CHARACTERISATION OF SOIL AND IRRIGATION WATER OF THE SUGARCANE BELT IN PALGHAT IN RELATION TO YIELD, NUTRIENT UPTAKE AND QUALITY OF CANE

By

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DECLARATION

I hereby declare that this thesis entitled **"CHARACTERISATION OF SOIL AND IRRIGATION WATER OF THE SUGARCANE BELT IN PALGHAT IN RELATION TO YIELD, NUTRIENT UPTAKE AND QUALITY OF CANE"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or society.

Vellanikkara,
21.08.1995.

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CERTIFICATE

Certified that the thesis entitled **"CHARACTERISATION OF SOIL AND IRRIGATION WATER OF THE SUGARCANE BELT IN PALGHAT IN RELATION TO YIELD, NUTRIENT UPTAKE AND QUALITY OF CANE"** is a record of research work done independently by Mr. S. VISVESWARAN 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.

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INTRODUCTION

Sugarcane is a minor crop in Kerala occupying only 6100 hectares of land under cultivation with a productivity of 65.3 t ha^{-1} (Anon, 1994). Nearly 40 per cent of the sugarcane cultivated in Kerala is in Palghat district with an area of 2362 ha, spread in between 10^{o} 15′ to 11^{o} 15′ N latitude and 76^{o} 15′ to 76^{o} 45′ E longitude.

Soil properties play a major role in determining the growth pattern, nutrient availability and yield of sugarcane crop. Light soils produce dense and deep rooting cane, richer in sucrose than heavy clay soils (Gijha *et al.*, 1973).

The growth of cane and uptake of major nutrients tend to decrease with increase in EC of irrigation water above 0.73 dS m^{-1} (Swamy *et al.*, 1986). Continuous application of poor quality irrigation water has been noted to produce an increase in pH, EC, exchangeable cations and ESP of the soil.

The effect of major nutrients on crop growth and yield are well understood and fertilizer containing these nutrients are widely in use. But there is little awareness of the role of micronutrients and studies on them are few.

Sugarcane cultivation in Palghat district is confined to three regions viz., Vannamada, Meenakshipuram and Attapadi, where the soils are mainly red, black and alluvial. Literature on major and minor nutrient status, physical properties, their effect on cane growth and yield are completely lacking with respect to these regions.

The present study has been undertaken as an initial step to get a detailed account of the soil properties of the above regions as well as the quality of irrigation water from different sources during different periods of the year. The following are the main objectives of the study.

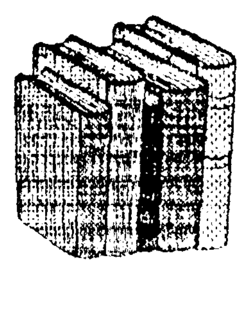
1. To study the physico-chemical characteristics of the sugarcane growing soils.

2. To monitor the periodical variations in the quality of water used for irrigating sugarcane.

3. To evaluate the influence of soil characteristics and irrigation water on the nutrient uptake, yield, dry matter and quality of cane.

4. To establish the inter-relationship between nutrient uptake, cane yield and total dry matter with that of major and micro nutrient status of the soils.

REVIEW OF LITERATURE



REVIEW OF LITERATURE

In India sugarcane is cultivated in different types of soils ranging in texture from sandy to clayey, although moderately heavy to medium deep loams are considered more suited. Each soil type requires its own set of management practices for producing good yields of sugarcane. A brief review of the nature and properties of the soils and irrigation water in sugarcane growing regions in India and their influence on the yield, quality and nutrient uptake by the sugarcane are presented in this chapter.

1. PHYSICO-CHEMICAL PROPERTIES OF SUGARCANE SOILS OF INDIA

1.1. Texture and particle size distribution

The growth and yield of sugarcane is influenced substantially by the physical and chemical properties of the soils.

The red and black soils of Andhra Pradesh growing sugarcane contain about 19.25 per cent and 10.15 per cent clay respectively. The sand contents of red soils in this region are upto 86.3 per cent where as in black soils it is about 21 per cent (Anon, 1965).

Parthasarathy (1972) has stated that the clay content in the soils of Jagadhri and Hamira sugar factory zones of Punjab ranged between 7.0 per cent and 24.6 per cent, the silt content between 8.8 and 37.0 per cent and the sand content btween 83.4 and 38.4 per cent.

Ranadive (1982) has reported that the laterite and lateritic soils found close to the Western Ghats of Kerala, Karnataka, Goa, Maharastra and eastern coast of Andhra Pradesh and Orissa and scattered spots in other states are also suited for sugarcane. These are red in colour, fairly deep, well drained, highly leached and slightly acidic (pH 5.0 to 6.5) with a low fertility index. They are very poor in Ca, Mg and K and low to moderate in P contents.

Kadam *et al.*, (1983) reported that the sugarcnae soils of Indapur taluk of Maharastra state were clayey in texture (20 - 60 per cent).

Alluvial soils form the largest soil group under sugarcane in India, extending from Gujarat to Assam. According to Kakde (1985) these soils are mostly sandy or silty loams and are poor in nutrient retention and require frequent irrigation. In South India sugarcane is grown in silty to heavy clay soils which are scattered along the river banks in different states.

Kakde (1985) has reported that soils of Deccan region in Maharashtra were mostly clay to loamy texture, with the clay content between 40 and 45 per cent or above. According to Kakde (1985), the surface soils of old alluvial basins of Uttar Pradesh contain 13.12 per cent clay, 17.44 per cent silt, 53.32 per cent fine sand and 12.23 per cent coarse sand.

The red soils occupy the second largest area under sugarcane (Kakde, 1985). These soils are more predominant in Kerala, Tamilnadu and Andhra Pradesh and adjoining regions of other states. They are rich in potash feldspar bearing minerals. Soils vary in texture and the red color is of varying shades. These are low in Ca, Mg, low in fertility index, excellent in drainage, low in organic matter and near neutral to acidic in reaction.

Kakde (1985) further states that black soils occupy more than 50 per cent of sugarcane in the South Gujarath to Karnataka and are scattered in various states. These soils are rich in aluminium and ferrugenous minerals, moderate to highly calcareous (3 - 15 per cent or more $CaCO_3$), with high content of Mg. These are low to medium fertile, highly responsive to manuring and irrigation under proper management and are dominated by montmorillonite type minerals.

1.2. Single value constants

The growth of any crop is a function of its bulk density which is also an index of soil structure and is indicative of total pore space. For an uncompacted soil it is about 1.2 to 1.3 Mg m^{-3}.

The bulk density of Rayagada, the main sugarcane belt of Orissa was 1.307 Mg m^{-3} (Parthasarathy 1972). The regur soils of Andhra Pradesh with hard sub-soil pan had a bulk density of 1.53 to 1.60 Mg m^{-3} (Rao *et al.*, 1978) which according to them is partly responsible for their lower productivity.

Indiraraja and Raja (1979) reported that the red soil, black wet land soil, black garden land soil, alkali soil and acid soil of Tamil Nadu had a bulk density of 1.59, 1.40, 1.31, 1.35 and 1.60 Mg m^{-3} respectively.

Srivastava (1985) observed that in clay loam soil the bulk density values ranging from 1.54 to 1.57 Mg m^{-3} can be considered to be critical for the growth and yield of sugarcane under sub-tropical field conditions. Reddy (1986) observed that the bulk density of regur soils of Andhra Pradesh was between 1.39 to 1.41 Mg m^{-3}.

Indiraraja and Raja (1979), in their field experiments with red soil, black wet land soil, black garden land soil, alkali soil and acid soil of Tamil Nadu, reported that the particle density values of above soils were 2.76, 2.74, 3.32, 2.36 and 3.16 Mg m^{-3} respectively. The corresponding pore space values of these soils were 49.7, 67.6, 71.2, 50.2 and 52.8 per cent respectively. The volume expansion of these soils varied widely and the respective values were 13.1, 50.5, 12.9, 33.8, 5.6 per cent with a water holding capacity of 36.3, 77.5, 51.5, 65.6 and 35.1 per cent respectively.

The water holding capacity of soils of Jagadhari mills and Haming mills area of Punjab and Haryana states were 41.3 for fresh alluvium and 36.3 for old alluvium (Parthasarathy 1972).

Kadam *et al.*, (1983) reported a water holding capacity of 30 to 90 per cent for the soils of Indapur taluk of Maharashtra.

1.3. Soil reaction

Sugarcane crop is noted to perform better between soil pH ranges of 5.5 and 8.7. Beyond this range the success is limited. The soils of the Indian Institute of Sugarcane Research farms, Lucknow were neutral in reaction (6.9 to 7.4) as reported by IISR (1958). The sites of Kurumba farm and Tamkuhi road farm in Eastern Uttar Pradesh were alkaline in reacation, whereas the pH of Fatepur of Western Uttar Pradesh was 7.3.

Rayagada soils of Orissa were acidic in reaction (pH 5.6). The pH of soils of Godavari delta in AP was 8.0 (Anon, 1965). In Pubjab and Haryana, the sugarcane is grown in soils having a pH range from 6.18 to 9.09 (Parthasarathy 1972), where as the Seohara sugarcane belt soils were in the neutral range.

The soils in the Coimbatore region are alkaline in reaction, and in Padegaon and Tituwaria regions of Maharastra it recorded a pH of 8.1 and 7.1 respectively (IISR, 1958).

Kadam *et al.*, (1983) reported that the pH of Indapur soils were found to be in the range of 7.5 to 9.0 indicating that the majority of these soils were alkaline in reaction.

1.4. Electrical conductivity

Soils are normally classified as saline or non-saline according to the electrical conductivity of the saturation extract. The EC of most Indian soils where sugarcane is cultivated is between 0.10 to 0.40 dS m^{-1} and most of the soils have a normal EC of around 0.25 dS m^{-1}.

Kadam *et al.*, (1983) reported that the electrical conductivity of Indapur soils vary from as low a value as 0.10 to 0.25 dS m^{-1}, the average being 0.25 dS m^{-1} at 27°C. The EC of three factory zone soils of Andhra Pradesh ranged between 0.122 to 0.902 dS m^{-1} (Rao *et al.*, 1983). Yadav (1986) reported that the EC of 1:2 saturation extract of sandy loam soils of IISR Lucknow farm was 0.2 dS m^{-1}. Rakkiyappan (1987) reported that the red soils of Ambur sugar factory, black soils of Sugarcane Breeding Institute, Coimbatore and alluvial soils of EID Parry farm Nellikuppam recorded an EC of 0.10, 0.10, and 0.20 dS m^{-1} respectively.

1.5. Nutrient status

Most of the sugarcane growing soils in India are low in nitrogen (N), medium in phosphorus (P) and high in potassium (K). The total N, total P, and organic matter of IISR soils (Lucknow) were 0.055 to 0.062, 0.043 to 0.040 and 0.22 to 0.922 per cent respectively (IISR 1958). The corresponding values for soils of Fatehpur and Kurumbha farm area of Uttar Pradesh varied from 0.025 to 0.43 (total N), 0.049 to 0.073 (total P), and 0.331 to 0.365 per cent (organic matter) (IISR, 1958). Yadav (1987) reported that the total N content of IISR farm Lucknow was between 0.05 and 0.08 per cent.

The organic matter , total N, total P and total K content of red soils of Ambur sugar factory reported by Rakkiyappan (1987) were 0.14, 0.03, 0.04 and 0.74 per cent respectively. The corresponding values for Alluvial soils of EID Parry Nellikuppam were 0.23, 0.08, 0.08 and 1.08 per cent, and the values for black soils of sugarcane Breeding Institute were 0.28, 0.08, 0.15 and 1.04 per cent respectively.

In a study on the macro and micronutrient composition of soils of Andhra Pradesh, Rao *et al.*, (1983) reported a medium to high status of available P and K and a low to medium status of available nitrogen.

Kadam *et al.*, (1983) reported that the organic carbon content of soils of Indapur was in the range of 0.13 to 1.22 per cent with a mean of 0.52. The total N varied from 0.01 to 0.11 per cent, the average being 0.05 per cent, whereas available P status of these soils were found to be in the range of 5 to 70 kg ha^{-1}, the average being 18 kg ha^{-1}. The available K of the soils was moderately high varying from 110 to 800 kg ha^{-1} with a mean of 460 kg ha^{-1}.

The organic carbon content of IISR soils of Lucknow was 0.4 per cent, the Olsen's P 10 kg ha^{-1}, and available potash 280 kg ha^{-1}. These soils were rated as low in nitrogen and phosphorus, and medium in available K (Yadav, 1986).

Srivastava *et al.,* (1985) noted that the organic carbon of the soils of Shahjahanpur district in Uttar Pradesh was between 0.05 - 1.34 per cent with a mean of 0.41 per cent. The available P status of these soils was between 0.06 - 27.86 kg ha^{-1} with a mean of 18.08 kg ha^{-1}.

Sharma and Kanwar (1987) observed that more that 50 per cent of the soils in sugar mill area of Punjab were deficient in N, P and K.

Indiraraja and Raja (1979) reported that the cation exchange capacity of red soil, black soil (wet land), black soil (dry land), alkaline soil and acidic soil of the sugarcane belts in Tamil Nadu was in the order of 12.8, 33.5, 22.1, 14.2 and 10.4 cmol(p^+) kg^{-1} respectively. The Ca content of these soils was 6.8, 22, 24, 5.2 and 6 cmol(p^+) kg^{-1}.

Kadam *et al.,* (1983) reported that the exchangeable Ca in the soils of Indapur was found to be in the range of 18 to 70 cmol(p^+) kg^{-1} with a mean value of 40 cmol(p^+) kg^{-1}. He attributed the high calcium carbonate content in the soil to the high CEC of the soil. The exchangeable Mg of these soils varied from 6 to 25 cmol(p^+) kg^{-1} with a mean of 10 cmol(p^+) kg^{-1}.

Yadav (1987) reported that the CaO and MgO content of soils of IISR farm Lucknow was 0.85 per cent and 0.74 per cent respectively.

2. MICRONUTRIENT CONTENT IN SOILS

Micronutrients play an important role in the proper growth and development of plants. Chlorosis due to iron deficiency in sugarcane crop grown on alkaline soils in Eastern Uttar Pradesh has been observed by Gupta and Rao (1980). The contents of Mn (16 to 400 ppm), Fe (6 to 12 ppm), Zn (0.5 to 6.00 ppm) and Cu (1.68 to 14.58 ppm) in the soils of three factory zones in Andhra Pradesh were considered to be in sufficiency levels as reported by Rao *et al.*, (1983). KAU (1985) reported that soil samples collected from Chittor Thaluk of Palghat district did not show any deficiency for Fe, Cu and Zn.

Ramanathan *et al.*, (1987) noted that in Coimbatore district of Tamil Nadu, soils with less than 5.43 $\pm$ 0.86 ppm DTPA soluble Fe can be expected to cause iron chlorosis. Similarly less tha 0.99 ppm Zn can also actuate the chlorotic condition in sugarcane, whereas Cu & Mn did no correlate with chlorotic condition.

Rao *et al.*, (1987) reported that the values of Mn, Fe, Zn and Cu of five factory zone soils of Andhra Pradesh ranged from 10.5 to 400, 6.5 to 296, 0.5 to 10.67 and 1.0 to 29.33 ppm respectively. Biswas and Mukherjee (1987) reported that Cu, Mn, Mo, Zn and B content in the soils of India ranged between 2 to 275, 90 to 4600, trace to 6, 2 to 95 and 7 to 80 ppm respectively.

Yadav and Yaduvanshi (1989) reported that only less that 30 per cent of sugarcane soils in India are deficient in Zn and Cu, 4 per cent in Mn and less than 1 per cent in Fe when tested for these elements (betweeen 1961 to 1983). They also reported that the critical value of DTPA extractable Zn, Cu, Mn and Fe in Indian soils are 0.85, 0.5, 2 and 4 ppm respectively.

3. NUTRIENT STATUS OF SUGARCANE CROP

3.1. Influence of major and micro nutrients

Sugarcane removes large quantities of major and micronutrients especially, K and N, when the soil supply is non-limiting. According to Husz (1972) an average crop of sugarcane removes 0.56 to 1.2 kg of N; 0.38 to 0.82 kg of P_2O_5; 1 to 2.5 of K_2O; 0.25 to 0.6 kg of Ca; 0.2 to 0.35 kg of Mg; 0.02 to 0.2 kg Na and 2 to 2.7 SO_4 per tonne of sugarcane produced.

There are varying reports on the quantity of nutrients removed by sugarcane crop. Ekambaram and Shakuntala (1976) studied in detail the major and mirconutrient composition of various plant parts of a 19 month crop.

Ruschel *et al.*, (1977) observed that the rate of uptake of N by the crop decreased with maturity and dropped suddenly at harvest. Singh (1978) reported 50.7 per cent of total N was taken up during tillering phase, 32.2 per cent during elongation and 9 per cent during the sugar accumulation phase.

Rao *et al.*, (1976) observed that the depression in juice sucrose and purity with an increase in glucose was associated with increased levels of N application. Rao *et al.*, (1983) reported that leaf N content of sugarcanes in some sugar factory zone areas of Andhra Pradesh ranged between 1.484 to 2.338 per cent.

Under Indian conditions the uptake of P was reported to be 30 kg ha^{-1} (Singh and Soni 1961) and 37.3 kg ha^{-1} (Parthasarathy *et al.*, 1979). Rao *et al.*, (1983) observed that P content of leaf in some sugar factory zone areas of Andhra Pradesh varied from 0.058 to 0.126 per cent.

The uptake of K by sugarcane crop has been reported to range from 316 to 560 kg ha^{-1} by Humbert (1968). Frits (1973) reported that even in soils of low K reserves, sugarcane crop removed 50 to 400 kg ha^{-1} per year. Parthasarathy *et al.*, (1979) estimated that 169.5 kg K_2O ha^{-1} was removed by a crop of 125 tons. Chowdhary and Rehman (1990) reported that a leaf K content of $\geq$ 1.55 per cent indicates sufficient available soil K for high cane yield. Pal *et al.*, (1990) observed that chlorotic leaf blade had more K, less Ca and HCl soluble Fe than the green ones. Unlike leaf N the sheath P and sheath K did not show any specific relationship with juice constituents.

The sugarcane crop during its long growth period is able to take up the required quantities of micronutrients through its extensive and deep root system (SBI, 1990), though the supply is affected by soil pH and interaction between other soil nutrients.

Ghosh *et al.*, (1990) reported that the uptake of N, P and S increased with the application of S; while Fe, Mn and Zn contents decreased and Cu content increased during earlier stages. But after 120 days, levels of Fe, Zn and Cu in the leaves increased but not Mn. They noted that sulphur application increased the dry matter, cane yield and sugar content.

The uptake of micronutrients was studied by Ekambaram and Shakuntala (1976). Uptake of Fe was found to be the highest, followed by

Mn, B, Cu and Zn. Cane crop yielding 100 t ha^{-1} removed 4 kg of Mn and 0.58 kg of Zn.

Narayanan and Morachan (1974) found that the N content of 3-6 leaves and P, K and moisture status of leaf sheath were correlated to final yield and juice quality. It was seen that maintenance of leaf N at 1.8 to 2 per cent, sheath moisture growth phase at 86 to 88 per cent and finally at 74 to 76 per cent at maturity phase improved yield and juice quality. It was reported that application of 185 kg ha^{-1} of N is essential for higher yield, growth and juice quality. Gupta and Rao (1980) worked out the critical concentration of minor elements in sugarcane plants for proper development as 3-20 ppm Cu, 17-259 ppm Zn, 4-124 ppm Fe, 15-39 ppm Mn, 1.5-9 ppm B and 0.05 - 0.5 ppm Mo.

Srivastava *et al.*, (1988) observed that the uptake of both Mn and Zn declined with increasing concentration of P, but relative decline in Mn uptake was greater than that of Zn.

Mn (15-115 ppm), Fe (45-480 ppm), Zn (6.10-24.6 ppm) and Cu (2-14.9 ppm) contents of 3-6 leaves in different sugar factory zone areas of Andhra Pradesh were noted to be within the critical levels as reported by Rao *et al.*, (1983).

4. INFLUENCE OF IRRIGATION WATER QUALITY ON SUGARCANE

In India about 15 per cent of the land is affected by soil salinity and alkalinity; and in the arid and semi-arid zones 56 per cent of the land has been adversely affected due to poor quality of irrigation waters

(Ramamoorthy 1970). Ramulu (1962) reported that bicarbonate rich waters were low in EC.

Pajanissami and Mosi (1973) observed that SAR of irrigation water showed a tremendous influence on various soil characteristics. They noticed that a high proportion of Na in irrigation water increases Na in exchange complex of soil and which in turn increases the Na content in crop plant and finally reduces the grain yield of rice crop.

Chen and Li (1981) reported that irrigating the soils with waste water diluted 4-6 times had little effect on major soil properties except EC and levels of soluble salts and non-exchangeable K which were all increased by diluted waste water irrigation.

Swamy *et al.*, (1986) reported that continuous application of poor quality irrigation water increased the pH, EC, exchangable Na and ESP of soil markedly. But Ramanathan (1987) noted that relationship between water quality and corresponding soil properties were not distinctly manifest. Scalopi *et al.*, (1989) observed that the diluted mill water application resulted in several beneficial effects in soil properties.

