

# A PRELIMINARY INVESTIGATION INTO THE EFFECT OF PLANT NUTRIENT LEVELS ON SUGARCANE FLOWERING

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## Abstract

The successful initiation and emergence of flowers is vital for breeding new sugarcane varieties. A number of factors, including the parent clone, temperature, moisture and the photoperiod treatment, have varying levels of influence on flowering. One factor that has not received much attention, is the effect of nutrition. Over the past two crossing seasons at Mount Edgecombe, leaf samples have been collected from control clones in each of nine photoperiod treatments and analysed for various nutrients including nitrogen, phosphorus and potassium. In addition, the amount of nutrients applied per plant over seven crossing seasons was determined. In this paper, preliminary results of the effect of various nutrients on numerous aspects of flowering in sugarcane are reported.

**Keywords:** sugarcane, flowering, nutrients

## Introduction

Over the years extensive research has been conducted in sugarcane crossing programmes, examining the factors contributing to flowering in an attempt to fine-tune procedures for maximum flower and seed production. The main thrust of these experiments was to induce flowering in clones that were shy- or non-flowering, so that the crossing range could be extended. Flowering of sugarcane is primarily a photoperiod response (Moore and Nuss, 1987). Other factors known to influence floral initiation and development are genotype, physiological maturity, latitude, temperature, relative humidity, soil moisture, light quantity and quality, nutrition and auxin relations (Stevenson, 1965; Coleman, 1969; Moore and Nuss, 1987; Nuss and Berding, 1999). Ultimately, flowering consists of a series of developmental states, each with somewhat different sets of requirements (Moore and Nuss, 1987).

Sugarcane produces flowers under a wide range of nutritional conditions. This does not mean, however, that specific plant food elements do not affect flowering (Arceneaux, 1967). Moisture relations and nutritional status are variable from season to season, and these can influence flowering within a variety at any particular location (Stevenson, 1965). Poorly grown cane on soil with a low fertility usually flowers better than well-nourished cane of the same variety on good soil (Brett, 1951; Stevenson, 1965). In the Hawaiian Islands, flowering is more profuse on certain soil types, even when conditions otherwise appear identical. These differences in flowering observed in the field were maintained when cane was planted in pots of 'flowering' and 'non-flowering' soil removed from the field (Coleman, 1960).

Although sugarcane must be growing vigorously for maximum flowering (Moore and Nuss, 1987), high levels of nitrogen, especially during initiation, may reduce or delay flowering (Van Dillewijn, 1952; Clements and Awada, 1967; Nuss and Berding, 1999), while too little nitrogen may affect flowering intensity, flower size and seed set. Cane age, genotype and the availability of water affect the extent to which nitrogen inhibits flowering (Nuss and Berding, 1999). Large differences are found among clones, with a few being so sensitive that flowering never occurs under normal nitrogen fertilisation levels (Gosnell, 1973).

Phosphate application appeared to reduce flowering (Gosnell, 1973), while application of potash stimulated flowering (De Almeida *et al.*, 1946). In a more comprehensive study, Menshawi (1978) traced the chemical status of the cane meristem in a flowering and a non-flowering variety during definite phases of flowering. An early increase in magnesium level appeared to accompany accumulation of the floral stimulus in the apical meristem. Amounts of manganese, phosphorus and zinc in the meristem increased as the floral primordia initiated and throughout maturation. In addition, the accumulation of the floral stimulus in the cane apex was accompanied by an increase in the content of specific proteinogenic amino acids and amides.

It is clear that the nutrients applied during cane growth may influence the extent of flowering. To further study this relationship, leaf samples were collected at regular intervals from parent varieties during the 1999 and 2000 crossing season at the SASA Experiment Station. In addition, the amount of nutrients applied on a per plant basis was determined for seven crossing seasons from 1994 to 2000, and again compared with the same aspects of flowering. It was hoped that the information gained would enable future improvements to flowering in the crossing programme to be achieved through manipulation of the fertiliser regime.

## Materials and method

### *Cane growth and flower induction*

The heated glasshouse and photoperiod facilities used in this work have been described previously (Brett and Harding, 1974). During September each year, cane is planted into bins (eight clones per bin) containing river sand. Tillers are removed and six or four primary stalks are allowed to develop in large or small bins, respectively. The cane is irrigated twice daily and fertilised fortnightly with 5:1:5 (46) (2.88 g per plant). The application of nitrogen ceases in December, following which a non-nitrogen containing fertiliser (potassium chloride and superphosphate in a ratio of 1:3) is applied (2.88 g per plant). In February, when

the first photoperiod treatments are imposed, the cane (between 150 to 200 days old) is moved daily into the flowering facilities. At Mount Edgecombe, the standard photoperiod treatment is a 30 second decline in daylength per day, with the daylength of 12h30 being regarded as the start of the initiation period. Artificial dawns and natural sunsets are used (Brett and Harding, 1974). The treatments commence at different times, with flowering peaks occurring approximately 100 days after the date on which the 12h30 daylength occurred. Four weeks after this date, the cane is fertilised with 3:1:3 (38) (0.72 g per plant). When the flowers emerge, the stalks are cut, marcotted and used in crossing.

