.55
120	0.44	0.39	0.38	0.44	0.71	0.70	0.78	0.55
121	0.39	0.38	0.38	0.30	0.59	0.51	0.52	0.38
122	0.41	0.44	0.36	0.30	0.60	0.65	0.52	0.63
200	0.46	0.54	0.36	0.36	0.71	0.78	0.55	0.63
201	0.43	0.43	0.36	0.36	0.65	0.62	0.59	0.65
202	0.46	0.38	0.43	0.41	0.71	0.49	0.55	0.46
210	0.49	0.38	0.38	0.28	0.54	0.55	0.49	0.46
211	0.41	0.33	0.30	0.11	0.36	0.41	0.35	0.46
212	0.39	0.38	0.35	0.39	0.57	0.54	0.60	0.51
220	0.30	0.38	0.39	0.43	0.49	0.60	0.49	0.51
221	0.41	0.35	0.35	0.44	0.54	0.62	0.59	0.57
222	0.44	0.39	0.36	0.41	0.62	0.60	0.51	0.59
n_0	0.43	0.42	0.37	0.34	0.62	0.62	0.55	0.48
n_1	0.45	0.42	0.41	0.35	0.65	0.64	0.62	0.56
n_2	0.42	0.40	0.36	0.35	0.58	0.58	0.52	0.54

Table 10. N, P and K per cent in sugarcane leaf with sheath at different stages of sampling

Stages of sampling	Leaf position				
	3	4	5	6	Mean
			Nitrogen		
1	1.30	1.41	1.24	..	1.31
2	1.33	1.33	1.22	1.22	1.27
3	1.24	1.25	1.17	1.10	1.19
4	0.81	0.78	0.72	0.71	0.76
5	0.68	0.67	0.60	0.54	0.62
6	0.43	0.41	0.38	0.35	0.39
			Phosphorus		
1	0.143	0.128	0.125	..	0.132
2	0.140	0.127	0.166	0.151	0.146
3	0.094	0.087	0.080	0.056	0.079
4	0.098	0.098	0.089	0.093	0.094
5	0.093	0.092	0.079	0.077	0.085
6	0.099	0.080	0.080	0.078	0.084
			Potassium		
1	1.16	0.93	0.83	..	0.97
2	1.04	1.01	0.95	0.90	0.98
3	0.78	0.66	0.52	0.33	0.57
4	0.81	0.63	0.41	0.50	0.58
5	0.73	0.63	0.57	0.49	0.61
6	0.50	0.47	0.36	0.41	0.44

.. During the first stage only three leaf positions were collected

Table 11. N, P and K per cent in sugarcane leaf without sheath at different stages of sampling.

Stages of sampling	Leaf position				
	3	4	5	6	Mean
			Nitrogen		
1	1.26	1.30	1.39	..	1.31
2	1.44	1.20	1.43	1.39	1.37
3	1.58	1.56	1.48	1.36	1.49
4	1.04	1.00	1.01	1.00	1.01
5	0.99	0.91	0.88	0.87	0.91
6	0.62	0.61	0.57	0.53	0.58
			Phosphorus		
1	0.158	0.154	0.154	..	0.155
2	0.161	0.152	0.151	0.159	0.156
3	0.129	0.115	0.113	0.088	0.111
4	0.131	0.124	0.123	0.120	0.124
5	0.123	0.119	0.115	0.120	0.119
6	0.125	0.116	0.124	0.121	0.122
			Potassium		
1	1.04	0.87	0.82	..	0.91
2	0.54	0.62	0.52	0.78	0.61
3	0.51	0.71	0.71	0.81	0.69
4	1.00	0.89	0.91	0.83	0.91
5	0.68	0.56	0.62	0.60	0.62
6	0.50	0.42	0.39	0.39	0.43

.. During the first stage only three leaf positions were collected

was noticed between the third and fourth stage of sampling which coincided with the flowering phase in which the nitrogen utilization was more.

The N content in the leaf without sheath varied from 0.53 to 1.58 per cent. The mean values of N in the first, second, third, fourth, fifth and sixth stages of sampling were 1.31, 1.37, 1.49, 1.01, 0.91 and 0.58 per cent respectively. The pattern of variation of N per cent in the leaf without sheath showed a different trend. The N content in leaf increased from the first to third stage of sampling and then decreased, which may be due to the fact that in sugarcane, the nitrogen fertilization ends by 90th day after transplanting. From fourth stage onwards, there was a steady decline in N content because of dilution effect. Shukla and Kamalabad (1990) also reported that the N content in the leaves decreased with age of crop.

The pattern of variation in the content of N with varying leaf position was different during different period of sampling. The third stage of sampling contained the maximum content of N in all the leaves. Also, the third leaf contained the maximum N content in all the stages except at the first stage of sampling. This might be due to the translocation of nitrogen at a faster rate especially during the early stages of crop growth. While a definite pattern of N distribution was lacking in leaf with sheath, the leaf without sheath revealed a clear pattern. Clements (1980) also suggested leaf without sheath for N analysis.

When the variation in the amount of N contained in the different leaves at different stages was examined, it was revealed that increasing levels of N resulted in increased content of this nutrient in leaf. Results also revealed that the second and third stages (Fig.2) showed comparatively more N in all the leaves without sheath with respect to varying levels of N. However, the third, fourth and fifth leaves collected during the second stage of sampling showed an increasing content of N with progressive increase in the levels of N supplied. In cashew, similar observations have been reported by Ghosh and Bose (1986).

2.2. **Phosphorus**

Data on the percentage of P in leaf with and without sheath during different stages of sampling as influenced by varying levels of the nutrient applied in the soil are presented in Tables 12 - 17 and the mean values in Tables 10 and 11.

The content of P in leaves with sheath varied from 0.056 to 0.166 per cent, during different stages of sampling. The

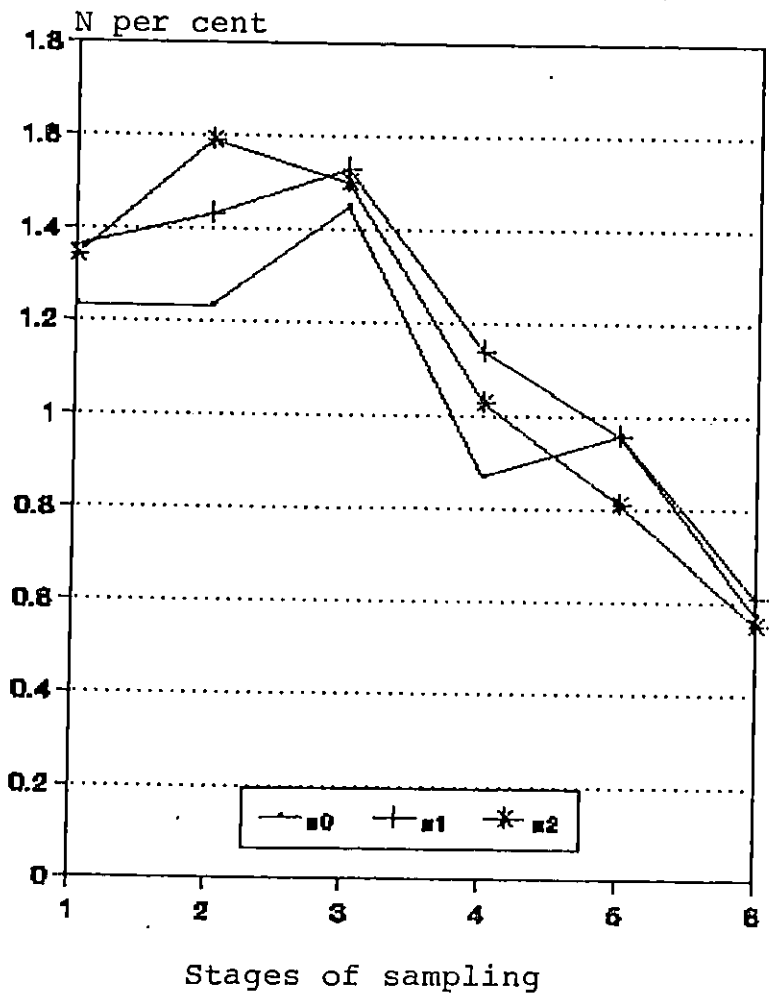

Fig.2 Relationship between stages of sampling and nitrogen per cent in leaves without sheath

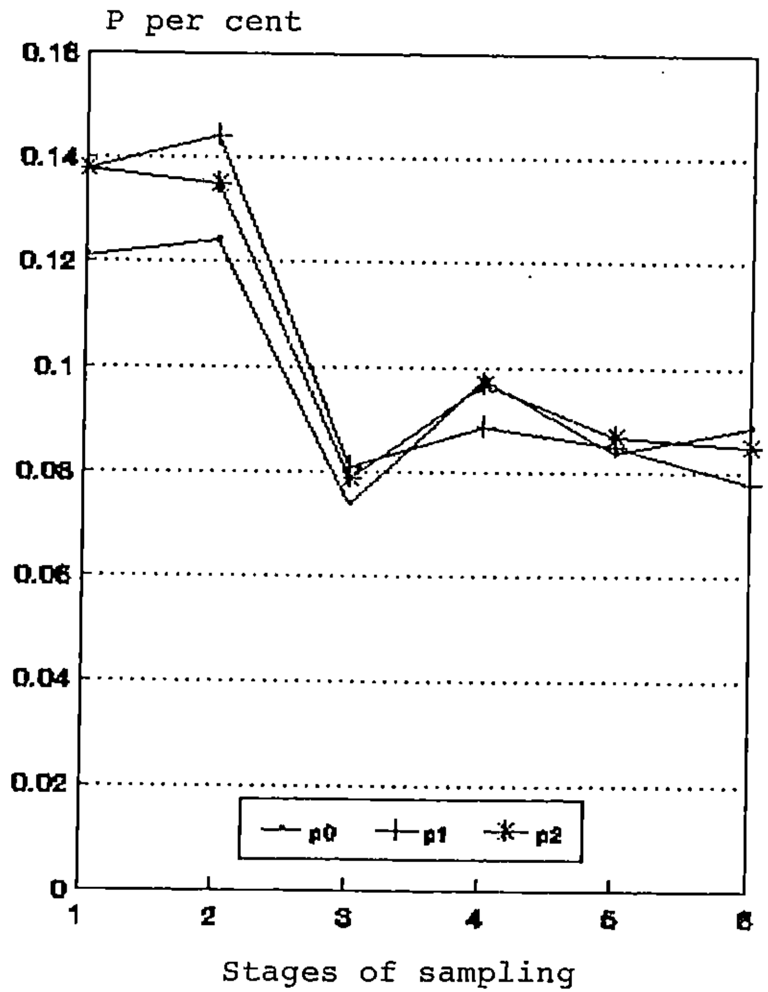

Fig.3 Relationship between stages of sampling and phosphorus per cent in leaves with sheath

Table 12. Phosphorus per cent in leaf at the first stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath			Leaf position without sheath		
	3	4	5	3	4	5
000	0.103	0.142	0.110	0.177	0.142	0.142
001	0.115	0.115	0.108	0.140	0.138	0.165
002	0.140	0.103	0.085	0.094	0.121	0.204
010	0.110	0.115	0.110	0.163	0.124	0.154
011	0.149	0.094	0.177	0.177	0.142	0.133
012	0.188	0.165	0.165	0.195	0.174	0.181
020	0.172	0.131	0.161	0.184	0.294	0.174
021	0.112	0.154	0.108	0.131	0.186	0.177
022	0.128	0.128	0.128	0.179	0.195	0.161
100	0.121	0.089	0.101	0.131	0.105	0.112
101	0.115	0.108	0.085	0.094	0.115	0.105
102	0.147	0.154	0.117	0.154	0.167	0.161
110	0.135	0.105	0.115	0.133	0.115	0.142
111	0.119	0.112	0.094	0.147	0.135	0.144
112	0.142	0.147	0.133	0.163	0.144	0.151
120	0.167	0.128	0.119	0.170	0.151	0.133
121	0.142	0.103	0.110	0.179	0.135	0.172
122	0.119	0.096	0.096	0.147	0.119	0.115
200	0.170	0.140	0.105	0.158	0.177	0.186
201	0.126	0.128	0.128	0.163	0.149	0.167
202	0.193	0.128	0.105	0.131	0.117	0.108
210	0.154	0.138	0.140	0.165	0.158	0.156
211	0.126	0.144	0.128	0.172	0.163	0.181
212	0.197	0.161	0.181	0.186	0.170	0.174
220	0.165	0.126	0.151	0.186	0.167	0.177
221	0.147	0.151	0.158	0.165	0.179	0.149
222	0.177	0.177	0.165	0.186	0.200	0.151
P_0	0.137	0.123	0.105	0.138	0.137	0.150
P_1	0.147	0.131	0.138	0.167	0.147	0.157
P_2	0.147	0.133	0.133	0.170	0.181	0.157

Table 13. Phosphorus per cent in leaf at the second stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.126	0.142	0.133	0.126	0.149	0.151	0.156	0.163
001	0.105	0.089	0.075	0.078	0.119	0.110	0.115	0.115
002	0.131	0.149	0.144	0.128	0.119	0.138	0.149	0.207
010	0.126	0.105	0.105	0.989	0.110	0.115	0.128	0.124
011	0.156	0.149	0.121	0.126	0.161	0.105	0.138	0.170
012	0.117	0.103	0.112	0.101	0.117	0.119	0.101	0.117
020	0.098	0.078	0.085	0.092	0.128	0.121	0.126	0.119
021	0.220	0.186	0.195	0.144	0.227	0.195	0.223	0.193
022	0.163	0.161	0.151	0.172	0.354	0.310	0.262	0.262
100	0.117	0.103	0.078	0.098	0.135	0.112	0.119	0.117
101	0.119	0.069	0.069	0.078	0.133	0.101	0.135	0.131
102	0.211	0.202	0.177	0.144	0.253	0.253	0.234	0.227
110	0.098	0.094	0.073	0.096	0.117	0.105	0.108	0.110
111	0.110	0.121	0.121	0.094	0.133	0.131	0.138	0.131
112	0.211	0.197	0.167	0.179	0.202	0.200	0.174	0.181
120	0.126	0.090	0.096	0.098	0.131	0.128	0.121	0.124
121	0.096	0.121	0.078	0.101	0.124	0.121	0.128	0.131
122	0.223	0.234	0.232	0.195	0.299	0.257	0.253	0.312
200	0.165	0.154	0.142	0.147	0.165	0.154	0.151	0.163
201	0.142	0.151	0.174	0.144	0.209	0.234	0.181	0.184
202	0.103	0.073	0.071	0.115	0.124	0.078	0.078	0.119
210	0.138	0.119	0.108	0.144	0.151	0.147	0.158	0.151
211	0.092	0.085	0.073	0.108	0.133	0.128	0.144	0.147
212	0.128	0.121	0.119	0.101	0.161	0.135	0.140	0.154
220	0.147	0.089	0.089	0.082	0.197	0.138	0.131	0.133
221	0.213	0.186	0.167	0.138	0.225	0.243	0.223	0.230
222	0.108	0.075	0.062	0.075	0.117	0.094	0.085	0.101
P_0	0.135	0.126	0.118	0.118	0.157	0.148	0.146	0.158
P_1	0.131	0.122	0.111	0.215	0.143	0.132	0.137	0.143
P_2	0.154	0.136	0.128	0.122	0.200	0.179	0.172	0.178

