MINERAL NUTRIENT STUDIES IN SUGAR CANE

A—RATE OF UPTAKE WITH INCREASING MATURITY.

B—FACTORS AFFECTING COMPOSITION OF THIRD LEAF BLADE.

By R. T. BISHOP

Introduction

The question is often asked; how soon after planting or cutting of sugar cane should fertilizers be applied? From the growth analysis experiment (2) the total amount of mineral nutrient in the above-ground portions of the crop in any week of the crop cycle could be calculated. The periods of maximum demand by the plant for a particular nutrient could therefore be ascertained.

It is accepted (7) that the chemical composition of the plant is influenced by a number of factors other than the fertility status of the soil. The weekly measurements of environmental factors prevailing for the duration of the growth analysis experiment has permitted an estimate of the degree to which each component influences plant composition.

Section A

Rate of Uptake with Increasing Maturity

The total amounts of N, P, K, Ca, Mg, and Na in the above-ground portions of the crop with increasing maturity of the crop are presented in Table 1.

TABLE 1

Variation in monthly mean weight of nutrients (lb/ac.) in the above-ground components of the crop with increasing maturity.

AGE (wks)	MONTH (1963)	N	P	(lb/acre) K	Ca	Mg	Na
11	Feb.	117.9	12.4	166.7	31 8	28.8	2 6
13	Mar.	120.9	12.8	176.2	26.0	32 2	3.7
17	Apr.	141.4	14.4	188 4	29.7	38.5	3.8
21	May	131.6	13.9	191.6	41.9	39.1	5.2
26	June	128.8	13.3	176.3	33.2	40 3	5.9
30	July	135 0	13.4	160 9	27 9	40.1	7.9
35	Aug.	150.1	16.1	167.9	30.8	45.8	3.5
39	Sept.	144.2	15.5	172.8	36.4	47.4	3.0
43	Oct.	150.5	15.7	191.4	41.3	49.3	3.3
48	Nov.	148.5	20.7	171.7	45 0	52 5	5.4
52	Dec.	156.2	21.5	168.7	42.9	56.3	9.2
	(1964)						
57	Jan.	155.4	20.6	165.4	51.6	58.0	4.1
61	Feb.	159.4	22.0	196.6	68.4	66.9	5.0
65	Mar.	152.7	21.3	177 8	66.6	59.5	7.5
69	Apr.	142.5	22.5	180 0	65 9	68.8	6.2
74	May	131.5	20.2	173.8	60 1	83.8	6.6
78	June	132.5	19.2	191 9	64.1	108 3	7.3
82	July	149.6	23.0	214.8	56.5	109.3.	6.7

Discussion of Table 1

(i) Nitrogen

Although the total N content of the crop does fluctuate from week to week, the amount present at 14 weeks is equal to the amount present after 83 weeks. This observation is in keeping with the results of Kobus (6) and Yuen and Borden (8) who respectively found that uptake of N was complete by the age of 60 and 90 days. Du Toit (5), however, found the uptake of N to continue throughout a full crop cycle. Although this contradiction indicates that the results presented in Table 1 may not hold generally, the implication is that N fertilizers should be applied in the very early stages of the crop development. The policy of the South African Sugar Association Experiment Station to recommend top-dressings of N fertilizer two months after planting or immediately after harvesting is therefore sound.

(ii) Phosphorus

While it is true that P accumulates with increasing age of the crop, there is a gradual decrease in the weight of P in the foliage. The apparent reason for the observed increase in total P content of the crop between weeks 43 and 48 was the advent of the first spring rains which fell during week 42. Although temperatures were adequate for normal nutrient uptake during this period, the increase in P content (which occurred in week 46) was considerably delayed. This possibly reflects the period required for renewed root activity following winter dormancy.

(iii) Potassium

As was the case for N, the total amount of K in the crop is the same if the crop is 18 weeks or 83 weeks old. With increasing age of the crop the amount of K in the foliage decreases while the amount of K in the stalk increases. These results are contrary to the findings of du Toit (5) and Ayres (1). Borden (4), however, found a similar trend.

(iv) Calcium

The absolute amounts of Ca in the above-ground portions of the plant increase with increasing maturity (8). Marked reductions of Ca content are observed to occur during certain periods (weeks 78 to 82). These reductions are the results of lower weights of trash and/or marked decreases in Ca% in the stalk without corresponding increases in other tissues. The former variation is due to experimental error, but the latter indicates an actual loss of Ca from the above-ground portions of the plant. This loss is discussed more fully in the section on Na.

