SOME OBSERVATIONS OF FROST DAMAGE IN SUGARCANE IN THE NATAL MIDLANDS

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Abstract

During the winter of 1990 minimum night temperatures were regularly recorded in and adjacent to cane fields in a frost-prone area of the Dalton district. Growth measurements and photographic records were made in six fields with cane of different ages and of four varieties. On nights when frost occurred, symptoms of damage were observed and related to temperatures recorded. Samples were regularly taken to monitor cane quality before and after frost. The results showed that dry matter, fibre and sucrose continue to accumulate after light frosts without detrimental effects on cane quality, provided there is still some green leaf present. During the winter period before and after frosts, sucrose content accumulated at a faster rate than at other times of the year.

Introduction

In the Natal Midlands large areas of cane are periodically subjected to frost. Some cold winters have caused severe crop loss. Low-lying valleys are regarded as frost traps, but frost occurs with varying distribution and intensity on the same night. It is therefore extremely difficult to predict its likely locality and severity.

Wilson (1960) recognised four different categories of frost damage to cane depending upon the severity of the symptoms. Roth (1966) linked the extent of frost damage to both low temperature and the duration of sub-zero temperature. He also associated a subsequent reduction in cane quality with various micro-organisms which develop after frost damage, and the effect of rain following frost. De Haas (1981) ranked commercial cane varieties according to their frost susceptibility. There are many conflicting opinions among farmers and agronomists on the importance of frost damage and how to manage the crop in frost-prone areas.

This study was done to observe the relationship between minimum temperatures and damage to the crop. Natural ripening and growth of sugarcane was monitored to compare what effects frost would have on sucrose production and cane quality.

Method

Two adjacent catchments were selected on the farm 'Hopewell', south-west of Dalton. These sites provided a wide range of slopes, aspects and altitudes from 955 m to 1072 m. The upper catchments are usually frost free but the low-lying valleys are prone to periodic frosts. In the area there were different cane varieties which had been winter harvested.

Minimum Temperatures

Five minimum thermometers were calibrated over a week. The study started at the end of May by placing the thermometers at specific sites in the catchments (See Figure 1, positions 1 to 13.)

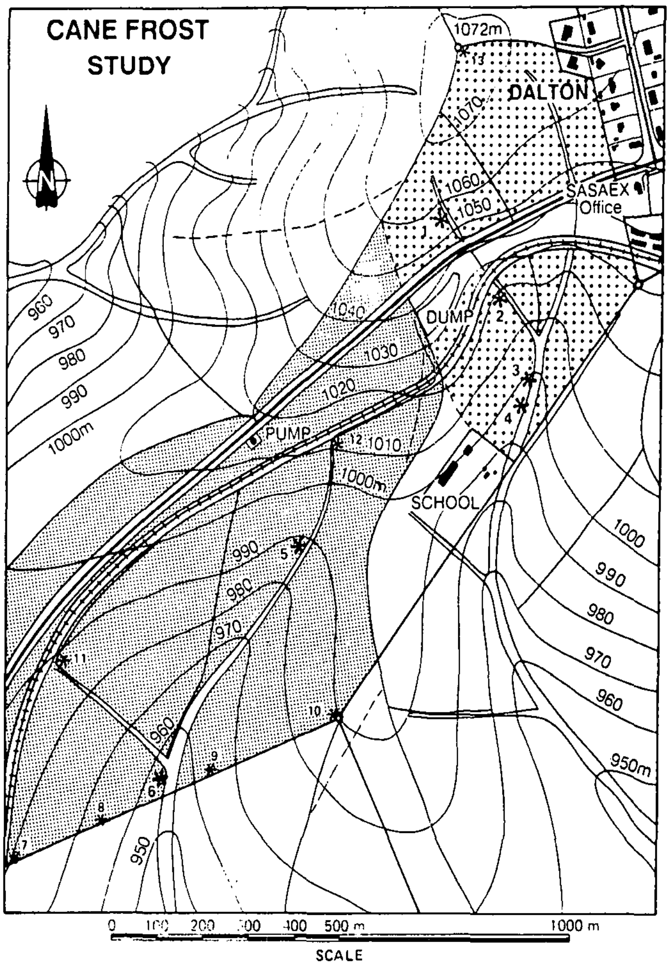

FIGURE 1 Map of frost study area.