Handelwal and Lal (1991) noticed that the EC of the soil increased with an increase in EC of irrigation water, whereas ESP and pH of soil increased with an increase in SAR of irrigation water.

Crops differ in their response to variations in the quality parameters of irrigation water. This has been noted by Gopalaswamy *et al.*, (1973) and they classified various crops as sensitive, semi-tolerant and tolerant crops with respect to their response to quality of irrigation water. Sugarcane was included under semi-tolerant crops.

Iyengar *et al.*, (1977) reported a marked reduction in growth and yield of cane by irrigating with sea water diluted to a salinity level of 10,000 to 15,000 ppm, though sugar content was not significantly affected.

Swamy *et al.*, (1986) noted that the uptake of all three major nutrients decreased with increase in the concentration of salts (EC) in irrigation water. Appreciable reduction in cane yield and depression in quality were noted when the salt content (EC) of irrigation water was more than 2.00 dS m^{-1}.

Thomas (1987) observed an inverse relationship between sugar yield and irrigation water quality. Bicarbonate content exceeding 671 ppm in irrigation water caused chlorosis in sugarcane. The low Ca content in irrigation water usually has an aggravating effect on bicarbonate.

Kingston and Macmohan (1990) observed that saline water restricts plant growth and ratoon cane seems to be more susceptible than plant cane to yield loss due to salinity. Also the ash content of juice was high in cane grown on saline soils.

Handelwal and Lal (1991) reported that grain and straw yields of rice crops decreased with an increase in EC and SAR of irrigation water, but the effect was less prominent in light textured soils. The grain and straw yields increased with increase in low boron in irrigation water but decreased at higher levels.

5. RELATIONSHIP BETWEEN NUTRIENT STATUS AND CANE YIELD SUGAR CONTENT AND QUALITY

Sugarcane exhausts the soils of the available plant nutrients to a far greater extent than most of the other crops. Nitrogen constitutes only a fraction (about 1 per cent) of the toal dry weight of mature cane. Nitrogen enhances rate of photosynthesis leading to increased growth rate resulting in higher yield of cane and sugar.

Sampio (1945) reported that application of nitrogenous fertilizers increased the yield and quality of juice only upto a certain level, beyond which the sugar content is likely to be reduced due to continued vegetative growth. Similiar results were obtained in India by Khan *et al.*, (1954), Kanwar and Kochar (1960), Bhoj and Singh (1960) and Marikulandai and Morachan (1964). Husz (1968) observed that there exists a limited possibility of decreasing ash content in cane by increasing the soil N.

Ibrahim (1978) reported that yield of sugarcane was significantly correlated with the exchangeble K and clay content and negatively correlated with ESP. The difference in sucrose and purity co-efficient of juice due to different treatments of N, P, and K did not differ markedly (Irfanuddin and Singh 1981). They observed that application of fertilisers slightly depressed sucrose, but considerably increased the overall production of CCS, being 50.3 per cent more compared to the control.

Addition of P and K significantly increased the tiller population but did not have any effect on available cane and juice quality (Yadav 1986). Addition of P increased the yield of cane and sugar content.

Verma *et al.*, (1991) reported that the juice quality showed no variation among different combinations of N, P, K and Zn treatments. Application of N, P and K increased the number of tillers and cane yield over N alone, while the effect of K and Zn was not significant. Similiar observation was made by Sachan *et al.*, (1993). They have reported that the major factors enhancing productivity were other than inherent soil fertility and fertilizer inputs.

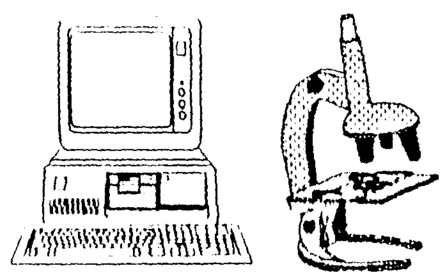
Reddy *et al.*, (1992) reported that, cane yield was positively and significantly correlated with available N and K content in soil. A positive but not significant correlation between cane yield and soil P_2O_5 level was also noticed by them. They noticed that exchangeable Ca content was positively correlated with yield in Chittor region while a significant negative correlation existed between exchangeable Ca and yield in Gajulamandyam region of Andhra Pradesh.

Somawanshi and Kadu (1988) observed that high soil organic carbon and high Mg : Ca ratio appeared to be associated with chlorosis in sugarcane.

Cambaria *et al.*, (1989) found that cane yield increased from 117 t ha^{-1} to 129 t ha^{-1} when 10 kg ha^{-1} of Zn was applied. However, further addition of Zn decreased the yields. Jayabal *et al.*, (1991) reported that 40 kg $ZnSO_4$ and 5 kg B increased the yield of sugarcane variety CoC 772, but further increase in both reduced the yield.

Ghosh *et al.*, (1990) observed that the critical levels of S for sugarcane production is 40 kg ha^{-1}.

MATERIALS AND METHODS



MATERIALS AND METHODS

1. SOIL SAMPLE COLLECTION

The sugarcane growing areas of Palghat district were grouped into three regions viz., Vannamada, Meenakshipuram and Attapadi. One hundred and ninety seven surface samples (0 - 15 cm) were collected from representative locations in the three regions: - Seventy nine samples from Vannamada, sixty six from Meenakshipuram and fifty two samples representing Attapadi regions respectively were used for the study.

The soils of the regions consisted of black soils (Eutrochrepts), red soils (Haplustalfs) and alluvial soils (Ustipsamments).

These samples were air dried, gently crushed, sieved through a 2 mm sieve stored in air tight containers. The relevant physico-chemical properties were determined by the procedures as presented below.

SOIL CHARACTERISTICS	METHOD	REFERENCE
1. Particle size analysis	Hydrometer method	Piper (1942)
2. Single value constants	Keen - Raczkowski Box	"
3. Soil reaction (pH)	1:2.5 soil water suspension using pH meter	Jackson (1958)
4. Electrical conductivity (EC)	EC of above suspension using conductivity bridge	"

SOIL CHARACTERISTICS	METHOD	REFERENCE
5. Organic carbon	Walkley & Black	Jackson (1958)
6. Total nitrogen	Kjeldhal disgestion and distillation	"
7. Total phosphorus	Vanadomolybdate Yellow Colour method	"
8. Total potassium	Flame photometric method using nitric acid-perchloric acid extract	"
9. Available nitrogen	Alkaline permanganate distillation	Subbiah & Asija (1956)
10. Available phosphorus	Olsen's extractant ascorbic acid blue colour method	Watanabe & Olsen (1965)
11. Available sulphur	Morgan's reagent extractable sulphate - sulphur turbidimetric method	Jackson (1958)
12. Exchangeable potassium and sodium	Neutral normal ammonium acetate extract; Flame photometric method	"
13. Exchangeable calcium and magnesium extractant versenate titration method	Neutral normal ammonium acetate	"
14. Available iron, manganese, zinc and copper	1:2 soil and DTPA extractant; atomic absorption spectrophotometric method (Perkin Elmer PE 3030 AAS)	"

2. CROP STUDIES

Twenty four farmer's fields, nine each from Vannamada and Meenakshipuram and six from Attapadi region were selected as observational plots. Setts of sugarcane (cultivar CoC 671) were planted during the second week of January 1992 and maintained as per recommendations of KAU (1989).

2.1. Biometeric observations

Single cane weight (SCW)

Four canes from each plot were harvested at random. At the point of break, the millable cane, tops and trash were separated and weighed:

Number of millable cane (NMC)

In each plot 10 m^2 area was marked out at two places at random. The average number of millable canes (stem) in the two areas were recorded and the total number of canes per hectare worked out.

2.2. Yield of cane

The yield of cane was estimated by multiplying single cane weight (SCW) with the number of millable canes (NMC) per hectare.

2.3. Juice extraction percentage

Four canes harvested from each plot were crushed individually in a power crusher. The weight of juice collected from each cane was noted and the mean worked out. The juice extraction percentage was calculated as

Juice extraction percentage

$$= \frac{\text{Weight of juice from single cane}}{\text{Single Cane Weight}} \times 100$$

2.4. Juice characteristics

The following characteristics were studied using the method noted against each item :

a.	Brix	Brix hydrometer spindle	Meade & Chen (1977)
b.	Polarity	Clarification of juice with lead sub acetate and reading in a Polarimeter	"
c.	Purity	$\frac{\text{Pol} \times 100}{\text{Brix}}$	Meade (1953)
d.	Commercial cane sugar per cent	[(sucrose – 0.4 (Brix - Sucrose)] x 0.73	"

2.5. Dry matter production of cane

The four millable canes (stem) harvested from each plot were cut to one fourth lengthwise. The one fourth portion selected by quartering from each sample was chopped to small bits. Exactly 100 grams of these fresh bits were dried in an electrical oven at 80° C to get a constant weight. The dry matter content of the cane was calculated as follows :

Dry matter of millable cane in kg ha^{-1}

$$= \frac{(\text{Dry weight of fresh stem bits} \times \text{SCW} \times \text{NMC})}{100}$$

The green tops and trash of the four samples were collected and dried in an electrical oven at 80° C to constant weight. The dry weight of the tops were determined by multiplying the mean of the sum total of the dry weight of four tops with NMC.

The dry matter production of above ground portion was obtained by summing up the total dry matter of stem and green top and trash.

2.6. Uptake of nutrients

The contents of N, P, K, Na, Ca, Mg, Fe, Mn, Zn and Cu of stem and top were analysed by the methods indicated below.

Except for N, the determination of these elements was done in an extract of 10 : 4 : 1 nitric acid, perchloric acid and sulphuric acid. (Jackson, 1958).

NUTRIENT	METHOD	REFERENCE
1. Nitrogen	Kjeldhal disgestion and distillation	Jackson (1958)
2. Phosphorus	Vanadomolybdate Yellow colour method in HNO_3 medium	"
3. Potassium and sodium	Flame photometer method	"
4. Calcium and magnesium	Versenate titration	"
5. Iron, manganese, zinc and copper	Direct reading atomic absorption spectro-photometric method (Perkin Elmer PE 3030 AAS)	"

3. IRRIGATION WATER QUALITY

Irrigation water samples from fourteen identified sources, used for irrigating sugarcane crop in the 24 sugarcane plots in the three regions were collected at monthly intervals, from January 1992 to November 1992 and classified as pre monsoon (January - May) and monsoon (June - November).

Irrigation water samples from well (open well) and bore well were taken, after pumping out water for five minutes using a motor pump, in clean, dry plastic bottles. The bottles were rinsed with sample water before collecting the sample.

The water samples from canal and river were sampled by immersing the closed bottle to about 30 cm depth inside the source. Then the cap was removed and water was collected in the bottle.

About 600 ml of water samples were collected from each sampling source. Two drops of toluene were added to prevent the microbial growth further. The methods followed for the determination of quality of water are described below.

1. pH	Using pH meter	Jackson (1958)
2. Electrical conductivity	Using conductivity Bridge	"
3. Sodium and potassium	Flame photometer	"
4. Calcium and magnesium	Versenate titration	"
5. Carbonate bicarbonate and chloride	Triple titration Method	"
6. Sulphate	Turbidimetry	"
7. Boron	Curcumin - Oxalic acid method using colorimetery	"

The residual sodium carbonate (RSC) content of the irrigation water was calculated by the formula given below (Wilcox - 1948).

$$RSC = (CO_3^{--} + HCO_3^-) - (Ca^{++} + Mg^{++})$$

where anionic and cationic concentrations are in milliequivalents per litre (me l^{-1}).

The sodium absorption ratio of the irrigation water (Richards - 1954) was worked out as follows.

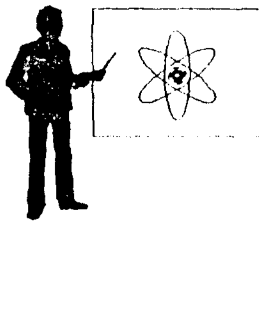
$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where cationic concentrations are in me l^{-1}

4. SATISTICAL ANALYSIS

Relationship between important soil properties with nutrient uptake, cane yield and parameters of juice quality of the three regions were worked out by adopting suitable statistical procedures (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION



RESULTS AND DISCUSSION

The results of the study on the physico-chemical properties of the soils of sugarcane belt in Palghat district, quality of irrigation water used and the influence of these properties on yield, dry matter production, nutrient uptake, and quality of sugarcane are presented and discussed in this chapter.

1. PHYSICAL PROPERTIES OF SOIL

1.1. Particle size distribution

The particle size distribution of the hundred and ninety seven samples included in the study are presented in Appendix-I and the mean and range values of the different soil separates in the soils of the three regions are given in Table 1. Region-wise comparison of the soil physico-chemical properties are presented in Table 2.

In Vannamada region the coarse sand fraction ranged from 22.95 to 55.48 per cent with a mean of 39.68 per cent. In Meenakshipuram region, the range observed was from 21.95 to 62.39 per cent with a mean value of 39.48 per cent. In Attapadi region the content of coarse sand however varied from 13.70 to 50.20 per cent with a mean of 28.43 per cent. Comparison of the physico chemical properties of the soils of the three regions revealed that the mean coarse sand fraction of the soils of Attapadi registered the lowest value and showed a significant variation from that of the other two regions (Table 2).

Table 1. Mean and range values of soil separates, per cent

Sl. No.	Region	Coarse sand	Fine sand	Silt	Clay
1.	Vannamada	39.68	23.10	12.74	24.11
		(22.95-55.48)	(4.23-45.22)	(4.34-28.74)	(9.20-43.84)
2.	Meenakshipuram	39.48	23.32	11.81	25.89
		(21.95-62.39)	(5.85-50.49)	(4.22-26.80)	(12.59-48.61)
3.	Attappadi	28.43	30.71	12.96	27.70
		(13.70-50.20)	(9.21-52.17)	(7.63-22.92)	(12.05-49.66)

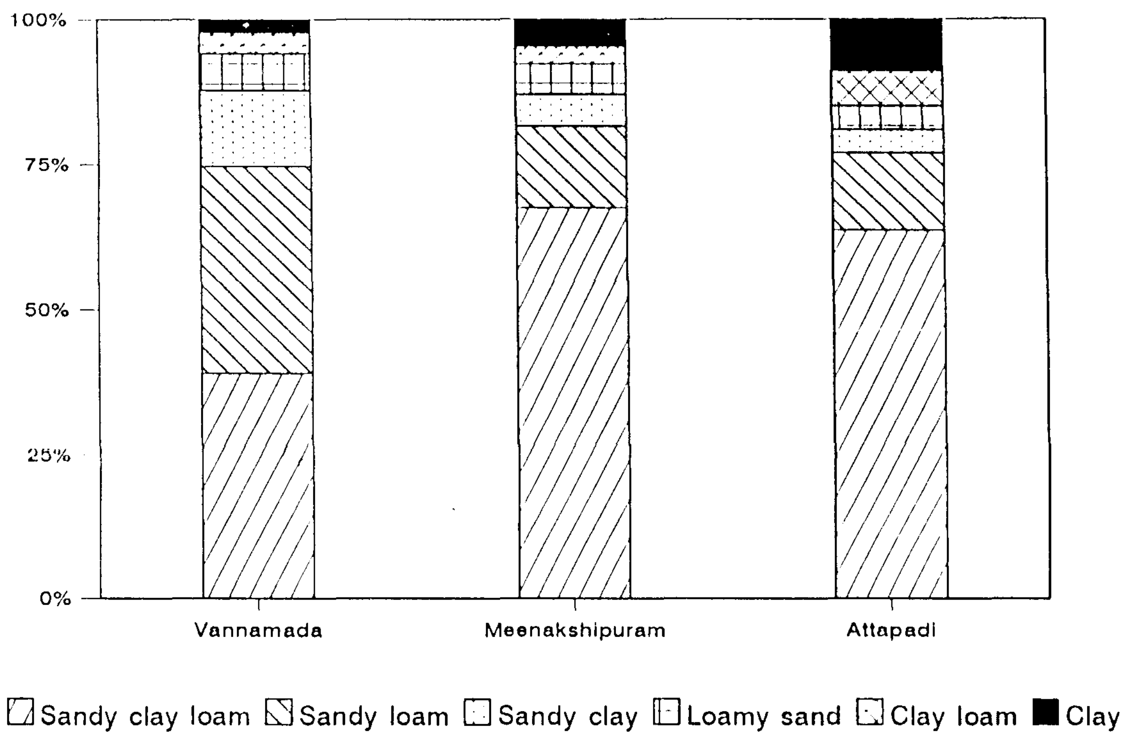


Fig. 1. The textural classes of soils of the regions

Table 2. Comparison of the soil physico-chemical properties of three regions - Mean table with CD values

		Mean Value			(CD 0.05)		
Sl. No.	Parameter	Vannamada (V)	Meenashi-puram (M)	Attapadi (A)	(V-M)*	(V-A)*	(M-A)*
1.	Coarse Sand %	39.68	39.48	28.43	2.61	2.79	2.90
2.	Fine sand %	23.10	23.22	30.71	3.20	3.42	3.55
3.	Silt %	12.74	11.81	12.96	NS	NS	NS
4.	Clay %	24.11	25.89	27.70	NS	NS	NS
5.	Bulk density	1.37	1.39	1.40	NS	NS	NS
6.	Particle desnity	2.30	2.31	2.34	NS	NS	NS
7.	WHC %	36.36	34.38	33.48	1.76	1.88	1.95
8.	Pore space %	46.58	45.08	44.85	NS	NS	NS
9.	Volume expansion %	11.10	9.41	7.25	1.63	1.75	1.82
10.	pH	7.56	7.43	7.52	NS	NS	NS
11.	EC (dS m^{-1})	0.32	0.35	0.29	NS	NS	NS
12.	Organic matter %	1.18	1.11	1.15	NS	NS	NS
13.	Total N %	0.071	0.070	0.075	NS	NS	NS
14.	Available N kg ha^{-1}	306.38	288.36	288.12	NS	NS	NS
15.	Total P %	0.12	0.11	0.10	NS	NS	NS
16.	Available P kg ha^{-1}	17.92	22.62	39.15	5.61	6.01	6.24
17.	Total K %	0.88	0.89	0.96	NS	NS	NS
18.	Available K kg ha^{-1}	271.92	262.25	309.18	NS	NS	NS
19.	Exchangeable Ca cmol(p^+) kg^{-1}	26.3	26.19	21.45	NS	NS	NS
20.	Exchnageable Mg Cmol(p^+) kg^{-1}	8.89	5.03	2.62	1.93	2.07	2.15
21.	Exchangeable Na cmol(p^+) kg^{-1}	0.72	0.57	0.25	0.21	0.22	0.23
22.	SO_4 - S (ppm)	107.56	117.88	140.41	13.92	14.91	15.48
23.	DTPA Fe (ppm)	48.52	56.86	40.36	NS	NS	NS
24.	DTPA Mn (ppm)	147.69	125.05	107.10	18.63	19.95	20.75
25.	DTPA Zn (ppm)	2.8	2.81	1.94	NS	NS	NS
26.	DTPA Cu (ppm)	2.89	2.83	3.64	0.48	0.51	0.53

V-M* - For comparing Vannamada and Meenakshipuram
V-A* - For comparing Vannamada and Attapadi
M-A* - For comparing Meenakshipuram and Attapadi NS - Not significant

The fine sand content of soils of Vannamada region ranged from 4.23 to 45.22 per cent with a mean of 23.1 per cent. In Meenakshipuram region, the variation in the fine sand content was between 5.85 and 50.49 per cent the mean being 23.32 per cent. In Attapadi region fine sand fraction showed a range value of 9.21 to 52.17 per cent, and a mean value of 30.71 per cent. The fine sand content of Attapadi soils was the highest and exhibited a significant variation from that of the other two regions (Table 2).

The analysis revealed that the silt content in the Vannamada region was between 4.34 and 28.74 per cent with a mean of 12.74 per cent. The variation of this fraction in the Meenakshipuram soils was between 4.22 and 26.80 per cent, with a mean value of 11.81 per cent. In Attapadi region the silt content was between 7.63 and 22.92 per cent, and the mean was 12.96 per cent.

The clay content in the Vannamada soils ranged from 9.2 to 43.84 per cent, with a mean of 24.11 per cent, while in the Meenakshipuram soils it varied from 12.59 to 48.61 per cent, with a mean of 25.89 per cent. In Attapadi region the values varied from 12.05 per cent to 49.66 per cent, with a mean of 27.70 per cent.

It was revealed that there was no significant variation in the silt and clay fractions of the soils of the three regions (Table 2).

Sugarcane flourished in a variety of soils ranging from sandy to heavy clays. Each textural class requires its own management practices for profitable crop production under varying conditions of climate and rainfall. The textural class also decides the manurial additions and soil improvers.

The soils of the sugarcane tract under study in Palghat district as seen in Table 1 and Fig. 1 comprise mainly of sandy clay loam (52.8 %) immediately followed by sandy loam (25.9%). Other textural classes include sandy clay, clayloam and loamy sand (21.8%).

In general, sugarcane does well in well drained medium loamy soil (Thuljaramrao *et al.*, 1983) and hence as regards the texture, the soils of the three regions under study are ideal for the growth of sugarcane.

1.2. Single value constants

Single value constants of the soils under study are given in Appendix II and their mean and range values in Table 3.