#### *Leaf samples*

From the beginning of March 1999 and 2000, leaf samples were collected fortnightly (one week after fertiliser application) from control bins of each of nine photoperiod treatments. In order to collect sufficient leaf material for nutrient analysis, the third and fourth leaves of one plant in all eight clones in one treatment were sampled and combined at each sampling date. The middle 30 cm of each leaf was retained, and the midrib removed. The leaves were dried and sent to the Fertilizer Advisory Service at the SASA Experiment Station for analysis. Nitrogen content was estimated using near infrared reflectance, while phosphorus, potassium, sulphur, calcium, magnesium, zinc, manganese, copper and iron content were determined using an X-ray spectrometer (Wood *et al.*, 1985).

#### *Data collection and analysis*

From flowering records, the average number of days to flowering, percentage initiation, emergence and flowering were calculated, as well as the number of viable seeds set per tassel. The number of initiated stalks was determined from the total number of flowered stalks and the number of stalks that initiated, but failed to produce a tassel. The number of initiated or flowered stalks was expressed as a percentage of the total number of mature stalks to obtain initiation or flowering percentages respectively. The percentage emergence was calculated from the number of initiated stalks that flowered. The number of days from the initiation daylength (12h30), to flower emergence is referred to as 'days to flower'. The method used to calculate the number of viable seeds per tassel has been described previously (Brunkhorst *et al.*, 2000).

Records of fertiliser application from the 1994 to 2000 crossing seasons enabled calculation of the approximate amount of nitrogen, phosphorus, potassium, sulphur, calcium and magnesium added per plant at each application. The levels of these nutrients, as well as zinc, manganese, copper and iron, in leaf samples were determined at each sample date. Data for the applied nutrients and the leaf sample results were compiled to indicate the values at six, four and two weeks prior to, during and after initiation. For comparative purposes, the date on which the daylength was 12h30 was regarded as the starting date of the initiation process and is referred to as the '12h30 date'. In addition, data for nutrients applied for six, four and two weeks leading up to emergence were obtained. The data were used to calculate the correlation coefficients between the amount of nutrient applied and days to flower, percentage flower initia-

tion, percentage flower emergence, percentage flowering and seeds per tassel for each nutrient separately. Correlation coefficients were also calculated between the leaf nutrient levels and each flowering variable.

### **Results and discussion**

Correlation coefficients between the amount of nutrient applied per plant and each flowering variable are presented in Table 1 (nutrients applied six weeks before and after the 12h30 date) and Table 2 (nutrients applied six weeks prior to flower emergence). Furthermore, correlation coefficients between leaf nutrient levels and each flowering variable are shown in Table 3.

#### *Nitrogen*

As high levels of nitrogen, especially during initiation, may reduce or delay flowering (Van Dillewijn, 1952), it is now common practice at Mount Edgecombe to cease application of nitrogen prior to six weeks before the 12h30 date. Nitrogen application recommences four weeks after the 12h30 date, through the application of 3:1:3 (38). In most crossing seasons used in this study, therefore, nitrogen was withheld for more than six weeks prior to the 12h30 date. Very little change was thus noted in the correlation coefficients over the weeks surrounding the 12h30 date for the amount of nitrogen applied (Table 1). In addition, no nitrogen was applied in any year in the six weeks before flower emergence, thus accounting for the identical correlation coefficients observed (Table 2). During this period when nitrogen was withheld, the amount of available nitrogen in the river sand would be decreasing, as is reflected in the leaf nitrogen values. Nitrogen levels within the plant averaged over all treatments combined for 1999 and 2000, declined up to two weeks before the 12h30 date, remained constant and then increased again four weeks later, presumably due to addition of 3:1:3 (38) (Figure 1a). This decline in nitrogen levels within the plant may account for the significant positive correlations between nitrogen and emergence, flowering and seeds per tassel over the period from six weeks before the 12h30 date to emergence (Tables 1 and 2). No association was observed between applied nitrogen and days to flower or the percentage of flower initiation, presumably due to the cessation of nitrogen application. High leaf nitrogen levels at the 12h30 date had a significant negative association with initiation, emergence and flowering (Table 3). In addition, high nitrogen levels within the leaf two weeks after the 12h30 date seemed to delay flowering, which was in agreement with results of previous work (Clements and Awada, 1967; Nuss and Berding, 1999). However, increased nitrogen uptake by the plant six weeks after the 12h30 date appeared to improve initiation and flowering, but may have had a negative effect on the number of seeds obtained per tassel (Table 3). In contrast, late application of nitrogen fertiliser before anthesis increased the number of grains per ear in cereals (Herzog, 1981).