At dusk the thermometers were placed on the ground as though measuring grass minimum temperatures. Each morning temperatures, wind and cloud conditions were recorded.

Sites 1, 3, 5 and 6 were the main measurement stations, with sites 2 and 4 being used less frequently. Once a week the thermometers were placed along the cleared boundary break at sites 7, 8, 9 and 10 and again at site 6, to obtain a different transect and to compare westerly with easterly aspects. At weekends minimum night temperatures were recorded on the ground under the cane canopy, at meristem height, at 3 m above ground level (above the cane canopy) and in the waterway 5 m from the other thermometers.

Growth Stations

Growth stations were established at six sites, each in a different field (Table 1, Figure 1). With less than one hectare of natural air drainage above it, site 1 was expected to be least affected by frost. Site 2 was expected to be relatively frost free. With a gentle slope and large drainage areas, site 3 was expected to be considerably colder than site 2. Site 4 is only 60 m below site 3, with similar slope and natural drainage area; trees on its lower boundary tend to dam up the flow of cold air, thus creating a frost trap. Site 5 was expected to be less prone to frost than site 4. Site 6, with a gentle slope and large natural drainage area, was expected to be the coldest site.

At every growth station the height to the top visible collar on marked stalks was regularly recorded. Dry leaves were stripped from the lower nodes and green leaves were counted so that emergence of new leaves could be recorded. Population counts of millable stalks were made for yield estimates.

Sample harvesting for mill analysis

At weekly or fortnightly intervals a 20-stalk sample was harvested near each growth station. Ten stalks or the entire stool was taken from a metre or less of cane row, the next metre of row was left unharvested and then another ten stalks were taken from the following metre. All stalks of less than 0,6 m were discarded as unmillable. Dry leaves were stripped from stalks and green leaves were cut off close to the collars to simulate the effects of burning. Each stalk was accurately topped at the meristem, then marked at 300 and 600 mm below the meristem for the analysis of stalk segments in the laboratory.

Another composite sample of 30 frosted stalks from site 6 was topped at the top visible collar. These were sub-divided into three, 10-stalk, sub-samples of equal mass. One sample was left intact, one was topped 300 mm below the collar and one was topped 600 mm below the collar. These sub-samples were taken to the laboratory for ethanol and normal cane quality analysis.

Photographic records

Every fortnight on the day the samples were prepared, two additional representative stalks from each site were selected and photographed. Dry leaves and sheaths were removed from one stalk and the other was split to show the top 300 to 400 mm of stalk and the rolled sheaths above the meristem. Field photographs were taken before and after frost to illustrate interesting field observations.

Results and Discussion

Rainfall recorded before and during the frost study was low. Only 27 mm was recorded from 2 May to 29 August 1990. Temperatures were lower than normal so favourable conditions for frost development prevailed during the period.

Temperature readings

Appendix A lists a sample of the temperatures at the grass minimum sites, with a brief description of morning weather conditions. Table 2 summarises all the grass minimum temperature recordings that were made at the various sites.

Sites 7 and 8 were selected on an easterly aspect to compare with sites 9 and 10 on a westerly aspect. Table 3 summarises the results.

There was no appreciable difference between aspects. However, sites 8 and 9 were warmer than 7 and 10, probably because the greater land slope was sufficient for the heavy cold air near the ground to slide off and accumulate in the valley bottom. The land slope at sites 7 and 10 was apparently insufficient to allow drainage of cold air. To substantiate this observation it may be noted that the relative density of air at 900 millibars pressure at different temperatures in kg per m3 is as follows (List, 1958):

0°C = 1,1478
5°C = 1,1272
10°C = 1,1073

Table 1

Characteristics of the various growth station sites

Site Number	1	2	3	4	5	6
Percentage land slope	18	16	6	6	8	4
Natural catchment area (ha)	<1	4	32	36	15	64
Likelihood of frost	None	Slight	Moderate	Strong	Moderate	Very Strong
Cane variety	N12	N12	N12	N16	NCo376	NCo293
Ratoon	2R	1R	1R	1R	5R	5R
Age in May (months)	23	11	11	11	12	12

Table 2

Summary of gross minimum temperature readings at sites 1 to 6

Site Number	1	2	3	4	5	6
Mean minimum temperature	5,1°	3,0°	1,5°	1,5°	1,8°	− 0,5°
Number of recordings	53	19	37	9	38	68
No. of days when frost occurred	1	9	16	16	17	37
Lowest temperature recorded	0°	−2,0°	−2,8°	−4,8°	−3,6°	−7,6°

