STUDIES ON THE NUTRITION OF SUGARCANE CROP

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(Syed Shaheer Hasan)
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INTRODUCTION

Sugarcane occupies a very important position among the agricultural crops. It plays a pivotal role in the rural economy of our country, especially in the northern region, where it is the main cash crop which sustains the farmers during the lean winter season when no other sources of income from cultivation are available to them. India is, after Brazil and Cuba, the largest cane-growing country in the world. In 1968-69 we had 2532 thousand hectares under the crop, yielding 124,676 thousand tonnes of cane, the average production per hectare being 49 thousand Kg (Anonymous, 1969). Sugarcane thus accounts for 8% of the total cropped area in the country and 2.5% of the area under food crops.

Sugarcane is a tropical plant which thrives best in a tropical climate but it is quite adaptable in nature and is extensively grown in sub-tropical regions as well. In India, the southern region constitutes the ideal climatic zone for sugarcane but ironically the south accounts for only about 11% of the total area under sugarcane in the country. Thus, 89% of the total area under the crop lies in the sub-tropical zone, i.e., the northern region, particularly in the states of Uttar Pradesh and Bihar. The yield of cane per hectare is, however, lower in northern India as compared to the south (Maharashtra and Tamil Nadu) but as it is not economical to produce sugarcane in the ideal zone (the cost of production
being double of that in the north) the sub-tropical zone is the major cane producing region in the country. The average yield in the south is between 70 and 80 tonnes per hectare while in the north it is as low as 40 tonnes/hectare. The percentage of sugar recovery in the South is 10.85-10.09 while in the north it is only 9.50. The bulk of the sugarcane produced in the country is contributed by North India. Of the Northern States, Uttar Pradesh heads the list in cane production, accounting for 50% of the total area under sugarcane in the country. However, it may be pointed out that inspite of having a large area under cane, the average production of cane and sugar in Uttar Pradesh is very low.

It is, therefore, in the interest of the nation, as well as the growers, that attempts should be made in a systematic and concerted manner to evolve a suitable package of agronomical practices to increase the yield of the cane as well as the rate of sugar recovery. Judicious manuring plays an important role in increasing the yield of cane as well as the recovery of sugar. We cannot create the ideal climate for the crop in North India but we can, without any doubt, endeavour to bring the production of cane and sugar at par, or as near to it as possible, with that in South.

Juice purity and sugar recovery depend on the stage of the maturity the crop has reached at the harvesting and crushing time. Farmers desire to harvest the crop as early as possible so that they may get the cash sorely needed by them in addition to getting the fields vacated for some
other crop. Thus, they often harvest the crop at a stage when the cane has not yet sufficiently matured which is bound to result in poor juice quality and poor sugar recovery. On the other hand, in case of bumper crops, harvesting is delayed beyond the period of maturity, owing to the inability of sugar mills and "Khandsari" units to accept surplus cane for crushing, as happened last year, resulting in colossal financial loss to the growers. If it were possible to accelerate the process of maturity and ripening or to delay it, according to the conditions in the sugar mills and "khandsari" units, by making suitable adjustments in the manuring schedule, it would be of immense benefit to the growers, the crushing industry as well as the national exchequer.

It is, therefore, proposed to undertake an investigation aimed at studying the response of various varieties of sugarcane to NPK application as regards yield, maturity and juice quality with special emphasis on the last two aspects.
REVIEW OF LITERATURE

Farm yard manure finds an important place in the fertilizer programme in all kinds of crops throughout the world specially in the underdeveloped countries. It was believed for a long time before the nineteenth century that the entire nutritional requirements of crop plants were provided by the organic fertilizers applied to the soil. As a result of chemical analysis of soils as well as of the ash of plants growing in them, early plant physiologists and soil chemists come to the conclusion that the composition of plants varied with the soil, plant part analysed and age of the plant (La Causseur, 1807; Boussingault, 1838, 1841; Liebig, 1840; Salm-Horstmar, 1849, 1851; Way, 1850; Wolff, 1871).

Besides the framework elements, carbon, hydrogen and oxygen, the importance of sulphur, phosphorus and nitrogen in the synthesis of proteins was soon established and these elements were rightly called as protoplasmic elements. In addition to these elements, the essentiality of potassium, calcium, iron and magnesium was also established (Sachs, 1860; Knop, 1861). However, farmyard manure does not contain the required quantities of the elements referred to above.

Calcium, iron and magnesium are supplied in sufficient quantity by gradual soil transformations. Sulphur and a part of nitrogen are supplied by decaying plant and organic matter. However, nitrogen, phosphorus and potassium are removed by crops at
a much higher rate than most soils can generate, and therefore, they must be added to the soil in various ways before sowing a crop. These three elements are, therefore, rightly called as critical elements.