#### *Phosphorus*

Excessive uptake of phosphorus was observed at various sample dates (Figure 1b), possibly due to marginal levels of nitrogen within the plant. The amount of phosphorus applied seemed

**Table 1. Nutrients and flower initiation: Correlation coefficients between various aspects of the flowering process and levels of applied nutrients at various dates before, during and after flower initiation.**

| Nutrient | Aspect of the flowering process | No. weeks before the 12h30 date |         |         | 12h30 date | No. weeks after the 12h30 date |         |         |
|----------|---------------------------------|---------------------------------|---------|---------|------------|--------------------------------|---------|---------|
|          |                                 | 6                               | 4       | 2       |            | 2                              | 4       | 6       |
| N        | Days to flower                  | 0.103                           | 0.099   | 0.098   | 0.093      | 0.079                          | 0.107   | 0.145   |
|          | % Initiation                    | 0.149                           | 0.151   | 0.153   | 0.158      | 0.162                          | 0.151   | 0.145   |
|          | % Emergence                     | 0.348**                         | 0.348** | 0.349** | 0.349**    | 0.344**                        | 0.378** | 0.413** |
|          | % Flowering                     | 0.378**                         | 0.378** | 0.380** | 0.384**    | 0.381**                        | 0.395** | 0.410** |
|          | Seeds/tassel                    | 0.511**                         | 0.518** | 0.521** | 0.524**    | 0.527**                        | 0.496** | 0.476** |
| P        | Days to flower                  | -0.091                          | -0.082  | -0.081  | -0.052     | -0.053                         | -0.057  | -0.088  |
|          | % Initiation                    | 0.162                           | 0.151   | 0.143   | 0.114      | 0.150                          | 0.178   | 0.255   |
|          | % Emergence                     | 0.352**                         | 0.333*  | 0.317*  | 0.291*     | 0.285*                         | 0.298*  | 0.333*  |
|          | % Flowering                     | 0.377**                         | 0.356** | 0.340*  | 0.307*     | 0.317*                         | 0.338*  | 0.401** |
|          | Seeds/tassel                    | 0.461**                         | 0.444** | 0.459** | 0.402**    | 0.366**                        | 0.377** | 0.395** |
| K        | Days to flower                  | 0.037                           | 0.037   | 0.038   | 0.047      | 0.040                          | 0.052   | 0.062   |
|          | % Initiation                    | 0.160                           | 0.157   | 0.155   | 0.149      | 0.166                          | 0.173   | 0.199   |
|          | % Emergence                     | 0.364**                         | 0.357** | 0.352** | 0.347**    | 0.345**                        | 0.371** | 0.403** |
|          | % Flowering                     | 0.393**                         | 0.386** | 0.381** | 0.375**    | 0.382**                        | 0.401** | 0.433** |
|          | Seeds/tassel                    | 0.514**                         | 0.511** | 0.519** | 0.505**    | 0.499**                        | 0.493** | 0.492** |
| S        | Days to flower                  | -0.314*                         | -0.290* | -0.288* | -0.220     | -0.206                         | -0.203  | -0.244  |
|          | % Initiation                    | 0.072                           | 0.058   | 0.047   | -0.001     | 0.061                          | 0.102   | 0.214   |
|          | % Emergence                     | 0.123                           | 0.101   | 0.079   | 0.032      | 0.037                          | 0.071   | 0.123   |
|          | % Flowering                     | 0.124                           | 0.102   | 0.079   | 0.023      | 0.054                          | 0.095   | 0.185   |
|          | Seeds/tassel                    | 0.078                           | 0.071   | 0.104   | 0.007      | -0.021                         | -0.003  | 0.007   |
| Ca       | Days to flower                  | -0.318*                         | -0.282* | -0.264* | -0.182     | -0.139                         | -0.176  | -0.278* |
|          | % Initiation                    | 0.050                           | 0.029   | 0.005   | -0.057     | -0.009                         | 0.038   | 0.120   |
|          | % Emergence                     | 0.088                           | 0.063   | 0.027   | -0.033     | -0.025                         | -0.075  | -0.128  |
|          | % Flowering                     | 0.083                           | 0.054   | 0.012   | -0.063     | -0.037                         | -0.041  | -0.033  |
|          | Seeds/tassel                    | 0.028                           | -0.003  | 0.006   | -0.113     | -0.152                         | -0.082  | -0.072  |
| Mg       | Days to flower                  | 0.075                           | 0.067   | 0.059   | 0.053      | 0.024                          | 0.085   | 0.156   |
|          | % Initiation                    | 0.156                           | 0.157   | 0.162   | 0.169      | 0.182                          | 0.161   | 0.152   |
|          | % Emergence                     | 0.357**                         | 0.355** | 0.356** | 0.355**    | 0.341*                         | 0.415** | 0.471** |
|          | % Flowering                     | 0.387**                         | 0.386** | 0.389** | 0.394**    | 0.390**                        | 0.418** | 0.440** |
|          | Seeds/tassel                    | 0.516**                         | 0.529** | 0.537** | 0.538**    | 0.538**                        | 0.468** | 0.418** |