(v) Magnesium

Unlike Ca, the amount of Mg in the stalk generally exceeds that in the trash. The amount of Mg in the foliage remains fairly constant while the absolute amount of Mg in the stalk shows a steady increase with age. These results indicate that Mg is probably an essential component in the structural cells of the stalk.

(vi) Sodium

The absolute amounts of Na in the crop fluctuate markedly. Actual losses of Na from the above-ground portions of the plant occur, e.g. 10.1 lb./ac. of Na was present in week 30 but only 2.6 lb/ac. in week 33. Subsequent pot experiments have shown that there is a marked accumulation of Na in the below-ground portions of the stalks. With a sudden flush of water into the plant this Na moves up the stalk, but once stalk elongation is complete the greater proportion migrates back to the stalk bases. The observed fluctuations of other nutrients are probably due to the same movement.

Section B:

Factors Affecting the Composition of Third Leaf Blade

The magnitude of the effects of environment on nutrient composition of the third leaf blades are presented in Table 2.

TABLE 2

Simple correlation coefficients between concentration (% dry matter) of nutrients in third leaf blade with environmental factors

	N	P	K	Ca	Mg	Na	Zn	Cu	Mn
Rainfall	0.18	0.02	0.02	-0.14	-0.11	0 02	-0 03	0.07	-0.08
Soil Moisture	0.37**	0.15	-0.01	-0.45***	-0.18	-0.13	0.04	0 01	-0.23
Stalk Increment	0.42***	0.31**	0.20	-0.47***	-0.37**	-0.33**	-0.05	0.11	-0.27*
Air Temperature	0.12	0.19	-0.05	-0.10	-0.67***	-0.46***	-0.41***	0.20	-0.29*
Total Radiation	0.07	0.18	0.01	-0.15	-0.69***	-0.48***	-0.41***	0.13	-0.39**
Evaporation	-0.05	0.07	-0.14	-0.08	-0.65***	-0.50***	-0.45***	0.06	-0.30
Soil Temperature	-0.24	0.30*	0.14	-0.07	-0.59***	-0.30**	-0.33**	0.31**	-0.21

(i) Stalk increment

When lagged correlation coefficients were calculated between stalk elongation and concentration of nutrients, all values for the macro elements exceeded the levels required for statistical significance.

There is little doubt that rate of stalk elongation, which controls the age of the leaf in position number three, influences the chemical composition of the leaf. As plant tissues get older the ratio of carbohydrates to inorganic nutrients increases. If the absolute amount of nutrient in the leaf remains constant or decreases, per cent nutrient decreases, e.g. N, P and K. If the rate of movement of nutrients into the leaf increases sufficiently to overcome the dilution effect, per cent nutrient increases, e.g. Ca and Mg. These trends are illustrated in Figure 1.

During weeks 13-18 and 58-60 no stalk elongation took place. The weight of third leaves and Ca% was high and N% was low for the same periods. When active stalk elongation was taking place, e.g. weeks 6-10 and 50-54 the opposite was true.

It is somewhat disconcerting to note that Ca% and Mg% are negatively correlated with stalk elongation since it is accepted that concentrations of nutrients in third leaf are at a maximum when the plant is actively growing. Thus, a low Ca% in the leaf may indicate ideal growing conditions (including soil fertility) and not a deficiency of Ca. The concentrations of Ca and Mg in other tissues of the plant are positively correlated with stalk elongation and sampling of these tissues may become necessary when estimating soil fertility. The negative relationship between Na% in third leaf and increases in stalk length may well prove a guide as to whether leaf samples are reliable or not (3).

(ii) Rainfall and soil moisture

Plant available moisture is the most serious single climatic factor which restricts crop production in most sugar cane producing countries. As expected, therefore, the correlation coefficients between moisture content of the soil and chemical composition of the third leaf blades are the same magnitude as those discussed above. This becomes even more apparent if the lagging of chemical composition behind soil moisture is taken into account.

(iii) Air temperature, total radiation, evaporation and soil temperature

The observed affects of radiation on the composition of third leaves are undoubtedly also due to seasonal influence on stalk elongation, e.g. during winter little or no stalk elongation occurs.

(iv) Age of crop

The chemical composition of the third leaf blade with increasing maturity of the crop is presented in Table 3.