In addition to the ten elements mentioned above, that are required in rather large quantities, a few other essential elements are required in very small quantities. These are referred to as trace elements or micronutrients. Since soils differ remarkably in their fertility status, capacity for regeneration and capability of stimulating and supporting plant growth, the use of organic manure alone in the fertilizing programme would not bring about the desired effect.

Determination of nutrient requirements by foliar analysis and study of soil and fertilizer relationship are helpful in determining the amount of macronutrients, in desired proportions in the form of inorganic or artificial fertilizers. Since nitrogen, phosphorus and potassium are removed in rather large quantities by crops and most soils require replenishment of these three critical elements, an understanding of the uptake, distribution and metabolism of these nutrients is necessary. A brief account of these three elements on plant growth and development is given below.

**NITROGEN**

Soil and atmosphere are the two sources of this element. Although atmosphere contains about 80% of nitrogen by volume, it is not available to the plants except a very limited
number of micro-organisms. The chief source of nitrogen is, therefore, the soil where it is present in the combined form as nitrates, nitrites or ammonium salts. All these salts are formed by various agents participating in the "Nitrogen Cycle".

The chief sources of nitrates are sodium nitrate, potassium nitrate, ammonium nitrate and calcium nitrate. Other sources of nitrogen are farmyard manure and urea. As the uptake of nitrogen in a majority of plants is high, and a part of nitrogen present in soil is destroyed by soil microorganisms, the fertility level comes down resulting in a deficiency of nitrogen in crops as they grow and mature.

Functions of nitrogen

Being absolutely essential for protein synthesis, it is an integral part of protoplasm and nucleus. Nitrogen is present in such important molecules as purines, pyrimidines, porphyrins and several co-enzymes. Purines and pyrimidines are found in nucleic acid, RNA and DNA, which are essential for protein synthesis.

The porphyrin structure is present in the molecules of chlorophylls and cytochrome enzymes which play a very important role in photosynthesis and respiration. To sum up "The physical basis of life" and the genetic mechanism determining the entire make up of generations are due to the presence of nitrogen in the form of complete organic molecules present in a plant cell (Steward and Duruzan, 1965).

PHOSPHORUS

It is available to the plants from soil where it is present as phosphate ions \( \text{H}_2\text{PO}_4^- \) and \( \text{HPO}_4^{2-} \). It is not present
in abundance in the soils and if present part of it is "fixed" and thus made unavailable to the plant. Since plants need a fairly large quantities of phosphorus for healthy growth, it is necessary to supply fresh quantities every season.

Functions of phosphorus

It is an important structural component of nucleic acids, nucleoproteins, phytin, phospholipids, ATP, NAD, NADP and numerous phosphorylated compounds. Maximum amount of phosphorus is found in the meristematic parts. Phosphorus is actively involved in the synthesis of nucleo-proteins, first by being present in nucleic acids and secondly by activating amino acids for protein synthesis.

Phosphorus plays a very important role in the energy transfer in respiration and photosynthesis through ATP. Phosphorus and nitrogen metabolism of plants is very much interlinked and the deficiency of one in the growing medium upsets the metabolism of the other in plants. To sum up, phosphorus is "involved practically in every synthetic reaction of the cell" and, therefore, influences vegetative as well as reproductive phases of growth (Hewitt, 1963).

POTASSIUM

It is the only monovalent cation essential for plant growth. Potassium is found in large amount in rapidly growing regions, e.g., buds, young leaves, root tips and developing fruits. It is present in exchangeable and water soluble forms in soil. It does not enter into the composition
of any important organic compound present in plants.

**Functions of potassium**

It acts as activator of about forty enzymes including the enzymes of phosphorylation and protein synthesis. As such, its deficiency results in the disturbance of most of the physiological processes. Potassium is essential for the formation of sugars and starch and also for their translocation through sieve tubes. It is needed in cell division, reduction of nitrate, development of chlorophyll and stomatal movements. Besides it is believed to be essential in maintaining the organisation, permeability and hydration of protoplasm (Evans and Sorger, 1966).

**NPK requirements of sugarcane**

As sugarcane is a very heavy feeder, drawing enormous quantities of NPK, besides other nutrients, from the soil, judicious application of chemical as well as organic fertilizers is necessary for good production of cane as well as for achieving desired maturity and ripening for good sugar recovery at the time most favourable to both the cane grower and sugar industry. A lot of work has been done in India, as well as abroad, on the nutrient needs of sugarcane but still there are many aspects of the problems that need further exploration and investigation, particularly in view of the evolution and introduction of new and improved varieties.

The commercial varieties of sugarcane differ greatly in their ability to extract nutrients from soil and in their content of mineral elements. The rate of nutrient absorptions also varies considerably with the age of the plant.
As early as 1933, Ayers reported that there was a very active absorption of nutrients in the sugarcane between 3 and 6 months of age, with potassium continuing to be absorbed in large quantities in the case of a 24 month crop in Hawaii (Humbert, 1968).