Bulk density

In Vannamada region the bulk density ranged from 1.1 to 1.56 Mg m^{-3}, with a mean of 1.37 Mg m^{-3}, where as in Meenakshipuram, the values varied between 1.13 to 1.60 Mg m^{-3} with a mean of 1.39 Mg m^{-3}. In Attapadi region the values ranged from 1.17 to 1.56 Mg m^{-3} with a mean of 1.40 Mg m^{-3}.

The bulk density of the soils of three region did not differ significantly. The lowest value observed was 1.10 Mg m^{-3} and highest was 1.60 Mg m^{-3}. The highest value observed may be due to higher content of sand in these soils. Sandy nature of soil was reflected on the higher particle density as well. Srivastava (1985) reported a bulk density value around 1.54 Mg m^{-3} as optimum for the growth of sugarcane. As such, the results of present study indicate that bulk density does not have any adverse effect on the growth of sugarcane in the soils of the three regions.

Table 3. Mean and range values of single value constant of soil

		Mg m^{-3}		Percentage		
Sl. No.	Region	Bulk density capacity	Particle density	Water holding	Pore space	Volume expansion
1.	Vannamada	1.37 (1.10-1.56)	2.30 (2.03-2.54)	36.36 (24.66-48.72)	46.58 (35.69-57.25)	11.10 (2.32-22.97)
2.	Meenakshipuram	1.39 (1.13-1.60)	2.31 (2.05-2.54)	34.48 (22.2-55.29)	45.08 (31.76-58.11)	9.41 (1.03-23.15)
3.	Attappadi	1.40 (1.17-1.59)	2.34 (2.04-2.67)	33.48 (25.44-42.68)	44.85 (34.84-54.77)	7.25 (2.22-20.31)

Particle density

The particle density of soils of Vannamada region ranged from 2.03 to 2.54 Mg m^{-3} with a mean of 2.30 Mg m^{-3}. In Meenakshipuram, it ranged from 2.05 to 2.54 Mg m^{-3} with a mean of 2.31 Mg m^{-3}. Particle density of Attapadi soils was between 2.04 and 2.67 Mg m^{-3} with a mean of 2.34 Mg m^{-3}.

Maximum water holding capacity

In Vannamada region maximum water holding capacity exhibited a range from 24.66 to 48.74 per cent with a mean value of 36.36 per cent, whereas in Meenakshipuram, the maximum water holding capacity was between 22.20 to 55.29 per cent with a mean of 34.48 per cent. The maximum water holding capacity of Attapadi soils was between 25.44 and 42.68 per cent with a mean value of 33.48 per cent.

Maximum water holding capacity of the soils of the three regions varied significantly (Table 2). Vannamada region soils registered the highest value followed by Meenakshipuram and the least in Attapadi.

The mean WHC of Vannamada soils was significantly higher than that of other two region inspite of lower clay content. The higher value observed can possibly be due to the presence of 2:1 clay.

Pore space

The pore space for the soils of Vannamada region varied from 35.69 to 57.25 per cent. Pore space values for Meenakshipuram soil ranged between 31.76 to 58.11 per cent while for the Attapadi region its ranged from 34.84 to 54.77 per cent. The mean pore space values for the three regions, viz. Vannamada, Meenakshipuram and Attapadi were 46.58, 45.08 and 44.85 percentage respectively.

The pore space of a soil is the indicative of its structural make up. No significant difference was observed between the regions.

Volume expansion

In Vannamada region volume expansion ranged from 2.32 to 22.97 per cent, with a mean value of 11.10 percentage. The volume expansion for soils of Meenakshipuram region varied between 1.03 to 23.15 per cent with a mean of 9.41 per cent. In Attapadi region the values were found to be within the range of 2.22 to 20.31 per cent, mean being 7.25 per cent.

Region wise comparison (Table 2) showed that Vannamada recorded the highest value in volume expansion and Attapadi the lowest, indicating the difference in clay mineral make up. Rajamannar and Venkitaraman (1976) have also reported the dominating influence of clay on volume expansion of soil.

2. CHEMICAL PROPERTIES OF SOILS

The result of analysis of soil samples organic matter, total N, total P and total K are presented in Appendix III and the mean and range values are presented in Table 4. The soil reaction, electrical conductivity, available and exchangeable nutrient status are presented in Appendix IV and their mean and range values in Table 5.

Table 4. Mean and range values of organic matter and total nutrient status of soils

Sl. No.	Region	Organic matter %	Total N %	Total P %	Total K %
1.	Vannamada	1.18 (0.54-1.96)	0.071 (0.04-0.136)	0.12 (0.06-0.24)	0.88 (0.35-1.70)
2.	Meenakshipuram	1.11 (0.60-1.93)	0.070 (0.032-0.132)	0.11 (0.05-0.24)	0.89 (0.43-1.78)
3.	Attappadi	1.15 (0.42-3.32)	0.075 (0.028-0.168)	0.10 (0.03-0.18)	0.96 (0.28-1.83)

2.1. Organic matter

The soils of Vannamada region exhibited a variation from 0.54 to 1.93 per cent, with a mean of 1.18 per cent, whereas in Meenakshipuram it varied from 0.60 to 1.93 per cent with a mean of 1.11 per cent. The Attapadi soils recorded both highest and lowest values of 0.42 per cent and 3.32 per cent respectively, the mean being 1.15 per cent.

Table 5. Mean and range values of pH, EC, available and exchangeable nutrients of soils

pH	EC $dS\ m^{-1}$	$kg\ ha^{-1}$			$(cmol(p^+)\ kg^{-1})$			ppm				
									DTPA extractable			
		N	P	K	Ca	Mg	Na	S	Fe	Mn	Zn	Cu
Vannamada												
7.56	0.32	306.38	17.92	271.92	26.30	8.89	0.72	109.56	48.52	147.69	2.80	2.89
(61.-8.7)	(0.07-0.80)	(190-451)	(4.3-51.9)	(101-683)	(8.64-59.52)	(1.2-29.04)	(0.15-3.16)	(29-246.5)	(12.4-150.6)	(26.2-273.2)	(tr-24)	(0.2-7.0)
Meenakshipuram												
7.43	0.35	288.36	22.62	262.25	26.19	5.03	0.57	117.88	56.66	125.05	2.81	2.83
(6.2-8.3)	(0.09-1.16)	(182-381)	(2.6-58.3)	(106-560)	(3.6-59.76)	(1.08-27.12)	(0.15-5.38)	(50.75-261)	(6.0-220)	(1.8-245.2)	(tr-46)	(0.8-9.2)
Attapadi												
7.52	0.29	288.12	39.15	309.18	21.45	2.62	0.25	140.41	40.36	107.10	1.94	3.64
(5.5-9.5)	(0.06-0.88)	(129-549)	(6.4-88.3)	(67-896)	(3.36-47.04)	(0.48-7.92)	(0.08-1.61)	(65.25-210.25)	(tr-186.8)	(17.2-293.4)	(tr-11.2)	(1.0-12.6)

tr - trace

2.2. Total nitrogen

The soils of Vannamada region showed a variation from 0.04 to 0.136 per cent with the mean value of 0.071 per cent. The total nitrogen content of Meenakshipuram soils ranged between 0.032 to 0.132 per cent, with a mean of 0.070 per cent. In Attapadi region it varied from 0.028 to 0.168 per cent with a mean of 0.075 per cent.

2.3. Total phosphorus

The lowest total P content in Vannamada region was 0.06 per cent and highest was 0.24 per cent. The mean value was 0.12 per cent. In Meenakshipuram region the range observed was from 0.05 to 0.24 per cent with a mean of 0.11 for the region. The total P content in soils of Attapadi region varied from 0.03 to 0.18 per cent, and the mean was 0.10 per cent.

2.4. Total potassium

In Vannamada soils the values for total K ranged from 0.35 to 1.70 per cent, with a mean value of 0.88 per cent. The value for Meenakshipuram were between 0.43 and 1.78 per cent, with a mean value of 0.89 per cent. In Attapadi region the range observed was from 0.28 to 1.83 per cent. The mean for the region was 0.96 per cent.

The organic matter content of the soils in the three regions was low which clearly reflected on the low total N content of the soil. Total P also recorded low value for the soils of all the three region. The low levels in the present study are characteristics of highly whethered tropical soils.

2.5. Soil reaction

In Vannamada region the pH values ranged from slightly acidic 6.1 to strongly alkaline 8.7, and the mean was 7.56. The corresponding pH values for Meenakshipuram were slightly acidic value of 6.2 to moderately alkaline value of 8.3 with a mean of 7.43. The mean pH value for the Attapadi region was 7.52 and the range was from 5.5 to 9.5.

The soil reaction is an important property that decides on the uptake of nutrients by plants. The soils of the study area showed pH varying from slightly acidic to alkaline condition. The ideal pH range according to Kakde (1985) for sugarcane production is between 5.5 and 8.7. Considering this factor the majority of the area fall with in this ideal range. Kerala soils in general are acidic in nature. The slight alkaline reaction in the sugarcane tract may be due to the predominance of free Ca and Mg bearing minerals present in the soils.

2.6. Electrical conductivity

The soils of Vannamada region exhibited a range between 0.07 and 0.80 dS m^{-1} with a mean of 0.32 dS m^{-1}. The variation in the electrical conductivity of soils of Meenakshipuram and Attapadi regions were from 0.09 to 1.16 dS m^{-1}, and from 0.06 to 0.88 dS m^{-1} respectively. The mean for the two regions were 0.35 and 0.29 dS m^{-1} respectively.

Electrical conductivity of the soils of the three region did not exhibit, significant variation and falls with in the safe limits. Sugarcane being a salt tolerant crop can with stand salinity upto 4 dS m^{-1} at 25°C. Mehred (1967) has observed 15 per cent inhibition at EC 4 dS m^{-1} at 25°C.

2.7. Available nitrogen

In Vannamada region the available N recorded a range value of 190 to 451 kg ha^{-1}, while in Meenakshipuram region the lowest value was 182 kg ha^{-1} and the highest value was 381 kg ha^{-1}. In the Attapadi region the values observed were 129 and 549 kg ha $^{-1}$. The mean values for the three regions were 306.38, 288.36 and 288.12 kg ha^{-1} respectively.

2.8. Available phosphorus

The available P content of soils of Vannamada region ranged from 4.3 to 51.9 kg ha^{-1}, with a mean of 17.92 kg ha^{-1}. In Meenakshipuram region, the available P content varied between 2.6 kg ha^{-1} and a value of 58.3 kg ha^{-1}, with a mean of 22.62 kg ha^{-1}. The Attapadi region recorded a lowest value of 6.4 kg ha^{-1} and highest value of 88.3 kg ha^{-1}, with a mean value of 39.15 kg ha^{-1}.

Available P in Attapady region showed a significantly higher value in comparison with the other two regions (Table 2).

2.9. Available potassium

The available K content of the soils of Vannamada region ranged from 101 kg ha^{-1} to 683 kg ha^{-1} and the mean was 271.92 kg ha^{-1}. In Meenakshipuram the available K content varied between 106 and 560 kg ha^{-1} with a mean of 262.25 kg ha^{-1}. The Attapadi soils exhibited a variation from 67 to 896 kg ha^{-1}. The mean value for the region was 309.18 kg ha^{-1}. In all the three regions the mean value for available N showed a medium rating. The available P and K contents of the Vannamada and

Meenakshipuram regions showed a medium rating while the rating for Attapadi was high. Nitrogen, P and K are crucial elements in the nutrition of sugarcane and has been directly correlated with cane yield and juice quality. Reddy *et al.*, (1992), Ibrahim (1978), Narayanan and Morachan (1974) Alvarez *et al.*, (1965). The wide variation in the content of available N, P and K noted warrants careful nutrient management depending on the fertility status of each soil.

2.10. Exchangeable calcium

The exchangeable Ca content in the soils of Vannamada region ranged from 8.64 to 59.52 cmol(p^+) kg^{-1}, with a mean 26.30 cmol(p^+) kg^{-1}. In Meenakshipuram region its value were between 3.6 to 59.76 cmol(p^+) kg^{-1}, with a mean 26.19 cmol(p^+) kg^{-1} and in Attapadi it varied between 3.36 to 47.04 cmol(p^+) kg^{-1}, and the mean was 21.45 cmol(p^+) kg^{-1}. The contents of exchangeable calcium in the three regions were on par.

2.11. Exchangeable magnesium

In Vannamada region the exchangeable Mg content varied from 1.2 to 29.05 cmol(p^+) kg^{-1} and mean for the region 8.89 cmol(p^+) kg^{-1}. In Meenakshipuram, the values ranged from 1.08 to 27.12 cmol(p^+) kg^{-1}, with the mean 5.03 cmol(p^+) kg^{-1}. The Attapadi soils exhibited a significantly lower content of exchangeable Mg and its value varied between 0.48 to 7.9 cmol(p^+) kg^{-1}, the mean being 2.61 cmol(p^+) kg^{-1} (Table 2).

2.12. Exchangeable sodium

The exchangeable Na content in the soils of Vannamada region varied from 0.15 to 3.16 cmol(p^+) kg^{-1} with a mean 0.72 cmol(p^+) kg^{-1}. In Meenakshipuram soils, the range was between 0.15 and 5.38 cmol(p^+) kg^{-1} and the mean was 0.57 cmol(p^+) kg^{-1}, where as in Attapadi soils, the variation was between 0.08 and 1.61 cmol(p^+) kg^{-1} with a mean of 0.25 cmol(p^+) kg^{-1}. It was observed that the mean exchangeable Na was significantly lower in soils of Attapadi in comparison with Meenakshipuram and Vannamada (Table 2).

Among the exchangeable cations, Ca and Mg were predominant in the three regions. Exchangeable Mg and Na content recorded significantly higher values in Vannamada and Meenakshipuram regions. The presence of free calcareous nodules in the soil has added to the status of exchangeable Ca as well as Mg.

2.13. Available sulphur

The sulphate sulphur status of the soils of Vannamada region ranged from 29.0 to 246.5 ppm, with a mean of 109.56 ppm. In Meenakshipuram region its value varied from 50.75 to 261.00 ppm and the mean was 117.88 ppm. In Attapadi region the values ranged between 65.25 to 210.25 ppm with a mean of 140.41 ppm. The mean sulphate S content was highest in Attapadi region and it varied significantly, compared to the other two regions (Table 2). The sulphate sulphur status of the soils of all the three regions was above the soil critical level fixed. Ghosh *et al.* (1990) has reported a critical level of 40 kg ha^{-1} S as optimum for the normal growth of sugarcane.

2.14. Iron

The content of Fe in Vannamada soils ranged from 12.40 to 150.60 ppm with a mean of 48.52 ppm. The value for Meenakshipuram soils was 6 to 220 ppm, the mean being 56.86 ppm. In Attapadi soils, the iron content ranged from traces to 186.8 ppm with a mean of 40.36 ppm. The difference in the mean content of available Fe was not found significant.

2.15. Manganese

The Vannamada soils recorded a value from 26.20 to 273.2 ppm for Mn and a mean of 147.69 ppm. In Meenakshipuram the value varied from 1.89 to 245.20 ppm with a mean 125.05 ppm, where as in Attapadi, its value ranged between 17.20 to 293.40 ppm with a mean of 107.10 ppm. The mean available Mn was highest in Vannamada region and this exhibited a significant variation with the other two region, where as the mean available Mn content of Meenakshipuram and Attapadi region did not show significant difference (Table 2).

2.16. Zinc

In Vannamada region, the value varied from traces to 24.00 ppm with a mean of 2.80 ppm. The Zn content of Meenakshipuram soils ranged from traces to 46.00 ppm with a mean of 2.81 ppm where as in Attapadi regions to value were from traces to 11.2 ppm with a mean of 1.94 ppm. The mean content of available zinc did not exhibit significant variation in the three regions.

2.17. Copper

The availabe Cu in Vannamada soil showed a variation from to 0.2 to 7.00 ppm, the mean being 2.88 ppm where as in Meenakshipuram it was between 0.80 and 9.2 ppm, with a mean of 2.83 per cent. In Attapadi region, the range was from 1.0 to 12.6 ppm, and the mean was 3.64 ppm. The mean available Cu was highest in Attapadi soils and it varied significantly from the other two regions (Table 2). The status of micro nutrients Fe, Mn, Zn and Cu is above the critical limits required for sugarcane as suggested by Yadav and Yaduvanashi (1989) for Indian soils.

Rao *et al.*, (1983) have suggested critical levels of 6 to 121, 16-400, 0.50-60 and 1.68 to 14.58 ppm in soils for Fe, Mn, Zn and Cu respectively. Judged from the above critical levels suggested all the micronutrients mentioned show soil levels above the sufficiency limit. Sufficiency of Fe, Cu, and Zn has been reported earlier from Chittor area of Palghat district (KAU, 1985).

3. CHARACTERISATION OF IRRIGATION WATER QUALITY

The water samples from various sources Viz borewell, openwell, canal and river water used to irrigate sugarcane in the 24 sites selected in the three regions were analysed for various quality parameters, during pre monsoon period from (January to May) and monsoon period (June - November). The mean value of various water quality parameters for respective periods, are presented in Table 6.

Table 6. Seasonal variation in quality of irrigation water (Mean values)

Source	Pre monsoon period (January -May)							Monsoon period (June - November)						
		$dS\ m^{-1}$	$Me\ l^{-1}$				ppm		$dS\ m^{-1}$	$Me\ l^{-1}$				ppm
	pH	EC	Cl^-	SO_4^{--}	RSC	SAR	B	pH	EC	Cl^-	SO_4^{--}	RSC	SAR	B
Borewell	8.5	1.91	7.06	14.51	1.57	0.82	1.83	8.3	1.48	4.7	11.16	4.4	0.73	2.06
Open well	8.6	0.78	5.54	4.38	NIL	1.06	1.28	8.1	0.46	2.5	4.59	0.99	0.91	1.46
Canal	8.4	0.31	4.85	4.16	0.20	1.01	0.78	8.1	0.31	1.97	4.46	0.81	0.54	1.00
River	8.4	0.37	1.62	2.06	0.08	0.92	1.17	7.9	0.29	0.68	2.23	0.43	0.65	0.82

3.1. pH

The pH during pre-monsoon period was in the order 8.6, 8.5, 8.4 and 8.4 for open well, bore well, canal and river water respectively.

During monsoon period the pH value for bore well was 8.3 followed by open well and canal 8.1 and river water 7.9.

The pH of the water used for irrigation from different sources exhibited a narrow range of variation and all were on alkaline side. This trend was observed both during the pre monsoon and monsoon seasons. Sugarcane according to Thuljaramrao (1983) grows well upto a pH of 8.5. Irrespective of the source, the pH of the irrigation water in the study area was not found to be a deleterious factor and hence suitable for irrigating sugarcane crop.

3.2. Electrical conductivity

The bore well water recorded the highest EC (1.91 dS m^{-1}) during pre-monsoon period and was appreciably higher than the other sources. During this period open well water registered an EC of 0.78 dS m^{-1} and canal water and river water only 0.31 and 0.37 dS m^{-1} respectively.

The EC of bore well water showed a decrease from 1.91 dS m^{-1} in pre monsoon on to 1.48 dS m^{-1} during monsoon period. Open well and river water also registered a decline during this period (0.46 dS m^{-1} and 0.29 dS m^{-1} respectively). The EC of canal water remained unchanged during monsoon period.

The EC is an important parameter with respect to quality of irrigation water. The highest EC recorded in the present study was 1.91 dS m^{-1} observed during pre monsoon season in bore well water. The EC of water from other source was comparatively less, registering values less than 1 dS m^{-1}.

Based on the rating for irrigation water suggested by Richards (1954), the water samples of bore well come under class C_3 (high salinity) while canal, open well and river water come under class C_2 (medium salinity). Sugarcane being a salt tolerant crop (Gopalaswamy *et al.*, 1973) the water from all the four sources in the present study can safely be used for irrigation, under assured drainage.

3.3. Chloride

The chloride concentration was appreciably higher in all the sources during pre-monsoon period. The bore well water registered the highest value (7.06 me l^{-1}) followed by open well water (5.54 me l^{-1}), canal water (4.85 me l^{-1}) and river water (1.62 me l^{-1}).

During monsoon period the concentrations recorded were 4.7 me l^{-1} for borewell followed by 2.5 me l^{-1} 1.97 me l^{-1} and 0.68 me l^{-1} for open well, canal and river water respectively.

3.4. Sulphate

The sulphate concentration during the pre-monsoon period also was highest in bore well water (14.5 me l^{-1}). The open well water was found to contain 4.38 me l^{-1} followed by canal water and river water (4.16 and 2.06 me l^{-1} respectively).

During monsoon period the sulphate concentration in the four sources under study were 11.16, 4.59, 4.46 and 2.23 me l^{-1} for bore well, open well, canal and river water respectively.

The concentrations of chloride and sulphate were highest in bore well, followed by open well, canal and river water and their concentrations were not injurious for the growth of sugarcane.

3.5. Residual sodium carbonate

The mean value for residual sodium carbonate (RSC) during pre-monsoon period was highest 1.57 me l^{-1} in bore well water, followed by canal water with a concentration of 0.2 me l^{-1}. In the case of river water RSC was only 0.08 me l^{-1} during this period, where as open well water recorded absence of any residual sodium carbonate.

The RSC values during monsoon for all the sources registered an increasing trend. The RSC of bore well water was highest (4.4 me l^{-1}) followed by that of open well water (0.99 mel^{-}) The RSC of canal water during this period was 0.81 me l^{-1} and that of river water 0.43 me l^{-1}.