The influence of age on N%, P% and K% is marked while Ca%, Mg% and Na% are apparently unaffected. Concentrations of Zn and Mn are also not seriously affected. In young plants (less than 11 weeks) Cu content is relatively high, but following a sudden reduction it remains relatively constant after approximately 16 weeks.

The age effect can roughly be corrected if it is accepted that for an increase in age of 1 week (after 16 weeks) concentrations of N, P and K decrease by 0.01%, 0.001% and 0.01% respectively.

TABLE 3

Variation in monthly mean concentration of nutrients in third leaf blade with increasing maturity

Age (Weeks)	Month (1963)	N	P	K	% Ca	Mg	Na	Zn	p.p.m. Cu	Mn
11	Feb.	2.44	0.23	1.42	0.31	0.25	0.035	22	11	94
13	Mar.	2.13	0.22	1.42	0.23	0.29	0.042	24	7	90
17	Apr.	1.96	0.21	1.46	0.21	0.22	0.029	23	5	55
21	May	1.73	0.20	1.49	0.26	0.26	0.065	23	5	85
26	June	1.65	0.17	1.18	0.29	0.31	0.079	24	5	90
30	July	1.81	0.18	1.14	0.22	0.32	0.062	25	4	72
35	Aug.	1.96	0.21	1.29	0.22	0.21	0.027	21	4	57
39	Sept.	1.76	0.19	1.35	0.27	0.24	0.039	22	4	41
43	Oct.	1.70	0.18	1.23	0.28	0.24	0.049	22	5	38
48	Nov.	1.66	0.19	1.18	0.29	0.22	0.037	19	6	40
52	Dec.	1.54	0.17	0.97	0.26	0.23	0.054	18	4	43
	(1964)									
57	Jan.	1.52	0.17	1.09	0.22	0.19	0.030	16	3	44
61	Feb.	1.62	0.18	1.12	0.24	0.19	0.018	19	4	62
65	Mar.	1.47	0.17	1.00	0.29	0.25	0.028	18	5	108
69	Apr.	1.48	0.18	0.92	0.32	0.28	0.035	18	5	98
74	May	1.37	0.16	0.93	0.33	0.29	0.037	18	4	92
78	June	1.23	0.14	0.93	0.31	0.32	0.042	23	3	88
82	July	1.34	0.16	1.09	0.32	0.30	0.039	19	3	76

Conclusions

Top dressings of N and K should be applied within 12 weeks of planting or harvesting. The Na results indicate that the below-ground portions of the stalks are areas of storage.

The fluctuations in the concentrations of nutrients in the third leaf blades are due largely to differences in maturity of the leaf sampled. For the taking of leaf samples the following procedures are recommended.

(i) Weekly increases in stalk length be made after a soaking rain. When elongation exceeds 0.2 ins. per day samples can be taken.

(ii) If the above is not possible samples should only be taken between 7 and 21 days after a soaking rain (provided mean air temperatures exceed 20°C).

(iii) Samples should not be taken from a crop less than 16 weeks old.

Summary

The absolute amounts of N, P, K, Ca, Mg and Na in the above-ground portions of the plant with increasing maturity have been calculated.

The correlation coefficients between concentrations of nutrients (N, P, K, Ca, Mg, Na, Cu and Mn) in third leaf blade and environmental factors (rainfall, soil moisture, stalk increment, air temperature, total radiation, evaporation and soil temperature) are presented. The influence of the age of the crop on concentration of nutrients in third leaf blades is also considered.