Table 14. Phosphorus per cent in leaf at the third stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.096	0.103	0.087	0.034	0.144	0.128	0.110	0.096
001	0.089	0.078	0.055	0.032	0.124	0.096	0.121	0.098
002	0.124	0.080	0.069	0.078	0.147	0.128	0.142	0.121
010	0.094	0.089	0.069	0.080	0.117	0.101	0.133	0.085
011	0.110	0.089	0.096	0.050	0.147	0.101	0.128	0.027
012	0.085	0.075	0.055	0.040	0.105	0.101	0.128	0.115
020	0.089	0.073	0.066	0.025	0.112	0.108	0.092	0.041
021	0.064	0.087	0.092	0.071	0.121	0.138	0.110	0.082
022	0.085	0.087	0.071	0.073	0.117	0.115	0.115	0.094
100	0.105	0.115	0.085	0.096	0.135	0.131	0.115	0.124
101	0.080	0.078	0.059	0.039	0.142	0.138	0.128	0.092
102	0.096	0.066	0.046	0.059	0.121	0.117	0.115	0.089
110	0.085	0.096	0.062	0.034	0.115	0.117	0.105	0.087
111	0.089	0.071	0.055	0.055	0.108	0.092	0.080	0.064
112	0.115	0.101	0.096	0.069	0.133	0.110	0.103	0.069
120	0.092	0.096	0.071	0.052	0.128	0.119	0.092	0.087
121	0.098	0.094	0.094	0.054	0.112	0.105	0.101	0.105
122	0.105	0.078	0.041	0.023	0.105	0.094	0.105	0.064
200	0.112	0.078	0.071	0.039	0.108	0.103	0.098	0.080
201	0.071	0.085	0.069	0.032	0.115	0.119	0.124	0.117
202	0.089	0.069	0.082	0.039	0.119	0.078	0.101	0.046
210	0.115	0.096	0.015	0.073	0.131	0.138	0.131	0.115
211	0.085	0.101	0.087	0.071	0.151	0.138	0.128	0.036
212	0.089	0.082	0.087	0.069	0.112	0.115	0.098	0.103
220	0.094	0.101	0.087	0.103	0.140	0.124	0.103	0.166
221	0.078	0.085	0.082	0.078	0.138	0.144	0.119	0.082
222	0.115	0.112	0.078	0.064	0.138	0.128	0.149	0.101
P_0	0.096	0.084	0.069	0.049	0.128	0.115	0.117	0.096
P_1	0.096	0.089	0.079	0.060	0.124	0.113	0.115	0.078
P_2	0.091	0.090	0.076	0.060	0.123	0.119	0.110	0.091

Table 15. Phosphorus per cent in leaf at the fourth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.124	0.121	0.128	0.170	0.163	0.128	0.121	0.156
001	0.073	0.092	0.078	0.112	0.121	0.108	0.112	0.087
002	0.144	0.133	0.112	0.108	0.188	0.156	0.126	0.121
010	0.110	0.096	0.085	0.069	0.112	0.101	0.128	0.110
011	0.124	0.119	0.119	0.089	0.156	0.135	0.140	0.147
012	0.119	0.135	0.096	0.103	0.158	0.156	0.149	0.128
020	0.154	0.115	0.115	0.115	0.170	0.181	0.167	0.200
021	0.133	0.144	0.108	0.098	0.193	0.174	0.158	0.140
022	0.082	0.092	0.087	0.082	0.098	0.110	0.124	0.098
100	0.064	0.059	0.069	0.142	0.138	0.115	0.096	0.110
101	0.108	0.103	0.103	0.089	0.112	0.124	0.158	0.163
102	0.101	0.094	0.080	0.085	0.115	0.101	0.101	0.087
110	0.087	0.078	0.087	0.066	0.103	0.103	0.105	0.105
111	0.126	0.124	0.124	0.131	0.177	0.151	0.158	0.154
112	0.085	0.069	0.069	0.080	0.105	0.089	0.103	0.101
120	0.165	0.184	0.124	0.119	0.179	0.179	0.172	0.170
121	0.059	0.062	0.066	0.059	0.101	0.094	0.092	0.087
122	0.124	0.131	0.108	0.119	0.154	0.151	0.142	0.149
200	0.105	0.108	0.089	0.096	0.174	0.161	0.154	0.154
201	0.110	0.110	0.089	0.101	0.131	0.144	0.140	0.115
202	0.057	0.073	0.055	0.073	0.075	0.089	0.078	0.092
210	0.071	0.059	0.071	0.075	0.115	0.103	0.098	0.096
211	0.069	0.059	0.050	0.062	0.098	0.112	0.103	0.121
212	0.071	0.073	0.087	0.069	0.112	0.105	0.119	0.096
220	0.073	0.078	0.080	0.075	0.119	0.096	0.105	0.108
221	0.059	0.082	0.052	0.069	0.096	0.105	0.087	0.082
222	0.073	0.075	0.073	0.064	0.096	0.103	0.082	0.087
P_0	0.098	0.099	0.089	0.108	0.135	0.125	0.089	0.108
P_1	0.096	0.090	0.088	0.083	0.126	0.117	0.123	0.118
P_2	0.102	0.107	0.090	0.089	0.134	0.133	0.125	0.125

Table 16. Phosphorus per cent in leaf at the fifth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.087	0.138	0.082	0.050	0.133	0.138	0.103	0.108
001	0.057	0.066	0.059	0.071	0.112	0.117	0.119	0.133
002	0.101	0.078	0.073	0.071	0.108	0.119	0.110	0.105
010	0.092	0.078	0.069	0.069	0.140	0.124	0.119	0.119
011	0.087	0.089	0.089	0.078	0.131	0.105	0.089	0.098
012	0.128	0.087	0.094	0.096	0.161	0.126	0.131	0.119
020	0.078	0.078	0.062	0.080	0.112	0.110	0.115	0.103
021	0.119	0.098	0.089	0.101	0.133	0.138	0.147	0.144
022	0.092	0.080	0.080	0.073	0.131	0.112	0.110	0.089
100	0.094	0.110	0.075	0.069	0.154	0.135	0.112	0.124
101	0.087	0.087	0.087	0.075	0.115	0.119	0.119	0.138
102	0.078	0.087	0.080	0.075	0.115	0.119	0.115	0.133
110	0.098	0.126	0.089	0.082	0.138	0.140	0.133	0.126
111	0.103	0.108	0.085	0.073	0.133	0.128	0.115	0.119
112	0.096	0.071	0.062	0.055	0.096	0.080	0.089	0.101
120	0.105	0.110	0.087	0.103	0.154	0.131	0.147	0.128
121	0.124	0.096	0.096	0.078	0.131	0.110	0.115	0.131
122	0.085	0.075	0.073	0.071	0.115	0.128	0.119	0.133
200	0.110	0.096	0.096	0.094	0.124	0.115	0.108	0.138
201	0.092	0.082	0.078	0.071	0.124	0.126	0.108	0.101
202	0.075	0.138	0.087	0.094	0.119	0.142	0.124	0.138
210	0.103	0.085	0.064	0.062	0.110	0.103	0.098	0.103
211	0.087	0.092	0.082	0.078	0.115	0.112	0.112	0.119
212	0.078	0.085	0.094	0.073	0.119	0.105	0.126	0.124
220	0.101	0.089	0.075	0.089	0.115	0.124	0.112	0.115
221	0.089	0.078	0.078	0.078	0.098	0.101	0.115	0.133
222	0.078	0.092	0.069	0.078	0.108	0.128	0.110	0.119
P_0	0.087	0.098	0.080	0.074	0.127	0.126	0.113	0.124
P_1	0.097	0.091	0.081	0.074	0.127	0.114	0.112	0.114
P_2	0.097	0.089	0.079	0.083	0.122	0.120	0.121	0.122

Table 17. Phosphorus per cent in leaf at the sixth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.204	0.069	0.080	0.121	0.110	0.124	0.131	0.115
001	0.094	0.082	0.064	0.078	0.158	0.115	0.165	0.115
002	0.101	0.124	0.087	0.096	0.147	0.115	0.115	0.115
010	0.096	0.102	0.103	0.075	0.156	0.124	0.138	0.133
011	0.105	0.085	0.085	0.073	0.133	0.119	0.138	0.124
012	0.098	0.094	0.144	0.078	0.158	0.128	0.135	0.115
020	0.115	0.112	0.103	0.098	0.147	0.140	0.133	0.115
021	0.115	0.082	0.087	0.087	0.131	0.121	0.126	0.135
022	0.098	0.082	0.057	0.078	0.193	0.110	0.147	0.121
100	0.082	0.052	0.066	0.048	0.094	0.089	0.089	0.094
101	0.119	0.085	0.085	0.110	0.151	0.147	0.151	0.138
102	0.101	0.075	0.089	0.078	0.101	0.115	0.112	0.128
110	0.101	0.055	0.069	0.059	0.138	0.124	0.121	0.131
111	0.115	0.062	0.059	0.066	0.124	0.121	0.126	0.082
112	0.098	0.080	0.080	0.069	0.115	0.101	0.105	0.126
120	0.128	0.110	0.082	0.096	0.158	0.131	0.133	0.161
121	0.087	0.087	0.087	0.064	0.119	0.115	0.119	0.128
122	0.135	0.098	0.078	0.112	0.128	0.124	0.200	0.151
200	0.085	0.082	0.071	0.110	0.131	0.115	0.112	0.181
201	0.098	0.082	0.089	0.073	0.140	0.124	0.131	0.119
202	0.110	0.089	0.080	0.080	0.124	0.120	0.119	0.119
210	0.071	0.064	0.071	0.059	0.135	0.105	0.112	0.098
211	0.057	0.046	0.064	0.046	0.094	0.094	0.064	0.089
212	0.078	0.071	0.062	0.075	0.092	0.089	0.096	0.085
220	0.059	0.052	0.082	0.066	0.112	0.105	0.115	0.110
221	0.075	0.075	0.075	0.052	0.105	0.101	0.119	0.135
222	0.073	0.073	0.071	0.062	0.119	0.115	0.108	0.101
P_0	0.110	0.082	0.079	0.088	0.128	0.119	0.125	0.125
P_1	0.091	0.073	0.082	0.067	0.127	0.112	0.115	0.109
P_2	0.098	0.086	0.080	0.079	0.135	0.118	0.132	0.128

mean values of P during the first, second, third, fourth, fifth and sixth stages of sampling were 0.132, 0.134, 0.079, 0.094, 0.085 and 0.084 per cent respectively. There was no regular pattern in the variation of P content in leaves with respect to different leaf position and stages of sampling. The maximum content of P was observed at the second stage of sampling in the fifth leaf.

The P content in leaves without sheath varied from 0.088 to 0.161 per cent. The mean values of P during the first, second, third, fourth, fifth and sixth stages of sampling were 0.155, 0.156, 0.111, 0.124, 0.119 and 0.122 per cent respectively. It was found that the mean values of P in leaves without sheath was more than that of leaves with sheath at all the stages of sampling. The mean content of P was only 1/9th of that of N. A sudden decrease in the content of P was observed between the second and third stages of sampling which may be due to more uptake of this element at the beginning of grand growth phase. Also, the P content was maximum in the third leaf in all the six stages of sampling. Desai *et al.* (1988) also observed that the P content in third leaf at grand growth phase was significantly higher.

The response to the application of increasing levels of P was more pronounced at the second stage of sampling as reflected from the nutrient content of leaves with sheath (Fig.3). When the translocation of P was considered, the third and sixth leaves were found to be satisfactory especially at a higher level of this nutrient. Also,a good plant response to the highest dose of the nutrient applied was evidenced from the leaf nutrient content. So one would think of applying a higher dose of this nutrient as most of the nutrients will not be available during the crop period because of fixation problems.

2.3. **potassium**

Data on the percentage of K in leaf with and without sheath during different stages of sampling as influenced by NPK treatments are presented in Tables 18 - 23 and the mean values in Tables 10 and 11.

The K content in leaf with sheath varied from 0.33 to 1.16 per cent. The mean values of K during the first, second, third, fourth, fifth and sixth stages of sampling were 0.97, 0.98, 0.57, 0.58, 0.61 and 0.44 per cent respectively. Dilution effect of K was not observed clearly as in the case of N which might be due to the preference of this monovalent cation by sugarcane, a perennial grass (Tisdale *et al.*, 1956). The third leaf at the first stage of sampling recorded the maximum content of K while it was lowest in the

Table 18. Potassium per cent in leaf at the first stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath			Leaf position without sheath		
	3	4	5	3	4	5
000	1.20	1.45	0.80	1.37	1.05	0.87
001	1.12	0.75	0.75	1.05	0.82	0.90
002	1.10	1.00	0.70	0.97	0.85	0.75
010	1.10	0.85	0.80	1.05	0.85	0.80
011	1.40	1.30	1.00	1.15	1.02	0.95
012	1.10	0.95	0.90	1.10	0.95	0.95
020	1.35	1.10	1.25	1.25	1.15	1.10
021	0.87	0.92	0.60	1.02	0.85	0.75
022	0.92	1.00	0.52	1.05	0.85	0.92
100	0.90	0.67	0.55	0.92	0.75	0.65
101	1.25	1.07	0.92	1.07	1.00	0.90
102	1.25	1.12	1.05	1.05	1.02	0.95
110	1.20	0.75	1.00	0.95	0.67	0.80
111	1.20	0.90	0.30	0.92	0.70	0.92
112	1.05	0.85	0.95	0.95	0.75	0.82
120	1.30	1.07	0.90	1.05	0.97	0.77
121	0.95	0.85	0.52	0.85	0.47	0.60
122	1.12	0.85	0.80	0.97	0.77	0.82
200	1.12	0.65	0.37	0.90	0.55	0.35
201	1.37	0.60	1.12	1.02	1.02	0.80
202	1.30	0.90	0.75	1.07	0.80	0.62
210	0.90	0.95	0.67	0.70	0.75	0.55
211	1.10	1.02	0.85	1.02	1.05	0.82
212	1.37	0.77	0.52	1.10	0.80	0.95
220	1.42	1.10	1.22	1.35	1.02	1.02
221	1.02	0.87	1.05	1.12	1.00	0.80
222	1.42	0.72	1.47	1.10	1.12	1.12
k_0	1.17	0.95	0.84	1.06	0.86	0.77
k_1	1.14	0.92	0.79	1.02	0.88	0.83
k_2	1.15	0.91	0.85	1.04	0.88	0.87