Lakshmi Kantam et al. (1960) reported from Anakapalle that the uptake of nitrogen was quite high from the fourth month onwards and reached the peak by the ninth month, while there was a marked fall in the uptake of nitrogen by the harvest time.

Results from Hawaii show that, with heavier doses of nitrogen, the uptake of nitrogen continues well into the second years growth (Humbert, 1968). Thus, sugarcane draws nutrients over a wide period. Co 419 crop harvested at 12 months and yielding 125.4 tonnes of cane per hectare removes 84.37 kg nitrogen, 37.25 kg phosphorus and 168.53 kg potassium per hectare. Co 740 crop harvested at 18 months in Maharashtra consumed 232.43 kg nitrogen and 76.82 kg of phosphorus per hectare and the yield varied from 185.1 to 192 tonnes per hectare.

Co 313 in Bihar consumed 157 kg nitrogen, 25 kg phosphorus and 218 kg potassium per hectare. Ojha et al. (1974) have reported that a 75 MT/ha crop removes 195 kg N, 60 kg P_2O_5 and 300 kg K_2O per hectare.

Thus, there is a wide variation in the quantities of major nutrients taken up by different varieties at different places. Similarly, the work done in India at the Sugarcane Research Station, Padegaon during 1967-68 (Anonymous, 1972) also supports the earlier findings of Burr et al. (1957) and
Vose (1963) regarding the varietal variations in nutrients taken up by crops at different locations.

The above observations also show that nitrogen, potassium and phosphorus are required in large quantities and play a very important role in growth and development, maturity and ripening. Moreover, if any of these nutrients is deficient, the uptake of other nutrients is affected, resulting in the disturbance of a number of metabolic processes.

Nutrient requirements are determined through field plot trials and soil analysis. Climate also plays a very extensive role in the utilization of nutrients and has to be taken into account in making calculations regarding the nutrient requirements of the crop. These are determined through crop logging/foliar analysis. The third to the 6th leaf laminae have been shown to be most suitable for estimating moisture and major and minor nutrients (Baver, 1962; LakshmiKantham, 1964 and Anonymous, 1972).

The life cycle of a 12 month old crop passes through 3 main phases, i.e., formative phase (first 120 days), the grand period of growth (150 to 270 days) and maturity phase (300 to 360 days) according to LakshmiKantham (unpublished work). They have found a significantly positive correlation between the mean leaf nitrogen in the grand period and yield.

**Nitrogen**

Nitrogen is the most important of the major nutrients. It has given the best and quickest return in terms of yield when applied at the proper stages of growth and in optimum doses. The nitrogen received by a crop amounts to 53% nitrogen
applied through fertilizers plus the available nitrogen in the unfertilized soil. Various factors such as low soil temperature and high air temperature have a deleterious effect on nitrogen absorption, resulting in its deficiency (Burr et al., 1957).

Three or four decades ago, nitrogen was applied to the crop mainly through oilseed cake. Today, however, mixed fertilizers i.e., organic as well as inorganic are widely used by farmers. It has been found that the application of inorganic nitrogenous fertilizers affects the pH of the soil badly which resulted in lower yield. It was also believed that the inclusion of concentrates in the manurial schedule would have an adverse effect on the quality and quantity of juice but this has not been borne out by recent investigations.

Forms of nitrogen

There are several inorganic nitrogenous fertilizers in use. Nitrogen is generally applied through ammonium sulphate, ammonium nitrate, calcium ammonium nitrate, urea or through compound fertilizers like ammonium, diammonium phosphate etc. All of them have been shown to be effective if applied on the same nitrogen basis (i.e., on the basis of their nitrogen content) Lakshmi Kanthan et al. (1964-65).

The continuous application of ammonium sulphate or other inorganic concentrated fertilizers have been reported to result in progressive decline in the cane yield at Shahjahanpur and Padegaon Research Stations. The decline was effectively checked when a basal dressing of compost was applied at Padegaon or when P2O5 and K2O equivalents of the compost were added to
the soil. The inclusion of sun-hemp in the form of green
manure in the rotation also arrested the decline in yield.
However, continuous application of ammonium sulphate at
Anakapalle for 18 years did not have any adverse effect on
yield as compared to continuous application of ammonium
sulphate and groundnut cake on the same nitrogen basis

The above discussion of the effect of ammonium sulphate
on yield makes it clear that a combination of organic and
inorganic manure should be preferred although in certain
cases only inorganic fertilizers may be used if the soil
and climatic conditions are favourable.

Levels of nitrogen

The efficiency of the utilization of nitrogen by the
sugarcane crop, estimated on the weighted average value of
applied nitrogen, depends upon the timing of application of
the nitrogenous fertilizers and adequate irrigation. Increased
levels of nitrogenous fertilizers have to be accompanied by
increased frequencies of irrigation. Maxwell (1898) noted
marked increase in transpiration when nitrogenous
fertilizers were applied to the pot in which cane was growing.