3.6. SAR

The sodium absorption ratio, a measure of sodium hazard, recorded the highest value during pre-monsoon periods irrespective of source. Open well water recorded the highest value (1.06) followed by canal water (1.01). River water recorded a value of 0.92 and bore well water the lowest value of 0.82 during this period.

Following the rainfall during monsoon period, there was a marginal decrease in SAR values for all the samples. During this period SAR of bore well water was 0.73. The highest SAR value of 0.91 was noticed for open well water followed by 0.65 for river water. The SAR of canal water was only 0.54 during this period.

The RSC and SAR for all the sources were within the safe limit and hence based on these parameters, the water is safe for irrigation. As expected the water samples from the different sources during monsoon season showed a decline due to the dilution effect during heavy monsoon.

3.7. Boron

The B content of irrigation water during pre-monsoon period was lower compared to monsoon period except in the case of river water. During pre-monsoon period, in bore well water the B content was highest (1.83 ppm). This was followed by open well water (1.28 ppm) river water (1.17 ppm) and canal water with the lowest B content (0.78 ppm), during both the periods of sampling.

During monsoon period the B content of all the sources except river water registered an increase. The B content of bore well water was 2.06 ppm, followed by open well water (1.46 ppm). In canal water it was 1.00 ppm, and in river water B content during this period was 0.82 ppm.

Among the four sources of irrigation water all the quality parameters, even though within the safe limits, recorded a slightly higher value in the bore well. These values were, however brought down due to the onset of monsoon but still were comparatively higher than the corresponding figures for canal, river and open well water.

4. CROP STUDIES

The yield of cane, dry matter production, uptake of nutrient elements of samples collected from 24 selected plots are presented in the Appendix V and the mean and range values for the regions are presented in Table 7. Region wise comparison of the above parameters is presented in Table 8.

4.1. Yield

The yield of sugarcane in Vannamada region varied from 82.72 to 119.85 t ha^{-1} with a mean of 105.31 t ha^{-1}. In Meenakshipuram, the yield ranged between 82.15 and 126.15 t ha^{-1} with a mean of 113.32 t ha^{-1}, while in Attapadi region the yield varied from 78.66 to 115.60 t ha^{-1}, the mean being 87.28 t ha^{-1}.

The yield of sugarcane among the three regions was found to be significantly different (Table 8 and Fig 2). The highest yield was recorded in Meenakshipuram and lowest in Attapadi region.

The mean yields of sugarcane (Table 8) obtained in all the three regions were comparatively much higher as compared to the state average of 63.5 t ha^{-1} (Anon, 1994). Better soil conditions, ensured irrigation facility with good quality irrigation water and better management practices adopted in these regions have resulted in the comparatively higher sugarcane yield. KAU (1992) has reported an yield of 133 t ha^{-1} for Thirumaduram variety, establishing the suitability of this variety for semi-arid tracts of Palghat.

Table 7. Mean and range value of plant uptake of nutrient elements

	Yield	Dry matter production	N	P	K	Na	Ca	Mg	Fe	Mn	Zn	Cu
	t ha^{-1}		kg ha^{-1}									
Vannamada												
	105.31	30.09	186.0	25.61	276	6.55	64.03	33.53	6.16	1.10	0.39	0.34
	(82.72-119.85)	(24.79-35.33)	(158.7-209.5)	(13.7-37.9)	(229-322)	(5.29-9.39)	(51.9-94.4)	(18.0-48.40)	(0.87-12.04)	(0.68-3.2)	(0.023-0.93)	(0.032-1.45)
Meenakshipuram												
	113.32	33.58	205.4	33.35	289	7.65	73.64	45.02	4.50	2.45	1.34	0.13
	(82.15-126.15)	(25.33-38.60)	(123.2-249.1)	(19.63-39.57)	(212-328)	(2.24-10.93)	(31.6-91.9)	(27.6-67)	(2.55-8.10)	(0.88-6.75)	(0.059-9.065)	(0.016-0.492)
Attapadi												
	87.28	26.57	149.5	22.88	205	3.89	58.87	21.00	7.88	1.54	0.39	0.59
	(78.66-115.6)	(23.98-37.77)	(118.8-233.9)	(17.5-36.4)	(162-313)	(1.6-8.87)	(20.3-106.2)	(4.2-32.0)	(4.11-17.0)	(0.70-3.03)	(0.033-1.528)	(0.011-2.157)

Table 8. Comparison of the yield, dry matter production and nutrient uptake of three regions (Mean table with CD value)

Parameter	Vannamada	Meenashi-puram	Attapadi	(CD 0.05) V-M*	V-A* or M-A*
Yield t ha^{-1}	105.31	113.32	87.28	13.697	15.313
TDM t ha^{-1}	30.09	33.58	26.57	4.292	4.798
Uptake of N kg ha^{-1}	186.0	205.4	149.5	33.44	37.61
Uptake of P "	25.61	33.35	22.88	7.27	8.13
Uptake of K "	276	289	205	42.57	47.59
Uptake of Na "	6.55	7.65	3.89	2.391	2.673
Uptake of Ca "	64.03	73.64	58.87	NS	NS
Uptake of Mg "	33.53	45.02	21.00	14.32	16.01
Uptake of Fe "	6.16	4.50	7.88	NS	NS
Uptake of Mn "	1.103	2.448	1.538	NS	NS
Uptake of Zn "	0.392	1.34	0.389	NS	NS
Uptake of Cu "	0.344	0.127	0.594	NS	NS

V-M* - For comparing Vannamada and Meenakshipuram
V-A* - For comparing Vannamada and Attapadi
M-A* - For comparing Meenakshipuram and Attapadi
NS - Not significant

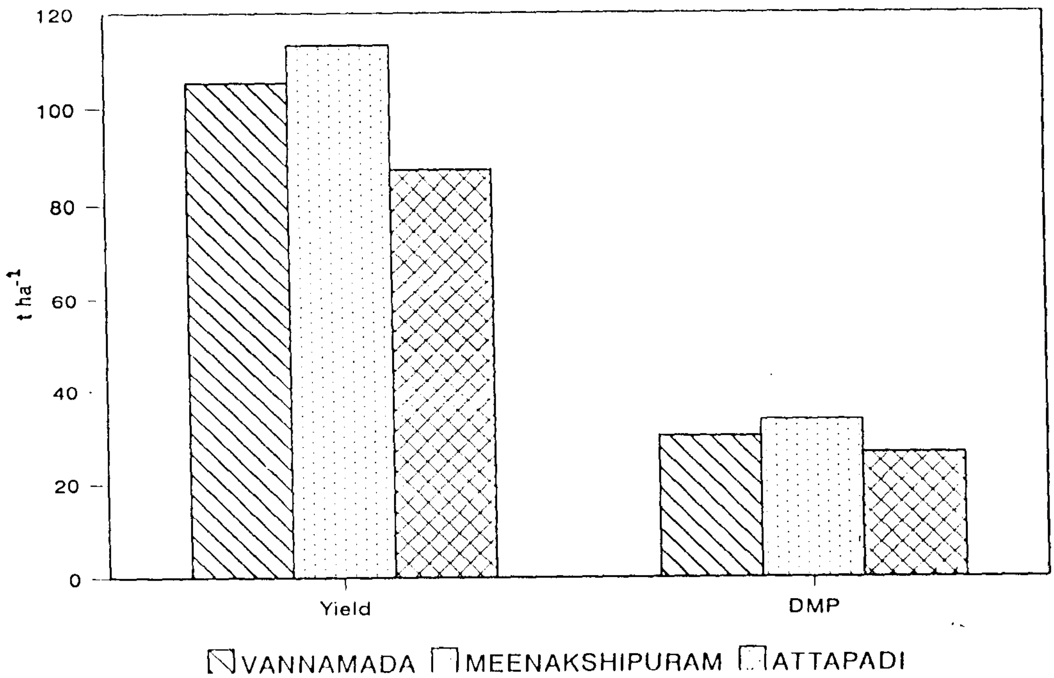


Fig. 2. Comparison of the yield and dry matter production of sugarcane of the three regions

4.2. Dry matter production

The dry matter production followed a similar trend as that of cane yield, with Vannamada region having a range between 24.79 and 35.33 t ha^{-1} with a mean of 30.09 t ha^{-1}. In Meenakshipuram it varied from 25.33 to 38.6 t ha^{-1} with a mean of 33.58 t ha^{-1}. In Attapadi the dry matter production showed a range between 23.98 and 37.77 t ha^{-1} with a mean of 26.57 t ha^{-1}.

Though the yield and dry matter production among the three regions were comparatively higher a significantly lower value for yield and dry matter production was observed in Attapadi (Table 8). This may be the result of comparatively poor growth of the crop in Attapadi, due to factors like variation in certain soil characteristics, elevation and slope in comparison to the other regions.

Sachan *et al.*, (1993) in a study on the effect of NPK on sugarcane in mollisols of Utter Pradesh suggested that thr major factors enhancing productivity were certain factors other than inherent soil fertility and fertility inputs.

4.3. Nitrogen

The uptake of N by sugarcane from Vannamada region varied between 158.7 and 209.5 kg ha^{-1} (Table 7) and the mean was 186.0 kg ha^{-1}. In Meenakshipuram region, the N uptake values ranged from 123.2 to 249.1 kg ha^{-1} with a mean of 205.4 kg ha^{-1}, while in Attapadi region it was appreciably lower compared to that of the other two regions. Here the value varied from a 118.8 to 233.9 kg ha^{-1} with a mean of 149.5 kg ha^{-1}.

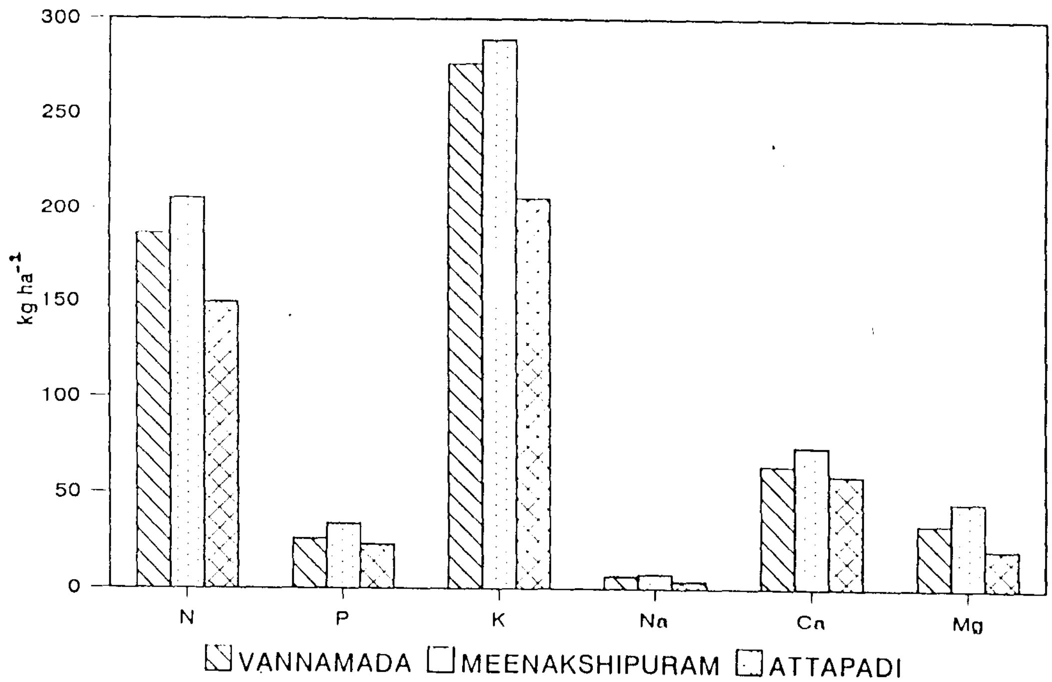


Fig. 3. Comparison of plant uptake of macro nutrient elements of the three regions

The uptake of nitrogen was highest in Meenakshipuram and lowest in Attapadi region and a significant variation was observed for uptake of N between the two regions (Table 8 and Fig 3). This may be attributed to the difference in dry matter production in these regions.

4.4. Phosphorus

The P uptake by sugarcane in Vannamada region showed a variation from 13.7 to 37.9 kg ha^{-1} with a mean of 25.61 kg ha^{-1}. In Meenakshipuram region the values varied between 19.63 and 39.57 kg ha^{-1} with a mean of 33.35 kg ha^{-1}. In Attapadi region the uptake of P by sugarcane ranged from 17.5 to 36.4 kg ha^{-1} with a mean of 22.88 kg ha^{-1}.

Comparison of the regions revealed that the uptake of P by plants was in the order Meenakshipuram > Vannamada > Attapadi, showing significant variations between regions (Table 8 and Fig 3).

Uptake of P recorded highest value in Meenakshipuram and lowest in Attapadi. The high available P status of the soil and low yields obtained in Attapadi region have resulted in a negative and significant correlation between available P status, yield, and dry matter production. The uptake of P also resulted in a non-significant and negative correlation with soil available P. It was also observed that the uptake of P increased significantly with an increase in uptake of N, K and Na. The comparatively poor crop growth in Attapadi region due to other unfavorable factors has resulted in the lower uptake of P inspite of high soil levels.

4.5. Potassium

In Vannamada region, the uptake of K ranged between 229 and 322 kg ha^{-1} with a mean value of 276 kg ha^{-1} and in Meenakshipuram it was between 212 and 328 kg ha^{-1} with a mean of 289 kg ha^{-1}. The uptake of K by sugarcane in Attapadi region was significantly lower than that of the other two regions. Here the uptake values ranged between 162 and 313 kg ha^{-1} with a mean value 205 kg ha^{-1}.

The uptake of K was significantly high in Meenakshipuram and Vannamada than in the Attapadi region (Table 8 and Fig. 3).

It was observed that as in the case of uptake of N and P, K also recorded highest value in Meenakshipuram and least in Attapadi (table 8).

The uptake of K also exhibited highly significantly positive correlation with yield and dry matter production (table 10).

4.6. Sodium

The uptake of Na in Vannamada samples varied between 5.29 and 9.39 kg ha^{-1} with a mean of 6.55 kg ha^{-1}, whereas the corresponding value for Meenakshipuram samples were 2.24 and 10.93 kg ha^{-1} the mean being 7.65 kg ha^{-1}. In Attapadi region the uptake of Na varied from 1.60 to 8.87 kg ha^{-1} with a mean of 3.89 kg ha^{-1}.

Both Meenakshipuram and Vannamada regions registered a significantly higher value of uptake than Attapadi (Table 8 and Fig 3).

Regarding Na, the uptake pattern followed similar trend as in the case of K indicating a supplementary interaction between the two nutrients in the plant system.

4.7. Calcium

The Ca uptake in the Vannamada samples exhibited a range from 51.9 to 94.4 kg ha^{-1} with a mean of 66.03 kg ha^{-1}. The corresponding range in the Meenakshipuram samples were 31.6 to 91.9 kg ha^{-1} with a mean of 73.64 kg ha^{-1}. In Attapadi region the variation in the uptake values were between 20.3 and 106.2 kg ha^{-1} with a mean 58.87 kg ha^{-1}.

The highest and lowest values of uptake of Ca were recorded in Attapadi region. The uptake of Ca showed a positive and significant correlation with yield and dry matter production (Table 10). The Ca uptake was found to increase significantly with increase in uptake of Na ($r = 0.408$).

4.8. Magnesium

In Vannamada region the uptake of Mg varied from 18 to 48.4 kg ha^{-1}. The uptake of Mg in Meenakshipuram samples ranged between 27.6 and 67.0 kg ha^{-1}. The corresponding range in Attapadi sample was between 4.2 and 32.0 kg ha^{-1}. The mean uptake of Mg in Vannamada, Meenakshipuram and Attapadi were 33.44 kg ha^{-1}, 45.02 kg ha^{-1} and 21.0 kg ha^{-1} respectively.

As in the case of the uptake of N, P and K, Mg also recorded a significant variation among regions. Highest uptake of Mg was recorded in Meenakshipuram and the lowest in Attapadi (Table 8 and Fig 3). The Mg uptake also recorded similar relationship as exhibited by Ca with yield and other yield attributes.

4.9. Iron

In Vannamada region the uptake of Fe varied from 0.87 to 12.04 kg ha^{-1} and the corresponding mean was 6.16 kg ha^{-1}. The Fe uptake in Meenakshipuram ranged between 2.55 and 8.10 kg ha^{-1} with a mean of 4.50 kg ha^{-1}, while in Attapadi region the values varied from 4.11 to 17.0 kg ha^{-1} with a mean 7.88 kg ha^{-1}.

The mean Fe uptake was higher in Attapadi region followed by Vannamada and Meenakshipuram. It was also observed that higher dry

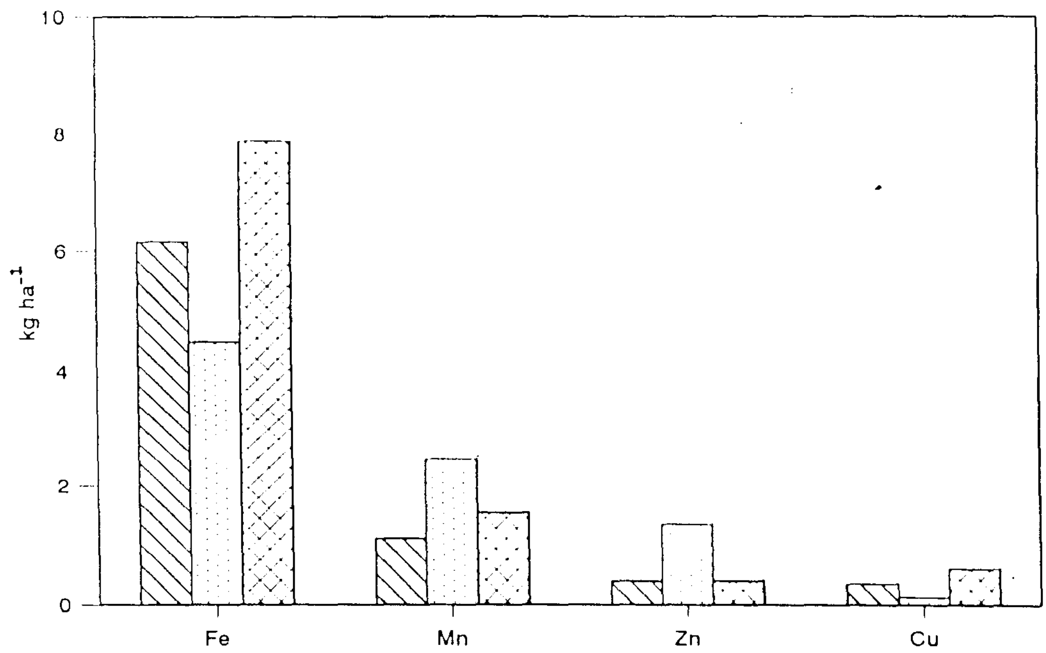


Fig. 4. Comparison of plant uptake of micro nutrient elements of the three regions

matter production did not result in greater uptake of micro nutrients especially Fe and Cu. Iron uptake was found to have a highly significant and positive correlation with copper, indicating a favourable Fe-Cu interaction both in soils and plants.

4.10. Manganese

The Mn uptake by sugarcane samples of Vannamada region showed a variation from 0.68 to 3.2 kg ha^{-1} with a mean of 1.1 kg ha^{-1}. In Meenakshipuram region the values varied between 0.88 and 6.75 kg ha^{-1} with a mean of 2.45 kg ha^{-1}. In Attapadi region the uptake of Mn by sugarcane ranged from 0.70 to 3.03 kg ha^{-1} with a mean of 1.54 kg ha^{-1}.

The highest mean uptake of Mn was in Meenakshipuram followed by Attapadi and Vannamada and was it found to have a non significant and positive correlation with yield and dry matter production. A significant and positive correlation was observed between Mn and P uptake. Similarly Mn uptake showed a significant positive correlation with Na and Zn uptake.

4.11. Zinc

In Vannamada region, the uptake of Zn ranged between 0.023 and 0.93 kg ha^{-1} with a mean of 0.39 kg ha^{-1} and that of Meenakshipuram region it was between 0.059 and 9.065 kg ha^{-1} with a mean 1.34 kg ha^{-1}. The uptake of Zn by sugarcane in Attapadi region ranged from 0.033 to 1.528 kg ha^{-1} with a mean value of 0.39 kg ha^{-1}.

The mean Zn uptake was highest in Meenakshipuram and lowest in Attapadi. Like Mn, uptake of Zn also showed a positive but non significant correlation with yield and dry matter production. Though the soils were sufficient with respect to Zn, the lower uptake of Zn may possibly be due to the antagonistic effect of K as reported by Rakkiyappan (1987).

4.12. Copper

The uptake of Cu by sugarcane in Vannamada samples varied between 0.032 and 1.45 kg ha^{-1} with a mean of 0.34 kg ha^{-1} where as the corresponding values for Meenakshipuram samples were 0.016 and 0.492

kg ha^{-1}, the mean being 0.13 kg ha^{-1}. In Attapadi region the Ca uptake values ranged from 0.011 to 2.157 kg ha^{-1} with a mean 0.59 kg ha^{-1}.