Table 19. Potassium per cent in leaf at the second stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	1.00	0.85	0.65	0.60	0.90	0.82	0.62	0.65
001	0.80	0.42	0.25	0.17	0.67	0.37	0.40	0.30
002	0.85	0.80	0.62	0.42	0.52	0.67	0.50	0.80
010	0.95	0.60	0.47	0.55	0.50	0.50	0.45	0.37
011	1.00	0.70	1.05	0.52	0.80	0.32	0.80	0.75
012	0.77	0.60	0.42	0.40	0.55	0.75	0.22	0.27
020	0.67	0.40	0.27	0.17	0.70	0.47	0.50	0.32
021	1.12	1.00	0.55	0.75	1.20	0.92	0.97	0.87
022	0.90	0.55	0.95	0.35	1.05	0.50	0.77	0.52
100	0.87	0.57	0.35	0.25	0.65	0.57	0.52	0.55
101	0.70	0.30	0.25	0.12	0.77	0.37	0.47	0.62
102	1.10	1.20	0.72	0.67	1.02	1.02	0.87	0.80
110	0.75	0.60	0.70	0.40	0.60	0.52	0.30	0.30
111	0.50	0.52	0.45	0.15	0.67	0.45	0.40	0.37
112	1.00	0.70	0.85	1.00	0.90	0.87	0.65	0.97
120	0.47	0.25	0.17	0.17	0.52	0.30	0.35	0.27
121	0.35	0.50	0.40	0.32	0.50	0.25	0.32	0.40
122	0.92	0.77	0.67	0.70	0.97	0.87	0.62	0.65
200	1.00	0.90	0.62	0.65	0.95	0.70	0.52	0.75
201	0.95	0.95	0.80	0.65	1.00	0.80	0.75	0.82
202	0.52	0.30	0.17	0.40	0.60	0.40	0.17	0.60
210	1.02	0.25	0.15	0.25	0.75	0.45	0.30	0.60
211	0.65	0.45	0.25	0.25	0.72	0.75	0.47	0.45
212	0.85	0.50	0.45	0.20	0.75	0.70	0.35	0.35
220	0.55	0.35	0.25	0.17	0.75	0.52	0.37	0.32
221	0.92	0.62	0.47	0.45	1.20	0.75	0.92	0.42
222	0.75	1.27	0.57	0.40	0.75	1.05	0.50	0.45
k_0	0.81	0.53	0.40	0.36	0.70	0.54	0.44	0.46
k_1	0.78	0.61	0.50	0.38	0.84	0.55	0.61	0.56
k_2	0.85	0.74	0.60	0.50	0.79	0.76	0.52	0.60

Table 20. Potassium per cent in leaf at the third stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.85	0.77	0.52	0.05	0.82	0.82	0.75	0.52
001	0.80	0.65	0.50	0.05	0.87	0.72	0.75	0.50
002	0.95	0.70	0.50	0.55	0.95	0.90	0.90	0.67
010	0.87	0.77	0.62	0.60	0.90	0.62	1.05	0.60
011	0.82	0.77	0.70	0.30	0.80	0.62	0.75	0.05
012	0.80	0.65	0.50	0.35	0.85	0.95	1.00	0.82
020	0.75	0.65	0.40	0.07	0.75	0.67	0.50	0.05
021	0.75	0.67	0.60	0.35	0.90	0.92	0.85	0.65
022	0.77	0.72	0.55	0.57	0.90	0.95	0.82	0.55
100	0.87	0.85	0.70	0.75	0.87	0.57	0.82	0.70
101	0.70	0.52	0.42	0.25	0.97	0.85	0.92	0.72
102	0.95	0.52	0.35	0.20	0.65	0.80	0.65	0.47
110	0.82	0.72	0.55	0.42	0.85	0.52	0.80	0.65
111	0.77	1.02	0.67	0.52	0.90	0.87	0.85	0.72
112	0.80	0.82	0.57	0.52	0.77	0.85	0.72	0.55
120	0.60	0.60	0.32	0.15	0.72	0.67	0.60	0.40
121	0.87	0.65	0.65	0.30	0.77	0.45	0.62	0.45
122	0.87	0.65	0.32	0.10	0.65	0.52	0.70	0.50
200	0.60	0.55	0.50	0.17	0.65	0.70	0.65	0.40
201	0.72	0.62	0.45	0.10	0.75	0.80	0.65	0.60
202	0.72	0.62	0.57	0.12	0.77	0.85	0.62	0.10
210	0.65	0.60	0.45	0.25	0.75	0.70	0.62	0.50
211	0.80	0.57	0.45	0.15	0.67	0.30	0.60	0.20
212	0.70	0.55	0.67	0.35	0.72	0.52	0.52	0.70
220	0.62	0.50	0.40	0.75	0.75	0.35	0.42	0.15
221	0.80	0.70	0.60	0.47	0.90	0.92	0.95	0.67
222	0.90	0.35	0.60	0.50	0.97	0.67	0.10	0.80
k_0	0.74	0.67	0.50	0.36	0.78	0.62	0.69	0.44
k_1	0.78	0.69	0.56	0.28	0.84	0.72	0.77	0.51
k_2	0.83	0.62	0.51	0.36	0.80	0.78	0.67	0.57

Table 21. Potassium per cent in leaf at the fourth stage of sampling as influenced by the NPK treatments

Treatment NPK	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	1.45	1.40	1.35	1.27	1.22	1.10	1.20	1.02
001	1.07	0.97	0.97	0.92	0.92	0.75	0.92	0.62
002	1.12	1.07	0.95	0.92	1.07	1.00	1.02	1.05
010	1.05	0.97	1.00	0.82	1.00	0.90	0.87	0.95
011	1.02	1.12	1.07	0.97	1.12	1.02	0.95	0.82
012	1.07	1.12	0.95	1.00	1.10	1.02	1.00	0.92
020	1.37	1.37	1.25	1.15	1.15	0.97	1.10	1.17
021	1.10	1.17	1.10	0.92	1.15	0.97	0.95	0.80
022	1.10	1.02	0.90	0.97	0.90	0.72	1.00	0.85
100	1.07	1.02	0.92	0.95	0.97	0.87	0.87	0.55
101	1.15	1.12	0.95	0.72	1.12	1.02	0.95	0.95
102	1.15	1.02	1.00	1.00	0.97	0.90	0.97	0.62
110	0.82	1.12	0.97	1.10	1.00	0.80	0.95	0.87
111	1.22	1.05	1.15	1.07	1.22	0.95	1.05	1.00
112	1.22	1.07	1.02	0.95	1.00	0.95	1.02	1.02
120	1.05	0.97	0.95	0.82	1.00	0.85	0.90	0.95
121	0.97	1.00	0.95	0.85	1.00	0.85	0.97	0.90
122	1.35	1.32	1.25	1.12	1.20	1.15	1.10	1.10
200	0.80	0.87	0.60	0.65	0.77	0.97	0.82	0.72
201	1.02	1.07	1.00	0.90	1.00	0.95	0.97	0.95
202	0.85	0.90	0.82	0.60	0.77	0.80	0.55	0.60
210	0.77	0.57	0.60	0.72	0.75	0.42	0.77	0.62
211	0.80	0.80	0.72	0.70	0.70	0.75	0.62	0.65
212	0.90	0.90	0.92	0.92	1.05	0.75	0.77	0.55
220	0.67	0.65	0.57	0.60	0.57	0.47	0.55	0.52
221	1.10	1.02	1.05	1.02	1.00	1.00	0.65	0.65
222	0.75	0.62	0.72	0.77	1.15	1.07	1.02	0.90
k_0	1.01	0.99	0.91	0.90	0.94	0.82	0.89	0.82
k_1	1.05	1.04	1.00	0.90	1.03	0.92	0.89	0.82
k_2	1.06	1.00	0.95	0.92	1.02	0.93	0.93	0.85

Table 22. Potassium per cent in leaf at the fifth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.85	0.80	0.70	0.60	0.80	0.75	0.75	0.72
001	0.65	0.72	0.60	0.55	0.65	0.65	0.70	0.62
002	0.87	0.85	0.67	0.65	0.75	0.62	0.65	0.62
010	0.90	0.70	0.62	0.57	0.70	0.55	0.62	0.62
011	0.87	0.82	0.77	0.60	0.85	0.75	0.65	0.70
012	0.95	0.75	0.90	0.72	0.85	0.82	0.75	0.77
020	0.85	0.80	0.72	0.67	0.80	0.72	0.75	0.70
021	0.75	0.70	0.77	0.67	0.65	0.60	0.62	0.65
022	1.02	0.80	0.80	0.70	0.80	0.60	0.70	0.62
100	0.50	0.47	0.27	0.35	0.70	0.35	0.57	0.55
101	0.50	0.45	0.35	0.32	0.62	0.55	0.70	0.60
102	0.80	0.75	0.75	0.55	0.72	0.60	0.75	0.75
110	0.80	0.45	0.60	0.45	0.57	0.27	0.50	0.50
111	0.75	0.72	0.57	0.55	0.75	0.55	0.75	0.70
112	0.72	0.72	0.60	0.55	0.77	0.72	0.70	0.75
120	0.65	0.72	0.52	0.50	0.60	0.40	0.47	0.40
121	0.75	0.50	0.45	0.27	0.60	0.32	0.55	0.67
122	0.92	0.90	0.75	0.67	0.75	0.60	0.77	0.67
200	0.52	0.30	0.25	0.25	0.47	0.30	0.42	0.32
201	0.95	0.77	0.77	0.57	0.70	0.60	0.70	0.60
202	0.75	0.70	0.67	0.55	0.72	0.60	0.65	0.80
210	0.27	0.40	0.25	0.15	0.57	0.45	0.42	0.22
211	0.57	0.30	0.42	0.45	0.45	0.35	0.42	0.32
212	0.75	0.55	0.57	0.37	0.60	0.60	0.50	0.62
220	0.45	0.30	0.27	0.20	0.55	0.42	0.40	0.40
221	0.67	0.50	0.32	0.27	0.50	0.55	0.55	0.55
222	0.55	0.45	0.47	0.55	0.80	0.75	0.70	0.65
k_0	0.64	0.55	0.47	0.42	0.64	0.47	0.54	0.49
k_1	0.72	0.61	0.56	0.47	0.64	0.55	0.63	0.60
k_2	0.81	0.72	0.69	0.59	0.75	0.66	0.69	0.69

Table 23. Potassium per cent in leaf at the sixth stage of sampling as influenced by the NPK treatments

Treatment NPK notation	Leaf position with sheath				Leaf position without sheath			
	3	4	5	6	3	4	5	6
000	0.55	0.42	0.65	0.42	0.70	0.57	0.50	0.50
001	0.75	0.65	0.62	0.60	0.62	0.55	0.52	0.50
002	0.65	0.52	0.50	0.55	0.55	0.42	0.52	0.45
010	0.52	0.47	0.47	0.52	0.77	0.70	0.65	0.60
011	0.60	0.60	0.60	0.47	0.57	0.52	0.45	0.47
012	0.75	0.55	0.62	0.62	0.57	0.50	0.47	0.42
020	0.72	0.57	0.52	0.55	0.65	0.42	0.55	0.50
021	0.60	0.55	0.35	0.27	0.45	0.32	0.35	0.20
022	0.57	0.50	0.50	0.47	0.65	0.60	0.52	0.55
100	0.45	0.37	0.37	0.20	0.20	0.25	0.15	0.32
101	0.37	0.45	0.27	0.17	0.57	0.25	0.40	0.35
102	0.57	0.75	0.50	0.45	0.65	0.60	0.52	0.57
110	0.37	0.50	0.62	0.20	0.57	0.62	0.32	0.40
111	0.40	0.60	0.57	0.10	0.55	0.32	0.25	0.45
112	0.47	0.65	0.22	0.42	0.52	0.47	0.47	0.50
120	0.35	0.40	0.40	0.25	0.57	0.20	0.30	0.35
121	0.45	0.50	0.47	0.40	0.67	0.52	0.45	0.32
122	0.62	0.50	0.40	0.40	0.55	0.45	0.40	0.40
200	0.20	0.20	0.10	0.12	0.30	0.40	0.12	0.20
201	0.42	0.35	0.32	0.40	0.55	0.40	0.50	0.40
202	0.50	0.30	0.37	0.37	0.62	0.52	0.55	0.47
210	0.30	0.22	0.07	0.15	0.22	0.17	0.22	0.10
211	0.65	0.35	0.30	0.20	0.25	0.32	0.35	0.12
212	0.42	0.47	0.35	0.50	0.35	0.32	0.27	0.30
220	0.57	0.47	0.35	0.37	0.20	0.22	0.25	0.15
221	0.40	0.37	0.30	0.15	0.30	0.27	0.22	0.35
222	0.37	0.35	0.25	0.30	0.45	0.42	0.30	0.32
k_0	0.45	0.40	0.39	0.31	0.46	0.39	0.34	0.35
k_1	0.52	0.49	0.42	0.31	0.50	0.39	0.39	0.37
k_2	0.55	0.51	0.41	0.45	0.55	0.48	0.45	0.44

sixth leaf at the final stage of sampling. The maximum content of K was observed in the third leaf at all the stages, confirms the fact that K is more associated with meristematic and newly formed tissues, as well as the actively growing nature of this leaf position in comparison with other leaves. Also the fourth and fifth leaves with sheath collected at the second stage of sampling showed more K content as well as more response to the increasing levels of K applied. However, the response to the application of increased K level was more pronounced at the fourth stage of sampling (Fig.4).

The K content in leaf without sheath varied from 0.39 to 1.04 per cent. The mean values of K during the first, second, third, fourth, fifth and sixth stages of sampling were 0.91, 0.61, 0.69, 0.91, 0.62 and 0.63 per cent respectively. The irregular distribution of K in the first six months might be due to an improper uptake pattern due to external factors of environment like flooding, unfavourable soil conditions etc. However, all the leaves without sheath at the fourth stage of sampling showed more content, as well as more response to increased levels of K applied (Fig.5).

3. RELATIONSHIP BETWEEN LEAF NUTRIENT LEVELS AND YIELD

As yield is a complex factor being influenced by many factors including leaf nutrient levels, it is more

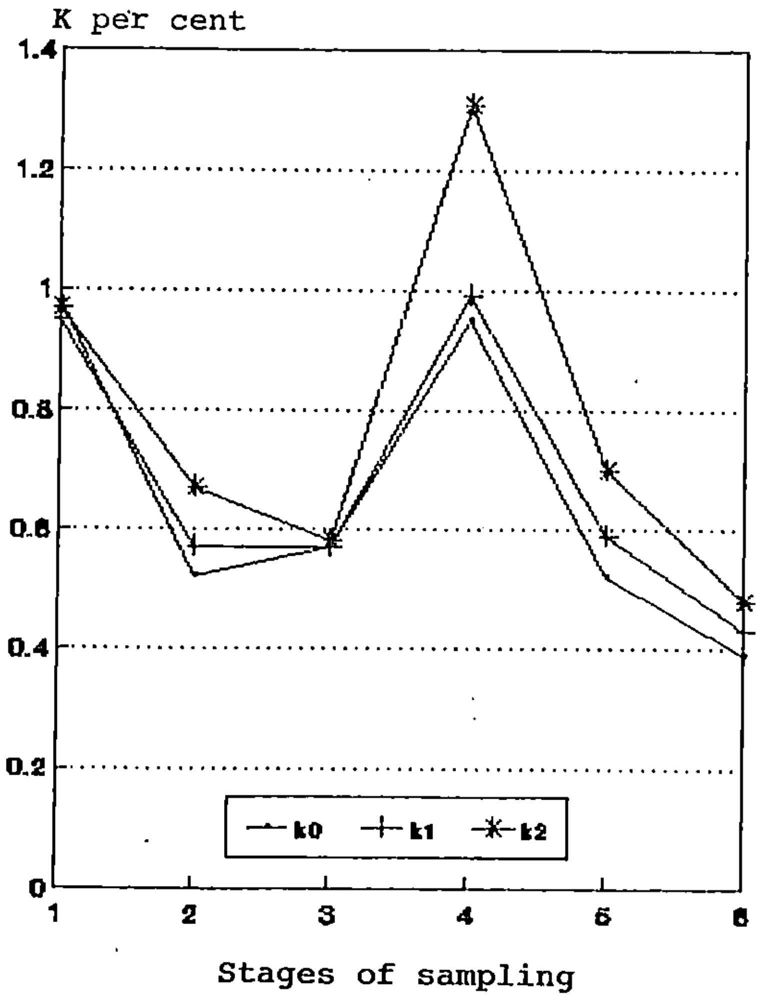

Fig.4 Relationship between stages of sampling and potassium per cent in leaves with sheath