LakshmiKantham et al. (1962) also reported marked
difference in cane and sugar yield when increased levels
of nitrogen were accompanied by greater frequency of
irrigation (Table-1).
Table 1. Average cane and sugar yield of Co 419 at different levels of nitrogen and intervals of irrigation (Lakshmikantham et al., 1962).

| LEVELS OF N/HA | IRRIGATION INTERVAL 6 days | 18 days | MEAN FOR LEVELS OF N
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<tr>
<td></td>
<td>Cane yield</td>
<td>Sugar yield</td>
<td>Cane yield</td>
</tr>
<tr>
<td>0 kg N</td>
<td>78.53</td>
<td>11.39</td>
<td>66.45</td>
</tr>
<tr>
<td>112 kg N</td>
<td>142.75</td>
<td>21.67</td>
<td>106.28</td>
</tr>
<tr>
<td>336 kg N</td>
<td>145.32</td>
<td>19.57</td>
<td>98.74</td>
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Time of application

The time of application of nitrogen to the crop has a crucial role in the growth as well as quality of the cane. According to the recommendation of Singh and Gupta (1960) and Lakshmikantham (1965), in a 12 month crop it should be completed within three months of planting. The optimum time depends upon rainfall or the availability of facilities for irrigation. The application of nitrogen, in 2 equal instalments, at 45 days and 90 days after planting was found to be optimum at Anakapalle. At Padegaon, nitrogen applied in 4-6 instalments was found most beneficial for an 18 month crop. In Northern India, nitrogen is generally applied to the crop in only one instalment either at the planting time or after the monsoon sets in. In Uttar Pradesh, however, the application of nitrogen 15 or 30 days before planting or at the time of planting was found desirable. Varietal differences were also noticed (Anonymous, 1972). The varieties with sparse root system, like Co. 997, responded better when the fertilizer was applied in a number of instalments as it is liable to be leached out by heavy rainfall or irrigation (Anonymous, 1972).
PHOSPHORUS

According to Dilleuwijn (1952), the sugarcane crop can absorb considerable quantities of phosphates from soils of very low concentrations and therefore we seldom come across the deficiency of this nutrient. However, deficiency of this nutrient, when present, results in low root extension, poor root/shoot ratio, interference in protein synthesis and increase in soluble nitrogen in the stem. In Maharashtra, soils under continuous cultivation have exhibited phosphate deficiency and have responded well to phosphatic fertilization when the fertilizer has been placed at the proper depth. However, the application of phosphatic fertilizers at Shahjahanpur and in Tamil Nadu and Andhra Pradesh did not show any beneficial effect on yield and quality of sugarcane. But at Mandya (Mysore) the application of phosphatic fertilizers at the rate of 112 kg P$_{2}$O$_{5}$ resulted in higher yield (Lakshmikantham, 1954; Patwardhan and Sirur, 1954; Mitra, 1960; Anonymous, 1972).

Application of phosphorus

The application of P$_{2}$O$_{5}$ through foliar spray resulted in a higher uptake of P$_{2}$O$_{5}$ than when the same amount was applied to the soil. Field trials have shown that the application of superphosphates through legumes is highly beneficial to the succeeding cane crop. The depth of placement too plays a positive role. Application of superphosphate at a depth of 15 cm in deep soils and half way down the ridge in medium soils has been beneficial. Response to ammonium sulphate also increased due to the depth of phosphates (Farooque, 1954;
Forms of phosphorus

The efficiency of different phosphatic fertilizers depends on the chemical composition of the soil. Rock phosphate is cheaper for acid soils. Superphosphate gives better results than bonemeal on acid soils while monocalcium phosphate is more effective than di or tri-calcium phosphate under limed as well as unlimed conditions. Mixed organic and inorganic fertilizers have also given good results. Where superphosphate, along with compost was applied, it resulted in maintaining the availability of \( P_2O_5 \) to a greater extent (Anonymous, 1972).

POTASSIUM

Potassium plays an important role in the metabolism of sugarcane. It is required in a quantity greater than any other nutrient. Its requirement by a sugarcane crop may exceed 900 kg \( K_2O \) per hectare. A 247 tonnes per hectare crop removes about 618 kg of \( K_2O \).

An increase in the amount of the potassic fertilizer results in increased concentration of \( K_2O \) in all parts of the cane plants. The deficiency of \( K_2O \) leads to the accumulation of free amino acids in the plants, a lower rendement and 'bunch top' (Humbert, 1968). \( K_2O \) is taken up at a very fast rate in the early stages of growth, but there is a sharp decline in the middle of the growth period. The intensity of light also affects the efficiency of \( K_2O \) utilization. Increase in moisture in a well aerated soil accelerates the rate of \( K_2O \) absorption but it is decreased if the soil is waterlogged. \( K_2O \) has an antagonistic effect on the utilization of calcium.
The application of K₂O has shown no pronounced effect on juice quality. Sulphate of potash as well as muriate of potash have been found to be equally effective (Kanwar and Kochhar, 1960; Anonymous, 1972).

