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Effect of time of planting on flowering response and leaf number of flue-cured tobacco in north Queensland

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Summary

The duration of the period between transplanting and floral initiation (PI) and the leaf production of commercial flue-cured tobacco varieties (Hicks Q46, NC95 and Sirone 2) were studied between 1976 and 1978. Field planting dates were early winter (EW), later winter (LW) and mid spring (MS) in each experiment plus mid autumn (MA) in the 1978 experiment.

In 1976 and 1977, floral initiation occurred earlier (mean of 5.5 days) in the EW experiments than in corresponding LW and MS experiments, but time of planting had little effect in the 1978 epxeriment. The varieties had a low-temperature-induced short-day flowering response. The duration of PI was negatively correlated ($r=-0.78$) with an index of field stress which was related to climate and irrigation practice. Indices ranged from 0.39 (most stressed) to 0.79 (least stressed).

Total leaf number depended on both the length of PI and the rate of leaf initiation. The latter was high in treatment MA (0.72 leaves per day), low in EW (mean=0.56 leaves per day) and increased as planting date was delayed (MS av.=0.72 leaves per day). Commercial leaf numbers of Hicks Q46 (*c.* 14) and Sirone 2 (*c.* 15) plants were low in treatment EW in 1976 and 1977. NC95 produced the highest commercial leaf number at all planting dates.

INTRODUCTION

The climate in north Queensland is suited to extending the growing period for tobacco by growing it commercially through the winter months. Growers are showing interest in planting into the field during the early to mid winter period. A recent survey of growers found that 14% and 57% planted in June and July respectively. The most popular time for transplanting previously had been the months of August and September.

There are several potential agronomic advantages from planting into the field during the early winter period: a decrease in irrigation frequency would be possible because of lower evaporative demand; there should be a reduction in plant loss from soil-borne diseases; and lower insect activity may allow reduced insecticide usage. Another potential advantage is that a grower could produce his quota from two crops because harvesting of the second crop could commence as that of the first crop is completed. Further benefits of this system of planting are that the number of bulk curing barns required would be substantially reduced (being halved in some instances) and that it would aid the introduction of mechanical harvesting to the north Queensland crop. Contract harvesters could service more growers over an extended harvest period and co-operative-owned harvesters could be shared by more members.

A major problem associated with early winter planted tobacco is the risk of early flowering at a low commercial leaf number (Foale 1974). Hopkinson (1969) reported that the transplanting of large seedlings, or cool temperatures during the post-transplant period, were both conducive to early flowering. He concluded that under correct management, floral induction began in field plants only after they had recovered from the stresses of transplanting. Low temperatures at this stage hastened recovery and therefore hastened flowering, whilst at the same time slowing the rate of leaf production. Large variations in flowering response and consequently commercial leaf number per plant, may therefore occur if small variations in planting time are associated with differences in temperature.

The experiments reported here determined the amount of variation in flowering time and leaf production induced by different planting dates. Separate experiments were conducted to determine the effect of planting date on the components of yield and leaf quality (B.P. Trendell, unpub. data).

MATERIALS AND METHODS

Location

The experiments were located on Southedge Tobacco Research Station (16°58′S; 145°21′E) on a red earth of granitic origin (Northcote 1974; Gn 2.14). The physical characteristics of this soil type have been described by McNee *et al.* (1978). Field capacity was determined as the soil moisture precentage at a soil moisture tension of 0.1 bars and was found to be 10.5%, 10.4% and 13.1% for the 1 to 15, 15 to 30 and 30 to 45 cm segments of the soil profile. Wilting point was similarly determined at 15 bars soil moisture tension to be 2.8, 4.6 and 5.9% respectively. The quantities of available water held in the 0 to 15, 15 to 30 and 30 to 45 cm profile segments were 16, 14 and 17 mm respectively.

Design and statistical analysis

Three planting occasions, early winter (EW), late winter (LW) and mid spring (MS) were compared in Experiments 1 (1976), 2 (1977) and 3 (1978). An additional planting, mid autumn (MA), was included in Experiment 3 (1978). Three commercial varieties, Hicks Q46, NC95 and Sirone 2, were grown in each experiment. Experiment 1 used four replicates of a split-plot design with planting date as the main plots and varieties as the sub plots. Experiments 2 and 3 were laid out in four replicates of a randomised block design for each planting date.

An analysis of variance was performed separately for each combination of planting date and year. Pairwise differences between variety means were tested by Student's *t*-test after overall differences had been established ($P<0.05$) in the analysis of variance.