\*\* Significant at  $P_{0.01} = 0.342$ ; n = 56

\* Significant at  $P_{0.05} = 0.264$ ; n = 56

to significantly improve emergence, flowering, and the number of seeds per tassel in the weeks leading up to the 12h30 date, and immediately thereafter (Tables 1 and 2). This is in agreement with a previous report that application of phosphate promotes flowering (Van Dillewijn, 1952). In wheat, flower formation is positively correlated with phosphorus supply (Rahman and Wilson, 1977). If levels of phosphorus increase after initiation

in the apical meristem (Menshawi, 1978), translocation of phosphorus from the leaf to the apical meristem could account for the slow decline in phosphorus levels observed within the leaf (Figure 1b). This could also explain the fact that no significant association was found between any of the flowering variables and phosphorus levels within the leaf (Table 3). Another possible explanation for the lack of correlation is that foliar diagno-

**Table 2. Nutrients before flower emergence: Correlation coefficients between various aspects of the flowering process and levels of applied nutrients at various dates prior to flower emergence.**

| Nutrient | Aspect of the flowering process | No. weeks before flower emergence |         |         | Emergence |
|----------|---------------------------------|-----------------------------------|---------|---------|-----------|
|          |                                 | 6                                 | 4       | 2       |           |
| N        | Days to flower                  | 0.113                             | 0.113   | 0.113   | 0.113     |
|          | % Initiation                    | 0.075                             | 0.075   | 0.075   | 0.075     |
|          | % Emergence                     | 0.396**                           | 0.396** | 0.396** | 0.396**   |
|          | % Flowering                     | 0.367*                            | 0.367*  | 0.367*  | 0.367*    |
|          | Seeds/tassel                    | 0.458**                           | 0.458** | 0.458** | 0.458**   |
| P        | Days to flower                  | 0.215                             | 0.204   | 0.192   | 0.169     |
|          | % Initiation                    | 0.034                             | 0.033   | 0.032   | 0.041     |
|          | % Emergence                     | 0.218                             | 0.207   | 0.196   | 0.195     |
|          | % Flowering                     | 0.218                             | 0.209   | 0.201   | 0.205     |
|          | Seeds/tassel                    | 0.268                             | 0.270   | 0.272   | 0.279     |
| K        | Days to flower                  | 0.147                             | 0.143   | 0.140   | 0.132     |
|          | % Initiation                    | 0.067                             | 0.066   | 0.066   | 0.069     |
|          | % Emergence                     | 0.344*                            | 0.341*  | 0.337*  | 0.336*    |
|          | % Flowering                     | 0.331*                            | 0.328*  | 0.325*  | 0.327*    |
|          | Seeds/tassel                    | 0.431**                           | 0.432** | 0.433** | 0.435**   |
| S        | Days to flower                  | 0.279                             | 0.259   | 0.240   | 0.203     |
|          | % Initiation                    | -0.051                            | -0.051  | -0.050  | -0.035    |
|          | % Emergence                     | -0.044                            | -0.055  | -0.065  | -0.066    |
|          | % Flowering                     | -0.065                            | -0.071  | -0.077  | -0.068    |
|          | Seeds/tassel                    | -0.240                            | -0.224  | -0.208  | -0.194    |
| Ca       | Days to flower                  | 0.095                             | 0.084   | 0.074   | 0.048     |
|          | % Initiation                    | -0.081                            | -0.083  | -0.086  | -0.078    |
|          | % Emergence                     | -0.316*                           | -0.321* | -0.325* | -0.326*   |
|          | % Flowering                     | -0.266                            | -0.271  | -0.275  | -0.272    |
|          | Seeds/tassel                    | -0.266                            | -0.258  | -0.251  | -0.246    |
| Mg       | Days to flower                  | 0.172                             | 0.171   | 0.171   | 0.168     |
|          | % Initiation                    | 0.064                             | 0.064   | 0.063   | 0.065     |
|          | % Emergence                     | 0.444**                           | 0.443** | 0.443** | 0.443**   |
|          | % Flowering                     | 0.379**                           | 0.379** | 0.378** | 0.379**   |
|          | Seeds/tassel                    | 0.367*                            | 0.368** | 0.368** | 0.369**   |

\*\* Significant at  $P_{0.01} = 0.368$ ; n = 48

\* Significant at  $P_{0.05} = 0.285$ ; n = 48

sis of phosphorus is not very sensitive, with internodes eight to ten being more reliable as indicator tissue (Hartt, 1959).