Table 3

Summary of characteristics and gross minimum temperatures at sites 7 to 10

Site Number	7	8	9	10
Aspect	Easterly	Easterly	Westerly	Westerly
Position	Upper slope	Lower slope	Lower slope	Upper slope
Percentage land slope	6	10	10	6
Mean minimum temperatures recorded	2,4°	3,4°	3,0°	2,5°

These differences explain why frost develops only on calm nights and why slight differences in wind drift and direction will affect the pattern of frost. Cloudy nights were warmer than clear nights due to clouds preventing the escape of reflected radiation. Windy nights were usually warmer than calm nights but there was more variation than might have been expected.

Temperature variation in and around the cane canopy

Appendix B lists a sample of the minimum temperatures recorded within or above the cane canopy, and the grass minimum temperature in the adjacent waterway.

On average, minimum temperatures on the ground were 5,7°C higher under the cane canopy than 5 m away in the waterway. This difference was even greater on calm clear nights. Minimum temperatures at the meristem were 3,2°C higher than in the waterway. This effect with a tall and full canopy explains why young, short cane is more vulnerable to frost damage than taller, older cane. Above the cane canopy minimum temperatures were only 2°C warmer than the grass minimum. By comparison the minimum temperature at the same height above a lawn measured was more than 6°C warmer than the ground temperature. The reasons for this are the loss of heat from the cane canopy due to back radiation and the settling of cold air above the canopy which traps the warmer air within the canopy. Even on windy nights this warm air was not displaced.

Growth measurements and visual frost damage

Initially, cane at all six sites carried eight or nine green leaves and was growing slowly. The height of cane measured to the top visible collar during June increased by a mean of 35 mm for all stations. During the same period there was a reduction in sheath length from an average of 399 mm to 393 mm. Nett stalk elongation in June was therefore a mean of 41 mm. During July and August there was no stalk elongation at any site and by the end of August the green leaves on non-frosted cane numbered only four or five. Eight mm of rain were recorded in June, nil in July and 11 mm before 30 August, so the soil was very dry.

The first frosts which caused visible cane damage (-6,4°C at Site 6) were recorded on 24 June. At site 6 there was leaf tip scorch and an estimated 30% loss of green leaf area of variety NCo293. Characteristic chlorotic, longitudinal stripes appeared on the leaves and there was a browning of the rolled leaves above the meristem, which was not damaged. Varieties N16 and NCo376 suffered only 15 to 20% loss of green leaf, and N12 was hardly affected.

The next destructive frost occurred on 1 July at site 6 with a grass minimum temperature of -7,6°C and -4,2°C at the meristem. This second frost inflicted far more damage than the first, partly because of the lower temperature and also because there was less live material in the canopy to freeze. Subsequent frosts therefore seem to have a cumulative effect on crop damage. At site 6, only 30 to 40% of the original green leaf area remained and in most stalks the meristem was destroyed down to the fourth or fifth node (Figure 2).

Across the boundary at the same altitude, taller cane (variety N12) showed far less damage. At sites 4 and 5 the N16 and NCo376 showed about 40 to 50% leaf scorch with some meristem damage in most stalks (Figure 3). At sites 2 and 3 in variety N12 there was even less damage, with only 10 to 20% leaf scorch and slight meristem damage at site 3. Cane at site 1 was unaffected by the frost. Frost damage at the colder sites was more severe than it would have been at the same temperatures had there been more rain and better growth, as stressed cane is more susceptible to frost. Another late frost in mid-August, although not as severe as the frost in July, caused further die-back of leaves at sites 4, 5 and 6.