Cultural data

In Experiments 1 and 2, plants were grown 53.4 cm apart at 1.22 m row spacing which gave a plant density of 15 367 per hectare. Plant spacing was reduced in Experiment 3 to 44.5 cm which gave a plant density of 18 440 per hectare. Transplanting dates and nitrogen rates are shown in Table 1. The latter were varied to meet anticipated changes in crop development at the different planting dates. In the EW planting of Experiment 2, the application was reduced because a significant amount of nitrogen was expected to be mineralized from the breakdown of a previous cover crop of cowpeas *(Vigna unguiculata).* Nitrogen was applied as a compound fertilizer (10N; 5P; 28.3K) in Experiments 2 and 3 but these three elements were applied separately in Experiment 1. Here, nitrogen was applied as nitram (34N), phosphorus as superphosphate (9.6P) and potassium as potassium sulphate (4OK).

Table 1. Rates of applied nitrogen, transplanting dates, average air temperature and stress indices during the first 35 days in the field at four planting dates, mid autumn (MA), early winter (EW), late winter (LW) and mid spring (MS) over three years

	Planting date									
	MA	EW			LW			MS		
	1978	1976	1977	1978	1976	1977	1978	1976	1977	1978
Nitrogen (kg/ha)	45	45	25	56	51	56	66	56	56	71
Transplant date	11 Apr	25 May	26 May	6 June	9 Aug	9 Aug	17 Aug	28 Oct	29 Sept	27 Sept
Air temperature (°C)	22.0	18.7	18.5	19.6	19.6	19.5	20.7	26.1	21.7	21.7
Stress index	0.47	0.50	0.79	0.47	0.45	0.60	0.42	0.39	0.42	0.39

All other cultural practices were similar with the exception of irrigation which varied in both quantity and timing between experiments and within planting times during the first 35 days in the field.

Environment factors

A stress index for plant growth in each experiment was development by summing three sources of water available to the plant in the surface 15 cm of soil during the first 35 days, and then dividing this amount by Class A pan evaporation. The equation was:

$$\text{Stress index} = \frac{\textit{soil moisture at transplanting+irrigation+rainfall}}{\text{total pan evaporation.}}$$

The respective contributions of irrigation and rainfall to this equation were limited to 16 mm which was the maximum amount of available water that could be held in the surface soil. The stress indices calculated are show in Table 1.

Mean daily air temperature (screen) is also shown in Table 1 for each planting time for the 35-day period.

Measurements

Leaf number (excluding cotyledons) and the physiological state of the apex were determined at weekly intervals after transplanting until the change from vegetative to floral growth was detected (Hopkinson and Hannam 1969). A plot was assumed to be floral when 60% of the sampled plants were committed to flower. Total leaf number included the bracts contained within the inflorescence and the number of commercial leaves per plant was determined at topping (inflorescence removal).

The number of day-degrees from transplanting (n=1) to floral initiation (n=t) was calculated for each variety by the equation:

$$\text{Day-degrees (°C)} = \overset{n=t}{\underset{n=t}{}} \quad \text{(max+min) daily } \underset{2}{\text{temperature}} - \text{T}$$

where T equals the threshold temperature for growth (Holmes and Robertson 1959).

Threshold temperatures were determined for each variety under controlled conditions in a growth cabinet which was set on a 12-hour light period at an intensity of $449 \mu E/m^2/s$. Relative humidity was maintained at 80% and plants were watered daily to a constant weight. Leaf plastochron indices based on a constant leaf reference length (Lamoreaux *et al.* 1978) were calculated each week as a measure of the rate of plant development at five temperature regimes (5.4, 7.1, 8.3, 12.8 and 14.4°C).

Day lengths for Cairns (17°S) at the beginning of each month were interpolated to enable the mean day length within the period from transplanting to floral initiation to be calculated.

RESULTS

Threshold temperature

Regression equations were fitted to the changes in leaf plastochron index (y) for each variety at the different temperatures (x). A comparison of the regression lines found the curves to be parallel but to differ in intercept. However as the intercepts differed only marginally and because the threshold temperatures could only be found by extrapolating outside the range of the fitted regression, we considered it more appropriate to use a pooled regression. The equation found was:

$$y=-0.059+0.028x-0.0009x^2 \ (\text{s.e.}^{b1}=0.011;\ \text{s.e.}_{b2}=0.0005;\ r^2=0.59)$$

The threshold temperature at which plant development ceased (y=0) was 2.3°C.