As in the case with uptake of Fe mean uptake of Cu was also highest in Attapadi soils followed by Vannamada and least in Meenakshipuram. The favourable Fe, Cu interaction has been observed in the uptake pattern as is evident from the significantly positive correlation between them. As in the case of Fe the uptake of Cu also showed a negative correlation with yield and dry matter production. The uptake of micronutrients followed the order Fe>Mn>Zn>Cu. In general, the uptake values of micronutrients obtained were low. The low uptake of micronutrients may be attributed to the higher pH values tending to neutrality and above.

5. JUICE QUALITY PARAMETERS

The juice quality parameters viz Brix, Pol (sucrose percentage), purity and commercial cane sugar (CCS) and percentage juice from cane are presented in Appendix VII. The range and mean values for the region are given in Table 9.

5.1. Brix

Brix, a measure of total soluble substances in the cane juice, did not show any appreciable variation. In Vannamada the brix value varied from 19.73 to 20.66 and the corresponding mean was 20.14. The brix value for the cane juice samples of Meenakshipuram ranged between 19.84 and 20.80 and with a mean of 20.38. In Attapadi region the brix value varied from 19.60 to 20.96 with a mean of 19.99.

Table 9. Mean and range values of juice quality parameters

Region	Brix	Percentage			
		Pol (sucrose)	Purity	CCS	Juice extraction
Vannamada	20.14	17.62	87.47	12.13	58.80
	(19.73 - 20.66)	(16.79 - 18.70)	(84.6 - 90.53)	(11.4 - 13.08)	(53.9 - 64.89)
Meenakshipuram	20.38	18.34	90.02	12.79	60.43
	(19.84 - 20.80)	(16.99 - 18.99)	(85.62 - 92.80)	(11.57 - 13.33)	(57.93 - 65.16)
Attappadi	19.99	17.08	85.41	11.62	65.55
	(19.60 - 20.96)	(16.11 - 19.51)	(81.30 - 93.08)	(10.68 - 13.82)	(62.63 - 70.11)

5.2. Pol (sucrose percentage)

The Pol (polarity reading) or sucrose percentage in the juice samples of Vannamada ranged between 16.79 and 18.70 with a mean of 17.62. In the case of Meenakshipuram samples, pol value exhibited a variation from 16.99 to 18.99 with a mean of 18.34. The values for the samples of Attapadi region ranged between 16.11 and 19.51 and the mean for this region was 17.08.

5.3. Purity

The purity coefficient or purity of the sucrose in the total soluble substance of the juice samples from Vannamada region showed a variation from 84.6 to 90.53 per cent with a mean of 87.47. In Meenakshipuram region it exhibited a range of 85.62 to 92.8 per cent with a mean of

90.02 per cent whereas in Attapadi region, purity values varied within the range from 81.30 to 93.00 per cent with a mean of 85.41 per cent.

5.4. Commercial cane sugar

The commercial cane sugar content or CCS of the cane juice samples of Vannamada region showed a variation from 11.4 to 13.08 per cent, the mean for the region being 12.13 per cent. In case of Meenakshipuram cane juice samples, CCS exhibited a range from 11.57 to 13.33 per cent with a mean of 12.79 per cent. The CCS for the samples from Attapadi region varied within the range of 10.68 and 13.82 per cent, for which the mean was 11.62 per cent.

5.5. Juice extraction percentage

The juice extraction percentage (the percentage of juice in the millable cane) in the samples of Vannamada was found to range from 53.9 to 64.89 with a mean of 58.80. In samples of Meenakshipuram, juice extraction percentage varied from 57.93 to 65.16 with a mean of 60.43, while in Attapadi region it showed a variation from 62.63 to 70.11. The mean for this region recorded was 65.55.

Observation of juice quality parameters viz, brix, pol value, purity and commercial cane sugar did not reveal any significant difference between the three region investigated.

The uptake of N, P, K and Na revealed a significant and positive correlation witn the juice quality parameters. This is contrary to the observation made by earlier workers Kadam *et al.*, (1983), Yadav, (1986) and Verma *et al.*, (1991).

6. CORRELATION STUDIES

6.1. Interrelationship between nutrient uptake, yield, dry matter production and juice quality of cane

The interrelationship between nutrient uptake, yield, dry matter production and juice quality parameters of cane are presented in the Table 10.

From correlation analysis it was found that dry matter production as expected had a highly significant positive correlation with yield (r = 0.925). Asokan (1981) had reported a highly significant positive correlation between cane yield and dry matter (r = 0.823). With yield, the uptake of major nutrients viz N, P, K and Na had a highly significant and positive correlation (r = 0.893, r = 0.819 and r = 0.840, r = 0.810 respectively).

The correlation of dry matter with uptake of nutrients showed a similar trend as that of yield with uptake of nutrients. The uptake of N exhibited a highly significant and positive correlation with dry matter (r = 0.937). The correlation between uptake of P, K and Na with dry matter was also highly significant and positive (r = 0.846, r = 0.795 and r = 0.822 respectively). The uptake of Ca, Mg, Mn and Zn also showed a positive, but not significant correlation with dry matter production (Table 10).

The uptake of Fe, however revealed a negative relationship with the juice quality as well as the uptake of other nutrients except Ca, Mn, Zn and Cu. The relationship between Ca, Mg and Zn though positive was of a low magnitude while the relationship with Cu was highly significant and positive. This shows the adverse effect of excess Fe on the quality parameters of cane juice as well as on the uptake of other major nutrients.

Table 10. Inter relationship between yield, dry matter production, juice quality parameters and uptake of nutrient elements.

	Yield																
Yield	1.00																
DMP	0.925**	DMP															
Brix	0.761**	0.838**	Brix														
Pol	0.820**	0.8777**	0.829**	Pol													
Purity	0.754**	0.786**	0.647**	0.980**	Purity												
C.C.S	0.804**	0.856**	0.784**	0.997**	0.980**	C.C.S											
Juice extraction %	-0.519**	-0.424*	-0.219	-0.251	-0.239	-0.249	Juice extraction										
Up take N	0.893**	0.937**	0.791**	0.813**	0.722**	0.722**	-0.437*	up take N									
P	0.819**	0.846**	0.652**	0.801**	0.771**	0.795**	-0.381	0.841**	P								
K	0.840**	0.795**	0.711**	0.776**	0.745**	0.783**	-0.595**	0.811**	0.758**	K							
Na	0.810**	0.822**	0.738**	0.766**	0.700**	0.760**	-0.469*	0.881**	0.818**	0.876**	Na						
Ca	0.304	0.354	0.097	0.178	0.205	0.183	-0.198	0.372	0.340	0.209	0.408*	Ca					
Mg	0.393	0.250	0.291	0.324	0.108	0.144	-0.143	0.302	0.082	0.324	0.276	0.147	Mg				
Fe	-0.208	-0.225	-0.266	-0.325	-0.145	-0.190	0.535**	-0.164	-0.265	-0.325	-0.188	0.307	-0.011	Fe.			
Mn	0.261	0.343	0.371	0.413*	0.315	0.404	0.290	0.321	0.439*	0.277	0.433*	0.202	0.209	0.145	Mn.		
Zn	0.185	0.208	0.298	0.222	0.252	0.286	0.231	0.179	0.222	0.222	0.294	0.108	0.272	0.157	0.801**	Zn.	
Cu	-0.247	-0.258	-0.264	-0.330	-0.114	-0.162	0.428*	-0.246	-0.244	-0.330	-0.186	0.321	-0.189	0.844**	0.154	0.131	Cu.

r (0.01) = 0.516 r (0.05) = 0.406

It was observed that the uptake of N depends on yield, and drymatter production as evident from its positive and highly significant correlation between these parameters (Table 10). Similar observations were made by Asokan (1981). The uptake of N exhibited a highly significant positive correlation with uptake of P and K (r = 0.841 and r = 0.811).

There exists a significant positive correlation between uptake of N and P (r = 0.841); uptake of N and K (r = 0.811) and between uptake of N and Na (r = 0.881). Also a highly significant and positive correlation exists between uptake of P and K (r = 0.758), and between uptake of P and Na (r = 0.818) and between K and Na (r = 0.876).

The uptake of Mn showed a significant positive correlation with uptake of N (r = 0.439) and uptake of K (r = 0.433). The uptake of Zn exhibited a highly significant positive correlation with uptake Mn (r = 0.801). There exist a highly significant correlation between the uptake of Cu and uptake of Fe (r = 0.844). Iron uptake was found to have a highly significant and positive correlation with that of Cu, indicating a favourable Fe-Cu interaction both in soil and plant.

6.2. Correlation between juice quality parameters and uptake of nutrients

The juice brix exhibited a highly significant and positive correlation with uptake of N (r = 0.791), uptake of P (r = 0.652), uptake of K (r = 0.711) and uptake of Na (r = 0.738).

Similarly there was a highly significant positive correlation for juice pol value with uptake of N (r = 0.813), uptake of P (r = 0.801), uptake of

K (r = 0.776) and uptake of Na (r = 0.766). The uptake of Mn also registered a significant and positive correlation with juice pol (r = 0.413).

The juice purity also registered a highly significant and positive correlation with uptake of N (r = 0.722), uptake of P (r = 0.771), uptake of K (r = 0.745) and uptake of Na (r = 0.700).

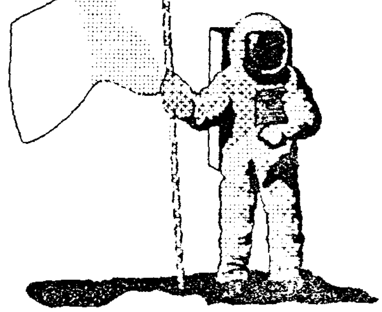
The CCS of juice also showed similar correlations. With uptake of N the CCS was found to have a positive and highly significant correlation (r = 0.722). Also with uptake of P, K and Na, the CCS showed highly significant positive correlation (r = 0.795, r = 0.785 and r = 0.760 respectively).

The juice extraction percentage was found to be correlated significantly and negatively with yield (r = -0.519) and dry matter production (r = -0.424). A negative and significant correlation was found to exist for juice extraction percentage with uptake of N (r = -0.437), uptake of K (r = -0.595) and with uptake of Na (r = -0.469). With uptake of P, the correlation was negative but not significant (r = -0.381).

All the juice quality parameters registered a positive but nonsignificant correlation with uptake of Ca, Mg, Mn and Zn, whereas with uptake of Fe and Cu the correlations were negative, but not significant (Table 10).

The juice pol recorded a positive and highly significant correlation with juice brix (r = 0.829). The juice purity also showed a significant and positive correlation with brix (r = 0.647). The correlation between purity and pol was highly significant and positive (r = 0.980). The CCS of juice also recorded a highly significant and positive correlation with brix (r = 0.784) pol (r = 0.997) and purity (r = 0.980).

SUMMARY AND CONCLUSION



SUMMARY AND CONCLUSION

An investigation was carried out to characterise the soil and irrigation water of the sugarcane belt of Palghat district in relation to nutrient uptake, yield and quality of sugarcane. One hundred and ninety seven soil samples representing the three regions, viz, Vannamada, Meenakshipuram and Attapadi in Palghat district, collected from a depth of 0-15 cm were subjected to the study. The soils of these regions consisted of black soils (Eutrochrepts) red soils (Haplustalfs) and alluvial soils (Ustipsamments). Twenty four farmer's fields growing sugarcane, comprising 9 each from Vannamada and Meenakshipuram regions and 6 from Attapadi region were identified as observation plots to assess the yield, dry matter production, nutrient uptake and quality parameters of sugarcane juice. Correlation studies were also made to determine the inter-relationship between nutrient uptake, yield, dry matter productions and juice quality of the cane. Samples of irrigations water from the four sources, viz., bore well, canal, open well and river water used for irrigating sugarcane plots were collected in the pre monsoon and monsoon periods for the determination of their quality parameters and effect on the crop. The salient findings are presented.

1. The reaction of the soils of all regions was mildly alkaline and did not register any significant variation. The EC of the soils recorded low value and both these parameters of the soils were within the safe limits for the growth of sugarcane. No significant variation between the regions was observed.

2. The sugarcane tract under study in Palghat district comprise mainly of sandy clay loam (52.8%) followed by sandy loam (25.9%). Other textural classes viz, sandy clay, clay loam,clay and loamy sand together constituted the remaining (21.8%).

3. The bulk density, particle density and pore space of the soils of the three regions did not show any significant variation. The mean values of both water holding capacity and volume expansion of the soils were significantly higher in Vannamada and lowest in Attapadi region. These physical properties had no adverse effect on the growth of sugarcane.

4. Organic matter content of the soils of the three regions was low which was reflected in the low total nitrogen content as well. Total P and K also recorded low values in the soils of the three regions. The low values of these nutrients noticed are characteristic of highly weathered tropical soils. The content of total N, P and K in the soils of the regions did not show any significant variation.

5. The mean values for available nitrogen in the soils of all the three regions showed a medium rating . The available P and K contents of Vannamada and Meenakshipuram regions showed a medium rating while the rating for Attapadi was high. Nitrogen, P and K are crucial elements in the nutrition of sugarcane and the wide variation in the content of these elements noticed in these regions warrants a careful nutrient management depending on the fertility status of the soil. The available sulphur content of the regions also followed the same trend as that of major nutrient elements and the status of available sulphur in the soils of all the three regions was above the soils' critical level needed for the growth of sugarcane.

6. Among the exchangeable cations Ca and Mg were predominant in all the three regions. The presence of free calcareous nodules in the soil has added to the status of exchangeable Ca as well as Mg. The exchangeable Mg and Na recorded a significantly higher value in the soils of Vannamada in comparison to the other two regions.

7. Available Fe and Zn in the soils of all the three regions were on par while the contents of Mn and Cu were significantly higher in the soils of Vannamada and Attapadi respectively. However the content of all these micro nutrients in the soils of the three regions were above the critical level suggested for the growth of sugarcane.

8. The pH of water used for irrigation, from the four sources, viz, bore well, Open well, canal and river exhibited a narrow range of variation, and all were on the alkaline side. This trend was observed both during pre monsoon and monsoon periods. Irrespective of the source, the water was suitable for irrigation.

9. The highest EC (1.91 dS m^{-1}) was observed during pre monsoon period in bore well water. The EC of other sources was comparatively low registering values less than 1 dS m^{-1} . Based on the rating of irrigation water the water samples of bore well come under C-3 (high salinity) while open well, canal and river water come under C-2 (medium salinity). Sugarcane being a salt tolerant crop, the water from all four sources can safely be used for irrigation under assured drainage.

10. The concentration of Cl^- and SO_4^{--} were highest in bore well followed by open well, canal and river water during both the periods, and their concentrations were also below the critical level fixed for irrigation water.

11. The mean RSC value during pre monsoon period was highest in bore well followed by canal water. River water recorded a low value while open well water recorded absence of any residual sodium carbonate. The RSC values for all the sources registered an increasing trend during monsoon season. Irrespective of the sources SAR recorded the highest value during pre monsoon period. Open well water recorded the highest value and, bore well the lowest. During monsoon season there was a marginal decrease in SAR values for all the samples, due to the dilution effect during monsoon rains. RSC and SAR for all the sources of water were within the safe limits for the irrigation of sugarcane.

12. The yield and dry matter production was significantly lower in Attapadi than in the other two regions. This may be the reflection of certain soil characteristics elevation and slope as compared to the other regions. However in comparison with the state average the yield was appreciably higher in all the three regions.

13. The uptake of nutrients, viz, N, P, K, Na, Ca, and Mg was highest in the soils of Meenakshipuram and lowest in Attapadi. Yield and dry matter production exhibited a significant positive correlation with uptake of N, P, K and Na.

14. The mean uptake of Fe and Cu was higher in Attapadi. The Fe uptake was found to have a highly significant positive correlation with Cu indicating a favourable Fe, Cu interaction both in soil and plant. The uptake of Mn and Zn was highest in Meenakshipuram. Uptake of both Mn and Zn exhibited a positive but non significant correlation with yield and dry matter. The uptake of micro nutrients

followed the order Fe > Mn > Zn > Cu. In general the uptake values obtained for micro nutrients were low. This may be attributed to high pH of the soil.

15. Juice quality parameters such as brix, pol value, purity and commercial sugar content did not exhibit any significant difference between the regions. Juice quality parameters were significantly and positively correlated with the uptake of N, P, K and Na.

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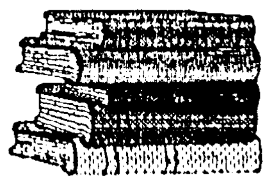

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APPENDICES

Appendix I. Particle size analysis of soils

Sample No.	Size separates (percentage)				Textural class
	Coarse sand	Fine sand	Silt	Clay	
Vannamada					
01	45.21	25.83	4.88	24.08	SANDY CLAY LOAM
02	35.34	29.18	8.86	26.62	SANDY CLAY LOAM
03	33.41	26.25	13.45	26.89	SANDY CLAY LOAM
04	33.52	8.38	27.50	30.60	CLAY LOAM
05	37.52	31.11	17.92	13.45	SANDY LOAM
06	26.10	20.50	26.70	26.70	SANDY CLAY LOAM
07	38.01	27.10	17.44	17.45	SANDY LOAM
08	45.24	32.43	8.93	13.40	SANDY LOAM
09	40.43	28.31	13.40	17.86	SANDY LOAM
10	51.40	30.20	9.20	9.20	LOAMY SAND
11	37.36	29.35	8.33	24.96	SANDY CLAY
12	37.58	8.14	12.55	41.83	SANDY CLAY LOAM
13	34.36	26.99	17.16	21.49	SANDY CLAY LOAM
14	33.41	26.25	13.45	26.89	SANDY CLAY LOAM
15	35.92	23.98	17.87	22.23	SANDY CLAY LOAM
16	30.81	24.21	18.00	26.98	SANDY CLAY LOAM
17	48.15	34.51	4.34	13.00	SANDY CLAY LOAM
18	35.50	10.15	12.55	41.83	SANDY CLAY
19	52.01	20.86	9.14	17.99	SANDY LOAM
20	38.26	30.47	8.96	22.41	SANDY CLAY LOAM
21	44.60	14.14	13.40	17.86	SANDY LOAM
22	42.95	30.69	13.18	13.18	SANDY LOAM
23	45.63	32.70	8.30	13.00	SANDY LOAM
24	43.42	31.12	12.73	12.73	SANDY LOAM
25	35.95	27.80	8.28	28.97	SANDY CLAY LOAM
26	49.18	29.08	8.70	13.04	SANDY LOAM
27	45.01	28.20	13.39	13.40	SANDY LOAM
28	46.42	14.19	17.51	21.88	SANDY CLAY LOAM
29	43.24	8.30	13.22	35.24	SANDY LOAM

Appendix I. (Contd...)

Sample No.	Size separates (percentage) Coarse sand	Fine sand	Silt	Clay	Textural class
30	35.42	28.34	13.59	22.65	SANDY LOAM
31	38.10	23.13	8.62	30.15	SANDY CLAY LOAM
32	39.80	8.57	9.39	42.24	SANDY CLAY
33	22.95	45.22	13.64	18.19	SANDY LOAM
34	40.10	6.12	13.44	40.34	SANDY CLAY
35	46.45	12.15	9.20	32.20	SANDY CLAY LOAM
36	34.44	14.96	9.20	41.40	SANDY CLAY
37	37.76	19.46	9.50	33.28	SANDY CLAY LOAM
38	51.72	23.50	9.92	14.86	SANDY LOAM
39	47.55	12.25	13.40	26.80	SANDY CLAY LOAM
40	36.53	4.23	16.93	42.31	CLAY
41	50.54	31.86	4.60	23.00	SANDY CLAY LOAM
42	35.33	27.68	9.27	27.82	SANDY CLAY LOAM
43	33.86	26.62	13.18	26.34	SANDY CLAY LOAM
44	34.00	8.51	28.74	28.75	CLAY LOAM
45	39.32	29.64	17.73	13.31	SANDY LOAM
46	25.88	20.34	26.89	26.89	SANDY CLAY LOAM
47	33.95	33.48	15.28	15.28	SANDY LOAM
48	46.64	33.50	8.73	13.13	LOAMY SAND
49	39.67	27.87	13.91	18.55	SANDY LOAM
50	55.48	26.87	9.20	9.20	LOAMY SAND
51	38.35	27.60	8.51	25.54	SANDY CLAY LOAM
52	26.71	19.34	12.45	41.50	SANDY CLAY
53	35.20	25.67	17.39	21.74	SANDY CLAY LOAM
54	34.52	25.00	13.49	26.99	SANDY CLAY LOAM
55	34.25	25.44	22.39	17.92	SANDY LOAM
56	30.90	19.28	17.93	26.89	SANDY CLAY LOAM
57	46.23	32.32	14.37	13.08	SANDY CLAY LOAM
58	24.93	20.58	12.53	41.96	SANDY CLAY
59	45.71	27.10	9.07	18.12	SANDY LOAM
60	39.60	29.38	8.84	22.18	SANDY CLAY LOAM

Appendix I. (Contd...)