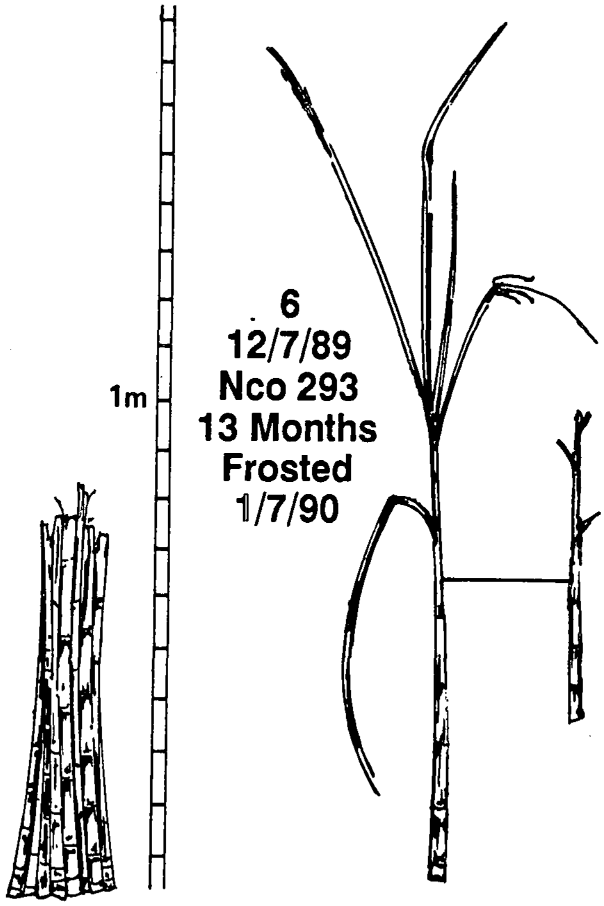

FIGURE 2 Thirteen month old NCo293 from Site 6, badly frosted on 1 July.

Regrowth after the frost damage was extremely slow. Where the meristem had been destroyed, bud swelling only had occurred by mid-August, with side shoots only 50 to 70 mm long by the end of September, despite good rain at the end of August. The die-back in cane leaves at site 6 had reduced the total cane height from about 2,5 m to less than 1,5 m, and no green leaves were visible above the dead canopy. Between the end of June and mid-October, stalk elongation in the relatively undamaged N12 at sites 2 and 3 amounted to only 45 mm. During this period one new leaf per stalk had emerged. By mid-October at site 6, side shoots were still below the dead canopy. The first signs of greening occurred in December 1990, when the side shoots emerged above the dead leaves. During this period it was possible to observe the amount of frost damage at the various sites. Cane at the warmer site 8 was not as severely affected as at site 7, but cane at site 10 was badly frosted. Average stalk elongation at site 3 between mid-October 1990 and the end of January 1991 was 443 mm, with a further six new leaves. By the end of January 1991 side shoots at sites 4, 5 and 6 had developed into thin stalks of 150 to 200 mm long. Frosted cane at site 6 was only slightly taller than the new ratoon at site 9, which had been harvested during the first period.

Cane quality of stalk samples taken from Site 6

Mean stalk mass of cane from all fields increased by about 20 grams per stalk from June to mid-August, which is equivalent to an estimated increase of 3,1 tons cane/ha in eleven weeks. There was an average of only 41 mm stalk elongation

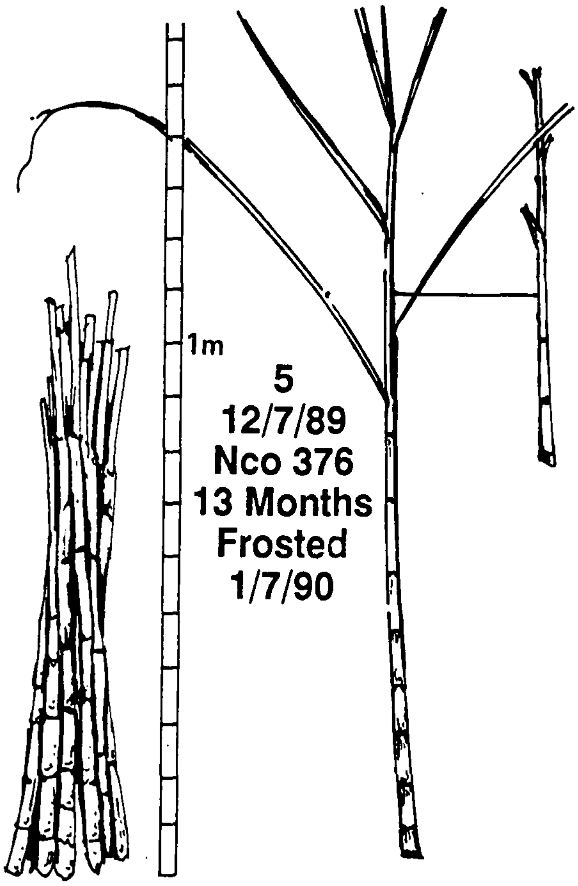

FIGURE 3 Thirteen month old NCo376 from Site 5, slightly frosted on 1 July.

during the study period. The growth developed from a thickening and hardening of nodes 4 to 8, which had lost their green leaves during this time. Dry matter % cane increased steadily from a mean of 20,7 in June to 24,1 in August. Using these data, the estimated increase amounted to 2,8 tons dry matter/ha in 11 weeks. Trends in the constituent parts of this increment are shown in Figure 4.