Floral initiation

The number of day-degrees from transplanting to floral initiation, averaged over the three varieties in each planting because of their similarity of response, is graphed against day length in Figure 1. Day-degrees to floral initiation increased with increasing day lengths in Experiments 1 and 2, but increased up to day length of 11.8 hours in Experiment 3 after which the curve flattened out. There was considerable variation between experiments in the number of day-degrees required for floral initiation within each planting date.

Within Experiments 1 and 2, floral initiation occurred earlier by six and five days respectively than in the other plantings (Table 2), but in Experiment 3 there was little difference between planting times. The flowering response of individual varieties within a planting varied markedly between experiments. For example, within the EW planting Sirone 2 and Hicks Q46 reached floral initiation in Experiment 2 seven and ten days earlier than in Experiments 1 and 3 respectively. Floral initiation occurred much earlier within the EW and LW treatments of Experiment 2 than in the other experiments. NC95 was slowest to reach floral initiation throughout and Sirone 2 was later than Hicks Q46 in nine of the ten trials.

Table 2. The number of days from transplanting to floral initiation and total and commercial leaf number per plant in three varieties grown at four planting dates mid autumn (MA), early winter (EW), late winter (LW), and mid spring (MS) over three years

Variety	Planting date									
	MA	EW			LW			MS		
	1978	1976	1977	1978	1976	1977	1978	1976	1977	1978
Floral initiation:										
Hicks Q46	32.0*a*	29.8*a*	23.5*a*	34.0*a*	38.5*a*	29.0	35.9*a*	35.8*a*	32.5*ab*	32.6*a*
NC95	36.2*b*	36.8*b*	33.5*b*	37.7*b*	43.8*b*	34.3	41.6*b*	46.3*b*	37.0*a*	38.8*b*
Sirone 2	32.5*a*	35.0*b*	27.0*c*	37.6*b*	40.3*ab*	32.5	38.3*c*	37.5*a*	30.8*b*	34.4*c*
Mean	33.6	33.9	28.0	36.4	40.9	31.9	38.6	39.9	33.4	35.2
s.d.	3.7	3.0	2.3	5.2	3.3	3.3	3.9	2.7	3.1	3.5
Total leaf number:										
Hicks Q46	38.5*a*	30.9*a*	28.8	38.6*a*	39.5*a*	34.9	39.4*a*	42.8*a*	39.7*a*	38.6*a*
NC95	42.9*b*	34.1*b*	32.4	42.6*b*	42.5*b*	38.7	43.4*b*	48.8*b*	42.4*b*	42.5*b*
Sirone 2	41.3*c*	32.3*c*	29.7	39.9*c*	40.9*ab*	36.9	40.7*c*	45.9*c*	41.8*b*	41.2*c*
Mean	40.9	32.4	30.3	40.4	41.0	36.8	41.2	45.8	41.3	40.8
s.d.	2.6	2.3	3.7	1.3	2.4	3.7	1.9	2.0	2.0	2.6
Commercial leaf number:										
Hicks Q46	19.8*a*	13.7*a*	14.6*a*	17.1*a*	19.5*a*	19.3*a*	20.1*a*	24.7*a*	20.7*a*	20.3*a*
NC95	22.0*b*	17.5*b*	17.4*b*	21.8*b*	23.1*b*	21.0*b*	24.2*b*	31.8*b*	24.3*b*	22.5*b*
Sirone 2	21.4*b*	15.6*c*	14.2*a*	18.0*a*	20.9*c*	20.1*ab*	21.8*c*	25.8*a*	23.7*b*	21.5*b*
Mean	21.1	15.6	15.4	19.0	21.2	20.1	22.0	27.4	22.9	21.4
s.d.	2.5	2.4	2.4	1.4	1.4	1.7	1.5	2.8	1.6	1.8

Means not followed by a common letter differ significantly at the 5% level.

Stress index and floral initiation

The stress indices calculated for the 35-day period after planting ranged from 0.39 (most stressed) to 0.79 (least stress; Table 1). A linear regression of stress index (*x*) versus days to floral initiation (*y*) was calculated across planting dates and is shown in Figure 2. Stress indices were negatively correlated with the time taken to reach floral initiation (r='−0.78).

Leaf number

In Experiments 1 and 2, total leaf number per plant increased as planting was delayed (Table 2), but there were no differences between plantings in Experiment 3. Leaf numbers of plants grown in the MA (*c.* 41) and EW (*c.* 40) plantings of Experiment 3 were similar to those recorded in the LW planting of Experiments 1 and 3 and the MS planting of Experiments 2 and 3. The EW and LW plantings in Experiment 2 produced fewer leaves per plant than the corresponding plantings in Experiments 1 and 3. At each planting, NC95 had the most leaves and Sirone 2 had more leaves than Hicks Q46.