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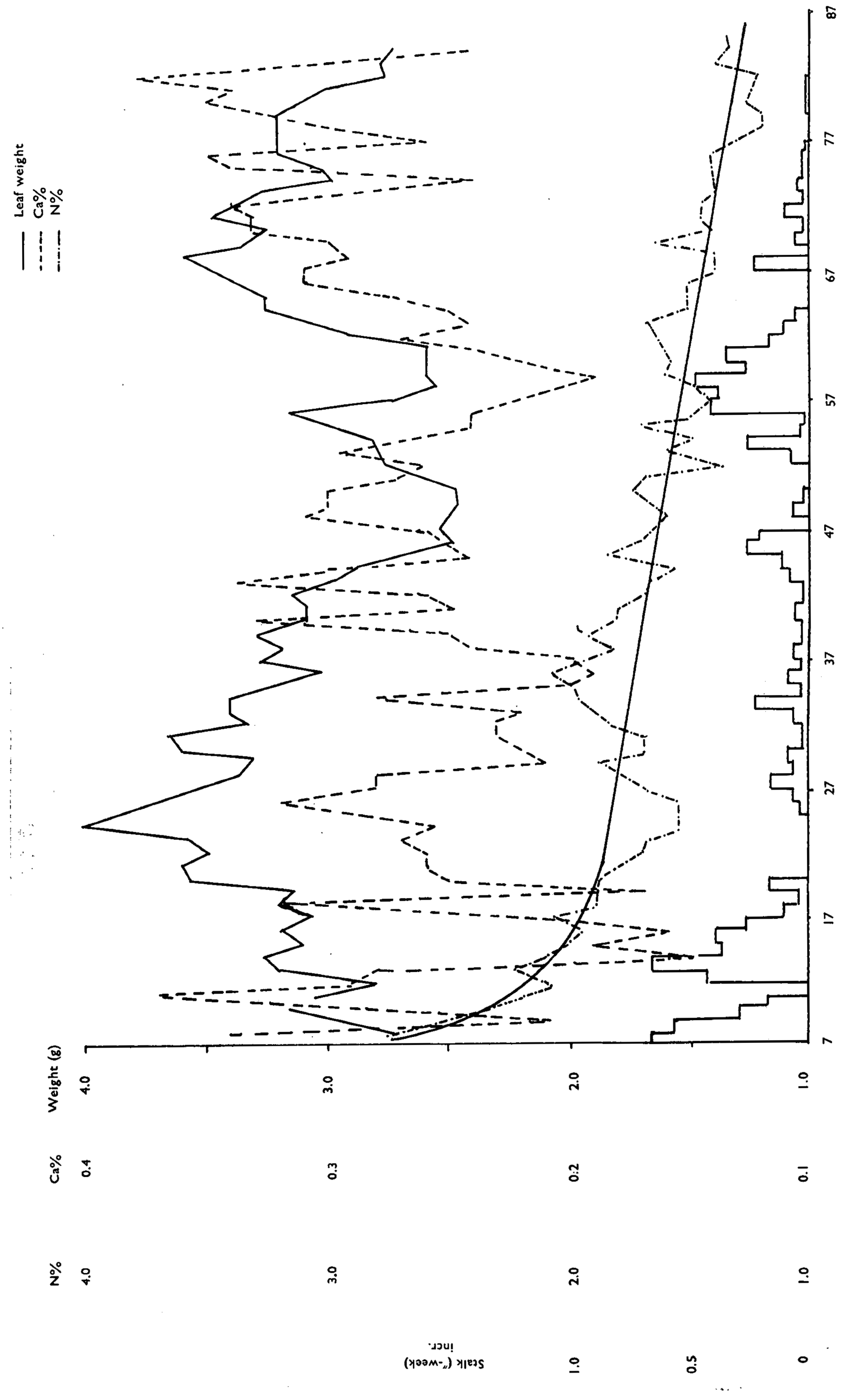

Fig. 1. Relationship between stalk elongation, weight of third leaves, Ca% and N% with increasing maturity of the crop.

Mr. du Toit (in the chair): Mr. Bishop states that all the nitrogen is taken up at an early age of the cane, up to about 17 weeks. My own findings are somewhat contradictory.

Radioisotope studies have shown that while there is growth, phosphate is taken up.

The pattern for nitrogen, phosphate and potash need not be identical, but it is a natural phenomenon that while there is growth nutrients will be taken up.

Mr. Bishop seems perturbed at the negative correlation between stalk increment and calcium and magnesium concentration. He feels that if that is so then foliar diagnosis for calcium and magnesium may not be valid.

In foliar diagnosis of calcium there are certain threshold values and it is only when the concentration falls below these critical values that a deficiency would be expected.

If there is an excessive amount of calcium and magnesium in the soil, and consequently in the leaf blade, under optimum growing conditions levels of nutrient will fall, but not necessarily below the critical value.

A negative correlation between concentration and elongation in this instance does not invalidate the foliar diagnosis.

The leaf analysis shows a fall of nitrogen concentration with age and Mr. Bishop tries to relate this to an apparent constant total amount of nitrogen in the cane plant after the 17th week.

Comparing the same periods for phosphate, the figures are 23 to 14, again a big difference, but constancy is not claimed for phosphate. It is therefore difficult to drawn conclusions from the leaf.

It is agreed that leaf nitrogen and phosphate will decrease with age, and will decrease in the cane stalk.

Potash also shows a fall but moisture status has something to do with it and in any case potash is not affected as much by age.