Sample No.	Size separates (percentage) Coarse sand	Fine sand	Silt	Clay	Textural class
61	39.10	28.32	13.96	18.62	SANDY LOAM
62	43.01	31.15	12.92	12.92	SANDY LOAM
63	47.10	34.11	4.71	14.09	LOAMY SAND
64	43.48	31.48	12.52	12.52	SANDY LOAM
65	55.13	7.78	9.27	27.82	SANDY CLAY LOAM
66	37.15	6.99	23.27	32.59	CLAY LOAM
67	39.60	9.90	9.10	41.40	SANDY CLAY
68	23.94	44.46	13.54	18.06	SANDY LOAM
69	36.76	10.38	13.21	39.65	SANDY CLAY
70	46.17	12.27	9.23	32.33	SANDY CLAY LOAM
71	34.73	15.61	9.03	40.63	SANDY CLAY
72	39.89	17.84	9.35	32.92	SANDY CLAY LOAM
73	51.81	14.15	19.32	14.72	SANDY LOAM
74	47.57	13.42	13.00	26.01	SANDY CLAY LOAM
75	31.45	7.87	16.84	43.84	CLAY
76	38.33	27.98	14.15	19.54	SANDY LOAM
77	44.38	30.38	12.62	12.62	SANDY LOAM
78	49.64	31.80	4.89	13.67	LOAMY SAND
79	43.98	30.56	12.73	12.73	SANDY LOAM
Meenakshipuram					
01	45.53	33.10	8.37	13.00	SANDY LOAM
02	33.48	31.28	8.81	26.43	SANDY CLAY LOAM
03	44.10	20.66	4.41	30.83	SANDY CLAY LOAM
04	34.38	34.99	4.37	26.26	SANDY CLAY LOAM
05	40.40	28.97	13.12	17.51	SANDY LOAM
06	41.99	36.54	4.39	17.08	SANDY LOAM
07	46.03	12.36	8.32	33.29	SANDY CLAY LOAM
08	35.28	29.12	13.35	22.25	SANDY CLAY LOAM
09	34.51	25.16	23.11	17.22	SANDY LOAM

Appendix I. (Contd...)

Sample No.	Size separates (percentage) Coarse sand	Fine sand	Silt	Clay	Textural class
10	34.01	22.37	13.08	30.54	SANDY CLAY LOAM
11	50.42	21.18	14.20	14.20	SANDY LOAM
12	39.53	31.02	8.41	21.04	SANDY CLAY LOAM
13	26.14	12.60	18.50	42.76	SANDY CLAY LOAM
14	48.61	11.74	8.81	30.84	SANDY CLAY LOAM
15	22.81	50.49	4.45	22.25	SANDY CLAY LOAM
16	45.48	26.39	11.49	16.64	SANDY LOAM
17	37.45	29.70	8.21	24.64	SANDY CLAY LOAM
18	35.59	33.78	4.38	26.25	SANDY CLAY LOAM
19	29.18	31.96	8.72	30.14	SANDY CLAY LOAM
20	40.51	15.83	21.78	21.88	SANDY CLAY LOAM
21	56.52	26.60	4.22	12.66	LOAMY SAND
22	40.96	15.42	13.07	30.55	SANDY CLAY LOAM
23	40.96	15.97	21.53	21.54	SANDY CLAY LOAM
24	29.31	27.03	26.30	17.36	SANDY LOAM
25	33.26	14.22	19.10	33.42	SANDY CLAY LOAM
26	36.25	11.46	14.26	38.03	SANDY LOAM
27	27.61	15.12	13.22	44.05	SANDY CLAY
28	45.40	6.14	13.22	35.24	SANDY CLAY LOAM
29	32.01	16.99	18.54	32.46	SANDY CLAY LOAM
30	30.95	5.85	14.59	48.61	CLAY
31	62.15	6.58	8.86	22.41	SANDY CLAY LOAM
32	50.64	14.88	8.65	25.83	SANDY CLAY LOAM
33	55.97	10.37	8.42	25.24	SANDY CLAY LOAM
34	51.54	10.32	8.47	29.67	SANDY CLAY LOAM
35	45.55	32.98	4.29	17.18	SANDY LOAM
36	44.12	10.67	9.06	36.15	SANDY CLAY
37	32.90	27.65	14.79	24.66	SANDY CLAY LOAM
38	34.21	25.45	22.41	17.93	SANDY LOAM
39	32.09	24.28	13.08	30.55	SANDY CLAY LOAM
40	41.56	29.92	14.26	14.26	SANDY LOAM

Appendix I. (Contd...)

Sample No.	Size separates (percentage)				Textural class
	Coarse sand	Fine sand	Silt	Clay	
41	41.33	29.92	8.22	20.53	SANDY CLAY LOAM
42	25.36	12.96	17.63	44.05	CLAY
43	39.37	20.29	13.45	26.89	SANDY CLAY LOAM
44	43.45	29.26	4.55	22.74	SANDY CLAY LOAM
45	36.12	11.04	8.79	44.05	CLAY
46	41.31	11.32	12.69	34.68	CLAY LOAM
47	39.58	29.68	8.79	21.95	SANDY CLAY LOAM
48	34.34	36.65	8.67	30.34	SANDY CLAY LOAM
49	32.21	24.16	21.82	21.81	SANDY CLAY LOAM
50	54.82	28.25	4.24	12.69	LOAMY SAND
51	46.00	32.05	8.78	13.17	SANDY LOAM
52	43.05	29.96	13.49	13.50	SANDY LOAM
53	35.41	26.40	16.97	21.22	SANDY CLAY LOAM
54	29.34	21.87	13.31	35.48	SANDY CLAY LOAM
55	37.02	27.12	13.45	22.41	SANDY CLAY LOAM
56	46.57	31.89	8.62	12.92	SANDY LOAM
57	30.35	21.97	8.67	39.01	SANDY CLAY
58	36.59	24.40	8.67	30.34	SANDY CLAY LOAM
59	45.42	32.77	8.72	13.09	SANDY LOAM
60	34.75	23.18	14.02	28.05	SANDY CLAY LOAM
61	30.67	32.81	9.13	27.39	SANDY CLAY LOAM
62	21.95	23.07	22.90	32.08	CLAY LOAM
63	27.25	29.13	13.08	30.54	SANDY CLAY LOAM
64	33.11	35.40	9.00	22.49	SANDY CLAY LOAM
65	62.39	16.63	8.39	12.59	LOAMY SAND
66	48.04	9.40	12.77	29.79	SANDY CLAY LOAM
Attapadi					
01	42.78	35.34	8.75	13.13	LOAMY SAND
02	44.45	22.98	18.60	13.97	SANDY LOAM
03	29.58	21.63	8.87	39.92	SANDY CLAY

Appendix I. (Contd...)

Sample No.	Size separates (percentage) Coarse sand	Fine sand	Silt	Clay	Textural class
04	27.38	28.28	13.00	30.34	SANDY CLAY LOAM
05	33.24	41.44	8.44	16.88	SANDY LOAM
06	22.24	50.93	13.39	13.44	SANDY LOAM
07	23.57	46.28	12.92	17.23	SANDY LOAM
08	22.95	32.39	13.40	31.26	SANDY CLAY LOAM
09	22.29	23.62	12.48	41.61	CLAY
10	20.19	18.13	16.44	35.24	CLAY LOAM
11	27.69	42.16	8.61	21.54	SANDY CLAY LOAM
12	29.69	39.47	7.81	23.03	SANDY CLAY LOAM
13	45.39	20.86	12.65	21.10	SANDY CLAY LOAM
14	29.76	31.52	12.81	25.61	SANDY CLAY LOAM
15	27.44	29.35	12.96	30.25	SANDY CLAY LOAM
16	25.95	33.33	15.69	25.03	SANDY CLAY LOAM
17	16.20	15.59	18.18	50.03	CLAY
18	29.87	31.94	8.49	29.70	SANDY CLAY LOAM
19	36.74	30.23	8.26	24.77	SANDY CLAY LOAM
20	46.62	29.40	9.59	14.39	SANDY LOAM
21	33.32	35.63	8.87	22.18	SANDY CLAY LOAM
22	19.57	19.56	21.74	39.13	CLAY LOAM
23	32.00	32.35	13.69	31.96	SANDY CLAY LOAM
24	20.23	11.03	22.92	45.82	CLAY
25	32.10	9.21	13.55	45.14	CLAY
26	29.25	25.10	20.75	24.90	SANDY CLAY LOAM
27	31.64	34.11	12.84	21.41	SANDY CLAY LOAM
28	37.60	15.30	12.85	34.25	SANDY CLAY LOAM
29	23.79	28.00	20.09	28.12	SANDY CLAY LOAM
30	25.59	24.16	20.96	29.29	SANDY CLAY LOAM
31	33.34	37.34	8.09	20.23	SANDY CLAY LOAM
32	13.70	25.62	21.67	39.01	CLAY LOAM
33	26.76	39.09	8.54	25.61	SANDY CLAY LOAM
34	28.15	34.60	12.42	24.83	SANDY CLAY LOAM

Appendix I. (Contd...)

Sample No.	Size separates (percentage)				Textural class
	Coarse sand	Fine sand	Silt	Clay	
35	23.17	40.45	10.40	25.98	SANDY CLAY LOAM
36	19.84	52.17	8.00	19.99	SANDY CLAY LOAM
37	27.51	34.60	12.97	25.92	SANDY CLAY LOAM
38	20.20	28.73	17.02	34.05	SANDY CLAY LOAM
39	26.50	10.30	13.54	49.66	CLAY
40	37.49	42.42	8.04	12.05	LOAMY SAND
41	28.49	41.63	8.54	21.34	SANDY CLAY LOAM
42	18.97	40.84	13.29	26.80	SANDY CLAY LOAM
43	41.99	16.05	7.63	34.33	SANDY CLAY LOAM
44	30.77	23.57	14.40	31.26	SANDY CLAY LOAM
45	24.18	34.73	13.70	27.39	SANDY CLAY LOAM
46	18.80	29.21	14.45	38.54	SANDY CLAY
47	23.15	39.60	16.55	20.70	SANDY CLAY LOAM
48	24.64	37.97	14.02	23.37	SANDY CLAY LOAM
49	25.97	41.30	12.38	20.45	SANDY CLAY LOAM
50	50.20	20.35	8.41	21.04	SANDY CLAY LOAM
51	27.65	47.45	8.30	16.60	SANDY LOAM
52	24.04	22.84	12.26	40.86	SANDY LOAM

Appendix II. Single value constants of soils

Sample No.	Mg m^{-3} Bulk density	Particle density	Percentage W H C	Pore space	Volume expansion
Vannamada					
01	1.35	2.32	36.71	39.72	3.10
02	1.32	2.28	36.78	46.67	8.10
03	1.42	2.25	33.31	46.63	12.78
04	1.40	2.50	44.44	56.98	22.97
05	1.27	2.25	46.44	52.40	16.47
06	1.28	2.27	43.31	53.47	16.64
07	1.41	2.33	38.55	50.34	17.52
08	1.40	2.26	37.84	50.78	16.47
09	1.39	2.32	36.76	48.75	13.12
10	1.34	2.18	31.31	44.81	9.02
11	1.38	2.49	38.37	51.36	9.88
12	1.39	2.47	37.08	51.00	10.54
13	1.43	2.38	35.18	42.28	2.32
14	1.41	2.25	29.26	41.00	4.96
15	1.21	2.26	39.02	46.55	9.37
16	1.34	2.24	33.88	42.49	4.61
17	1.53	2.35	25.02	37.41	4.06
18	1.36	2.33	35.06	46.37	6.85
19	1.46	2.24	24.63	37.65	2.82
20	1.23	2.25	33.92	40.98	4.78
21	1.32	2.26	34.51	43.98	10.63
22	1.43	2.32	29.86	45.25	5.68
23	1.46	2.42	33.78	46.99	11.22
24	1.38	2.18	30.28	40.87	5.54
25	1.43	2.51	41.80	52.80	17.86
26	1.51	2.34	27.04	40.68	7.02
27	1.33	2.26	33.01	45.84	4.78
28	1.44	2.32	34.58	44.19	11.74
29	1.56	2.30	33.73	46.00	20.00
30	1.39	2.22	30.87	35.69	9.64

Appendix II. (Contd...)

	Mg m^{-3}		Percentage		
Sample No	Bulk density	Particle density	W H C	Pore space	Volume expansion
31	1.38	2.37	42.29	51.76	18.35
32	1.30	2.13	41.79	48.97	16.78
33	1.35	2.21	47.53	50.15	19.69
34	1.37	2.25	32.86	43.30	6.80
35	1.33	2.18	35.73	45.00	10.53
36	1.24	2.18	45.66	50.75	14.00
37	1.35	2.10	35.51	43.62	13.53
38	1.37	2.13	36.22	45.24	6.01
39	1.39	2.26	37.57	47.24	21.83
40	1.30	2.43	43.77	54.42	10.78
41	1.38	2.36	38.33	43.73	6.10
42	1.28	2.34	36.68	47.68	6.89
43	1.43	2.31	33.21	47.49	12.61
44	1.46	2.54	39.98	57.25	19.78
45	1.23	2.28	46.02	52.66	21.96
46	1.29	2.25	43.26	53.14	16.57
47	1.42	2.36	38.24	48.69	16.88
48	1.40	2.32	37.79	50.41	16.39
49	1.34	2.16	36.72	53.42	13.70
50	1.34	2.18	34.51	44.85	9.08
51	1.38	2.41	38.69	50.33	10.40
52	1.40	2.50	36.97	51.25	10.37
53	1.43	2.40	32.97	42.70	3.70
54	1.42	2.41	33.41	43.00	9.72
55	1.27	2.25	38.13	45.87	10.12
56	1.36	2.25	33.14	42.23	5.12
57	1.46	2.39	28.82	38.29	3.90
58	1.37	2.40	34.84	48.43	7.28
59	1.46	2.22	24.66	36.73	2.85
60	1.31	2.29	33.68	44.39	11.91
61	1.35	2.15	34.23	43.79	11.34

×

Appendix II. (Contd...)

Sample No	Mg m^{-3} Bulk density	Particle density	Percentage W H C	Pore space	Volume expansion
62	1.45	2.37	29.34	43.33	6.33
63	1.40	2.23	30.13	41.28	6.45
64	1.48	2.48	33.57	47.47	11.52
65	1.26	2.33	48.74	52.88	12.96
66	1.36	2.37	42.72	51.69	18.86
67	1.45	2.26	37.52	50.53	18.47
68	1.41	2.23	39.47	47.69	19.84
69	1.38	2.30	33.16	44.86	6.92
70	1.36	2.17	40.54	49.50	12.89
71	1.25	2.23	45.63	51.27	14.03
72	1.37	2.14	35.53	44.06	13.54
73	1.10	2.03	43.73	47.98	2.82
74	1.42	2.35	36.51	48.08	20.11
75	1.37	2.35	43.55	47.78	13.42
76	1.36	2.04	35.48	37.70	11.23
77	1.48	2.45	30.88	46.27	5.50
78	1.44	2.31	29.74	43.78	5.73
79	1.46	2.42	33.78	46.99	11.12
Meenakshipuram					
01	1.54	2.35	25.15	38.62	5.17
02	1.36	2.30	37.43	48.24	11.79
03	1.20	2.30	40.02	55.27	11.34
04	1.43	2.32	32.72	44.28	9.04
05	1.31	2.14	36.77	45.14	10.09
06	1.44	2.38	32.87	44.93	8.54
07	1.36	2.49	34.60	48.45	6.66
08	1.33	2.27	39.80	49.84	16.03
09	1.31	2.25	33.66	44.49	7.93
10	1.35	2.33	32.24	48.97	9.67

Appendix II. (Contd...)

	Mg m^{-3}		Percentage		
Sample No	Bulk density	Particle density	W H C	Pore space	Volume expansion
11	1.23	2.11	37.86	46.39	5.94
12	1.55	2.45	26.39	40.09	2.05
13	1.50	2.30	38.49	50.44	6.46
14	1.50	2.46	27.02	36.74	2.54
15	1.33	2.32	35.42	41.18	4.05
16	1.60	2.49	22.51	37.18	1.70
17	1.46	2.54	32.32	47.87	6.97
18	1.37	2.32	35.19	44.04	6.99
19	1.35	2.33	39.59	48.14	1.03
20	1.43	2.32	30.90	41.62	5.54
21	1.47	2.44	28.28	41.48	2.13
22	1.26	2.33	48.74	52.88	12.96
23	1.36	2.37	42.72	51.69	18.86
24	1.45	2.26	37.52	50.53	18.47
25	1.20	2.09	46.41	58.11	18.96
26	1.19	2.10	55.29	57.79	23.15
27	1.13	2.33	47.27	57.42	21.87
28	1.41	2.30	38.34	48.95	17.17
29	1.38	2.16	33.39	43.80	11.04
30	1.29	2.05	37.24	45.19	18.01
31	1.35	2.25	22.20	33.37	6.13
32	1.49	2.36	25.71	39.46	2.68
33	1.54	2.45	25.70	40.96	3.12
34	1.50	2.41	26.87	40.77	3.77
35	1.44	2.38	33.29	45.59	8.78
36	1.29	2.22	35.10	45.78	10.44
37	1.32	2.32	35.25	41.93	12.80
38	1.38	2.25	32.44	39.19	11.94
39	1.34	2.33	36.78	48.29	10.73
40	1.31	2.10	29.14	45.81	6.29
41	1.46	2.54	32.30	42.36	2.64

Appendix II. (Contd...)

	$Mg\ m^{-3}$		Percentage		
Sample No	Bulk density	Particle density	W H C	Pore space	Volume expansion
42	1.37	2.30	38.28	50.39	15.33
43	1.50	2.25	24.31	36.37	3.70
44	1.37	2.21	33.93	43.89	8.20
45	1.23	2.32	35.98	54.97	14.20
46	1.34	2.35	37.94	40.56	15.60
47	1.38	2.31	33.89	44.00	7.27
48	1.35	2.35	39.27	48.66	11.28
49	1.44	2.33	30.48	41.56	5.91
50	1.47	2.43	29.33	41.19	2.55
51	1.48	2.31	28.89	40.10	7.17
52	1.33	2.24	33.12	43.16	5.08
53	1.47	2.42	34.23	46.49	12.36
54	1.56	2.28	33.38	46.24	21.35
55	1.42	2.25	27.49	31.76	5.55
56	1.49	2.37	33.42	38.27	6.49
57	1.38	2.35	38.75	48.66	12.83
58	1.20	2.35	40.34	55.89	11.62
59	1.45	2.33	31.52	44.30	9.26
60	1.30	2.14	36.76	45.12	10.48
61	1.36	2.20	35.31	45.84	12.25
62	1.33	2.19	37.82	47.30	13.11
63	1.27	2.33	48.22	53.34	14.77
64	1.50	2.24	29.38	33.18	6.49
65	1.46	2.46	32.49	39.93	3.14
66	1.50	2.41	29.93	40.86	3.86
Attapadi					
01	1.22	2.32	38.74	45.34	8.60
02	1.21	2.15	41.58	50.32	3.36
03	1.46	2.28	32.33	37.47	6.50

Appendix II. (Contd...)

	Mg m^{-3}		Percentage		
Sample No	Bulk density	Particle density	W H C	Pore space	Volume expansion
04	1.41	2.35	32.76	46.31	7.97
05	1.51	2.44	34.99	43.53	7.04
06	1.38	2.26	31.64	44.33	5.33
07	1.49	2.37	29.15	44.22	9.39
08	1.43	2.26	30.32	43.13	8.63
09	1.51	2.49	30.26	45.50	11.69
10	1.59	2.30	33.70	46.07	20.31
11	1.43	2.37	30.65	44.11	6.86
12	1.42	2.30	33.40	45.84	12.22
13	1.45	2.44	31.36	39.84	2.88
14	1.45	2.40	31.64	39.47	2.96
15	1.32	2.36	36.15	46.75	4.81
16	1.29	2.27	31.96	40.78	6.34
17	1.24	2.24	42.68	52.57	12.25
18	1.44	2.42	30.39	43.46	2.31
19	1.48	2.52	30.28	43.59	3.28
20	1.17	2.08	31.98	46.80	5.02
21	1.40	2.28	30.64	43.22	6.84
22	1.37	2.34	33.87	46.67	7.09
23	1.38	2.20	33.73	44.24	11.01
24	1.29	2.19	37.94	48.49	9.83
25	1.35	2.23	34.98	45.25	7.90
26	1.48	2.50	31.19	46.25	6.67
27	1.54	2.67	27.48	49.41	6.35
28	1.38	2.39	31.99	44.76	2.63
29	1.43	2.63	30.20	43.52	4.30
30	1.46	2.47	30.71	44.09	5.14
31	1.57	2.60	34.61	43.28	5.79
32	1.26	2.35	39.78	50.35	5.29
33	1.30	2.40	37.59	49.10	3.95
34	1.44	2.51	30.98	44.65	10.98

Appendix II. (Contd...)