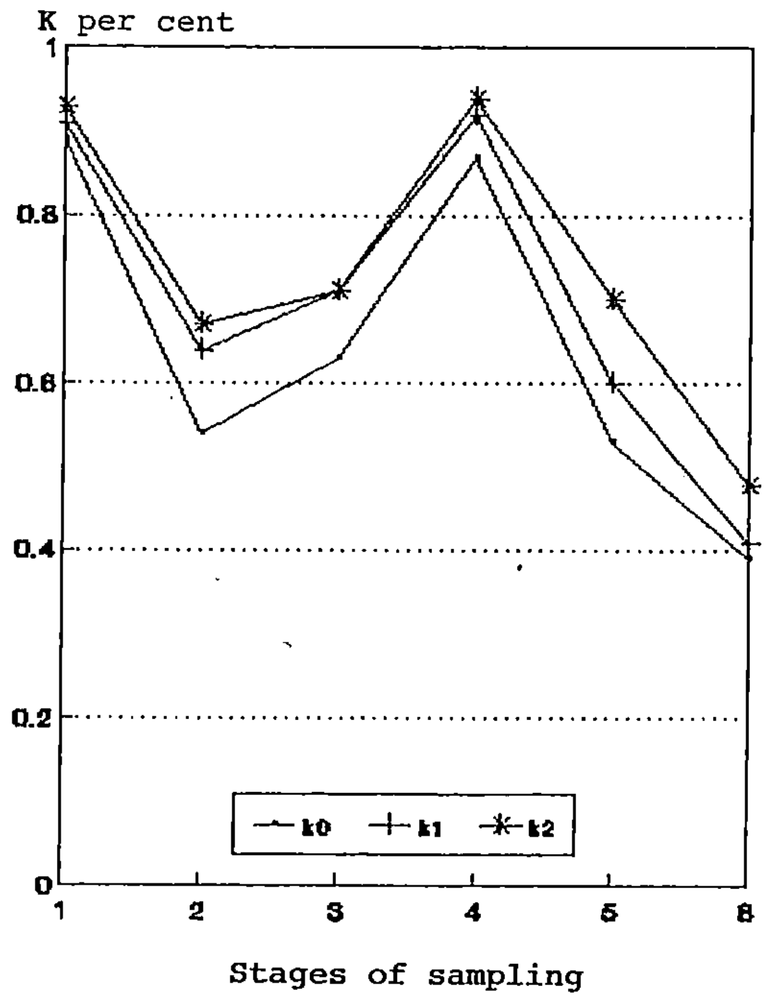

Fig.5 Relationship between Stages of sampling and potassium per cent in leaves without sheath

meaningful to find out the influence of these independent variables on yield. Path analysis has been employed in this context. It provides not only a precise estimation of direct effects of NPK at different leaf positions with and without sheath on yield, but also their indirect effects through each of the other component. The yield is also limited by various soil characteristics, climatic conditions and crop growth which are accounted as residual effect.

3.1.First stage of sampling

Path analysis showing the influence of NPK content in different leaf positions on cane yield revealed a high residual effect of 0.6110 for leaves with sheath and 0.8039 in case of leaves without sheath.

The residual effect of two path analysis indicated that the extent of role played by the NPK content in different leaf positions on yield was low. Alternatively, these observations clearly suggested the slight influence of other limiting nutrient elements at this stage of sampling . Path coefficients also revealed the very little direct effect of various leaf nutrient contents on yield, which again indirectly suggested the role to be played by other limiting nutrient elements at this stage, so as to get a clear picture of direct and indirect effects of yield contributing variables towards yield.

3.2. Second stage of sampling

Table 24 and 25 show the direct and indirect effects of NPK content in different leaves with sheath (with a residual of 0.2288) and without sheath (with a residual of 0.2924) respectively on cane yield. As there is a drastic reduction in the residual effect as compared to the previous stage of sampling, it may be concluded that the NPK content in different leaf positions at this stage influenced the yield to a greater extent.

3.2.1. *Nitrogen*

Path coefficients revealed that the N level in the fifth leaf with sheath had a very high and positive direct effect on the yield of sugarcane followed by that in the sixth leaf. This might be attributed to the low content of this nutrient in these leaf positions . The negative direct effect of N-3 and N-4 suggested the possibility of more N content in the third and fourth leaves, so that any increase in the N level of these leaf positions would decrease the yield of sugarcane. Clements (1980) reported a high concentration of N in the third leaf and Lakshmikantham (1973) reported a high content of N in the fourth leaf. Experiments revealed the several limitations of leaf positions, as crop logging was more widely used under different ecological conditions. This was particularly true

Table 24. Path analysis showing direct and indirect effects of NPK in different leaves positions with sheath on yield of sugarcane at the second stage of sampling

	Nutrient content at different leaf positions											
	N-3	P-3	K-3	N-4	P-4	K-4	N-5	P-5	K-5	N-6	P-6	K-6
N-3	-0.0663	-0.0087	0.0163	-0.0666	-0.0119	-0.0257	0.3000	-0.0438	0.0129	0.0989	0.0116	-0.0065
P-3	-0.0020	-0.2854	-0.1839	0.1290	0.3104	0.1203	-0.0746	0.5320	-0.4050	-0.0499	-0.0198	0.0945
K-3	0.0038	-0.1858	-0.2825	0.0301	0.2199	0.1532	-0.0328	0.3857	-0.4708	0.0020	-0.0635	0.0892
N-4	-0.0086	0.0721	0.0166	-0.5110	-0.0733	-0.0174	0.4936	-0.1357	0.2343	0.1692	-0.0087	-0.0052
P-4	0.0023	-0.2558	-0.1793	0.1081	0.3463	0.1416	-0.1291	0.5767	-0.5406	-0.0411	-0.0163	0.1015
K-4	0.0063	-0.1271	-0.1603	0.0329	0.1817	0.2700	0.0101	0.3070	-0.5376	0.0694	-0.0111	0.0908
N-5	-0.0266	0.0285	0.0124	-0.3373	-0.0598	0.0036	0.7478	-0.1408	0.0004	0.1121	-0.0027	-0.0064
P-5	0.0048	-0.2501	-0.1794	0.1142	0.3289	0.1365	-0.1734	0.6072	-0.4830	-0.0469	-0.0250	0.0966
K-5	0.0010	-0.1383	-0.1591	0.1432	0.2240	0.1737	-0.0004	0.3509	-0.8357	-0.0283	-0.0217	0.0905
N-6	-0.0183	0.0397	-0.0015	-0.2408	-0.0396	0.0522	0.2336	-0.0794	0.0658	0.3589	0.0312	0.0097
P-6	0.0030	-0.0222	-0.0705	-0.0174	0.0221	0.1118	0.0079	0.0596	-0.0714	-0.0439	-0.2546	0.0353
K-6	0.0032	-0.2003	-0.1871	0.0196	0.2609	0.1820	-0.0358	0.4352	-0.5616	0.0260	-0.0668	0.1347

residual = 0.2288

Underlined figure are direct effects

Table 25. Path analysis showing direct and indirect effects of NPK in different leaves positions without sheath on yield of sugarcane at the second stage of sampling

	Nutrient content at different leaf positions											
	N-3	P-3	K-3	N-4	P-4	K-4	N-5	P-5	K-5	N-6	P-6	K-6
N-3	0.5749	0.0621	-0.0033	-0.2227	-0.0920	-0.0099	0.1462	0.1225	0.0286	0.1467	-0.2124	0.0068
P-3	-0.0530	-0.6735	0.3191	-0.0961	0.5554	-0.0148	-0.0204	-0.6249	-0.0756	-0.0111	0.8144	-0.0587
K-3	-0.0046	-0.5252	0.4092	-0.0775	0.4612	-0.0229	0.0308	-0.5496	-0.0954	-0.0060	0.6421	-0.0810
N-4	0.2863	-0.1448	0.0710	-0.4471	0.1421	-0.0077	0.1607	-0.1348	-0.0095	0.0857	0.2060	-0.0095
P-4	-0.0887	-0.6274	0.3166	-0.1066	0.5962	-0.1085	-0.0095	-0.6478	-0.0798	-0.0164	0.8246	-0.0614
K-4	0.1403	-0.2458	0.2309	-0.0845	0.2722	-0.0406	0.0878	-0.2828	-0.0557	0.0252	0.3867	-0.0672
N-5	0.2769	0.0456	0.0416	-0.2366	-0.0186	-0.0117	0.3036	0.0250	-0.0059	0.1152	-0.0032	-0.0474
P-5	-0.1028	-0.6146	0.3285	-0.0880	0.5640	-0.0168	-0.0111	-0.6848	-0.0875	-0.0231	0.8661	-0.0711
K-5	-0.1451	-0.4494	0.3443	-0.0373	0.4195	-0.0199	0.0158	-0.5284	-0.1134	-0.0668	0.6250	-0.0899
N-6	0.3709	0.0330	-0.0108	-0.1684	-0.0429	-0.0045	0.1357	0.0695	0.0333	0.2275	-0.1109	0.0229
P-6	-0.1304	-0.5856	0.2805	-0.0983	0.5248	-0.0168	-0.0010	-0.6331	-0.0756	-0.0269	0.9367	-0.0769
K-6	-0.0258	-0.2611	0.2190	-0.0281	0.2418	-0.0180	0.0950	-0.3217	-0.0673	-0.0344	0.4757	-0.1514

residual = 0.2924

Underlined figure are direct effects

in case of leaf N as shown by various field and greenhouse experiments (Humbert, 1963). The indirect effect of this element in the fifth and sixth leaf positions through the content in the fourth leaf was also comparatively high and negative. However, the indirect effect of N in the fourth leaf through fifth and sixth leaves was high and positive. This again indicated the deficient amount of N in the fourth leaf to exert its influence on cane yield.

Path coefficients of N content in different leaf positions without sheath on yield revealed the high and positive direct effect of third leaf on yield. This is because, as the residual effect was comparatively high, the limiting factors of growth other than N might kept the level of leaf N below optimum, which is in agreement with the findings of Prevot and Ollagnier (1961). Also, the N content in this leaf exhibited a significant correlation with the yield of sugarcane (Fig. 6). The N content in the fourth leaf exhibited a high and negative direct effect on yield. The indirect effect of all other leaf positions through N-4 was also negative which revealed the high level of this nutrient present in this leaf position. The N content in the fifth and sixth leaves without sheath had a positive direct effect on the yield of sugarcane and the indirect effects of all other leaf positions through N-5 and N-6 were positive.

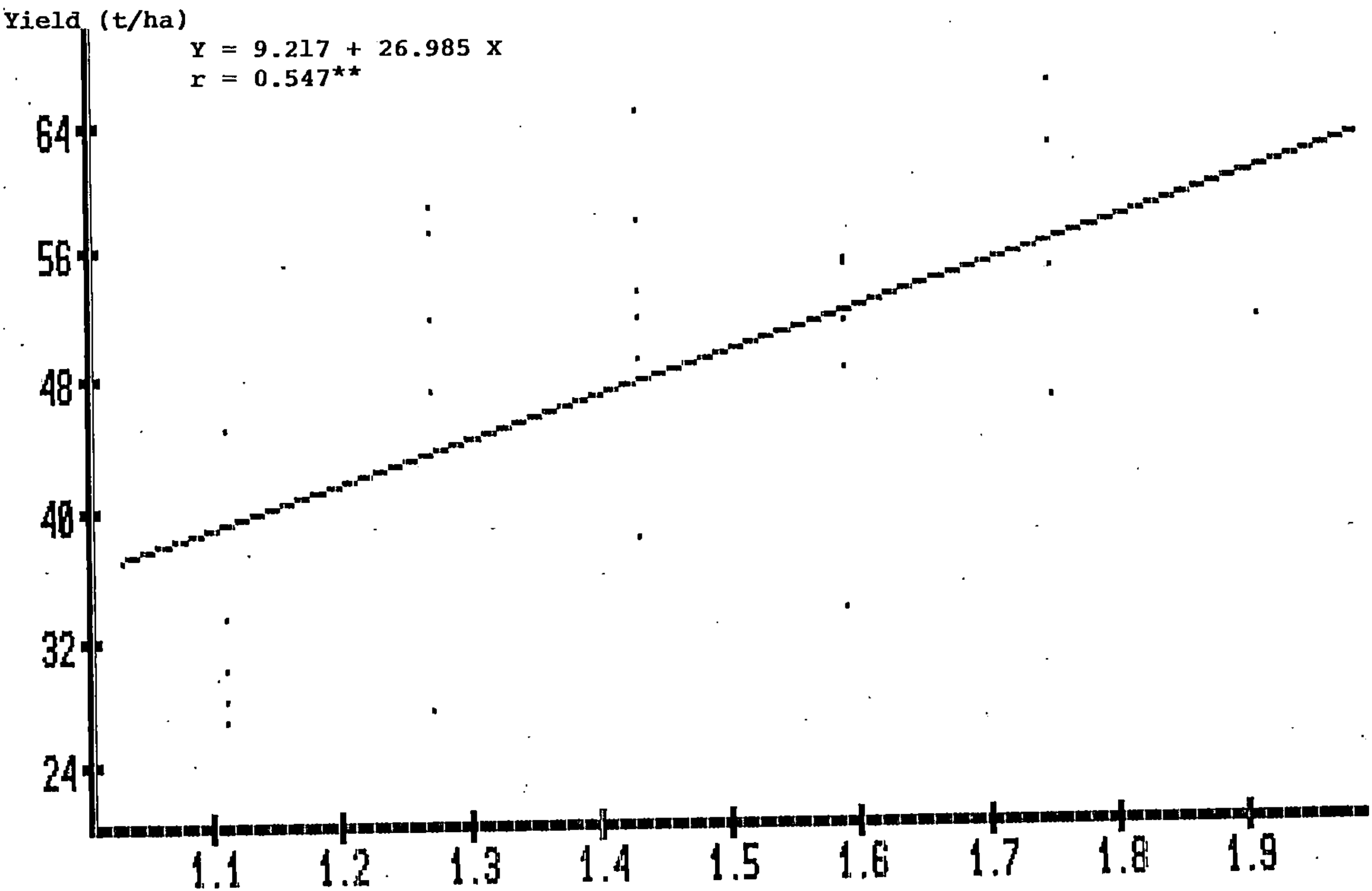

Fig.6 Relationship between N per cent in the third leaf without sheath at the second stage of sampling and mean yield

This might be due to the lower content of this nutrient in these leaf positions, as the experimental area was irrigated and located in a hot and sunny place, where increased rate of growth resulted in lower N level through out the year (Humbert, 1963).

3.2.2. *Phosphorus*

Phosphorus is required for various metabolic activities in plant, of which photosynthesis is important, especially in early growth period. Path coefficients of P content in leaf with sheath on yield revealed that the maximum positive direct effect on yield was through the fifth leaf followed by that of fourth leaf. This might be due to the lower content of this nutrient in these leaf positions. The negative direct effect of P-3 and P-6 might be attributed to the higher photosynthetic rate which was due to a higher content of P present in these leaf positions. The results are in conformity with the findings of H.S.P.A., (Humbert, 1963). The indirect effect of N content in all the leaf position through P-4 and P-5 showed the antagonistic effect of these two nutrients i.e., absorption of phosphorus by sugarcane influenced the nitrogen uptake inversely. This is in conformity with the findings of Gupta *et al.* (1969). Also, increase in the level of leaf K resulted in increased content of P in the fifth leaf as revealed from the direct and indirect effect of P-5 and K-5 which showed the synergistic effect of these two nutrients.