The application of K₂O however, has not been found profitable in Bihar, Uttar Pradesh, Rajasthan, West Bengal, Gujrat, Tamil Nadu, Madhya Pradesh and Andhra Pradesh (Anonymous, 1972).

**Studies on the maturation and ripening of sugarcane**

Sugarcane stores sugars in immature storage tissues in a small number of fully elongated joints near the base of stalk during the early period of growth and development. At this stage, the main concern of the plant is growth and the maximum accumulation of sugar takes place only when the plant has attained full, successful growth, which is followed by maturation. After this, the process of growth slows down owing to the depletion of water and nitrogen resources. The salient physiological feature of the plant at this stage is one of sugar accumulation rather than utilization, except in the region of expanding internodes with green leaves. For the plant as a whole, a potential is created for maximum sugar accumulation in the storage tissues already laid down. The process of ageing, maturation and ripening are not the same in the physiological sense though they appear to be so to a lay observer. Maturation occurs when the fulfilment of the potential referred to above has been achieved. Under natural conditions, ripening follows maturation which depends upon the ageing process though ageing, maturity and ripening are not synonymous.
It is possible to prevent the plant from maturing inspite of age by supplying water and nitrogen in abundance, while early ripening may be achieved by withholding water, nutrients etc., although the plant is by no means mature.

The modern commercial cane varieties mature and ripen about 2-4 months later than the growers would like. The use of ripening agents, growth controlling compounds, field management, such as topping, water regulation and fertilizer programming, can be so manipulated as to ripen the crop at the precise moment the farmers wish to harvest the crop. Similarly, ripening can be delayed and the farmers saved from losses, if the crop cannot be harvested at the time of ripening under normal conditions. Last year, the cane growers of Uttar Pradesh had to suffer huge losses owing to the inability of the sugar mills and "khandsari" units to crush all the available crop. It is precisely such a situation where scientific control of ripening is called for. The quality of the sugarcane is determined by its sucrose percentage which reaches the optimum level when the cane is fully ripened. It is the stage at which the crop should be harvested but it is seldom possible to do so under natural conditions. Excess of nitrogen available to the plant at the harvest time results in a low sucrose content (Nickel and Tanimoto, 1968).

Clement (1940) reported poor sugar accumulation owing to heavy nitrogen fertilization although potential storage capacity had increased. It has been found that if nitrogen is applied to ratoons older than 15 weeks, it results in low sucrose yield (Samuel and Alers-Alers, 1964).
Bonnet (1964) recommended that all nitrogen should be applied at planting or immediately after harvest.

Climate has a tremendous influence on maturity and as such on ripening and sucrose content. The age of the cane at harvesting influences the maturation profile within the stalk. Each variety reaches its ripening peak after which sucrose content declines if the cane is not harvested.

Ripening in physiological terms is a senescent stage immediate between the rapid growth phase and ultimate death of the plant. The agronomical concepts of ripening are usually based upon the appearance of internodes no longer subtended by green leaves and a parallel accumulation of sucrose in each successive internode towards a common high value.

Studies on sucrose and glucose distribution of sugarcane stalks of increasing age revealed that sucrose values are higher towards the centre and decline towards each end. The differences were accentuated in younger joints of the green leaf area. The difference in sucrose values at the joints are, in all probability, on account of differential invertase distribution. Sacher et al. (1963) noted that intercalary meristems bear much more invertase than the central internodal tissues. The vacuole invertase decline (and hence growth decline) is a motivating force towards sucrose retention over utilization. Sucrose may accumulate in large quantities in green leaf storage region but as long as growth and metabolic processes continue at high levels, there is little expectation that sucrose will long remain in storage. It means that climatic and cultural factors alter the balance between sugar
utilization and storage by altering the invertase control system. There are, thus, mounting evidences that water, nitrogen source, temperature and the cane genotype bear a powerful influence over invertase regulatory mechanism.

The role of nutrients in maturation and ripening

Nitrogen:

As pointed out earlier nitrogen has a deleterious effect on ripening if late irrigation is accompanied by growth stimulation through residual nitrogen. It has the same effect if nitrogen is applied in heavy doses or delayed too long in the growing season. Unusual rainfall pattern too prevent the utilization of nitrogen early in the growing season and encourage non-utilization late in the season.

In our country, nitrogen, in the form of Ammonium sulphate is indiscriminately used by farmers to stimulate growth because they get paid for the tonnage of the cane crop and not on the basis of sugar content. It causes loss to the crushing industry which ultimately affects the consumers by raising the cost of sugar production. All nitrogen fertilizers are equally effective, except liquid ammonium nitrate. Ammonium sulphate, however, raises the pH and hence it has a deleterious effect in acid soils. It is recommended in areas having pH 7 or higher. It has been shown that excess of nitrogen available to the cane at the harvesting affects the quality of the cane.