	Mg m^{-3}		Percentage		
Sample No	Bulk density	Particle density	W H C	Pore space	Volume expansion
35	1.24	2.04	38.87	54.77	10.05
36	1.55	2.65	31.78	46.34	8.42
37	1.41	2.36	32.56	44.77	6.62
38	1.33	2.41	36.09	47.71	9.85
39	1.20	2.23	39.89	46.43	9.78
40	1.54	2.63	25.44	40.93	4.57
41	1.47	2.40	29.28	42.05	4.96
42	1.31	2.26	37.31	47.43	8.67
43	1.32	2.28	38.26	49.06	8.85
44	1.38	2.26	30.24	40.12	2.22
45	1.27	2.20	40.79	49.14	8.62
46	1.34	2.07	38.16	41.02	11.16
47	1.59	2.51	31.25	44.04	12.73
48	1.41	2.14	32.41	34.84	7.97
49	1.35	2.30	33.53	44.27	4.72
50	1.46	2.45	37.87	40.39	5.51
51	1.53	2.50	27.58	42.72	4.41
52	1.54	2.56	27.82	43.55	6.39

Appendix III. Organic matter and total nutrient status of soils

Sample No.	Percentage			
	Organic matter	Total N	Total P	Total K
Vannamada				
01	1.16	0.064	0.16	0.53
02	1.50	0.100	0.20	0.55
03	0.93	0.060	0.13	0.60
04	0.92	0.060	0.12	1.48
05	0.76	0.052	0.11	1.18
06	0.86	0.056	0.12	1.25
07	1.26	0.080	0.17	1.23
08	0.86	0.056	0.12	1.13
09	1.02	0.068	0.14	0.83
10	0.72	0.048	0.14	0.70
11	0.80	0.044	0.06	0.78
12	0.92	0.060	0.07	0.88
13	1.92	0.140	0.22	0.53
14	0.76	0.056	0.09	0.70
15	0.80	0.052	0.07	0.88
16	0.81	0.056	0.09	0.83
17	0.64	0.044	0.08	0.45
18	1.40	0.088	0.12	0.53
19	1.26	0.080	0.11	0.55
20	0.86	0.044	0.06	1.08
21	1.32	0.088	0.18	0.60
22	0.72	0.044	0.06	0.40
23	0.76	0.048	0.06	0.60
24	1.40	0.088	0.12	1.18
25	1.00	0.068	0.12	1.40
26	1.26	0.080	0.11	1.13
27	1.76	0.116	0.24	1.09
28	1.90	0.136	0.22	1.60
29	1.90	0.128	0.25	1.43
30	1.40	0.100	0.16	1.03
31	0.94	0.064	0.13	1.48
32	1.16	0.076	0.16	1.25
33	0.94	0.064	0.13	1.30
34	0.90	0.060	0.12	0.70

Appendix III. (Contd...)

Sample No.	Percentage			
	Organic matter	Total N	Total P	Total K
35	0.70	0.048	0.10	0.85
36	1.20	0.080	0.17	1.45
37	0.66	0.048	0.08	0.80
38	0.54	0.044	0.06	0.40
39	1.60	0.104	0.22	1.35
40	1.34	0.084	0.15	1.68
41	1.16	0.072	0.15	0.55
42	1.55	0.104	0.16	0.58
43	1.12	0.076	0.12	0.58
44	0.92	0.060	0.11	1.38
45	0.76	0.052	0.10	1.08
46	0.86	0.056	0.11	1.15
47	1.26	0.084	0.16	1.13
48	0.86	0.056	0.11	1.03
49	1.02	0.064	0.13	0.75
50	0.72	0.044	0.13	0.73
51	0.80	0.052	0.06	0.75
52	0.92	0.048	0.07	0.83
53	1.93	0.128	0.18	0.58
54	0.80	0.052	0.08	0.68
55	0.83	0.056	0.07	0.80
56	0.86	0.060	0.08	0.78
57	0.66	0.048	0.08	0.50
58	1.39	0.088	0.11	0.50
59	1.26	0.084	0.10	0.58
60	0.86	0.040	0.07	0.95
61	1.33	0.088	0.15	0.63
62	0.76	0.048	0.07	0.93
63	0.80	0.056	0.07	0.60
64	1.46	0.092	0.11	0.68
65	0.96	0.068	0.22	0.70
66	1.36	0.092	0.19	0.73
67	1.19	0.080	0.14	1.25
68	0.97	0.064	0.12	1.28
69	0.93	0.060	0.12	0.65
70	0.73	0.044	0.10	0.80

Appendix III. (Contd...)

Sample No.	Percentage Organic matter	Total N	Total P	Total K
71	1.26	0.084	0.15	1.38
72	0.72	0.052	0.08	0.53
73	0.60	0.052	0.09	0.38
74	1.66	0.100	0.16	1.28
75	1.37	0.088	0.14	1.70
76	1.46	0.096	0.17	0.55
77	1.80	0.112	0.07	0.35
78	0.80	0.052	0.07	0.53
79	1.46	0.104	0.11	1.15
Meenakshipuram				
01	0.66	0.032	0.05	0.70
02	0.80	0.052	0.07	1.05
03	0.92	0.044	0.07	1.38
04	1.20	0.060	0.09	0.68
05	1.26	0.084	0.17	0.70
06	0.86	0.068	0.10	0.53
07	0.64	0.040	0.05	0.43
08	1.32	0.084	0.15	0.88
09	0.60	0.032	0.05	0.48
10	1.50	0.096	0.11	1.50
11	1.90	0.120	0.16	0.83
12	0.96	0.060	0.08	0.85
13	1.56	0.100	0.13	0.83
14	0.80	0.052	0.07	0.68
15	0.72	0.044	0.06	0.93
16	0.96	0.052	0.08	0.68
17	0.86	0.044	0.06	0.55
18	0.60	0.032	0.05	0.63
19	0.72	0.036	0.05	0.60
20	0.92	0.060	0.08	0.63
21	0.60	0.040	0.05	0.55
22	1.42	0.080	0.20	1.50
23	1.50	0.100	0.20	0.85
24	1.22	0.080	0.16	1.30

Appendix III. (Contd...)

Sample No.	Percentage			
	Organic matter	Total N	Total P	Total K
25	1.68	0.088	0.24	1.78
26	1.00	0.068	0.14	1.48
27	1.38	0.092	0.19	1.50
28	1.46	0.096	0.20	1.25
29	1.82	0.020	0.24	1.08
30	1.36	0.096	0.19	1.53
31	0.88	0.064	0.10	0.80
32	0.94	0.064	0.08	1.35
33	0.88	0.044	0.07	0.78
34	0.88	0.044	0.07	1.70
35	0.86	0.068	0.11	0.55
36	0.66	0.044	0.06	0.48
37	1.40	0.112	0.14	0.78
38	0.60	0.036	0.06	0.53
39	1.47	0.092	0.11	1.45
40	1.87	0.116	0.14	0.80
41	0.93	0.056	0.08	0.78
42	1.53	0.096	0.12	0.78
43	0.80	0.056	0.07	0.65
44	0.94	0.060	0.08	0.65
45	1.00	0.068	0.14	9.80
46	0.88	0.060	0.12	1.18
47	0.67	0.036	0.05	0.58
48	0.73	0.040	0.06	0.65
49	0.93	0.048	0.08	0.55
50	0.60	0.040	0.05	0.48
51	1.33	0.084	0.11	1.05
52	1.80	0.120	0.18	1.08
53	1.93	0.128	0.16	0.48
54	1.93	0.132	0.20	1.35
55	1.47	0.104	0.15	0.95
56	0.73	0.040	0.05	0.65
57	1.00	0.052	0.06	0.73
58	1.00	0.052	0.07	1.28
59	1.26	0.064	0.07	0.65
60	1.43	0.104	0.09	0.68

Appendix III. (Contd...)

Sample No.	Percentage			
	Organic matter	Total N	Total P	Total K
61	1.00	0.068	0.12	0.98
62	1.60	0.104	0.20	0.75
63	1.93	0.128	0.18	1.50
64	1.00	0.068	0.11	0.73
65	0.60	0.032	0.05	0.70
66	0.64	0.032	0.05	0.50
Attapadi				
01	1.46	0.104	0.12	0.85
02	1.62	0.116	0.14	1.40
03	1.17	0.076	0.10	0.83
04	0.72	0.036	0.05	1.83
05	1.00	0.072	0.09	1.58
06	1.42	0.104	0.12	0.58
07	1.16	0.060	0.09	0.70
08	0.90	0.044	0.07	0.48
09	0.80	0.040	0.06	0.70
10	1.16	0.060	0.09	1.48
11	0.80	0.040	0.06	0.85
12	1.46	0.104	0.12	0.65
13	0.80	0.060	0.08	0.40
14	0.93	0.068	0.11	0.50
15	0.72	0.052	0.06	0.55
16	0.80	0.056	0.07	0.70
17	2.76	0.168	0.22	0.93
18	0.44	0.028	0.04	0.40
19	0.90	0.056	0.08	0.43
20	0.42	0.028	0.03	0.30
21	1.72	0.108	0.14	0.70
22	1.60	0.116	0.14	0.70
23	2.80	0.168	0.24	0.85
24	1.10	0.056	0.08	0.70
25	1.00	0.052	0.08	1.80
26	0.72	0.036	0.05	1.08
27	1.10	0.072	0.09	1.70

Appendix III. (Contd...)

Sample No.	Percentage Organic matter	Total N	Total P	Total K
28	1.12	0.072	0.09	0.70
29	1.10	0.072	0.09	0.28
30	1.40	0.100	0.12	0.28
31	0.88	0.064	0.08	0.75
32	2.26	0.164	0.20	0.75
33	3.32	0.200	0.24	0.43
34	0.92	0.060	0.07	1.00
35	1.00	0.072	0.10	1.75
36	0.80	0.056	0.08	1.53
37	1.10	0.064	0.10	1.70
38	1.06	0.072	0.08	1.60
39	1.22	0.076	0.10	1.35
40	0.80	0.056	0.10	1.15
41	1.10	0.080	0.15	0.78
42	1.16	0.084	0.14	1.70
43	0.80	0.056	0.10	1.73
44	0.70	0.044	0.06	0.65
45	0.90	0.064	0.08	0.70
46	0.94	0.064	0.13	1.15
47	1.22	0.084	0.14	1.50
48	1.46	0.104	0.18	1.50
49	0.96	0.076	0.08	1.30
50	0.50	0.040	0.04	1.15
51	0.66	0.044	0.05	0.45
52	0.70	0.044	0.06	0.53

Appendix IV. pH, EC, available and exchangeable nutrient content of soils

Sample No.		dS m^{-1}	kg ha^{-1}			cmol(p^{+}) kg^{-1}			ppm				
										DTPA extractable			
	pH	EC	Av. N	Av. P	Av. K	Ca	Mg	Na	Av. S	Fe	Mn	Zn	Cu
Vannamada													
01	7.4	0.20	440	33.9	134	14.88	5.76	0.25	101.50	62.60	242.20	5.40	3.20
02	7.8	0.33	375	18.0	146	26.88	11.76	0.39	116.00	53.60	71.20	6.40	3.00
03	7.8	0.23	395	22.3	168	26.88	10.32	0.36	123.25	28.60	183.40	trace	3.00
04	8.5	0.53	322	16.7	683	30.00	29.05	2.17	116.00	50.80	198.40	2.80	4.40
05	8.5	0.36	328	25.3	347	36.00	28.32	1.81	108.75	13.40	161.20	0.80	3.20
06	8.7	0.45	353	13.3	381	31.68	25.20	1.56	130.50	27.20	165.00	2.20	3.60
07	7.6	0.55	319	13.6	370	30.48	17.28	1.41	130.50	49.00	184.60	4.60	3.00
08	8.0	0.42	314	11.6	337	29.28	20.40	1.98	174.00	21.40	122.00	3.00	3.40
09	7.5	0.41	322	24.0	236	29.16	9.96	1.29	108.75	73.20	210.20	1.00	2.40
10	7.9	0.32	297	30.0	202	8.64	8.64	0.50	72.50	72.20	100.40	2.60	3.20
11	8.2	0.21	372	17.5	224	24.24	4.32	0.35	65.25	32.20	100.00	1.20	2.80
12	7.1	0.10	319	5.1	246	24.12	4.68	0.21	58.00	40.80	99.20	2.40	2.60
13	7.1	0.13	356	7.3	134	13.68	2.96	0.17	50.75	35.20	179.60	1.40	2.20
14	7.2	0.11	330	6.9	202	9.12	7.89	0.15	29.00	40.00	78.00	2.00	2.40
15	7.3	0.09	283	4.7	246	20.88	4.12	0.24	36.25	43.00	127.60	5.60	2.80
16	7.2	0.10	314	12.0	235	18.24	2.88	0.20	43.25	48.20	108.00	6.60	3.00
17	6.6	0.21	333	10.3	118	12.96	3.84	0.37	43.50	42.60	102.40	2.00	1.80
18	6.5	0.07	268	4.3	134	19.50	7.20	0.22	50.75	80.60	108.80	3.00	3.20
19	7.0	0.26	333	10.7	146	11.52	2.16	0.30	87.00	67.20	103.80	24.00	2.20
20	6.1	0.09	210	6.0	325	11.79	2.85	0.21	58.00	69.00	103.80	trace	2.40
21	7.4	0.22	297	36.0	162	18.96	3.36	0.35	65.25	150.60	144.40	trace	3.40
22	6.8	0.14	249	13.3	101	24.96	1.68	0.27	94.25	75.40	197.20	0.60	3.60
23	7.7	0.14	448	51.9	162	14.88	4.56	0.24	87.00	37.80	123.60	17.40	2.20
24	7.6	0.23	235	24.0	358	20.88	4.08	0.35	87.00	29.00	110.20	1.00	2.60
25	8.4	0.57	305	27.4	442	47.28	15.60	0.63	174.00	69.60	195.60	0.40	3.80
26	7.5	0.33	328	20.6	336	15.12	7.20	0.54	159.50	50.60	206.60	0.20	4.00
27	7.8	0.45	193	50.2	319	45.16	1.92	0.46	145.00	37.00	244.80	6.00	4.20
28	7.8	0.74	241	27.2	673	24.00	12.48	1.36	116.00	147.80	145.60	4.20	5.40
29	7.4	0.65	266	21.4	442	30.24	6.00	1.41	94.25	81.40	204.40	6.40	5.20
30	7.3	0.41	288	28.0	297	16.08	2.40	0.54	87.00	73.60	230.00	1.20	3.60
31	8.6	0.58	302	27.9	454	47.76	14.88	3.16	188.50	25.60	204.40	0.00	4.00
32	8.2	0.62	302	16.4	375	59.52	12.24	2.18	181.25	18.60	273.20	7.20	3.40
33	7.9	0.31	249	8.6	403	55.64	14.64	0.91	152.25	12.40	148.60	8.80	3.00
34	8.1	0.25	252	9.3	190	50.10	12.72	0.37	159.50	20.20	144.60	2.40	3.80
35	8.1	0.31	260	5.7	252	20.04	21.60	0.54	152.25	24.80	209.00	0.60	1.60

Appendix IV. (Contd...)

Sample No.	dS m^{-1}		kg ha^{-1}			cmol(p^{+}) kg^{-1}			ppm				
										DTPA extractable			
	pH	EC	Av. N	Av. P	Av. K	Ca	Mg	Na	Av. S	Fe	Mn	Zn	Cu
36	7.8	0.38	266	10.0	442	52.56	1.68	0.48	159.50	26.80	125.80	1.60	2.40
37	7.8	0.58	272	13.6	157	24.96	4.60	1.25	145.00	28.60	108.00	5.40	0.80
38	6.8	0.21	385	5.7	101	9.84	1.20	0.29	130.50	12.80	44.80	0.20	0.80
39	8.0	0.41	244	25.7	414	35.52	7.20	0.98	137.75	60.00	155.20	1.40	2.80
40	7.9	0.43	190	29.3	532	31.44	2.40	0.68	79.75	14.00	156.40	1.40	3.00
41	7.5	0.22	437	32.6	146	14.64	5.76	0.26	137.75	62.60	244.80	0.80	3.00
42	7.7	0.35	378	16.3	157	26.64	11.76	0.39	152.25	52.00	70.60	2.80	2.80
43	7.5	0.25	398	20.2	169	26.64	10.32	0.39	116.00	23.00	174.80	0.60	2.80
44	7.8	0.55	315	14.8	672	29.76	29.04	2.20	130.50	47.00	193.80	0.60	4.00
45	8.3	0.38	330	23.6	358	35.76	28.08	2.69	195.75	14.00	165.40	0.80	3.20
46	8.1	0.47	356	14.6	393	31.44	25.20	2.37	159.50	24.60	164.60	trace	3.40
47	7.7	0.56	322	15.9	380	30.24	17.28	2.15	130.50	44.80	178.60	trace	2.60
48	8.1	0.44	316	12.9	347	29.04	20.16	1.01	159.50	20.80	121.40	0.40	3.00
49	7.6	0.43	325	22.7	247	28.80	9.84	1.90	94.25	29.40	98.20	3.60	2.60
50	7.9	0.44	308	28.7	213	8.64	4.08	1.28	79.75	69.00	108.60	3.20	3.00
51	8.3	0.23	370	18.0	224	24.12	4.92	0.34	79.25	67.00	102.40	3.20	7.00
52	7.2	0.12	322	6.4	258	24.24	5.28	0.22	72.50	38.80	179.60	0.40	2.60
53	7.1	0.14	358	9.0	146	13.44	3.12	0.18	65.25	33.00	77.00	3.40	2.00
54	7.3	0.13	333	9.5	213	9.12	7.29	0.15	43.50	36.30	102.60	2.60	2.20
55	7.4	0.12	286	5.6	258	20.64	4.08	0.25	50.75	39.80	122.80	2.60	2.40
56	7.2	0.12	316	12.9	246	18.00	2.88	0.21	43.50	44.40	103.80	0.20	2.80
57	6.8	0.22	336	12.0	123	12.72	3.84	0.38	58.00	41.20	101.80	0.20	1.40
58	6.6	0.09	272	7.3	134	19.44	4.56	0.29	50.75	76.00	176.60	trace	3.00
59	7.0	0.11	336	11.6	146	11.28	2.16	0.28	79.75	70.20	205.40	11.00	2.20
60	6.2	0.24	218	8.2	325	11.52	1.92	0.24	65.25	50.40	101.80	2.60	2.60
61	7.4	0.24	300	33.0	162	18.48	3.60	0.33	79.25	144.40	138.80	3.20	3.20
62	6.8	0.16	252	22.7	106	24.24	1.92	0.25	101.50	73.40	195.00	1.60	3.40
63	7.8	0.16	451	6.0	108	15.36	4.56	0.27	79.75	33.40	118.60	1.20	2.20
64	7.6	0.24	247	34.7	353	20.40	3.84	0.38	94.25	25.60	107.20	4.40	2.60
65	7.8	0.80	294	13.7	202	46.08	2.88	0.47	181.25	17.60	43.00	trace	2.30
66	8.1	0.27	219	11.2	208	24.24	3.12	0.32	246.50	33.40	219.40	3.60	4.40
67	8.1	0.61	305	21.9	381	59.04	11.28	0.43	152.25	24.00	263.80	1.60	3.00
68	7.8	0.32	252	15.4	392	51.36	6.00	0.87	203.00	16.80	146.00	1.00	2.80
69	8.0	0.27	259	12.9	185	49.92	12.00	0.39	188.50	112.00	133.20	0.60	3.40
70	8.2	0.32	277	21.4	264	23.76	20.40	0.56	101.50	18.00	241.00	9.80	1.60
71	7.7	0.38	269	35.3	431	51.84	1.68	0.50	116.00	25.60	219.20	2.80	2.00
72	7.6	0.58	274	15.0	153	24.96	5.28	0.27	123.25	25.60	33.00	0.80	0.60
73	6.7	0.23	328	7.9	101	9.84	1.68	0.32	79.25	13.20	44.60	0.20	0.20
74	7.9	0.42	249	24.3	403	35.52	6.72	0.98	137.75	12.80	155.80	1.60	2.80
75	7.8	0.44	193	27.9	521	32.16	2.16	0.65	130.50	62.80	158.20	1.20	2.60
76	7.3	0.24	300	32.6	162	15.36	5.52	0.36	94.25	14.80	141.80	0.80	3.00
77	6.9	0.16	252	15.6	106	27.84	12.72	0.24	87.00	145.20	123.20	2.20	3.40
78	7.6	0.15	448	23.2	157	27.60	12.24	0.36	101.50	75.60	198.00	1.00	2.00
79	7.6	0.45	249	9.0	353	29.52	28.32	0.29	94.25	26.20	26.20	1.00	2.60

Appendix IV. (Contd...)