#### Potassium

High levels of supplied potassium appeared to improve emergence, flowering, and the number of viable seeds per tassel (Tables 1 and 2), over the entire period investigated. Significant positive associations were found between leaf potassium

levels two weeks before the 12h30 date and four weeks thereafter, and percentage initiation, emergence and flowering (Table 3). A marked decline in average potassium levels within the leaf was observed at the 12h30 date (Figure 1c). This was possibly caused by translocation to the apical meristem as Menshawi (1978) observed a slight increase in potassium levels in the apex shortly before initiation, followed by a decline after initiation. Many reports have shown an intimate relation-

**Table 3. Flowering and nutrients in the leaves: Correlation coefficients between various aspects of the flowering process and leaf nutrient levels at various dates before, during and after flower initiation.**

| Nutrient | Aspect of the flowering process | No. weeks before the 12h30 date |        |         | 12h30 date | No. weeks after the 12h30 date |         |          |
|----------|---------------------------------|---------------------------------|--------|---------|------------|--------------------------------|---------|----------|
|          |                                 | 6                               | 4      | 2       |            | 2                              | 4       | 6        |
| N        | n                               | n = 8                           | n = 11 | N = 15  | n = 16     | n = 15                         | n = 14  | n = 11   |
|          | Days to flower                  | -0.197                          | 0.467  | 0.058   | 0.194      | 0.705**                        | 0.450   | -0.166   |
|          | % Initiation                    | 0.110                           | -0.245 | -0.476  | -0.663**   | -0.318                         | -0.011  | 0.709*   |
|          | % Emergence                     | 0.391                           | -0.282 | -0.185  | -0.592*    | -0.408                         | -0.174  | 0.361    |
|          | % Flowering                     | 0.209                           | -0.300 | -0.358  | -0.680**   | -0.448                         | -0.136  | 0.613*   |
|          | Seeds/tassel                    | -0.147                          | -0.105 | -0.477  | 0.139      | 0.075                          | -0.075  | -0.524   |
| P        | n                               | n = 8                           | n = 11 | N = 15  | n = 16     | n = 15                         | n = 14  | n = 11   |
|          | Days to flower                  | -0.040                          | 0.467  | 0.307   | 0.162      | 0.319                          | 0.524   | 0.168    |
|          | % Initiation                    | -0.480                          | 0.078  | -0.158  | -0.441     | -0.507                         | -0.450  | -0.312   |
|          | % Emergence                     | -0.512                          | 0.089  | -0.165  | -0.429     | -0.315                         | -0.348  | -0.558   |
|          | % Flowering                     | -0.584                          | 0.022  | -0.208  | -0.468     | -0.498                         | -0.468  | -0.460   |
|          | Seeds/tassel                    | -0.392                          | -0.102 | -0.470  | -0.150     | -0.109                         | -0.167  | -0.569   |
| K        | n                               | n = 8                           | n = 11 | N = 15  | n = 16     | n = 15                         | n = 14  | n = 11   |
|          | Days to flower                  | 0.560                           | -0.142 | -0.136  | 0.098      | -0.275                         | -0.353  | -0.339   |
|          | % Initiation                    | 0.135                           | 0.581  | 0.768** | 0.552*     | 0.590*                         | 0.715** | 0.673*   |
|          | % Emergence                     | -0.165                          | 0.395  | 0.552*  | 0.284      | 0.468                          | 0.566*  | 0.484    |
|          | % Flowering                     | -0.048                          | 0.563  | 0.744** | 0.490      | 0.615*                         | 0.714** | 0.675*   |
|          | Seeds/tassel                    | 0.367                           | -0.167 | 0.037   | 0.075      | -0.098                         | -0.370  | -0.477   |
| S        | n                               | n = 8                           | n = 11 | N = 15  | n = 16     | n = 15                         | n = 12  | n = 10   |
|          | Days to flower                  | 0.222                           | 0.258  | -0.098  | -0.140     | -0.003                         | -0.384  | -0.419   |
|          | % Initiation                    | -0.037                          | 0.619* | 0.699** | 0.521*     | 0.384                          | 0.043   | 0.443    |
|          | % Emergence                     | -0.038                          | 0.337  | 0.592*  | 0.380      | 0.275                          | 0.102   | 0.491    |
|          | % Flowering                     | -0.102                          | 0.508  | 0.698** | 0.501*     | 0.355                          | 0.038   | 0.549    |
|          | Seeds/tassel                    | 0.254                           | 0.193  | -0.153  | 0.145      | 0.356                          | 0.070   | 0.252    |
| Ca       | n                               | n = 8                           | n = 11 | N = 15  | n = 16     | n = 15                         | n = 14  | n = 11   |
|          | Days to flower                  | -0.729*                         | 0.388  | 0.022   | -0.305     | -0.294                         | -0.137  | 0.123    |
|          | % Initiation                    | 0.338                           | 0.022  | -0.288  | -0.279     | 0.203                          | -0.249  | -0.611*  |
|          | % Emergence                     | 0.661                           | -0.031 | -0.009  | -0.086     | 0.208                          | -0.055  | -0.682*  |
|          | % Flowering                     | 0.533                           | -0.019 | -0.169  | -0.229     | 0.190                          | -0.201  | -0.706*  |
|          | Seeds/tassel                    | -0.230                          | -0.111 | -0.011  | -0.100     | 0.291                          | 0.420   | -0.077   |
| Mg       | n                               | n = 8                           | n = 11 | N = 15  | n = 16     | n = 15                         | n = 14  | n = 11   |
|          | Days to flower                  | -0.852**                        | -0.005 | 0.104   | -0.074     | 0.227                          | 0.325   | 0.317    |
|          | % Initiation                    | 0.264                           | -0.279 | -0.439  | -0.455     | -0.348                         | -0.392  | -0.557   |
|          | % Emergence                     | 0.509                           | 0.069  | -0.214  | -0.468     | -0.167                         | -0.267  | -0.875** |
|          | % Flowering                     | 0.384                           | -0.117 | -0.360  | -0.489     | -0.355                         | -0.393  | -0.786** |
|          | Seeds/tassel                    | -0.050                          | -0.052 | -0.573* | 0.073      | 0.102                          | 0.090   | -0.338   |