Clements (1959) claimed that cane growing in a field with abundance of nitrogen as well as surplus moisture can never achieve a highly ripened status. Maturation is, however, improved by applying all the nitrogen with the seed at planting
Sandy soils may, however, be given in split doses as they are prone to severe leaching (Bonnet, 1962).

Samuels and Alers-Alers (1964) supplied variable combinations of NPK to ratoons ranging in age from 3 to 21 weeks. Working on the variety PR 900 grown in a humid area on salty clay soil, they observed that nitrogen application (equal to 125 lbs per acre) at 15 weeks significantly lowered the sucrose content of a 12 month crop. The nitrogen effect was produced even in the presence of phosphorus and potassium. Higher nitrogen application (250 lbs per acre) significantly lowered sucrose content when applied to a 3 week ratoon crop.

**Phosphorus**

Cross (1925) reported beneficial effect of phosphorus on ripening of ratoon cane which was heavily fertilized with ammonium sulphate.

Rege and Sanan Bhatti (1943) fixed the agrobiological rate of nitrogen, phosphorus and potassium in Deccan soils at 3:1:9. They also reported that the application of phosphorus showed a tendency to promote flowering in sugarcane.

Rege and Mascarenhas (1952) concluded that nitrogen and phosphorus ratios above 2:1 are conducive to higher tillering, early maturity and higher sugar recovery without affecting cane tonnage.

Samuels in 1953 concluded according to Havangi et al. (1957) that phosphate had no considerable effect on the sucrose content. The results of hundreds of field experiments in Java
have shown that on an average phosphate application does not affect maturity.

Singh (1956) observed that a survey of data so far available does not fully support the view that phosphorus hastens the process of ripening of cane.

Arakeri (1956), in summarizing the results of experiments conducted at Padegaon in phosphate deficit soils, has stated that application of phosphatic fertilizer is observed to increase tillering and to accelerate growth in early stages which finally results in early maturity.

Samuel and Landru (1954) studied the components of available sucrose percent cane from a series of experiments that had responded to NPK fertilization. They found significant reduction in brix, polarization, purity and available sugar in stalks and juice of the potassium deficient crops. It was found that when potassium was available to the soils in adequate amounts, nitrogen application significantly increased brix, polarization values and percent extractability.

Divekar (1957) reported that spray of superphosphate at the rate of 5 lbs per acre induced profuse tillering resulting in more number of plants per acre. The treated plants also showed better growth in terms of height and girth of cane. He also reported early maturity as well as production of richer cane as a result of spray applications. According to him, the treated cane reached maturity by the middle of October while the untreated plants reached maturity by the end of November.

Havangi et al. (1957) reported no beneficial effect on the sucrose content by phosphate application although there
was an increase in tillering and therefore in the number of canes per acre. It was also reported by them that soil rich in \( \text{P}_2\text{O}_5 \) or application of phosphates to phosphate deficient soil brought about early maturity.

Tandon and Bhoj (1957) reported that wherever phosphate showed a beneficial effect on cane yield, it generally had a depressing effect on the juice quality.

Application of phosphates through soil or through foliar spray did not, however, show any appreciable response of sugarcane regarding yield or juice quality of cane, according to recent survey (Anonymous, 1977).

**Potassium**

Potassium poses many problems to the workers concerned with the maturation and ripening of sugarcane. There are conflicting reports regarding its effect on cane yield and quality. In certain cases an increase in the tonnage and quality has been observed while in others very little or no influence of any kind has been reported. The inconsistencies obtained with potassium in different regions show that the element performs some highly localised functions related to sugar transport and storages which are essentially independent of the nitrogen levels found in leaf sheath.

Landrau et al. (1959) obtained erratic responses to potassium fertilization with two varieties grown on Vega Baja silty clay in the humid to semi-humid Rio Piedros areas. The same experiment gave significant yields to nitrogen applied at the rate of 300 lbs per acre, but there was no response to phosphorus.
Humbert (1963) stressed the need to maintain adequate potassium in both sugarcane and sugarbeet to ensure optimum quality. Leurington et al. (1963) have, however, been puzzled by inconsistencies between available soil potassium and the tissue potassium as indicated by foliar potassium index.

Many workers, like Hartt (1969), have noted an apparent relationship between potassium deficiency and low sucrose yields. This response was confined to humid and semi-humid regions.

There is, therefore, a strong evidence of specific K/N ratio needed for high juice quality. This has been supported by Humbert (1958) and Bonnet (1962).

Interesting but unsubstantiated explanations of the role of potassium in sugarcane maturation are available from the work of Acevedo—Reinos (1962) based on changing foliar potassium content as a function of age. There was early decrease followed by late increase in potassium content of leaf blades. It was, therefore, proposed that maturity might be increased by late aerial potassium application.