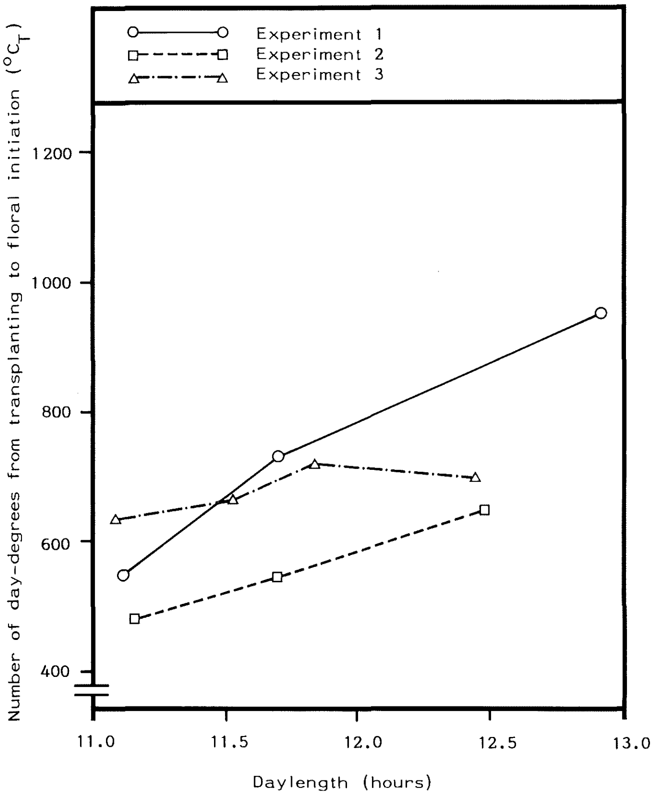

Figure 1. The number of day-degrees from transplanting to floral initiation averaged over three varieties (Hicks Q46, NC95 and Sirone 2) grown at three daylengths in Experiments 1 (1976) and 2 (1977) and four daylengths in Experiment 3 (1978). Daylengths correspond to planting in mid autumn (11.55 hours), early winter (11.3 hours), later winter (11.74 hours) and mid spring (12.61 hours).

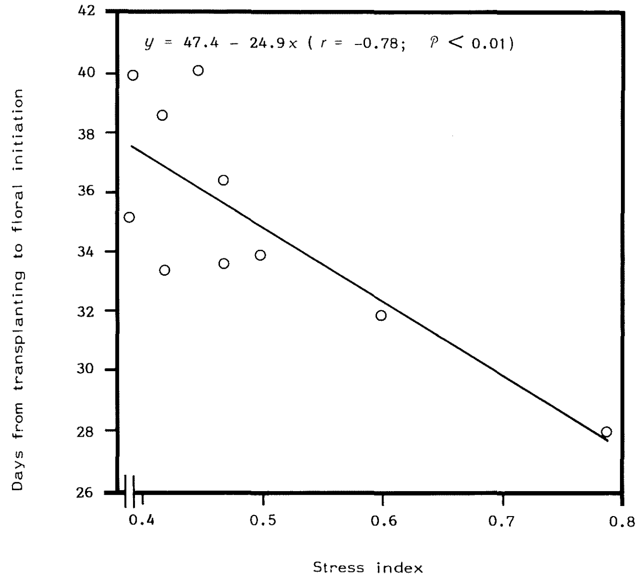

Figure 2. The relationship between stress index for plant growth and the number of days from transplanting to floral initiation across planting dates in Experiments 1, 2 and 3. Least stress is indicated by a high index.

Both commercial (Table 2) and total leaf number per plant were similarly related to planting date. Hicks Q46 produced an average of 14 commercial leaves in the EW planting of Experiments 1 and 2 compared with 17 for the same period in Experiment 3. Similarly, Sirone 2 averaged 15 leaves in Experiments 1 and 2 and 18 leaves in Experiment 3. NC95 had the highest commercial leaf number in each experiment. Commercial leaf numbers in the MA planting of Experiment 3 (*c.* 21) were comparable with those recorded in the LW planting of each experiment.