\*\* Significant at  $P \leq 0.01$

\* Significant at  $P \leq 0.05$

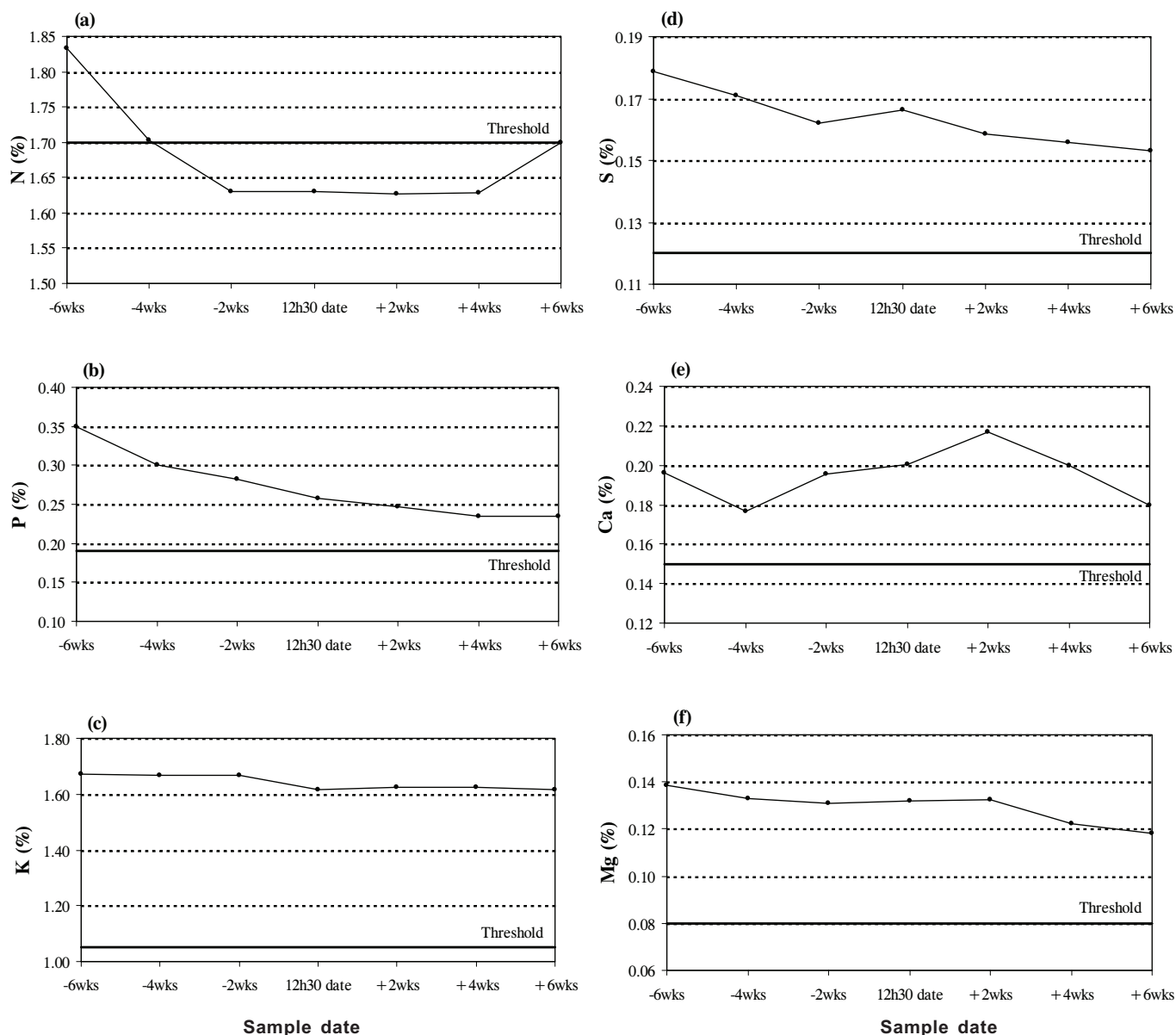
ship between potassium and almost every aspect of plant physiology, with numerous functions being attributed to potassium (De Armas and Musienko, 1980). Low potassium levels in the leaves of *Solanum sisymbriifolium* were correlated with a high proportion of sterile female flowers (Wakhloo, 1975).