Mr. Bishop: Uptake of nutrients occurs only when the crop is actively growing, and it would be dangerous to generalize from this experiment. But the experiment covered 88 weeks during which time there were periods of both growth and no growth. It was not a case of taking a sample during active growth and one during no growth and trying to draw a conclusion. We have gone through a long series of growth cycles and covered a wide series of growth conditions and the overall picture is that generally the greater part of the nitrogen is taken up in the young stage when growth is greatest.

Mr. du Toit: Might not nitrogen deficiency in the soil cause a slowing down of uptake?

Mr. Bishop: When most of the experiment had been harvested we top-dressed with N, P and K so as to get an age effect to eliminate the effects of depletion in the soil. The experiment was given adequate N, P and K and then resampled and the leaf nitrogen trend did hold. It took up the nitrogen and the leaves were higher in concentrations of P and K but the decrease of nitrogen with age was still apparent. The lack of apparent uptake was not total in the plant but was an overall percentage decrease which shows that this is due to a physiological effect of the cane rather than to age of the plant. Mr. du Toit thinks that leaf per cent is not a good enough indication on which to base the constancy of nitrogen throughout the plant, but it is accepted that young cane has a greater percentage of foliage than older cane. In trash formation nitrogen is partly withdrawn from dying leaves to other parts of the plant.

The recovery of nutrients from older leaves in the plant is far greater for N than for P. Trash is low in N but high in P.

The critical level of calcium is much lower than will ever be experienced if there is optimum calcium in the field. However, if the calcium in the soil approaches a critical level and there is still rapid unfolding of leaves then it might be pushed below the critical level.

Dr. Dodds: In what form does sodium occur in the soil? It will occur naturally but is it also included in fertilizer?

Mr. Bishop: Most sodium in our soils is present in ionic form, not as a salt. It is seldom more than 25 ppm as exchangeable sodium, which is very low in comparison to other nutrients. In brackish areas there might be quite high concentrations of free sodium chloride. A certain amount will go on to the fields in fertilizer as an impurity.

Mr. Glover: You say that all nitrogen is taken up in 60 or 90 days, or at any rate most of it. Chemistry and plant physiology disagree here. Serial production of stalks occurs in cane and consequently continuous uptake of nitrogen while there is vegetative growth, stopping only when flowering takes place. There might be confusion in an experiment of this kind running all the time, as opposed to the clear-cut effects obtained with a plant that reaches a fixed maturity. Cane grows all the time, at times more quickly than at other times. Not all stalks are of the same physiological age, nor are the leaves, so during analysis it would be best if they were separated into age of stalk. If they are not separated and are analyzed in bulk then such a uniform level of nitrogen appearing in the plant might readily occur. There is no real conflict between the results of Mr. du Toit and Mr. Bishop.

In Table 2 the nitrogen correlation with stalk increment is .42, effectively representing 17 per cent of accountable variation, which is rather low. The highest one is magnesium which is particularly interesting from a climatic point of view. This accounts for about 40 to 50 per cent of the variation of the magnesium in relation to air temperature, radiation, etc.

The physiological age of material being sampled is most important.

Mr. Bishop: That is certainly the greatest weakness of this experiment.

The correlation coefficients are low but it must be appreciated that a computer was used. The correlations were used only as a guide and once they indicated useful trends they were graphed.

Mr. du Toit: I do not agree with Mr. Glover that we should be perturbed by the .42 nitrogen stalk correlation coefficient. This is highly significant and means that growth is correlated with composition but we do not expect the complete elimination of nitrogen variability.

Mr. Glover: The reason why I thought the simple correlations were low is that it is easy to produce a simple correlation between nitrogen and just about any other factor. In a similar type of growth analysis experiment I found it only possible to find a true correlation between fertilizers applied or nutrients themselves, by tackling the whole group of major elements as one. The prime correlation was the interdependent, the dynamic, system of N, P and K with growth in general. After that you could split into N, Ca, etc. and by the time you got down to simple correlations they made no sense. The true answer came from the linking of the interactions of N, P and K, which are what cause growth. It is unsatisfactory to take N alone as a simple correlation.

Mr. Wyatt: The Experiment station recommends top dressing with fertilizer two months after planting. I agree if you are planting in spring, but surely not in February?

Mr. Bishop: We do take the time of the year into account. Of course if your plant is deficient in nitrogen you will always get a response to nitrogen. But if you want to get optimum growth response to nitrogen application you must supply it in the early stages, and if we are contemplating a 12-month crop this will be even more necessary.