Conversely, potassium increases at the late growth stages were also explained in terms of continued absorption as utilization decreased and transport (redistribution) of the element from young to old tissues within the plant.

Conclusion

The average yield of sugarcane in India is much lower than those in other sugarcane growing countries of the world. The same is true for the quality of sugarcane produced annually.

In spite of the introduction of new high yielding
varieties, the sugarcane production in Northern India is far less than that in the South. The sugar recovery is also poor as compared to the Southern region. One of the reasons is that sugarcane in North is grown as a 8 or 12 month crop. It is harvested in November to give way to wheat cultivation. This results in the harvesting of the cane when it is not fully mature and full ripening has not taken place. Harvesting can not be delayed as it would prove uneconomical, moreover, in the cold months of December and January, there will be inversion of sugar thus reducing sugar recovery.

It is, therefore, necessary to apply fertilizers in such an amounts and at such a time that it would ensure the maturing and ripening of the cane at the predetermined harvesting time in November. For this purpose some pot and field experiments are planned as described in the next chapter. The first planting will be done in the spring of 1980 at the farm of the Sugarcane Research Station, Shahjahanpur, U.P.
MATERIALS AND METHODS

It has been proposed to select three high yielding cane varieties viz.: Co. J 58, Co. 1158 and Co. J 1148 representing one each of early, mid and late maturation periods for three field experiments to be conducted during 1980-82. The response of these varieties will be tested in relation to the effect of different doses, time and method of NPK application, as well as to the best source of nitrogen and phosphorus, by considering various growth and yield parameters for correlation studies. The juice quality will also be tested in each experiment.

All the experiments will be conducted at the Sugarcane Research Station, Shahjahanpur (U.P.). The soil of each experimental plot will be analysed before sowing. Sowing of setts, irrigation, weeding and harvesting will be done according to standard agricultural practices. The meteorological data will be collected during the course of each experiment at the experimental site. The experiments will be laid out statistically and they will be conducted in small plots, each bed measuring 10 sq m (4m x 2.5m). Each treatment will be replicated thrice. The results will be statistically analysed at the 5 percent level of probability. The details of each experiment of the proposed study are as follow:

Experiment 1

The first experiment will be conducted according to a factorial randomised block design during the year 1980.
effect of different levels of nitrogen, phosphorus and potassium on the three selected sugarcane varieties will be studied on maturity, growth, yield and cane quality. Thus three nitrogen levels (100, 150 and 200 kg N/ha); three phosphorus levels (50, 75 and 100 kg P$_2$O$_5$/ha) and three potassium levels (150, 200 and 250 kg K$_2$O/ha) and their combinations will be studied with an unfertilized control. Urea, mono-calcium superphosphate and muriate of potash will be taken as the sources of nitrogen, phosphorus and potassium respectively.

Experiment 2

This experiment will be conducted in 1981 on the basis of the results obtained in Experiment 1. Thus, the most responsive variety with optimum dose recorded will be applied by considering the effect of three sources of nitrogen (urea, ammonium sulphate, and calcium ammonium nitrate) and three sources of phosphorus (monocalcium superphosphate, diammonium phosphate and sodium dihydrogen orthophosphate) with a uniform optimum potassium dose obtained in Experiment 1 in the form of muriate of potash on maturity, growth, yield and quality of the selected variety.

Experiment 3

This experiment will be conducted in 1982 to study the effect of the methods and time of application of fertilizers in the variety tested in Experiment 2 on maturity, growth, yield and quality of juice. Thus, the effect of two methods (broadcast and in furrows) of fertilizer application and six types of application of fertilizer viz.; (1) Full at sowing; (2) Half at sowing and half at pre-monsoon; (3) Half at sowing and half at post-monsoon; (4) 3/4 at sowing and 1/4 at
pre-monsoon; (5) $\frac{3}{4}$ at sowing and $\frac{1}{4}$ at post-monsoon; and
(6) $\frac{1}{2}$ at sowing, $\frac{1}{4}$ at pre-monsoon and $\frac{1}{4}$ at post-monsoon, will
be studied. The dose and source of nitrogen and phosphorus
will be selected on the basis of the results obtained in
Experiment 1 and 2. Potassium will be uniformly applied at
the optimum rate in the form of muriate of potash obtained
in Experiment 1.

**Maturity**

The maturity of the cane will be noted and the time
taken for maturity under the influence of various treatments
will be recorded.

**Growth characteristics**

Plants will be collected for growth characteristics at
two stages (pre-monsoon and post-monsoon) from each bed. The
following parameters will be recorded:

1. Tiller number/plant
2. Leaf number/plant
3. Number of nodes/plant
4. cane height/plant
5. Fresh weight/plant
6. Dry weight/plant.

In addition, the leaves of the sampled plants after completing
the above growth observations will be sampled and utilised
for the estimation of their nitrogen, phosphorus and
potassium contents on the basis of percent dry weight.