Sample No.	dS m^{-1}		kg ha^{-1}			cmol(p^{+}) kg^{-1}			ppm				
										DTPA extractable			
	pH	EC	Av. N	Av. P	Av. K	Ca	Mg	Na	Av. S	Fe	Mn	Zn	Cu
Meenakshipuram													
01	7.0	0.11	328	8.2	190	9.84	2.40	0.15	58.00	32.40	78.00	1.60	1.80
02	6.2	0.27	314	2.6	313	19.44	8.88	0.27	58.00	34.00	105.80	0.40	1.60
03	7.5	0.18	266	14.6	420	22.56	6.76	0.32	50.75	25.00	110.40	0.20	1.60
04	7.8	0.33	266	45.5	184	27.12	1.26	0.36	87.00	185.20	148.60	3.60	2.40
05	7.9	0.28	297	43.3	190	33.84	4.08	0.52	116.00	109.80	117.60	1.60	3.80
06	7.6	0.35	311	31.7	134	30.00	2.88	0.45	101.50	128.80	187.20	2.20	2.40
07	7.4	0.29	322	7.7	106	29.04	3.60	0.30	116.00	38.00	136.00	3.60	1.80
08	7.1	0.16	249	21.0	246	23.52	1.44	0.49	94.25	137.40	116.20	2.60	2.60
09	7.5	0.27	367	3.4	123	25.52	2.40	0.35	130.50	26.60	78.40	9.80	1.00
10	7.6	0.18	193	15.4	448	26.64	1.92	0.61	87.50	220.00	118.60	0.40	1.20
11	6.9	0.12	201	35.6	235	20.16	1.64	0.26	137.75	97.00	245.20	4.40	4.20
12	6.5	0.12	260	25.3	252	19.92	2.16	0.34	108.75	91.80	127.80	trace	1.60
13	7.2	0.28	182	8.6	235	23.76	1.44	0.61	79.75	113.60	196.00	2.60	4.40
14	6.8	0.13	297	42.9	179	5.52	2.52	0.30	123.25	165.00	1.89	3.40	9.20
15	7.5	0.26	269	30.9	269	15.36	5.28	0.36	72.50	37.20	208.20	1.60	3.20
16	6.6	0.11	297	18.4	179	3.60	2.40	0.27	108.75	51.80	101.40	1.80	2.80
17	6.2	0.11	305	7.7	146	14.88	3.60	0.35	94.25	56.80	138.40	1.20	3.20
18	7.1	0.11	272	4.3	168	15.12	3.36	0.42	101.50	58.40	144.40	3.00	3.40
19	7.1	0.14	305	4.7	196	17.76	5.52	0.43	130.50	29.80	84.60	trace	1.60
20	6.5	0.15	269	4.7	162	15.84	4.32	0.26	94.25	64.20	113.00	1.20	2.40
21	7.6	0.18	381	11.6	140	9.12	2.40	0.42	137.75	15.20	41.20	0.20	1.40
22	8.1	0.31	319	17.6	459	54.72	17.04	0.46	87.00	12.60	43.00	4.20	4.20
23	8.0	0.41	347	20.2	246	56.16	2.88	2.12	152.25	25.40	203.80	0.60	4.40
24	8.0	0.79	305	15.0	403	49.60	3.36	2.45	130.50	37.20	112.20	4.00	5.00
25	8.3	0.54	316	18.0	560	49.20	3.36	5.38	174.00	67.20	165.40	2.40	2.60
26	8.3	0.58	335	15.9	448	59.76	7.92	3.21	137.75	22.60	90.20	1.20	3.80
27	7.8	0.58	308	20.2	470	35.76	4.08	1.41	181.25	16.20	111.40	trace	3.00
28	7.9	0.51	328	34.7	381	30.24	5.52	0.37	261.00	14.60	77.80	1.20	3.40
29	7.0	0.38	283	54.4	398	21.36	3.36	0.37	210.25	208.80	146.00	4.20	3.80
30	8.0	0.41	336	16.7	470	39.36	5.04	0.46	217.50	15.20	62.50	1.60	3.60
31	7.9	1.07	372	16.7	230	11.76	2.64	0.36	246.50	5.80	37.60	1.20	2.00
32	7.6	1.16	330	12.4	409	20.64	1.44	0.33	130.50	10.20	75.00	0.40	3.00
33	8.1	0.23	221	5.1	218	21.12	1.44	0.26	152.25	6.00	69.20	1.00	1.60
34	7.9	0.47	246	30.4	532	25.92	1.44	0.39	145.00	22.60	180.20	0.40	5.60
35	7.6	0.36	314	41.5	140	29.52	3.36	0.43	116.00	124.00	109.60	1.20	2.40
36	7.3	0.32	325	18.9	112	29.52	3.36	0.32	101.50	22.20	131.00	1.20	1.60
37	7.1	0.24	252	30.9	241	23.38	1.68	0.48	79.75	35.80	112.60	2.40	2.40
38	7.4	0.18	369	15.0	129	25.68	2.16	0.35	116.00	31.80	68.60	2.80	0.80
39	7.5	0.29	196	24.9	443	27.12	1.92	0.57	94.25	23.20	110.40	0.80	1.00

Appendix IV. (Contd...)

Sample No.	$dS\ m^{-1}$		$kg\ ha^{-1}$			$cmol(p^+)\ kg^{-1}$			ppm				
										DTPA extractable			
	pH	EC	Av. N	Av. P	Av. K	Ca	Mg	Na	Av. S	Fe	Mn	Zn	Cu
40	7.9	0.20	204	43.3	241	20.40	1.44	0.28	130.50	18.60	238.40	3.20	3.80
41	6.5	0.14	263	34.7	246	20.16	1.92	0.35	116.00	91.40	120.40	2.40	1.40
42	7.2	0.30	185	19.3	241	20.38	1.20	0.59	94.25	86.00	191.40	9.60	4.40
43	6.7	0.25	300	49.3	185	23.28	1.20	0.33	79.75	109.40	155.80	14.40	3.20
44	7.8	0.25	258	7.3	190	12.48	10.80	0.23	116.00	65.40	193.20	0.40	4.20
45	8.1	0.27	218	33.9	287	50.88	6.00	0.26	159.50	32.20	176.20	46.00	3.40
46	7.9	0.29	297	46.3	353	27.36	4.32	0.32	145.00	30.40	119.00	1.00	3.20
47	7.1	0.16	274	13.7	162	14.64	3.12	0.43	94.25	37.40	140.00	0.80	3.20
48	7.1	0.09	308	13.7	190	17.52	4.32	0.41	87.00	55.00	80.40	trace	1.40
49	6.6	0.16	272	14.2	157	14.88	4.56	0.28	65.25	27.20	108.60	0.60	2.40
50	7.5	0.20	301	22.3	134	9.84	1.68	0.40	87.00	60.20	39.40	4.20	1.20
51	7.4	0.35	330	29.6	330	16.32	5.80	0.53	94.25	12.20	201.80	2.00	1.80
52	7.7	0.46	196	58.3	325	44.88	2.16	0.52	116.00	48.00	240.60	0.80	4.20
53	7.7	0.73	244	27.9	129	24.24	12.00	0.25	101.50	36.40	151.80	2.00	5.00
54	7.3	0.65	269	25.6	431	30.48	5.52	0.29	87.00	141.00	207.80	3.00	5.20
55	7.2	0.43	291	23.6	291	16.32	1.92	0.55	79.75	81.80	222.40	1.40	3.40
56	7.1	0.13	330	8.2	190	35.76	27.12	0.15	101.50	29.60	75.20	1.20	1.40
57	7.0	0.29	330	14.6	213	32.16	24.24	0.29	87.00	32.80	107.80	1.00	1.20
58	7.5	0.20	269	14.6	409	30.48	16.56	0.34	79.75	106.00	109.60	3.80	1.00
59	7.7	0.35	269	42.4	190	29.28	18.24	0.34	87.00	22.00	147.20	2.20	2.00
60	7.8	0.30	300	41.2	196	29.76	18.24	0.50	116.00	92.00	113.40	1.60	3.40
61	7.9	0.82	300	14.6	213	21.36	3.60	0.49	101.50	17.40	44.80	1.00	2.20
62	8.0	0.29	325	12.0	218	45.84	2.64	0.34	166.75	32.60	223.80	0.30	4.20
63	8.1	0.42	339	15.9	448	24.96	3.12	0.48	174.00	15.60	63.40	0.40	3.60
64	7.8	1.05	378	16.3	213	12.48	2.88	0.36	130.50	7.00	39.80	0.60	1.00
65	7.2	0.87	286	21.9	190	9.12	4.08	0.22	101.50	27.20	57.20	5.00	0.80
66	8.0	0.20	274	32.6	129	21.84	1.08	0.28	159.50	18.40	178.80	0.60	2.30
Attapadi													
01	6.6	0.23	302	38.2	252	14.40	0.96	0.20	159.50	117.20	161.60	2.60	6.4
02	6.5	0.25	244	24.0	448	17.28	1.20	0.33	152.25	20.60	54.80	2.60	3.6
03	7.5	0.21	256	69.5	252	17.76	1.92	0.21	130.50	82.40	161.00	1.60	1.2
04	7.5	0.21	269	75.3	896	19.20	3.36	0.23	145.00	61.40	127.80	2.00	6.8
05	7.5	0.15	353	65.2	504	6.76	4.52	0.16	166.75	28.20	123.00	1.60	3.8
06	6.2	0.17	288	80.6	157	19.68	2.15	0.21	195.75	164.00	86.00	2.40	4.8
07	7.2	0.11	308	27.9	190	21.36	3.12	0.30	159.50	54.20	158.80	2.00	4.4
08	7.4	0.15	326	9.9	123	23.28	1.68	0.25	94.25	34.40	114.20	0.80	3.4
09	7.4	0.13	350	15.9	196	20.88	5.04	0.24	159.25	33.00	126.60	0.60	4.0
10	7.6	0.30	272	38.2	459	24.72	4.56	0.25	145.00	18.80	120.80	0.80	3.5
11	6.8	0.12	283	59.6	252	20.16	5.04	0.22	181.25	95.20	133.80	5.80	5.2

Appendix IV. (Contd...)

Sample No.	pH	EC	Av. N	Av. P	Av. K	Ca	Mg	Na	Av. S	Fe	Mn	Zn	Cu
	$dS\ m^{-1}$		$kg\ ha^{-1}$			$cmol(p^+)\ kg^{-1}$			ppm	DTPA extractable			
12	7.9	0.43	325	39.9	175	20.64	5.04	0.18	174.00	39.80	255.00	2.80	3.4
13	7.8	0.44	370	27.0	101	20.40	1.44	0.13	195.75	12.40	51.60	4.40	1.2
14	7.5	0.27	360	24.4	126	16.58	2.40	0.13	203.00	37.40	240.20	7.20	3.2
15	7.4	0.11	350	21.9	151	12.72	3.12	0.14	166.75	45.40	143.20	2.00	4.0
16	6.5	0.10	340	66.9	196	10.80	3.36	0.14	166.75	77.20	153.60	1.00	3.4
17	8.5	0.33	258	11.6	269	10.56	5.28	1.06	210.25	35.00	293.40	1.40	7.8
18	7.3	0.21	339	7.7	101	47.04	3.84	0.28	116.00	35.40	79.80	0.60	2.0
19	6.6	0.16	397	11.6	101	10.32	3.60	0.13	65.25	75.20	131.60	1.40	3.0
20	7.3	0.08	129	53.6	67	6.96	1.20	0.28	87.00	35.60	75.40	2.80	1.80
21	7.5	0.21	342	27.4	196	19.92	4.56	0.15	116.00	25.00	48.20	0.60	5.00
22	7.8	0.24	302	6.4	196	23.76	6.48	0.17	130.50	40.20	100.60	0.80	6.00
23	6.3	0.22	370	14.6	252	28.08	3.84	0.18	87.00	164.60	218.80	2.60	12.60
24	6.7	0.06	280	12.4	190	9.82	1.92	0.17	94.25	40.00	195.00	2.40	4.80
25	7.6	0.13	272	51.9	826	20.64	1.20	0.28	101.50	18.20	98.60	1.80	2.60
26	8.1	0.21	286	11.1	319	36.48	4.56	0.16	145.00	6.60	96.40	11.20	3.00
27	8.2	0.32	269	39.0	616	26.88	1.44	0.16	137.75	6.40	74.80	0.80	2.00
28	5.5	0.21	288	14.6	196	13.92	1.44	0.23	72.50	186.80	67.20	4.00	5.60
29	6.7	0.16	300	8.6	151	15.36	4.88	0.23	72.50	74.20	69.00	0.80	5.00
30	7.2	0.19	323	15.4	151	17.52	0.72	0.16	87.00	70.20	111.80	1.40	4.60
31	7.9	0.19	230	6.4	210	22.08	1.44	0.17	130.50	4.40	30.60	0.20	1.60
32	7.8	0.78	339	54.0	196	34.56	2.40	0.08	130.50	100.00	123.60	0.60	2.80
33	7.1	0.59	249	6.4	106	13.92	0.96	0.14	101.50	18.20	125.60	1.00	2.80
34	7.3	0.40	230	42.0	302	10.32	1.20	0.23	116.00	9.20	78.00	2.00	2.20
35	7.8	0.37	280	54.9	630	16.08	0.72	0.18	123.25	10.80	91.20	2.60	2.60
36	8.0	0.23	371	55.7	476	17.76	0.72	0.17	174.00	13.20	86.00	1.20	2.40
37	8.9	0.31	277	88.3	574	27.60	1.68	0.24	210.25	14.60	94.60	2.00	3.80
38	8.1	0.44	263	27.0	510	37.44	0.48	0.24	159.50	17.20	70.60	0.40	2.80
39	8.1	0.48	252	45.4	414	36.72	2.48	0.29	145.00	2.80	98.60	0.60	3.40
40	8.3	0.23	247	64.3	342	17.04	3.60	0.13	152.25	10.80	44.60	2.80	2.80
41	8.2	0.28	227	42.9	224	20.16	1.68	0.15	145.00	14.40	53.00	1.60	2.40
42	7.9	0.88	549	80.6	588	28.80	1.44	0.23	159.50	10.40	82.00	4.40	2.60
43	8.0	0.23	232	27.4	728	3.36	7.92	0.27	145.00	21.60	114.60	1.20	2.40
44	5.8	0.86	269	82.7	179	36.24	1.44	0.32	79.75	36.40	79.40	0.80	2.00
45	8.4	0.29	232	14.6	190	46.32	0.96	0.26	174.00	2.20	110.60	1.60	5.80
46	7.8	0.28	294	46.4	353	27.12	4.32	0.27	130.50	22.60	160.80	1.60	3.20
47	8.2	0.30	168	58.7	470	22.52	2.40	0.21	145.00	18.00	41.20	1.80	3.60
48	8.1	0.38	277	45.9	476	31.44	0.96	0.21	137.75	16.20	36.60	0.20	4.00
49	8.3	0.25	227	76.7	403	28.08	0.48	0.33	137.75	trace	47.00	0.40	2.20
50	9.5	0.19	162	18.4	342	22.08	0.96	1.61	210.25	trace	17.20	0.40	1.00
51	8.3	0.39	184	6.4	118	20.16	1.20	0.20	145.00	6.20	33.80	trace	1.00
52	7.6	0.60	277	80.6	134	21.36	2.40	0.23	130.50	14.40	76.20	0.80	2.80

Appendix VI. Juice quality parameter of sugarcane

Sl. No.	Brix	Percentage Pol (sucrose)	Purity	CCS	Juice extraction
Vannamada					
1	19.95	17.80	89.22	12.37	56.03
2	20.03	17.47	87.22	12.01	53.90
3	19.73	16.79	85.08	11.40	56.41
4	20.13	17.74	88.22	12.26	64.89
5	20.66	18.70	90.53	13.08	58.33
6	20.06	18.13	90.40	12.67	60.80
7	20.37	17.53	86.06	11.97	60.47
8	19.93	16.86	84.60	11.41	57.55
9	20.40	17.52	85.90	11.95	60.85
Meenakshipuram					
1	20.8	18.99	91.30	13.33	64.83
2	20.16	18.00	89.30	12.51	65.16
3	20.20	18.20	90.00	12.70	57.93
4	20.26	17.65	87.71	12.12	60.82
5	20.56	18.64	90.80	13.04	58.04
6	20.63	18.94	91.81	13.33	60.84
7	20.80	18.97	91.20	13.31	58.10
8	19.84	16.99	85.62	11.57	60.13
9	20.18	18.72	92.80	13.23	58.04
Attappadi					
1	19.88	16.48	82.90	11.04	62.63
2	19.81	16.11	81.30	10.68	65.76
3	20.96	19.51	93.08	13.82	61.76
4	19.60	17.66	90.10	12.33	70.11
5	19.73	16.55	83.90	11.15	66.06
6	19.94	16.19	81.20	10.72	67.02

Appendix V. Yield, dry matter production and uptake of nutrients elements of sugar cane

Sl. No.	Yield (t ha^{-1})	Dry matter (t ha^{-1})	N (kg ha^{-1})	P	K	Na	Ca	Mg	Fe	Mn	Zn	Cu
Vannamada												
01	119.85	30.63	205.3	37.9	313	9.39	61.3	39.1	7.26	1.191	0.669	0.091
01	116.28	30.07	176.1	28.2	306	6.34	65.9	29.9	3.56	0.661	0.165	0.716
03	90.92	29.18	177.1	22.8	263	6.02	94.4	33.0	5.77	1.170	0.023	0.035
04	110.04	30.81	205.5	25.6	267	6.00	76.2	48.4	11.66	0.945	0.162	0.430
05	118.80	35.33	209.5	37.3	322	7.65	54.0	18.0	3.12	3.199	0.763	0.032
06	94.38	23.10	158.7	21.6	227	5.43	56.7	18.6	3.87	0.930	0.930	0.058
07	107.72	30.49	180.6	13.7	280	6.07	38.0	67.9	7.72	0.964	0.403	0.158
08	107.07	31.37	177.2	21.7	271	6.70	51.9	18.5	3.44	0.773	0.233	0.134
09	82.72	24.79	184.4	21.8	232	5.29	77.8	28.3	12.04	0.960	0.180	1.450
Meenakshipuram												
01	98.28	28.06	175.9	20.6	253	5.58	31.6	27.6	4.56	2.44	0.145	0.058
02	126.15	38.60	226.1	36.9	226	10.54	80.2	58.2	8.1	6.75	9.065	0.492
03	121.08	36.06	249.1	39.0	245	6.65	91.7	33.2	9.84	1.74	0.297	0.149
04	108.19	28.77	179.3	24.1	271	5.18	87.6	67.0	5.2	0.88	0.059	0.071
05	121.55	36.14	217.0	39.6	228	10.93	91.9	38.8	2.55	1.77	0.424	0.107
06	124.50	37.96	235.5	37.7	214	10.11	67.6	43.4	3.29	3.49	0.289	0.095
07	119.22	36.29	245.3	38.8	323	9.84	66.3	66.8	2.85	2.23	0.535	0.088
08	82.15	25.33	123.3	19.6	212	2.22	54.1	36.8	3.95	1.27	0.969	0.064
09	117.98	34.89	197.2	35.8	327	7.80	91.7	33.4	4.20	1.46	0.281	0.016
Attapadi												
01	87.40	23.98	118.8	17.5	162	2.05	42.2	32.0	4.50	0.817	0.153	0.011
02	78.66	24.49	148.1	21.0	176	5.76	106.2	20.4	11.79	2.58	0.071	1.269
03	115.60	37.77	237.9	36.4	313	8.87	61.0	4.2	5.25	0.85	0.33	0.017
04	80.96	24.22	132.1	21.7	197	3.07	73.9	20.0	17.00	3.03	1.528	2.157
05	80.19	24.47	126.9	20.1	204	1.60	20.3	19.6	4.62	0.70	0.241	0.100
06	80.84	24.49	138.7	20.6	182	1.99	49.6	30.2	4.11	1.25	0.310	0.011

CHARACTERISATION OF SOIL AND IRRIGATION WATER OF THE SUGARCANE BELT IN PALGHAT IN RELATION TO YIELD, NUTRIENT UPTAKE AND QUALITY OF CANE

By

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ABSTRACT OF THE THESIS
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ABSTRACT

The investigation undertaken, envisages the characterisation of the soil and irrigation water of three sugarcane growing regions namely Vannamada, Meenakshipuram and Attapadi in Palghat district and their relation to the nutrient uptake, yield and quality of sugarcane. One hundred and ninety seven surface soil samples (0-15cm) from the three regions were characterised for the major physico-chemical properties. Twenty four farmer's plots were identified as observation plots to assess the yield, dry matter production and quality parameters of sugarcane juice and the inter relations between these parameters. Samples of irrigation water from four commonly used sources namely bore well, open well, canal, and river water used for irrigating sugarcane plots were collected in the pre monsoon and monsoon periods for determination of quality parameters and to study their effects on the crops.

The soils of the three regions were predominantly mildly alkaline in reaction. The EC of these soils were on par with each other and were with in safe limits. The major texture of soils of the area was sandy clay loam, followed immediately by sandy loam. The bulk density, particle density

and pore space of the three region did not vary significantly. The water holding capacity and volume expansion of the soils were significantly higher in Vannamada and lowest in Attapadi regions. None of the physical properties had any adverse effect on the growth of sugarcane.

Organic matter, total N, P and K recorded low values in soils of the three regions. The rating of available N was medium in all the three regions. For available P and K, the rating for Vannamada and Meenakshipuram regions was medium while for Attapadi it was high. Available S followed the same trend as that of the major nutrient elements and its status in the soils of the three regions was above the critical level. Exchangeable Ca and Mg dominated in all the three regions. Exchangeable Mg and Na were significantly higher in the soils of Vannamada. The levels of micro nutrients viz. Fe, Mn, Zn and Cu in the soils of the three regions were above the sufficiency limits.

The quality parameters of irrigation waters such as pH, EC, Cl^- and SO_4^{--} contents, RSC and SAR studied were within the safe limits for the irrigation of sugarcane.

All the three regions recorded high values in yield and dry matter production. However, in comparison Attapadi registered lower values than the other regions.

The uptake of N, P, K, Na, Ca and Mg were highest in soils of Meenakshipuram and lowest in Attapadi region. The yield and dry matter production exhibited a significant positive correlation with uptake of N,P,K and Na. The uptake values obtained for micro nutrients were low, which may be attributed to high pH of the soils.

Soil of the three regions did not show any significant variation in juice quality parameters such as brix, pol value, purity and commercial cane sugar content. Juice quality parameters were significantly and positively correlated with N, P, K and Na.