Fibre % cane increased on average from 10,1 to 10,9 or an estimated 0,9 tons fibre /ha. Pol % cane increased on average from 7,4 to 10 or an estimated 1,9 t/suc/ha and non-pol % cane, although variable, showed no change at 3,3. This is a reasonable correlation with the projected increase previously calculated. This comparison demonstrates that the regression lines produced a reliable assessment of the actual growth.

Of particular interest is the mean of 1,9 t sucrose accumulated during the study period, which was equivalent to 0,8 t/suc/ha/ month from June to mid-August. The crop at Site 1 was harvested by 3 August and the yield was 126 t cane/ha at 13,6% sucrose in 25,5 months. (The estimated

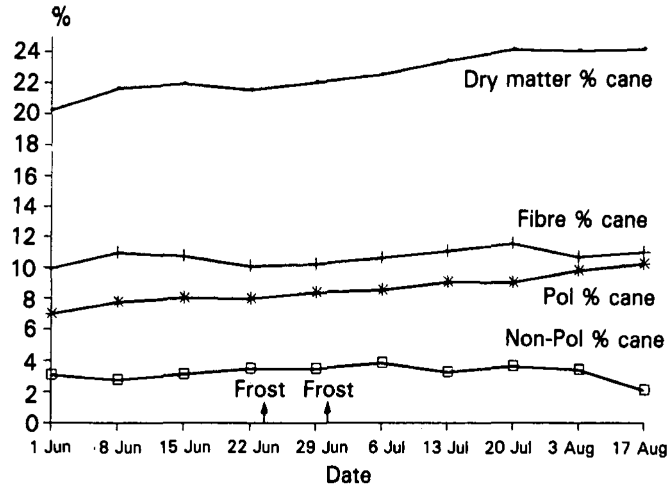

FIGURE 4 Dry matter % cane, fibre % cane, pol % cane and non-pol % cane for the period 1 June to 17 August.

yield of this field on 20 July from the regression line was 879 g/stalk x 132 000 stalks/ha, which is equivalent to 116 t cane at 13% sucrose.) The actual yield amounted to a mean of 0,67 t/suc/month but during the last three months the mean for all fields was 0,8 t/suc/month, including those that were badly frosted. It is clear from these data that the ripening phase of cane during winter is more efficient in sucrose production than during the summer months when lush growth occurs.

Date	Dry matter % cane	Fibre % cane	Pol % cane	Non-Pol % cane
1/6/90	20.1	9.93	6.98	3.05
8/6/90	21.6	10.95	7.76	2.76
15/6/90	21.9	10.73	8.03	3.13
22/6/90	21.5	10.05	7.98	3.48
29/6/90	22.0	10. 2	8.35	3.48
6/7/90	22.5	10. 6	8.5	3.83
13/7/90	23.4	11.03	9.05	3.25
20/7/90	24.1	11.55	9.0	3.6
3/8/90	24.0	10.65	9.73	3.37
17/8/90	24.1	10.95	10.18	2.07

FIGURE 5 Mean cane analysis per sample date.

Ethanol sample

Table 4 shows the analysis of a freshly milled sample of cane from site 6 taken seven weeks after the severe frost.

Following the frost, microbial degradation took place in the young leaf sheaths and in the top of the stalk, causing an increase in the ethanol content. Analysis of the mass of pol per stalk showed that there was no sucrose above the meristem following frost damage. Growers are tempted to

Table 4

Cane and ethanol analysis of matched 10-stalk samples of badly frosted NCo293 from site 6

	Mass of stalk (g)	Ethanol ppm	Pol % cane	Non-pol % cane	Fibre % cane	Dry matter % cane	Purity % cane	Pol per stalk (g)
1. Topped at collar	462	1 636	7,89	4,37	17,93	30,19	64,35	36,5
2. Topped at meristem (57 g of sheaths cut off)	406	1 182	8,68	4,1	16,71	29,49	67,92	35,2
3. Topped 300 mm below meristem (196 g of tops cut off)	268	757	11,54	3,18	11,11	25,83	78,39	30,9

top short frosted cane well above the meristem to facilitate better loading of the crop, but it is apparent that this can lead to a considerable reduction in sucrose % and cane purity, and an increase in fibre %. Frosted cane should therefore be topped below the frost damaged part of the stalk.