**Leaf analysis**

After noting the growth characteristics, each leaf
sample will be wiped free of any adhering dust by washing in
tap water. It will then be kept for drying in an oven at a temperature of 80°C for 24 hr. Dry weight of each sample will be taken after proper drying. Fully mature leaf blades will be detached from the shoots, finely powdered to pass through a 40 mesh screen and stored in screw-capped polythene tubes for analysis (Lundegardh, 1951). The total nitrogen, phosphorus and potassium contents will be determined at the selected stages of growth.

Digestion

Digestion of leaf samples will be done by the method of Lindner (1944). This is summarized below:

Before weighing the leaf powder for digestion, a sufficient amount will be spread in a thin layer on a clean sheet of paper and dried overnight at 70°C in an oven. The dried powder will be taken out and kept in a dessicator for a while. For digestion, 100 mg of each sample will be weighed and transferred to a 50 ml Kjeldahl flask carefully and 2 ml chemically pure sulphuric acid will be added. The mixture will be heated gently on a temperature controlled heating assembly till the sample is broken down and partially dissolved. The heating will be continued for two hours in order to reduce the leaf nitrates completely by the organic matter. Dense fumes will be given off at this stage and the contents will turn black. The flasks will be cooled for 10 minutes. After cooling, 0.5 ml of chemically pure 30 percent hydrogen peroxide will be added and the solution will be heated again. Dense fumes will begin to come out and the contents will
change from black to colourless. After heating for about fifteen minutes, when the fumes clear off, the contents will be cooled again. When the contents in the Kjeldahl flasks become perfectly colourless they will be diluted with double distilled water and transferred, with five or six washings, to 100 ml volumetric flasks and made upto volume.

**Estimation**

(i) **Nitrogen** : Total nitrogen in leaves will be estimated after nesslerization by the method of Lindner (1944). A 10 ml aliquot of the peroxidase-digested material will be transferred to a 50 ml volumetric flask. To this, 2 ml of 2.5 N sodium hydroxide will be carefully added with the help of a microburette to partially neutralize the excess of acid. Then, 1 ml of sodium silicate solution will be added to prevent turbidity. The volumes will be made upto the mark. Of this solution, 5 ml will be pipetted into a test tube marked at 10 ml and 0.5 ml of Nessler's reagent added drop by drop, shaking the tube after adding each drop. Water will be added to make up the volume to 10 ml. The contents will be allowed to stand for five minutes to allow maximum development of colour. The solution will then be transferred to a colorimetric tube and the optical density read at 525 nm on a "Spectronic-20" colorimeter. A blank will be run with each sample. The reading of each sample will be compared with a calibration curve obtained by using known dilutions of a standard ammonium sulphate solution.
(ii) **Phosphorus**: Total phosphorus will be estimated by the method of Fiske and Subba Row (1925). Briefly, a 5 ml aliquot of the original peroxidase-digested solution will be taken in a test tube marked at 10 ml. To it, 1 ml molybdic acid (2.5% ammonium molybdate in 10 N \( H_2SO_4 \)), followed by 0.4 ml 1:2:4 aminonaphthol sulphonic acid, will be added carefully when the colour will turn blue. Water will be added then to make up to volume. After waiting for five minutes, the blue coloured solution will be transferred to a colorimetric tube and the optical density read at 625 nm on a "Spectronic-20" colorimeter. A blank will be run with each sample. The phosphorus content of each sample will be obtained by comparing its optical density with a calibrated curve plotted by taking known dilutions of a standard solution of monobasic potassium phosphate.

(iii) **Potassium**: Potassium will be estimated flame photometrically. For this, 1 ml of the digest will be taken and read at 768 nm. A blank will be run side by side. The readings will be compared with a calibration curve plotted for different dilutions of a standard potassium sulphate solution.

**Yield characteristics** The following observations will be recorded for the purpose:

1). Cane height/plant
2). Cane weight/plant
3). Number of nodes/plant and
4). Cane yield (tons/hectare).

**Juice quality/cane quality**: The quality of cane will be judged on the basis of the values of brix, pol (polarization)
and purity of cane juice. Brix, which indicates the percentage of total solids in the juice, will be measured with Brix hydrometer. Pol, indicating the percent juice, will be determined with polarimeter. The purity is determined by the proportion of sucrose to total solids and is given by:

\[
Purity = \frac{\text{Sucrose}}{\text{Total solids (brix)}} \times 100
\]

**Statistical analysis**

All the experiments will be statistically designed and the data collected will be subjected to statistical analysis. The significance of the results will be determined at the 5% level of probability. The results will be discussed in the light of the publications of other workers.
REFERENCES


Divakar, M.V. 1957. Preliminary studies on foliar feeding of phosphate on growth and maturity of sugarcane. Proc. 3rd All India Conf. SRDW, pp. 94-96.


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