Path coefficients of P content in leaves without sheath revealed the high and positive direct effect of fourth and sixth leaves on yield, whereas the third and fifth leaves has a high and negative direct effect on the yield of sugarcane. From the above data, it may be concluded that the nutrient failed to show a clear uptake pattern with respect to different leaf positions. The response to the phosphate application has been variable due to several factors. Soil contain widely varying quantities of total phosphorus, and show even wider variations in available phosphorus. Also, the lack of response to the applications of phosphate are often related to the soil's ability to fix large quantities so that it is not available to the plant. The indirect influence of P and K contents in all other leaf positions through P-4 and P-6 were also high and positive indicating the synergistic effect of P and K. This could be confirmed from the negative indirect influence of all these leaf positions through K-4 and K-6.

3.2.3. *Potassium*

Path coefficients of K content in different leaf positions with sheath showed the positive direct effect of fourth and sixth leaves on yield. This might be attributed to the low content of K because of the climatic condition that was prevalent in the area at this stage of crop. During the monsoon season, the maximum and minimum temperatures was low and the relative humidity was high (Appendix I). Hence the rate of evaporation was low, which resulted in a low content of K at the stage of sampling in all the leaf position. The K level in the third and fifth leaves had negative direct effect on yield indicating the content of K in sufficient amounts, to exert the influence on yield. This might be because of more sheath moisture observed in the third and fifth leaves at this stage of sampling (Table 26) because high K level during the growing period of crop are always accompanied by high sheath moisture (Humbert, 1963).

Path coefficients of K content in leaf without sheath showed the high and positive direct effect of K-3 on the yield of sugarcane. This might be due to the low content of K in this leaf position because the content of K in different leaf position are highly variable and are generally less in leaves (Singh and Lal, 1961). The indirect influence of K-4, K-5 and K-6 through K-3 was positive which clearly revealed that if the content of K in the third leaf was increased it would result in a corresponding increase of K content in other leaf positions. However, the P content in different

Table. 26 Sheath moisture percentage of different leaf positions at various stages of sampling

Stage of sampling	Sheath moisture content in different leaf positions			
	3rd	4th	5th	6th
1	81.25	80.85	80.85	79.66
2	78.62	77.43	79.51	78.04
3	79.09	77.18	78.34	77.26
4	76.47	76.16	73.32	75.54
5	74.32	71.18	73.14	74.02
6	70.93	70.44	72.27	70.25

leaf positions through K-3 showed a positive influence, though not considerable on cane yield.

3.3. Third stage of sampling

Path analysis showing the direct and indirect effects of NPK content in different leaf positions with sheath revealed a high residual effect of 0.7908 while it was 0.2961 in case of leaves without sheath. As the contribution by the NPK content in different leaf positions with sheath on yield was very low, the NPK content in leaf without sheath alone discussed under this stage of crop growth (Table 27).

3.3.1. *Nitrogen*

Path analysis of N content in different leaf positions without sheath revealed that none of the leaf positions had high and positive direct effect on yield. This might be due to the migration of this nutrient to the younger tissues of cane stalk for reutilization. However, the fifth leaf contributed more on yield followed by fourth leaf, though their content were not as high to exert the influence on yield of cane. The sixth leaf had a negligible contribution while the third leaf contributed negatively on yield, though the influence was not high. Inspite of decreased N content, the growth was continued, as the stored N assumed great significance in sugarcane. The

Table 27. Path analysis showing direct and indirect effects of NPK in different leaves positions without sheath on yield of sugarcane at the third stage of sampling

	Nutrient content at different leaf positions											
	N-3	P-3	K-3	N-4	P-4	K-4	N-5	P-5	K-5	N-6	P-6	K-6
N-3	-0.2554	-0.0224	0.1642	0.0391	-0.0009	0.0078	0.0369	0.0374	0.1677	0.0033	-0.0379	-0.0017
P-3	0.0248	0.2310	-0.1540	0.0046	0.0104	0.0057	0.0983	-0.1117	0.0595	0.0001	-0.0070	-0.1660
K-3	0.0697	0.0592	-0.6014	-0.0252	0.0040	-0.0255	0.0681	-0.0956	-0.2385	0.0025	-0.0326	0.5733
N-4	-0.0591	0.0064	0.0897	0.1689	0.0037	0.0061	-0.0170	0.0105	0.0428	0.0086	-0.0057	-0.0522
P-4	0.0136	0.1417	-0.1427	0.0375	0.0169	0.0008	0.0215	-0.0890	0.0212	0.0015	-0.0531	0.2951
K-4	0.0362	-0.0239	-0.2803	-0.0187	-0.0002	-0.0548	0.0232	-0.0233	-0.3026	0.0015	0.0041	0.4170
N-5	-0.0261	0.0628	-0.1132	-0.0079	0.0010	-0.0035	0.3617	0.0137	-0.1204	0.0034	0.0147	-0.2166
P-5	0.0432	0.1165	-0.2596	-0.0080	0.0068	-0.0058	-0.0224	-0.2215	-0.0487	0.0010	-0.0317	0.2886
K-5	0.0650	-0.0209	-0.2176	-0.0110	-0.0005	-0.0252	0.0661	-0.0164	-0.6590	0.0034	0.0080	0.3490
N-6	-0.0456	0.0016	-0.0794	0.0780	0.0014	-0.0045	0.0667	-0.0113	-0.1199	0.0187	-0.0478	0.2434
P-6	-0.0629	0.0105	-0.1272	0.0062	0.0058	0.0014	-0.0346	-0.0456	0.0343	0.0058	-0.1540	0.4610
K-6	0.0004	-0.0368	-0.3322	-0.0085	0.0048	-0.0219	-0.0752	-0.0614	-0.2208	0.0044	-0.0682	1.0416

residual = 0.2961

Underlined figure are direct effects

indirect influence of P and K content of different leaf positions through N content in all the leaf positions were negligible.

3.3.2. *Phosphorus*

Like N, phosphorus content of leaves in different leaf positions failed to show any significant influence on the yield of sugarcane, as revealed from the path coefficients. This might be due to decreased translocation of this nutrient to the stalk and aerial parts as a result of water stagnation that prevailed in the experimental area at this stage of crop growth. The direct effect of P-3 and P-4 was positive but low, while the fifth and sixth leaves contributed negatively an yield. So, it is not meaningful to consider the nitrogen and phosphorus content of different leaves for the final yield prediction.

3.3.3. *Potassium*

Path coefficients of K in different leaf positions showed the high and positive influence of K-6 as well as the high and negative influence of K-3 and k-5 on yield. The negative direct effect of K-3 suggested the possibility of this nutrient in a higher level at the third leaf. Innes and Chinloy(1951) also found a highly significant relationship between yield response to potassium fertilization and K level in the third leaf. The high and positive effect of K level in the sixth leaf suggested the deficiency of this element in this leaf position which might be due to the leaching loss of K from this leaf position, as heavy rainfall was observed during this month of sampling. The indirect influence of N and P content in different leaf positions through K-6 was low, showing no influence with this nutrient. Also, the direct effect of K level in the fourth leaf on yield was negative but not high.

3.4. **Fourth stage of sampling**

Table 28 and 29 show the direct and indirect effects of NPK content in different leaf positions with sheath (with a residual effect of 0.3005) and with out sheath (with a residual effect of 0.3305) respectively on cane yield.

3.4.1. *Nitrogen*

Path coefficients of N content in different leaf positions with sheath on yield revealed that only N-3 and N-4 had a high and positive direct effect on the yield of sugarcane. This might be due to the utilization of N from these leaf positions for the initiation of floral primordia, which is the first phase of arrowing (flowering). Also, the indirect effect of N content in the fifth and sixth leaves through fourth leaf was also high and positive, which further

Table 28. Path analysis showing direct and indirect effects of NPK in different leaves positions with sheath on yield of sugarcane at the fourth stage of sampling

	Nutrient content at different leaf positions											
	N-3	P-3	K-3	N-4	P-4	K-4	N-5	P-5	K-5	N-6	P-6	K-6
N-3	0.3049	0.1840	0.0206	0.3423	-0.2030	-0.2410	0.0004	-0.2004	0.1050	-0.0526	0.0207	0.0185
P-3	0.1325	0.4233	0.0531	0.1136	-0.4026	-0.5851	0.0001	-0.4609	0.3115	0.0067	0.0393	0.1500
K-3	0.0658	0.2358	0.0952	-0.1830	-0.2125	-0.8772	-0.0002	-0.2888	0.5360	0.0294	0.0478	0.2937
N-4	0.1275	0.0588	-0.0213	0.8186	-0.1124	0.1195	0.0006	-0.0712	-0.1244	-0.0978	0.0012	-0.1310
P-4	0.1396	0.3842	0.0456	0.2075	-0.4435	-0.5143	0.0002	-0.4299	0.2776	-0.0325	0.0388	0.1205
K-4	0.0727	0.2449	0.0826	-0.0967	-0.2255	-1.0114	-0.0001	-0.3039	0.5399	0.0215	0.0413	0.2995
N-5	0.1437	0.0393	-0.0236	0.5642	-0.0714	0.0959	0.0009	-0.0294	-0.1264	-0.0960	-0.0030	-0.1014
P-5	0.1179	0.3765	0.0531	0.1125	-0.3680	-0.5933	0.0001	-0.5182	0.3368	-0.0110	0.0465	0.1856
K-5	0.0540	0.2224	0.0861	-0.1718	-0.2077	-0.9209	-0.0002	-0.2943	0.5929	0.0274	0.0400	0.3275
N-6	0.1230	0.0217	-0.0215	0.6137	-0.1107	0.1664	0.0007	-0.0438	-0.1244	-0.1304	0.0122	-0.1277
P-6	0.0894	0.2350	0.0644	0.0135	-0.2437	-0.5910	0.0001	-0.3405	0.3351	-0.0225	0.0707	0.2066
K-6	0.0149	0.1673	0.0737	-0.2825	-0.1408	-0.7979	-0.0003	-0.2533	0.5115	0.0438	0.0385	0.3797

residual = 0.3005

Underlined figure are direct effects

Table 29. Path analysis showing direct and indirect effects of NPK in different leaves positions without sheath on yield of sugarcane at the fourth stage of sampling

	Nutrient content at different leaf positions											
	N-3	P-3	K-3	N-4	P-4	K-4	N-5	P-5	K-5	N-6	P-6	K-6
N-3	0.9445	-0.1824	0.0427	-0.2948	0.2161	-0.0832	0.4600	-0.1360	-0.0325	-0.3880	-0.0741	0.0520
P-3	0.3315	-0.5198	0.3445	-0.1023	0.5275	-0.1556	0.2208	-0.3548	-0.4717	-0.0628	-0.1302	0.2295
K-3	0.0520	-0.2309	0.7756	-0.0392	0.2583	-0.3115	0.0045	-0.1966	-0.7845	0.1370	-0.0722	0.3633
N-4	0.8246	-0.1574	0.0900	-0.3377	0.1952	-0.0595	0.5163	-0.1124	0.0551	-0.3849	-0.0719	0.0760
P-4	0.3477	-0.4670	0.3412	-0.1123	0.5871	-0.1767	0.2227	-0.3995	-0.4278	-0.1100	-0.1447	0.2720
K-4	0.1990	-0.2049	0.6121	-0.0509	0.2628	-0.3947	0.0367	-0.1636	-0.6008	0.0536	-0.0732	0.3342
N-5	0.7157	-0.1891	0.0058	-0.2872	0.2154	-0.0239	0.6071	-0.1483	-0.0107	-0.4270	-0.0755	0.0727
P-5	0.2797	-0.4015	0.3319	-0.0826	0.5105	-0.1405	0.1959	-0.4595	-0.4386	-0.1205	-0.1510	0.2860
K-5	0.0318	-0.2538	0.6298	-0.0193	0.2600	-0.2455	0.0067	-0.2086	-0.9660	0.1871	-0.0762	0.4237
N-6	0.6162	-0.0549	-0.1786	-0.2186	0.1086	0.0356	0.4359	-0.0951	0.3040	-0.5948	-0.0616	0.0138
P-6	0.3961	-0.3831	0.3167	-0.1375	0.4806	-0.1634	0.2595	-0.3926	-0.4168	-0.2074	-0.1767	0.3055
K-6	0.0932	-0.2264	0.5345	-0.0487	0.3030	-0.2503	0.0838	-0.2493	-0.7763	-0.0155	-0.1024	0.5271

residual = 0.3305

Underlined figure are direct effects

indicated the insufficiency of this nutrient in the fourth leaf. However, the direct effects of N-5 and N-6 were not high to influence the yield of cane.

Path coefficients of N level in the third and fifth leaves without sheath showed a high and positive direct effect on cane yield. The indirect effect of each of these two characters through the other was also positive. This suggested that the vegetative growth was still in progress and the nutrient content in these leaf positions was utilized for the dry matter production. However, the P and K content in different leaf positions had no influence on the N content in the third and fifth leaf. Thus, N-4 and N-6 influenced the yield much more when compared to the other leaf positions at this stage of crop growth. This observation indicated the continued uptake of N and their storage in leaves where they form a part of chlorophyll molecule and combines with carbohydrates to form proteins (Kakde, 1985).

3.4.2 *Phosphorus*

Path analysis of P level at different leaf positions with sheath showed that the high and positive direct effect of P-3 was nullified by P-4. The P content at the fifth leaf showed a high negative direct effect an yield while the direct effect of P-6 on yield was negligible. As the stage was set for flowering, all the nutrients including phosphorus might have been utilized for the floral initiation, which was the first phase among the chain of physiological process that was leading to flowering. Thus the high and positive direct effect of third leaf with sheath and fourth leaf without sheath might be due to the utilization of this nutrient from these leaf positions for flowering. The third and fifth leaves without sheath also showed a high and negative direct effect which might be due to increased rate of photosynthesis. The phosphorus content of all other leaf positions both with and without sheath failed to show any influence on the yield of sugarcane.

3.4.3. *Potassium*

Path coefficients of K content in different leaf positions showed that the level of K in the fourth leaf with sheath and fifth leaf without sheath showed a high and negative direct effect which might be due to the significant increase in the leaf sheath K levels in these leaf positions because of high soil moisture observed in the experimental area at this period (Richards and Wadleigh 1952). The high and positive direct effect of third and sixth leaves without sheath and the fifth leaf with sheath suggested the possibility of K utilization from this leaf positions for the initiation of reproductive growth (flowering phase). Humbert and Silva (1954) also reported a significant drop in leaf sheath K levels prior to the emergence of tassels. The high and positive direct effect of K in the fifth and sixth leaves with sheath might be due to improper translocation of this nutrient in these leaf positions because of an internal shift in water balance, and subsequent redistribution of K in the leaves of the plant. The direct effect of K in the third leaf with sheath was positive but not high enough to exhibit the influence on yield. Also, the P content in all the leaf positions showed a negative indirect effect through K in the fourth leaf with sheath while N failed to show any considerable effect through this leaf position.

3.5. Fifth stage of sampling

Path analysis showing the influence of NPK content in different leaf positions on cane yield revealed a high residual effect of 0.6709 for leaves with sheath and 0.5290 for leaves without sheath. As the extent of role played by the nutrient contents in different leaf positions on cane yield was low, their influence was not presented.

3.6. Sixth stage of sampling

Path analysis showing the direct and indirect effects of NPK content in different leaf positions with sheath revealed a high residual effect of 0.4496 while it was 0.2299 in case of leaves without sheath. As the extent of role played by limiting nutrients other than NPK content in case of leaves with sheath on yield was more, the influence of nutrient content in leaves without sheath on yield (Table 30) alone is discussed at this maturity stage of the crop.