#### Sulphur

Apart from a slight negative effect on days to flower due to the amount of sulphur applied before the 12h30 date, addition of

sulphur seemed to have no effect on any of the flowering variables over the entire period investigated (Tables 1 and 2). However, leaf sulphur levels two weeks before the 12h30 date were associated with improved initiation, emergence and flowering (Table 3). A decline in average sulphur levels within the leaf was observed over the six weeks preceding the 12h30 date (Figure 1d), followed by a slight increase at the 12h30 date. This raises the question of whether sulphur is perhaps not also involved in the floral stimulus at the apex.





**FIGURE 1. Changes over time in average nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg) content of the third and fourth leaves.**

### *Calcium and magnesium*

Addition of large amounts of calcium before the 12h30 date seemed to delay flowering (Tables 1 and 2), and may negatively affect emergence if applied in large amounts in the six weeks prior to emergence (Table 2). In addition, high leaf levels of calcium six weeks after the 12h30 date appeared to reduce initiation, emergence and flowering (Table 3).

A significant positive association was observed between the amount of magnesium applied and emergence, flowering and seeds per tassel over the entire period under investigation (Tables 1 and 2). High magnesium levels in the leaf six weeks before the 12h30 date seemed to delay flowering, and emergence and flowering may be reduced if magnesium levels are high six weeks after the 12h30 date (Table 3). A slight negative association was also observed between high magnesium levels two weeks before the 12h30 date and seeds per tassel. Magnesium

levels increase in the apical meristem during the period preceding initiation (Menshaw, 1978). However, only slight declines in average leaf magnesium or calcium were observed during this period (Figures 1e and 1f). The declines occurred instead two weeks after the 12h30 date. One possible explanation is that luxury uptake of potassium about six weeks before the 12h30 date may have caused magnesium and calcium deficiencies (JH Meyer, 2001, personal communication).

### *Micronutrients*

High leaf levels of zinc four weeks before the 12h30 date seemed to delay flowering, while high levels two weeks before the 12h30 date negatively affected the number of viable seeds per tassel (data not shown). Initiation and flowering seemed to improve if levels of zinc in the leaf were high four and six weeks after the 12h30 date respectively. Manganese levels within the leaf had no association with any of the flowering variables (data not

shown). Menshawi (1978) observed an increase in manganese and zinc levels in the apical meristem in the period after initiation as the flower matures. If manganese and zinc were translocated from the leaf to the meristem, this would account for the decrease in their average leaf levels observed from the 12h30 date onwards (data not shown). This would also seem to account for the fact that no association was found between manganese and zinc in the leaf and any of the flowering variables at the 12h30 date and two weeks thereafter (data not shown). A significant association was found between copper levels in the leaf two weeks after the 12h30 date and seeds per tassel, while high levels of iron six weeks after the 12h30 date seemed to improve flower initiation, flowering and flower emergence (data not shown). No other associations were observed.

The data for leaf nutrients were obtained from only two years and this may not be sufficient to make definite conclusions. As the sample size used was small and not replicated, some of the significant correlation coefficients observed may be artifacts of the data. In addition, the results for leaf nutrient levels and amount of nutrients applied per plant are confounded with seasonal effects, photoperiod treatment, temperature, the clones used, and moisture levels. The amount of water applied and rainfall will also affect the amount of nutrients absorbed by the plants. In addition, complex interactions between nutrients within the plant and during uptake may have also affected the results. In all cases except nitrogen, leaf nutrient compositions exceeded the threshold values (Figure 1a to f). There is therefore scope to improve the fertilising schedule to reduce these levels based on the threshold approach, while considering the effect each nutrient may have on flowering.

Different clones may initiate inflorescence primordia on different dates under the same photoperiod (Moore, 1974), and it may have therefore been incorrect to use the 12h30 date to signify the start of the initiation process. Therefore, in future experiments a method for determining the exact date of initiation and other flowering stages would have to be determined from various methods reported in the literature (Clements and Awada, 1967; James and Miller, 1972; Julien, 1972; Moore, 1974; Menshawi, 1978).