Leaf initiation

Leaf initiation rates were lowest in the EW experiments (mean of 0.56 leaves per day (s.d. 0.06)) and increased as planting was delayed (LW mean=0.65 (s.d. 0.04); MS mean=0.72 leaves per day (s.d. 0.06)). The mean rate recorded for the MA planting of Experiment 3 (0.72 leaves per day) was similar to that recorded in the MS planting. There were no consistent varietal effects upon the rate of leaf initiation.

DISCUSSION

Flue-cured tobacco varieties are generally regarded as day-neutral (Spector 1956). However, Muraoka and Ohori (1957) recorded a short-day response in the variety Bright Yellow across a range of combinations of temperature (15° to 23°C) and daylength (8 to 12 hours), but a day-neutral response at 13° and 28°C. Shinohara (1971) also reported a short-day response in Iwata Hicks when temperatures decreased from 27° to 20°C but the response was obscure at low temperatures (10° to 15°C). More recently, Thomas *et al.* (1975) found that the photoperiodic response of the flue-cured variety, Coker 319, was not day-neutral but was quantitative ambi-photoperiodic since flowering occurred under any daylength, but occurred more rapidly under long or short days than under intermediate days.

Iwata Hicks and Hicks Q46 are both selections from American broadleaf Hicks and therefore could be expected to have a similar flowering response. The results of Figure 1 support these earlier findings (Muraoka and Ohori 1956; Shinohara 1971) in that the varieties in question exhibited a low-temperature-induced short-day response. In Experiment 3, the relationship was not as pronounced at the shorter daylengths, nor was a short-day response evident at the longer day-lengths. Two factors most likely account for this response pattern. Firstly, a much narrower range of temperature was recorded between EW and MS plantings in Experiment 3 than in Experiment 1 (Table 1). Secondly, there was a smaller difference between the planting date treatments in the degree of stress the plants were subjected to in Experiment 3 compared with Experiment 2 (Table 1). A rise in temperature from 21° to 30°C (Coolhaas 1955) and increased water stress (Ferguson 1982) have both delayed floral initiation in tobacco, and in these experiments the same relationship between water stress and floral initiation was found. Ferguson (1982) analysed rainfall expectation for the months of June and July and concluded that there was a moderate (June, 70% chance<18 mm) to high (July, 80% chance<5 mm) probability of receiving low rainfall during these months. We conclude that there is scope for manipulation of the timing of irrigation of winter crops of tobacco to achieve a more favourable flowering response.

The number of leaves produced by a plant depended on both the time taken to reach floral initiation and the rate at which leaf initiation occurred. The low leaf number per plant recorded in the EW planting arose from a combination of early floral initiation and low rate of leaf initiation (Table 2). The latter response was consistent with earlier findings (Hopkinson 1967; Haroon *et al.* 1972) which showed the rate to be temperature dependent. Similarly, floral initiation was reached at the same time in plants in the MA (Experiment 3) and EW plantings in Experiment 1, but total leaf number per plant was greater in the former because of a higher rate of leaf initiation (0.72 versus 0.49 leaves per day).

An increase in total leaf number per plant resulted in an increase in commercial leaf number (Table 2) but the increase was not proportional. This was most probably because of the variable numbers of leaves (14 to 18) present in the transplants, and the subjective method of assessment of the first commercial leaf at the base of the plant.

In summary, we conclude that for the early winter months to be considered a viable growing period, the commercial leaf number of existing varieties needs to be increased. Ferguson (1982) has since investigated post-transplant stress as a means of achieving this objective and has found that up to 35 days without water was beneficial. A shift to earlier planting (MA) has also been indicated by the results, but the possibility of a late wet season delaying land preparation may restrict this proposal to the better drained soils. At present however, exisitng legislation governing the sowing of seedbeds precludes field planting before 20 May.

An alternative approach would be to find a variety better adapted to the cooler temperatures or short day conditions. NC95 showed this ability in terms of leaf number but it has been found to have unacceptably low yield from the tip leaves. Since these experiments were completed, a new variety (ZZ100) has been released by the Department of Primary Industries, which displays many of the attributes required for early winter plantings.

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ERRATA

Page 85, Measurements. Equation should read:

$$\text{Day-degrees (°C)} = \sum_{n=1}^{n=t} \frac{\text{(max+min) daily temperature} - \mathrm{T}}{2}$$

Page 86, line 3. Equation should read:

$$y = -0.059 + 0.028x - 0.0009x^2 \ (\text{s.e.}_{b1} = 0.011;\ \text{s.e.}_{b2} = 0.0005;\ r^2 = 0.59)$$

Page 87, line 6.

($r = -0.78$).