As the crop was ready for harvest, all the nutrients might have been exhausted and utilised by the crop for the sugar production. Hence , possibility of existing high influence through NPK content in different leaf positions on yield was minimum. However, the N content in the fourth and fifth leaves showed a high and negative influence on cane yield indicating the sufficiency of this nutrient in these leaf positions. This might be due to the continued absorption of this nutrient by the crop. Ayres(1952) reported that the nitrogen uptake leveled off only at about 12 months of crop age. The direct and indirect influence of other leaf positions through N-3 was high and positive indicating the possible deficiency in the third leaf. P content in the third and fourth leaves showed a high and negative indirect effect on yield which revealed that any increase in the

Table 30. Path analysis showing direct and indirect effects of NPK in different leaves positions **without sheath** on yield of sugarcane at the sixth stage of sampling

	Nutrient content at different leaf positions											
	N-3	P-3	K-3	N-4	P-4	K-4	N-5	P-5	K-5	N-6	P-6	K-6
N-3	0.5462	-0.3651	0.2930	0.0697	-0.2212	-0.2465	-0.2072	0.0156	0.0423	0.0966	0.0101	-0.0610
P-3	0.3104	-0.6423	0.2635	-0.0315	-0.1930	-0.2448	-0.0073	0.0183	0.0868	-0.0815	0.0089	-0.0537
K-3	0.3143	-0.3324	0.5091	-0.0103	-0.2165	-0.6374	-0.1297	0.0166	0.1663	-0.0834	0.0062	-0.1396
N-4	0.2701	-0.1436	0.0374	-0.1410	-0.1488	0.2406	-0.1794	0.0096	-0.0291	0.1492	0.0058	-0.0080
P-4	0.3698	-0.3794	0.3374	-0.0642	-0.3267	-0.1935	-0.1592	0.0189	0.0872	0.0758	0.0115	-0.0519
K-4	0.1588	-0.1855	0.3828	0.0400	-0.0746	-0.8478	0.0176	0.0090	0.1436	-0.1206	0.0042	-0.1314
N-5	0.3111	-0.0129	0.1815	-0.0695	-0.1429	0.0410	-0.3639	0.0060	-0.0026	0.1742	0.0056	-0.0426
P-5	0.2812	-0.3879	0.2799	-0.0446	-0.2042	-0.2512	-0.0720	0.0303	0.0762	0.0517	0.0114	-0.0569
K-5	0.1154	-0.2787	0.4232	0.0205	-0.1424	-0.6084	0.0047	0.0115	0.2001	-0.1996	0.0009	-0.1361
N-6	0.1156	0.1147	-0.0931	-0.0461	-0.0543	0.2241	-0.1390	0.0034	-0.0875	0.4563	0.0075	0.0359
P-6	0.2143	-0.2210	0.1232	-0.0318	-0.1457	-0.1377	-0.0796	0.0134	0.0068	0.1328	0.0258	-0.0023
K-6	0.1911	-0.1979	0.4079	-0.0065	-0.0974	-0.6396	-0.0891	0.0099	0.1563	-0.0939	0.0003	-0.1742

residual = 0.2299

Underlined figures are direct effects

level of P at this stage would decrease the yield. Other leaf positions failed to show any influence on cane yield. The K content in the fourth and sixth leaves showed a high and negative influence on yield which might be due to a better K – H_2O relationship in these leaves. However, the K content in the third and fifth leaves showed a high and positive influence on yield which might be due to the deficiency of this nutrient because of its utilization in the sugar production and other cane juice quality parameters. In general, the indirect influence of N, P and K content in the third leaf through each other was synergistic as revealed from the negative direct and indirect effect of P as well as positive direct and indirect effects of N and P in the third leaf.

4. PREDICTION OF YIELD BASED ON LEAF NUTRIENT LEVELS

Since the foliar diagnosis technique can be best utilized to predict yield based on the nutrient levels of leaf, attempts were made to formulate prediction equation, considering the nutrient status of different leaf positions. The nutrient ratios were not taken into consideration in formulating yield prediction models, as high fluctuation was observed during the different stages, which other wise should remain constant through out the crop period. This was in conformity with the findings of

Perumal (1983) who reported that the absolute values of nutrients should be given priority as they were reliable than nutrient ratios in predicting cane yield. The residual, direct and indirect effects of NPK content in different leaf positions on yield as estimated using path analysis was taken up for formulating yield prediction equation using multiple regression (step-down) model. Stepwise regression analysis was done separately for each stage, between yield and NPK content of leaves with sheath as well as without sheath. The highest R^2 value was observed in the second stage of sampling ($R^2 = 0.7279$). The maximum prediction was observed with the model as follows:

$$Y = 30.63-12.529\ X_1 + 23.515\ X_2 - 16.098\ X_3 + 19.840\ X_4 + 159.049\ X_5 - 25.907\ X_6 + 12.603\ X_7 - 22.943\ X_8$$

Where : Y is the yield of sugarcane

X_1 is the nitrogen per cent in the fourth leaf with sheath at the second stage of sampling.

X_2, X_3, X_4 are the nitrogen per cent in the third, fourth and fifth leaves without sheath respectively at the second stage of sampling.

X_5 is the phosphorus per cent in the fifth leaf with sheath at the second stage of sampling and

X_6, X_7, X_8 are the potassium per cent in the third, fourth and fifth leaves with sheath respectively at the second stage of sampling.

The F value of the above model was significant at 1 per cent level. This means the yield can be predicted with a precision of 73 per cent at the second stage of sampling.

From the above result, it can be concluded that for yield prediction models, the fourth leaf with sheath and the third, fourth and fifth leaves without sheath can be taken as index leaves for N. For P estimation, the fifth leaf with sheath and for K estimation the third, fourth and fifth leaves with sheath can be taken as index leaves. This is also in conformity with the present criteria of selecting third, fourth, fifth and sixth leaves with sheath for P and K and the above leaves without sheath for N analysis (Clements, 1980).

5. INFLUENCE OF NPK ON NUTRIENT UPTAKE OF SUGARCANE

The nurient content and uptake of major nutrients in different aerial parts of sugarcane at harvest stage with respect to different NPK treatments was furnished in Tables 31a and 31b respectively. The simple correlation coefficients between nutrient uptake of N, P and K at harvest and nutrient content of leaves with

Table 31a. NPK content in different aerial parts of sugarcane at harvest stage as influenced by NPK treatments

Sl. No.	NPK Treatment notation	Nutrient content (per cent)								
		Green tops			Trash			Stalk		
		N	P	K	N	P	K	N	P	K
1	000	0.56	0.117	0.56	0.194	0.012	0.184	0.192	0.108	0.147
2	001	0.48	0.113	0.62	0.189	0.010	0.202	0.196	0.113	0.162
3	002	0.52	0.113	0.58	0.198	0.014	0.200	0.194	0.110	0.154
4	010	0.41	0.115	0.56	0.192	0.018	0.188	0.200	0.102	0.142
5	011	0.49	0.102	0.54	0.194	0.010	0.196	0.188	0.108	0.174
6	012	0.48	0.113	0.59	0.198	0.018	0.188	0.196	0.121	0.168
7	020	0.49	0.126	0.52	0.201	0.026	0.184	0.184	0.118	0.149
8	021	0.45	0.113	0.41	0.194	0.018	0.202	0.196	0.127	0.154
9	022	0.42	0.111	0.57	0.189	0.022	0.205	0.206	0.136	0.168
10	100	0.44	0.073	0.32	0.204	0.008	0.196	0.200	0.113	0.151
11	101	0.47	0.110	0.38	0.198	0.012	0.192	0.246	0.118	0.158
12	102	0.52	0.101	0.61	0.208	0.012	0.202	0.224	0.108	0.164
13	110	0.47	0.104	0.43	0.216	0.018	0.184	0.206	0.110	0.141
14	111	0.59	0.094	0.42	0.208	0.018	0.196	0.276	0.112	0.146
15	112	0.52	0.097	0.48	0.198	0.012	0.224	0.198	0.124	0.151
16	120	0.55	0.124	0.35	0.204	0.030	0.188	0.208	0.116	0.136
17	121	0.45	0.101	0.49	0.212	0.022	0.192	0.194	0.128	0.142
18	122	0.49	0.128	0.54	0.194	0.018	0.202	0.192	0.124	0.149
19	200	0.55	0.110	0.21	0.208	0.018	0.184	0.239	0.098	0.158
20	201	0.52	0.107	0.43	0.214	0.014	0.196	0.225	0.108	0.144
21	202	0.51	0.105	0.52	0.210	0.018	0.232	0.216	0.116	0.148
22	210	0.46	0.089	0.19	0.194	0.024	0.174	0.201	0.112	0.121
23	211	0.36	0.073	0.36	0.204	0.012	0.188	0.212	0.124	0.138
24	212	0.48	0.084	0.42	0.212	0.018	0.216	0.254	0.110	0.146
25	220	0.45	0.096	0.31	0.208	0.024	0.180	0.246	0.134	0.130
26	221	0.49	0.102	0.36	0.218	0.022	0.192	0.239	0.128	0.142
27	222	0.53	0.098	0.39	0.224	0.021	0.228	0.259	0.118	0.158

Table 31b. Nutrient uptake of different aerial parts of sugarcane at harvest stage as influenced by NPK treatments

Sl. No.	NPK Treatment notation	Nutrient uptake (kg/ha)											
		Green tops			Trash			Stalk			Total		
		N	P	K	N	P	K	N	P	K	N	P	K
1	000	22.38	4.69	22.38	7.34	0.454	6.95	21.04	11.84	16.11	50.76	16.98	45.45
2	001	15.26	3.59	19.71	5.83	0.308	6.22	33.91	19.55	28.03	55.00	23.45	53.96
3	002	29.75	6.47	33.18	4.28	0.303	4.32	32.98	18.70	26.18	67.01	25.47	63.68
4	010	19.17	5.37	26.18	3.45	0.323	3.37	30.36	15.48	21.56	52.98	21.17	51.12
5	011	6.84	1.42	7.53	2.77	0.143	2.80	19.82	11.38	18.34	29.43	12.94	28.67
6	012	19.50	4.60	23.98	8.55	0.776	8.12	26.46	16.34	22.68	54.51	21.71	54.78
7	020	13.62	3.50	19.39	4.18	0.540	3.82	30.39	19.68	24.85	48.49	23.72	48.06
8	021	21.96	4.87	17.62	7.10	0.659	7.40	29.32	19.00	23.04	57.48	24.53	48.06
9	022	16.58	4.38	22.50	4.50	0.524	4.88	33.25	21.95	27.12	54.33	26.85	54.50
10	100	20.48	3.40	14.97	8.00	0.314	7.69	34.28	19.37	25.88	62.76	23.08	48.46
11	101	21.25	4.99	17.18	5.82	0.329	5.26	49.15	23.58	31.57	75.82	28.89	54.01
12	102	28.34	5.50	33.24	4.51	0.261	4.39	43.94	21.19	32.17	76.79	26.95	69.80
13	110	23.41	5.17	21.41	7.70	0.640	6.55	38.93	20.79	27.65	70.04	26.60	54.61
14	111	17.35	2.75	12.34	5.54	0.479	5.21	53.54	21.73	28.32	76.43	24.96	45.87
15	112	45.67	8.71	43.08	9.41	0.570	10.65	35.56	22.27	27.12	91.64	31.55	80.85
16	120	36.48	8.21	23.30	5.48	0.806	5.05	27.08	15.10	17.71	69.04	24.12	46.06
17	121	31.91	7.16	34.38	6.20	0.643	5.61	31.74	20.94	23.23	69.86	28.74	63.60
18	122	41.11	10.73	45.30	5.07	0.471	5.28	47.69	30.80	37.01	93.87	42.00	87.59
19	200	20.38	4.06	7.78	4.49	0.388	3.97	35.23	13.56	23.29	60.10	18.01	35.04
20	201	22.94	4.71	18.97	4.10	0.269	3.76	63.14	30.30	40.41	90.18	35.28	63.14
21	202	65.99	13.59	62.28	10.20	0.873	11.25	44.37	23.83	30.40	120.56	38.29	103.93
22	210	44.53	7.85	16.16	6.91	0.855	6.20	37.61	20.99	22.68	85.11	29.69	45.62
23	211	28.95	5.87	28.95	3.27	0.193	3.02	44.94	26.29	29.26	77.16	32.35	61.23
24	212	60.71	10.61	53.12	9.85	0.836	10.03	26.52	11.48	15.24	97.08	22.93	78.39
25	220	31.66	6.75	21.81	22.42	0.259	1.94	34.29	18.68	18.12	88.37	25.69	41.87
26	221	27.23	5.66	20.00	4.37	0.441	3.85	45.41	24.32	26.98	77.01	30.42	50.83
27	222	39.31	7.25	28.93	5.54	0.519	5.65	64.39	29.35	39.28	109.24	37.12	73.86

and without sheath respectively at different leaf positions and stages of sampling has been furnished in Table 32 and 33.

5.1. **Nitrogen**

Uptake of N varied from 29.0 kg/ha in $n_0p_1k_1$ treatment to 120.56 kg/ha in $n_2p_0k_2$ treatment. The coefficients of simple correlation between N uptake and N content of leaf in relation to different leaf positions and stages of sampling showed that N content in leaf with sheath failed to give a significant positive correlation with N uptake irrespective of leaf position and stage of sampling. This might be attributed to the decreased dry matter production and low nutrient status of experimental crop. However, the third and sixth leaves without sheath had a significant and positive correlation with uptake at the second (tillering) stage of the crop, showing the sensitivity of these leaf positions to the uptake of nitrogen.

5.2. **Phosphorus**

Uptake of phosphorus ranged from 16.98 kg/ha in $n_0p_0K_0$ treatment to 42.00 kg/ha in $n_1p_2k_2$ treatment, which is in conformity with the findings of Parthasarathy *et al.* (1979). The coefficients of simple correlation between uptake of P and P content of leaf in relation to different leaf positions and stages of sampling revealed that P content in the third leaf without sheath had a significant

Table 32. Coefficients of simple correlation between nutrient uptake of sugarcane and nutrient content of leaves with sheath at different leaf positions and stages of sampling

Stages of sampling	Leaf position			
	3	4	5	6
		Nitrogen		
1	0.105	0.045	0.235	..
2	0.003	0.205	0.283	0.185
3	0.212	0.001	0.200	0.222
4	-0.058	0.372	0.243	0.302
5	-0.255	-0.222	-0.261	-0.121
6	0.073	-0.241	0.207	0.200
		Phosphorus		
1	0.052	0.100	-0.145	..
2	0.131	0.101	0.135	-0.126
3	-0.056	-0.009	-0.142	-0.082
4	-0.335	-0.280	-0.161	-0.329
5	-0.202	-0.100	-0.258	-0.044
6	-0.196	-0.039	-0.164	-0.178
		Potassium		
1	0.095	-0.291	0.065	..
2	-0.128	0.096	-0.030	0.239
3	0.261	-0.220	-0.059	-0.138
4	-0.021	-0.056	0.006	-0.121
5	0.188	0.185	0.235	0.083
6	0.065	0.014	-0.139	0.207

** - Significant at 1% level

* - Significant at 5% level

.. During the first stage only three leaf positions were collected

Table 33. Coefficients of simple correlation between nutrient uptake of sugarcane and nutrient content of leaves without sheath at different leaf positions and stages of sampling

Stages of sampling	Leaf position			
	3	4	5	6
		Nitrogen		
1	0.144	0.166	-0.065	..
2	0.529**	0.125	0.345	0.535**
3	0.128	0.003	0.076	0.089
4	0.173	0.161	0.166	0.249
5	-0.167	-0.054	-0.173	-0.325
6	-0.044	-0.187	-0.070	0.248
		Phosphorus		
1	-0.150	-0.097	-0.251	..
2	0.258	0.261	0.172	0.266
3	-0.089	0.009	0.098	-0.035
4	-0.178	-0.271	-0.379	-0.333
5	-0.450*	0.044	0.047	0.159
6	-0.130	-0.047	0.078	-0.059
		Potassium		
1	-0.128	-0.115	0.027	..
2	-0.042	0.302	-0.184	0.169
3	-0.155	0.041	-0.225	0.078
4	-0.008	0.089	-0.130	-0.024
5	0.144	0.181	0.261	0.417*
6	0.171	0.210	0.296	0.219

** - Significant at 1% level

* - Significant at 5% level

.. - During the first stage only three leaf positions were collected negative correlation with uptake at the fifth stage of sampling. Low available P content in the soil may be the reason for the nonsignificant uptake of P especially in the early stages of crop growth.