### Conclusions

Many factors are involved in the flowering response of sugarcane, and it is clear that nutrient balances within the plant could play an important role in the accumulation of a flowering stimulus in the apical meristem. Understanding these complex interactions, especially within the reproductive organs, could have a significant impact on flower and seed production in the crossing programme at Mount Edgecombe. Future controlled experiments will focus on the role of macro- and micronutrients - in particular nitrogen, phosphorus, potassium, magnesium, and sulphur - in the floral development of sugarcane. This should lead to the establishment of a simple, practical fertiliser regime for the crossing programme.

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### REFERENCES

- Arceneaux, G (1967). Flowering of sugarcane. *Proc Int Soc Sug Cane Technol* 12: 780-784.
- Brett, PGC (1951). Flowering and pollen fertility in relation to sugarcane breeding in Natal. *Proc Int Soc Sug Cane Technol* 7: 43-56.
- Brett, PGC and Harding, RL (1974). Artificial induction of flowering in Natal. *Proc Int Soc Sug Cane Technol* 15: 55-66.
- Brunkhorst, MJ, Coetzee, NA and Nuss, KJ (2000). Efficiency of the germination test for predicting seedling numbers at Mount Edgecombe. *Proc S Afr Sug Technol Ass* 74: 234-237.
- Clements, HF and Awada, M (1967). Experiments on the artificial induction of flowering in sugarcane. *Proc Int Soc Sug Cane Technol* 12: 795-812.
- Coleman, RE (1960). Factors involved in the flowering of sugarcane (*Saccharum* spp.). *Proc Int Soc Sug Cane Technol* 10: 805-814.
- Coleman, RE (1969). Physiology of flowering in sugarcane. *Proc Int Soc Sug Cane Technol* 13: 992-1000.
- De Almeida, JA, Valsecchi, O and Gomes, FP (1946). The flowering of the sugarcane. *Int Sug* 48: 174-176. Comments by H. M. -L.
- De Armas, R and Musienko, N (1980). Influence of K/N relationship in fertilization upon some foliar indicators and yields of sugarcane. *Proc Int Soc Sug Cane Technol* 17: 404-410.
- Gosnell, JM (1973). Some factors affecting flowering in sugarcane. *Proc S Afr Sug Technol Ass* 47: 144-147.
- Hartt, CE (1959). The growth of sugar cane as influenced by phosphorus - The critical range of plant phosphorus. *Proc Int Soc Sug Cane Technol* 10: 467-473.
- Herzog, H (1981). Wirkung von zeitlich begrenzten Stickstoff- und Cytokiningaben auf die Fahnenblatt- und Kornentwicklung von Weizen. *Z Pflanzenernaehr Bodenkd* 144: 241-253. Cited by Marschner, H (1986).
- James, NI and Miller, JD (1972). Shoot apex development in early-, mid-, and late-season flowering sugarcane clones. *Proc Int Soc Sug Cane Technol* 14: 334-340.
- Julien, MHR (1972). The photoperiodic control of flowering in *Saccharum*. *Proc Int Soc Sug Cane Technol* 14: 323-333.
- Marschner, H (1986). *Mineral nutrition of higher plants*. Academic Press, London, 155-172 pp.
- Menshawi, ZA (1978). Chemical constituents of the sugarcane apex associated with floral evocation. *Proc Int Soc Sug Cane Technol* 16: 1885-1901.
- Moore, PH (1974). Investigations on the flowering of *Saccharum*. II. Number of spindle leaves and date of induction. *Proc Int Soc Sug Cane Technol* 15: 7-16.
- Moore, PH and Nuss, KJ (1987). Flowering and flower synchronization. Heinz, DJ (Ed) In: *Sugarcane improvement through breeding. Developments in Crop Science II*. Elsevier, New York, 273-311.
- Nuss, KJ and Berding, N (1999). Planned recombination in sugarcane breeding: Artificial initiation of flowering in sugarcane in sub-tropical and tropical conditions. *Proc Int Soc Sug Cane Technol* 23: 504-508.
- Rahman, MS and Wilson, JH (1977). Effect of phosphorus applied as superphosphate on rate of development and spikelet number per ear in different cultivars of wheat. *Aust J Agric Res* 28: 183-186. Cited by Marschner, H (1986).

- Stevenson, GC (1965). *Genetics and breeding of sugar cane*. Longmans, London, 72-97 pp.
- Van Dillewijn, C (1952). *Botany of sugarcane*. Waltham, Mass., USA, 222, 243 pp.
- Wakhloo, JL (1975). Studies on the growth, flowering and production of female sterile flowers as affected by different levels of foliar potassium in *Solanum sisymbriifolium* Lam. I. Effect of potassium content of the plant on vegetative growth and flowering. *J Exp Bot* 26: 425-433.
- Wood, RA, Meyer, JH, and Govender, M (1985). A rapid system of cane leaf analysis using X-ray spectrometry and infra-red reflectance. *Proc S Afr Sug Technol Ass* 59: 195-201.
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