Conclusions

Farmers in frost-prone areas should develop a management programme to allow for unpredictable occurrences of frost and the damage it causes.

It is important to plant tall, early maturing cane varieties such as N11, N16 or N21. Although these varieties are susceptible to frost, this is unimportant provided they are harvested in winter and not in the spring or summer. In this way there should be no loss of production. The best time to plant these areas is in March, as frost damage is relatively harmless during the first winter when no stalk has formed. The roots and meristem are below ground and will be unaffected provided night temperatures do not drop below -10°C.

Frost resistant varieties like N12 should be planted adjacent to frost-prone areas so that damage can be minimised in winters when frosts are more widespread.

If young cane is frosted and there is meristem damage, it is preferable to harvest the cane rather than allow sideshoots to grow, provided there is sufficient length of stalk to handle the crop.

Some farmers believe that frost ripens cane. This study has shown that sucrose accumulation during the period June to August was much greater than the mean monthly figure for the duration of the crop. Therefore if frosts occur in April, May or early June, there is rarely a need to harvest before July. However, all frosted cane must be milled before the end of August, provided it is tall enough to be handled. If the cane is not millable, it should be weeded until a new canopy is restored.

Where mills have observed a drop in cane quality following widespread frosting, this may be due to cutting partly mature cane which has not been properly topped, rather than the deterioration of sucrose.

If all cane growers in frost-prone areas adopt these simple management practices, frost will not normally have any adverse effects on productivity.

Acknowledgements

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Appendix A

A sample of grass minimum temperatures recorded at the various frost sites, and morning weather observations

Date	Sites										Cloud, wind direction and knots, etc
	1	2	3	4	5	6	7	8	9	10	
M 28/5	6,8	6,4	0,4		3,8	−0,2					0/8, dead calm, dew
T 5/6	4,6	3,2	3,6		3,2	−0,8					1/8, NE 2–5, light dew and frost, cold front
T 19/6	2,2	F	−1,0	F	−2,0	−4,8	F	F	F	F	0/8, crisp and calm, heavy dew and frost
W 20/6			−0,4			−3,8					0/8, clouding during night, N 5–10, black frost
M 25/6	0,6	F	−3,4	F	−2,0	−7,2	F	F	F	F	0/8, SE drift, black frost
S 30/6					5,0	5,2	5,2			4,4	6/8, SE 1–2, 4 mm rain clearing
S 1/7	F	F	F	F	F	−7,6	F	F	F	F	0/8, E 2–5, white all stations
M 2/7	0,0			−4,8	−2,2	−4,2					0/8, NE 5–10, little frost, chill factor
T 3/7	2,6	−2,0	−2,8			−3,6					3/8, NE 10, black frost
F 6/7	6,8		2,8	3,0		1,6					8/8, dead calm, light dew
S 28/7						2,4	4,4	5,6		4,6	2/8, NW 5–10, no dew
F 3/8						2,8	3,4		4,4	3,2	2/8, NW 2–5, night bergwind, no dew
Mean temp.	5,1	3,0	1,5	1,5	1,8	−0,5	2,4	3,4	3,0	2,5	
No. of nights	53	19	37	9	38	68	10	4	4	10	

Appendix B

A sample of minimum temperatures on different nights, at different sites, above, in and below the cane canopy and in the waterway 5 metres away

Date	Site	Grass minimum temperature in waterway	On ground below cane canopy	At meristem height below canopy	Three metres above ground and above canopy	Weather conditions
S 3/6	6	−0,6	8,0	3,6	3,6	Clear calm
M 4/6	1	6,8	11,8	11,6	9,6	Cloudy and windy
M 11/6	1	3,6	6,4	5,2	3,8	Light cloud & wind
S 24,6	6	−6,4	0,2	−2,2	−1,6	Clear calm
S 1/7	6	−7,6	−1,0	−4,2	−4,4	Clear, light wind
S 15/7	6	−4,4	4,4	1,2	1,8	Clear, calm
Mean		0,2	5,9	3,4	2,2	