5.3. Potassium

Uptake of potassium ranged from 28.67 kg/ha in $n_0p_0k_1$ treatment to 108.93 kg/ha in $n_2p_0k_2$ treatment. Other than the sixth leaf without sheath at the fifth stage of sampling, all other leaf positions failed to show a significant correlation with the uptake of potassium at all the stages of sampling. Thus it may be concluded that the third and sixth leaf positions without sheath collected at the second stage of sampling had a high influence on the uptake of N.

6. DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM

Experimental plots with a yield of less than 60 t/ha were considered as low yielding and those above that were considered as high yielding. The mean value, coefficient of variation and variance of each of the nutrient ratios and those of the elements for both low yielding and high yielding population are given in Table 34. The variance ratio for the low yielding versus high yielding groups in the case of each of the nutrient ratios and elements are

Table 34. Sugarcane leaf norms for N, P and K

Forms of Expression	Low yielding Population Mean	CV (%)	Variance S_A	High yielding Population Mean	CV (%)	Variance S_B	Variance Ratio S_A/S_B
N	1.36	18	0.057	1.43	15	0.047	1.213
P	0.149	42	0.00396	0.158	38	0.0036	1.100
K	0.64	42	0.076	0.67	36	0.059	1.288
N/P	9.191	26	5.707	11.270	18	4.112	1.388
N/K	2.498	27	0.479	3.924	15	0.324	1.476*
K/P	4.529	35	2.449	5.105	25	1.686	1.352
P/K	0.474	37	0.032	0.366	39	0.020	1.600*
P/N	0.144	39	0.00315	0.146	32	0.00217	1.448*
K/N	0.532	38	0.042	0.485	36	0.031	1.355
NP	0.271	38	0.011	0.328	34	0.023	0.846
NK	0.842	48	0.170	0.937	39	0.139	1.223
PK	0.111	73	0.00672	0.109	62	0.00462	0.688

Ref :Walworth & Sumner (1987)

also given in Table 34. It may be noted that N/K, P/K and P/N had the highest variance ratios and hence these nutrient ratios were used for developing DRIS indices.

A major advantage of DRIS is its ability to diagnose plants sampled at various growth stages. The DRIS indices based on properly selected nutrient expressions should therefore, also show reduced dependence on plant age. Also, the position of sampled leaves on plants may also have a limited impact on diagnostic results when DRIS is used (Walworth and Sumner,1987). However, a wide variation in the DRIS indices for N, P and K was observed in this experiment with respect to different leaf positions which might be due to certain limitations observed in the experiment.

When the K content of leaf with sheath was 0.15 per cent (Table 35), a N content of 1.27 per cent was found to be in excess while a P content of 0.094 per cent was in more or less sufficient amount. But when the level of K in the leaf was 0.60 per cent, the N content of 1.59 per cent was observed to be slightly limiting and a P content of 0.126 per cent was much limiting . In other words, when the K level was increased in this leaf ,the crop needed more nitrogen and phosphorus to get a balanced nutrient system. This imbalance might have resulted in a lower yield of 33.8 t/ha. At an intermediary level of K (0.52 per cent) the

Table 35. Effect of NPK treatments on the nutrient content of leaves with sheath and calculated DRIS indices in sugar cane

Treatment	Leaf position	Leaf Composition(%)			DRIS indices			Order of Requirement
		N	P	K	N	P	K	
	3	1.27	0.126	1.00	−62	−31	+94	N>P>K
000	4	1.75	0.142	0.85	−18	−27	+45	P>N>K
	5	1.11	0.133	0.65	−40	−13	+53	N>P>K
	6	1.59	0.126	0.60	− 3	−22	+25	P>N>K
	3	1.27	0.110	0.50	− 7	−19	+26	P>N>K
111	4	1.59	0.121	0.52	+ 5	−21	+16	P>N>K
	5	1.27	0.121	0.45	− 5	−12	+17	P>N>K
	6	1.27	0.094	0.15	+53	− 6	−47	K>P>N
	3	1.43	0.108	0.75	−21	−34	+55	P>N>K
222	4	1.27	0.075	1.27	−75	−89	+164	P>N>K
	5	1.43	0.062	0.57	+19	−67	+48	P>N>K
	6	1.59	0.075	0.40	+33	−45	+12	P>K>N

leaf N content of 1.59 per cent was almost in a balanced condition while the leaf P content was still in an imbalanced condition (DRIS index of N,P and K was +5, -21 and +16 respectively). But if the K level was increased from 0.52 to 0.65 per cent, the P content also increased from 0.121 to 0.133 per cent which directly reflected in the deficient condition of N. From the DRIS indices, it was observed that the P content in the leaf responded positively only upto a K level of 0.65 per cent. This could be confirmed from the leaf N, P and K contents i.e., when the leaf K was increased from 0.65 to 0.85 per cent, it would result in the supplement of nitrogen and phosphorus as the DRIS indices revealed that these nutrients were in a deficient condition. This might be the reason for the decreased yield from 58.1 to 33.8 t/ha. As the leaf K was still increased from 0.85 per cent to a maximum of 1.27 per cent, the increase in the negative DRIS index became more and more. However, the maximum yield of 66.6 t/ha was observed despite the severe imbalance condition noticed among the leaf N and P levels. Considering the findings from plant analysis through DRIS indices, it may be suggested to find out an economic level of fertilizer recommendations, to get high yield .

DRIS indices of P content in the leaf with and without sheath (Table 36), revealed that it was the limiting nutrient irrespective of treatment and leaf positions except when the K content was very low (0.37 per cent). At this level of K, the N content of 1.59 per cent was found to be slightly limiting while the P content of 0.131 per cent was found to be in excess. At this particular leaf nutrient composition, the yield was 58.1 t/ha which was correspondingly more than that of high plant K levels. But when K content was increased from 0.37 to 0.40 per cent, the leaf P content also increased while the N level of 1.27 per cent was found to be slightly limiting than that of 1.59 per cent. When the content of N was increased beyond 1.27 per cent, the extent of N imbalance was also increased. Thus, the P and K contents influenced the balance of N at the level of 1.27 per cent. This might be the reason for the high yield of 58.1 t/ha. Any increase in K content above 0.40 per cent (for e.g. to 0.45 per cent), the phosphorus content was also reduced considerably (from 0.138 to 0.131 per cent) which could also be revealed from the DRIS index. Also any increase in the content of K above this level of 0.40 per cent made the K to accumulate in the leaf there by making it in an excess amount, as well as the need for the supply of N and P as the imbalance of these two nutrients increased with increase in the level of K. Thus, at a higher content of leaf K (i.e., when it was

Table 36. Effect of NPK treatments on the nutrient content of leaves without sheath and calculated DRIS indices in sugar cane

Treatment	Leaf position	Leaf Composition(%)			DRIS indices			Order of Requirement
		N	P	K	N	P	K	
	3	1.59	0.149	0.90	-32	-24	+56	N>P>K
000	4	1.75	0.151	0.82	-17	-23	+40	P>N>K
	5	1.75	0.156	0.62	- 3	-15	+18	P>N>K
	6	1.43	0.163	0.65	-22	-10	+32	N>P>K
	3	1.43	0.133	0.67	-19	-19	+38	N,P>K
111	4	1.43	0.131	0.45	+ 1	-12	+11	P>N>K
	5	1.27	0.138	0.40	- 2	- 6	+ 8	P>N>K
	6	1.59	0.131	0.37	- 4	+ 7	- 3	N>K>P
	3	1.75	0.117	0.75	- 4	-35	+39	P>N>K
222	4	1.27	0.094	1.05	-59	-55	+114	N>P>K
	5	1.59	0.085	0.50	+20	-42	+22	P>N>K
	6	1.59	0.101	0.45	+16	-28	+12	P>K>N

1.05 per cent), a severe imbalance of N and P existed, as revealed from the DRIS indices, though a high yield of 66.6 t/ha was observed corresponding to this leaf nutrient composition. The DRIS indices also clearly showed the need to find out the optimum dose of nutrients to be applied to get higher yield. Also, the DRIS indices for K in the leaves with and without sheath suggested that potassium may not be a limiting nutrient eventhough the range of this nutrient was below the normal level irrespective of treatments and leaf positions. This is in conformity with the findings of Khan *et al.*(1988) in coconut.

7. EFFECT OF NPK ON JUICE QUALITY OF SUGARCANE

The different parameters of cane juice (brix, pol and CCS per cent) at harvest stage as influenced by NPK treatments has been furnished in Table 37.

7.1. Nitrogen

Results revealed that the brix and pol per cent were unaffected by different levels of nitrogen. The mean brix per cent at the three levels of nitrogen were 17.16, 17.69 and 17.40 respectively which were not found to be significant. The mean pol per cent with respect to the three levels of nitrogen were 15.73, 15.46 and 14.11

Table 37. Juice quality parameters of sugarcane as influenced by NPK treatments

Treatment NPK notation	Brix (%) R_1	Brix (%) R_2	Brix (%) Mean	Pol (%) R_1	Pol (%) R_2	Pol (%) Mean	CCS (%) R_1	CCS (%) R_2	CCS (%) Mean
000	18.24	15.11	16.67	15.04	12.71	13.88	10.32	8.81	9.57
001	16.31	17.84	17.07	15.04	16.41	15.73	10.89	11.87	11.38
002	19.34	16.14	17.74	17.95	14.86	16.41	13.04	10.76	11.90
010	15.43	17.34	16.39	13.64	15.71	14.68	9.69	11.29	10.49
011	15.84	16.91	16.38	14.63	16.12	15.38	10.60	11.85	11.22
012	16.84	16.51	16.68	15.40	15.22	15.31	11.11	11.02	11.04
020	16.54	21.14	18.84	15.91	19.46	17.69	11.74	14.09	12.92
021	14.84	18.21	16.53	13.11	17.39	15.25	9.31	12.79	11.05
022	18.41	17.91	18.16	17.09	17.62	17.36	12.42	13.12	12.77
100	16.01	16.54	16.28	13.29	13.22	13.26	9.15	8.91	9.03
101	17.41	18.71	18.06	16.82	17.32	17.07	12.43	12.57	12.50
102	19.71	18.94	19.33	18.27	17.69	17.98	13.27	12.89	13.08
110	18.11	19.94	19.03	16.16	18.44	17.30	11.53	13.38	12.46
111	19.04	18.91	18.97	14.83	17.45	16.14	9.85	12.64	11.25
112	16.11	17.24	16.68	14.91	14.75	14.83	10.82	10.31	10.57
120	18.51	16.91	17.78	16.90	15.93	16.42	12.19	11.65	11.92
121	16.64	17.24	16.94	11.41	14.70	13.06	6.98	10.26	8.62
122	15.61	16.84	16.22	12.88	13.48	13.18	8.84	9.10	8.97
200	14.90	19.94	17.42	9.65	18.01	13.83	5.66	12.92	9.29
201	16.11	16.54	16.33	13.54	14.79	14.17	9.38	10.56	9.97
202	17.94	17.81	17.88	16.50	16.80	16.65	11.94	12.29	12.12
210	16.41	16.14	16.28	14.00	12.95	13.48	9.77	8.75	9.26
211	14.94	18.64	16.79	11.62	16.85	14.23	7.71	12.10	9.91
212	19.91	18.44	19.18	19.79	16.32	18.06	14.80	11.60	13.20
220	17.94	14.64	16.29	15.53	10.81	13.17	10.92	6.95	8.94
221	18.64	18.54	18.59	16.89	16.51	16.70	12.14	11.77	11.96
222	17.21	18.44	17.82	14.64	16.85	15.75	10.20	12.16	11.18

respectively which was not altered by different N levels. But a decreasing trend in pol per cent with increased N level was noticed. This is in conformity with the findings of Prasad *et al.* (1982) in calcareous saline - sodic soils of Bihar. The mean CCS per cent at the three levels of N were 11.37, 10.93 and 10.64 respectively (Fig. 7). As in case of brix and pol per cent, the different levels of N failed to exert a significant influence on CCS per cent of cane juice.

7.2. Phosphorus

Results revealed that the different levels of phosphorus application had no effect on brix and pol per cent. The mean brix per cent at the three levels of phosphorus were 17.41, 17.37 and 17.46 per cent respectively. The different levels of phosphorus failed to show any significant influence on the brix per cent of cane juice. Similar findings were reported by several workers (Gill and Singh., 1976), Pannu *et al.* (1985). The mean CCS per cent at the three levels of phosphorus were 10.98, 11.04 and 10.92 (Fig. 8). As the effect of different levels of phosphorus on brix and pol per cent of juice was not significant, the influence of graded levels of phosphorus on CCS per cent was also not significant.

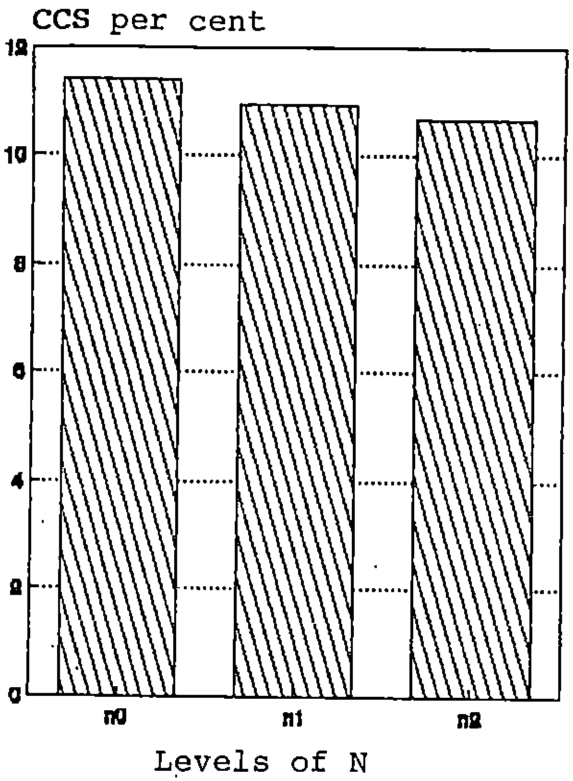

Fig.7 Relationship between CCS per cent and the levels of N applied

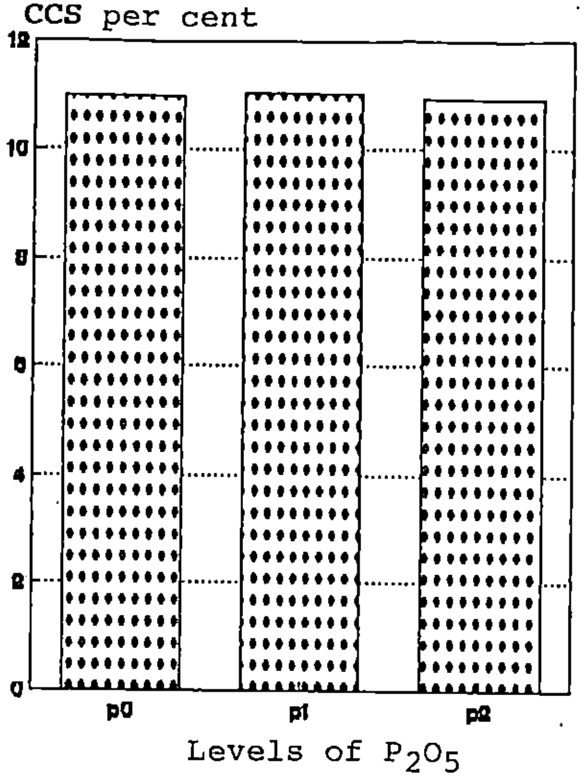

Fig.8 Relationship between CCS per cent and the levels of P_2O_5 applied

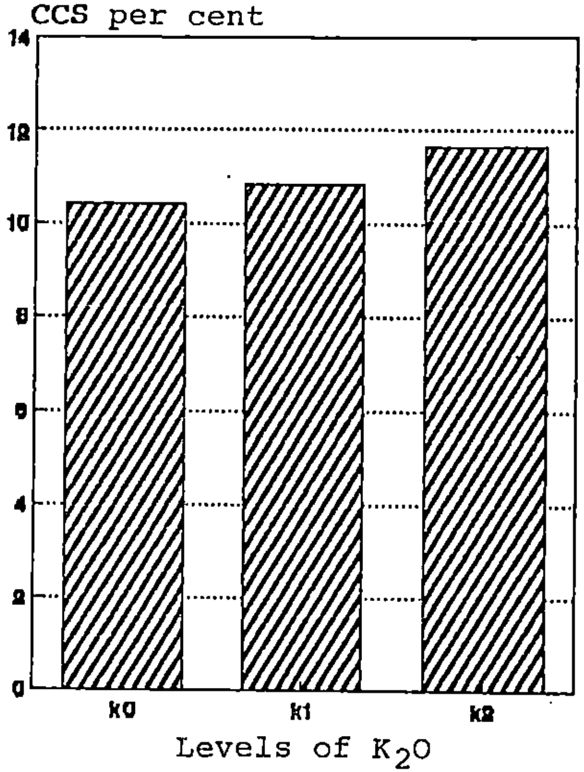

Fig.9 Relationship between CCS per cent and the levels of K_2O applied

7.3. Potassium

The mean brix and pol per cent with respect to k_0, k_1, k_2 levels were 17.21, 17.29, 17.47 and 14.85,15.30, 16.16 respectively. A steady increase in brix and pol per cent was observed with increased potassium levels, showing the positive effect of potassium on juice quality. Similar finding was reported by Yadav and Prasad (1991). The mean CCS per cent at the three levels of potassium were 10.42, 10.87 and 11.65 respectively (Fig.9). It was observed that the different levels of potassium had a positive influence on CCS per cent. However, the increase in CCS per cent was not statistically significant.

7.4. NPK Interaction

Results revealed that there was no significant difference in brix and pol per cent among the combinations of NP, NK and PK treatments. However, in PK combination the pol per cent varied from 13.65 per cent (p_0k_0) to 17.01 per cent (p_0k_2). When the NPK interaction was considered, the mean brix per cent varied from 16.23 in case of $n_1p_2k_2$ to 19.32 per cent in case of $n_2p_1k_1$. It was observed that the brix and pol per cent was not affected due to the different treatments and this was in conformity with the findings of Ahmed and Rajasekaran (1993). The different treatment combinations of N, P and K also failed to exert a significant influence on the CCS per cent of cane juice.

Summary

SUMMARY

A field fertiliser trial in sugarcane with different levels of NPK was undertaken at the Sugarcane Research Station, Tiruvalla to standardise the leaf position and stage of sampling in relation to yield, to predict the yield with more accuracy based on the nutrient content of leaves and to know the influence of different leaf positions during different stages of sampling on the nutrient uptake of sugarcane at harvest stage. The influence of different NPK treatment on quality parameters of cane juice at harvest stage was also analysed. The salient findings are as follows.

1. Among the three major nutrient elements, only nitrogen seemed to exhibit a significant influence on cane yield. The increase in yield of cane beyond the N level of 165 kg/ha was not conspicuous.

2. Among the different levels of N, P and K applied, NPK interaction was found to be significant. The treatment combination of N at 330.0 kg/ha, P_2O_5 at 165.0 kg/ha and K_2O at 165.0 kg/ha recorded the highest yield.

3. The nitrogen content of the leaf with sheath gradually declined from 0.35 to 1.41 per cent from the first to sixth stage of sampling. The N content of leaf without sheath varied from 0.58 to 1.58 per cent,with the amount of N content increased upto the third stage and there after decreased.

4. The maximum nitrogen accumulation was noted in the third leaf without sheath at the third stage of sampling.

5. The third, fourth and fifth leaves with and without sheath collected during the second stage of sampling showed an increasing content of N with progressive increase in the levels of N applied.

6. The phosphorus content of the leaf with sheath at different stages of sampling varied from 0.056 to 0.166 per cent, while it was from 0.088 to 0.161 per cent in leaves without sheath. There was no regular pattern in the variation of P content of leaves with respect to different leaf positions and stages of sampling.

7. The mean content of phosphorus in leaves was 1/9th of that of N.

8. The maximum content of P was observed in the fifth leaf with sheath at the second stage of sampling.

9. The response to the different levels of P applied was more pronounced at the second stage of sampling with a good plant response to the application of P_2O_5 at 165.0 kg/ha.

10. The potassium content of the leaf with sheath varied from 0.33 to 1.16 per cent with the age of the crop, while it was from 0.39 to 1.04 per cent in leaves without sheath. The decrease in the content of K with increasing age of the crop was not conspicuous in both the cases.

11. The maximum content of K was observed in all the leaves with sheath collected at the second stage of sampling whereas in the case of leaves without sheath, leaf sample collected at the fourth stage of sampling registered the maximum K content.

12. The fourth, fifth and sixth leaves with sheath collected at the second stage of sampling showed an increased content of K with progressive increase in the levels of K applied.

13. The extent of role played by the NPK content in different leaves with sheath at the first, third and fifth stages of sampling on yield was very low, while the role played by NPK content in leaves without sheath at the first and fifth stages of sampling on yield was found to be low.

14. The residual effect of path analysis showed that the extent of role played by the NPK content in different leaf positions and stages of sampling was comparatively more at the second stage of sampling.

15. The N content in the fourth leaf with sheath collected at the second stage of sampling had a high influence on the yield of sugarcane while the N content of the third leaf without sheath at the second stage of sampling exhibited a significant correlation with the yield of sugarcane.

16. The P content in the fifth leaf with sheath collected during the second stage of sampling showed more response in relation to leaf K as well as high and positive direct effect on the yield of sugarcane. The P content of leaves without sheath at this stage failed to show a clear uptake pattern with respect to different leaf positions.

17. The third and fifth leaves with sheath collected at the second stage of sampling revealed the sufficient level of K to exert their influence on the yield of sugarcane.

18. Stepwise regression model was fitted separately for each stage between yield and NPK content of leaves with sheath as well as without sheath. The maximum predictability of 73 per cent (R^2 = 0.7297) was obtained for the second stage of sampling for the model $Y = 30.63 - 12.529 X_1 + 23.515 X_2 - 16.098 X_3 +$

$19.840\ X_4 + 159.049\ X_5 - 25.907\ X_6 + 12.603\ X_7 - 22.943\ X_8$ Where Y is the yield, X_1 is the N per cent in the fourth leaf with sheath at the second stage of sampling, X_2, X_3 and X_4 are the N per cent in the third, fourth and fifth leaves without sheath respectively at the second stage of sampling. X_5 is the P per cent in the fifth leaf with sheath at the second stage of sampling and X_6, X_7 and X_8 are the K per cent of third, fourth and fifth leaves with sheath respectively at the second stage of sampling.

19. The coefficient of simple correlation between nutrient uptake of N at harvest stage and leaf N was found to be significant and positive in the third and sixth leaves without sheath at the second stage of sampling.

20. The coefficients of simple correlation between nutrient uptake of P and K and the corresponding leaf nutrient content at different leaf positions revealed the significant and negative influence of P at the third leaf without sheath and the significant and positive influence of K at the sixth leaf without sheath collected at the fifth stage of sampling.

21. Analysis of plant through DRIS indices at the second stage of sampling revealed the nutrient imbalance among N and P in leaf with sheath, when the K level was

increased beyond 0.65 per cent. Plant analysis also showed the need to find out optimum dose of nutrients to obtain high yield from the leaf nutrient content and their corresponding DRIS indices.

22. The different levels of nitrogen and phosphorus had no significant influence on the brix, pol and CCS per cent of cane juice. But the brix, pol and CCS per cent increased with increasing levels of potassium, though not significant statistically.

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* Originals not seen

Appendices

Appendix - I

Weather parameters for the crop period (Mar-'92-Feb-'93)

Month	Rainfall (mm)	Maximum Temperature(°C)	Minimum Temperature(°C)	Relative Humidity(%)
MAR	nil	34.0	23.9	93.0
APR	12.8	34.5	25.7	87.0
MAY	276.4	33.0	25.0	87.0
JUN	654.8	30.7	23.8	92.0
JUL	586.8	30.0	22.6	91.0
AUG	461.0	30.0	23.0	93.2
SEP	324.2	30.6	24.7	85.2
OCT	383.0	30.6	24.0	86.2
NOV	322.6	32.3	25.0	85.0
DEC	6.2	32.9	22.4	75.2
JAN	nil	31.2	19.5	77.3
FEB	2.0	32.5	21.4	77.3

Appendix - II

General characteristics of soil

Sl. No.	NPK Treatment notation	pH	EC (dS/m)	Organic C(%)	Available N (ppm)	Available P (ppm)	Available K (ppm)
1	000	5.5	0.008	2.14	218	4.35	52.5
2	001	5.4	0.022	2.21	224	4.67	70.0
3	002	5.4	0.020	2.12	234	3.81	65.0
4	010	5.7	0.006	2.15	247	4.46	46.2
5	011	5.2	0.032	1.98	196	2.22	53.7
6	012	5.5	0.030	2.03	210	3.07	45.0
7	020	5.5	0.006	2.11	220	4.03	55.0
8	021	5.6	0.015	2.12	228	5.95	53.7
9	022	5.4	0.021	2.10	241	3.51	67.5
10	100	5.4	0.015	2.27	239	4.88	37.5
11	101	5.5	0.009	2.12	223	3.07	47.5
12	102	5.3	0.019	1.97	243	1.37	56.7
13	110	5.5	0.007	2.23	259	3.82	60.0
14	111	5.6	0.025	2.15	218	3.50	42.5
15	112	5.6	0.010	2.08	230	2.64	50.0
16	120	4.9	0.015	2.14	236	4.13	41.2
17	121	5.6	0.016	2.27	245	4.46	40.0
18	122	5.6	0.012	2.03	243	1.69	42.5
19	200	5.5	0.017	2.14	219	4.34	36.2
20	201	5.3	0.037	1.98	241	2.97	58.7
21	202	5.6	0.009	2.14	249	4.24	55.0
22	210	5.3	0.015	2.12	226	3.81	36.2
23	211	5.7	0.012	2.12	242	3.71	60.0
24	212	5.3	0.031	1.98	228	3.59	41.2
25	220	5.3	0.012	2.18	242	4.13	33.7
26	221	5.4	0.007	2.29	211	7.01	45.0
27	222	5.1	0.032	2.00	226	4.03	61.2

ABSTRACT

A field trial to study the relationship of sugarcane yield and nutrient status through foliar diagnosis was carried out at Sugarcane Research Station, Tiruvalla during 1992, with the hybrid variety CoTl 88322 (Madhuri). The experiment was laid out in a 3^3 factorial randomised block design consisting of three levels each of nitrogen (0, 165.0 and 330.0 kg N/ha), phosphorus (0, 82.5 and 165.0 kg P_2O_5/ha) and potassium (0, 82.5 and 165.0 kg K_2O/ha).

In order to standardise the leaf position, the leaf that just began to unroll (spindle like) was taken as the first leaf and the second, third, fourth, fifth and sixth leaves were counted from first leaf below. At the end of germination phase only third, fourth and fifth leaves were collected as no sixth leaf was found at this stage and from the second stage onwards the sixth leaf was included in the study. For standardising the best season suited for the collection of leaf and to predict yield, samples were collected at six different stages of plant growth. The stages of sampling were : (1) Germination phase (2) Tillering phase (3) At the beginning of grand growth phase (4) After grand growth phase but before flower formation (5) After flower formation but before maturity phase and (6) At the time of harvest. Attempts were made to find out the direct and indirect contributions of N, P and K in different leaves with and without sheath on yield and to predict yield based on the step-wise regression analysis. Attempt

was also made to find out the influence of leaf nutrient content at different leaf position collected at various stage of sampling on the nutrient uptake of sugarcane. Studies were also made to find out the influence of different levels of N, P and K on cane juice quality and nutrient uptake of sugarcane at harvest stage.

Observations revealed that the N content in the leaf with sheath varied from 0.35 to 1.41 per cent, while it was from 0.53 to 1.58 per cent for leaf without sheath. The N content of leaf with sheath showed a gradual decline with age of crop while the N content in the leaf without sheath increased from first to third stage and there after decreased. The differences in the levels of N applied reflected in N content of leaves at the second and third stage of sampling. The P content in the leaf with sheath varied from 0.056 to 0.166 per cent and the leaf without sheath varied from 0.088 to 0.161 per cent. Phosphorus distribution at different leaves in all the stages were rather inconsistent in both the cases. The response to the different levels of P applied was more pronounced in the second stage of sampling. Potassium per cent in leaf with sheath varied from 0.33 to 1.16 per cent while it was from 0.39 to 1.04 per cent for leaves without sheath. The content of potassium in the leaves without sheath was low in all the stages compared to leaves with sheath. The decrease in K content with age was not conspicuous. The effect of different levels of K was clearly reflected in the fourth stage of sampling.

Results also showed that the extent of role played by the NPK content of leaves with sheath on yield at the first, third and fifth stages of sampling was low while the NPK content of leaves without sheath at the first and fifth stage of sampling had a little influence on final yield of sugarcane. The nitrogen content in the fourth leaf with sheath and third and fourth leaves without sheath collected at the second stage of sampling established a significant influence on the yield of sugarcane. The P and K contents of the fifth leaf with sheath collected at the second stage of sampling established a significant effect on yield of sugarcane.

Observations revealed that among the stages of sampling, the second stage is recommended for N, P and K. Regarding the leaf positions, the third, fourth and fifth leaves without sheath is ideal for diagnostic purpose in relation to N, while the above leaves with sheath is ideal for diagnostic purpose in relation to K. For P, the fifth leaf with sheath is found to be the best.

Stepwise regression model fitted with yield and percentage of nutrients in different leaf positions at various stages sampling gave a maximum prediction of 73 per cent (R^2 = 0.7297) when the nutrient content of the third, fourth and fifth leaves collected at the second stage of sampling was considered.

The nitrogen content at the third and sixth leaves without sheath collected at the second and fifth stages of sampling had a significant correlation with the nutrient uptake of sugarcane at harvest stage. The different treatments of NPK failed to play a significant influence on the brix, pol and CCS per cent of cane juice.