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Effect of time of planting on yield and quality of flue-cured tobacco in north Queensland

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Summary

The effect of field planting times on yield and leaf quality were studied in the varieties, Hicks Q46 and Sirone 2, between 1976 and 1978. Early winter (EW), late winter (LW) and mid spring (MS) plantings were made each year as well as a mid autumn (MA) planting in 1978.

The three year averages of saleable yields were 2 219, 2 735 and 696 kg/ha for EW, LW and MS respectively. The saleable yield for MS was 78% lower than total yield and showed the adverse effect of seasonal conditions on late plantings. The MA planting yielded 3 077 kg/ha compared with 2 814 kg/ha (EW) and 3 000 kg/ha (LW) in 1978.

Total harvested leaf areas per plant averaged 11 610 cm^2 (EW), 18 670 cm^2 (LW) and 23 134 cm^2 (MS). In each year there was a consistent increase in leaf area as planting time was delayed. A corresponding decrease in leaf weight per unit area was observed.

A subjective leaf quality assessment indicated a decrease in leaf quality as planting time was delayed. However, results within planting times were variable and inconsistent. Total alkaloid concentrations in leaf were determined in 1976 and 1977 and averaged 4.6% (EW), 3.7% (LW) and 3.6% (MS).

The results indicated that commercially acceptable yields from early planted crops are achievable. Transplanting into the field in late autumn and the adoption of management practices which maximize leaf number per plant and per hectare, would produce acceptable yield of leaf with favourable leaf quality.

INTRODUCTION

We have described the potential agronomic advantages of extending the growing period for tobacco in north Queensland in a previous paper (Ferguson, Shepherd, Jacobsen, Trendell and McNee 1984). The aim of our research was to assess management strategies aimed at the maintenance of productivity over an extended growing season. Our paper records the variation in the components of yield and leaf quality from two varieties grown at different planting times. It discusses the application of the results to the concept of an extended growing season.

One of the components of yield is leaf number per hectare (Woltz and Mason 1966). Hawks (1970) and Collins (1978) proposed that a leaf number of 300 000 per hectare was the most desirable for the production of high yield of good quality leaf. The leaf number per hectare varies in relation to the number of plants per hectare and the number of leaves per plant. Our earlier study (Ferguson *et al.* 1984) showed that commercial leaf number per plant was lower in an early winter planting because of a shorter vegetative period after transplanting, during which leaves were produced at a slower rate. The average leaf number from this planting time in 1976 and 1977 was 238 000 per hectare.

Temperature not only influences the rate at which leaves are initiated in tobacco (Haroon, Long and Weybrew 1972), but also determines leaf area and thickness (Raper, Johnson and Downs 1971). Leaf thickness or weight per unit area is a component of both yield and leaf quality. Thick leaves have low filling-power in a cigarette and must be used in greater quantity than thin leaves of high filling-power to achieve a given degree of cigarette hardness (Akehurst 1981).

Increasing or decreasing leaf number per hectare has also been shown to alter leaf quality by modifying the levels of total alkaloids (Chaplin, Ford, Pitner and Currin 1968; Miner 1980), total nitrogen and reducing sugars (Miner 1980) within the leaf.

MATERIALS AND METHODS

Planting times were early winter (EW—late May/June), later winter (LW—August) and mid spring (MS—September/October) in Experiments 1 (1976), 2 (1977) and 3 (1978) with an additional planting time, mid autumn (MA—April), included in Experiment 3. More than two varieties were grown in these experiments but for conciseness, only the data from the registered varieties Hicks Q46 and Sirone 2 are presented to show the effect of planting time. Details of the site and experimental design were described previously (Ferguson *et al.* 1984). However, to enable easier interpretation of the results contained in this paper, it should be noted that intra-row plant spacing was reduced in Experiment 3 to provide 20% more plants per hectare. On average, 25% more nitrogen was applied in Experiment 3. The one exception to this comparison was EW Experiment 2, which received less than half the nitrogen applied to Experiment 3. The low nitrogen application was made because additional nitrogen was expected to be available to the crop from the breakdown of a leguminous cover crop ploughed under three months earlier.

Cultural

Cultural practices and the environment during the first 35 days in the field were also stated previously. Irrigation was applied on a six-day frequency after the first 35 days. Excessive irrigation (73mm) was applied once just prior to flowering in the EW planting of Experiment 3. The resultant leaching of nutrients had an adverse effect on leaf quality. The usual cultural operations of topping (inflorescence removal; *c.* eighth week) and the application of desuckering chemicals were adopted.

Temperature

Air temperatures during the first five weeks, have been given in our previous paper (Ferguson *et al.* 1984) as the average of the daily maximum and minimum. Similar average temperatures for the 5 to 13-week period for each planting are given here because by the thirteenth week after transplanting most dry matter accumulation has taken place (Raper and McCants 1967). Temperatures were lower in EW (*c.* 19.0°C), particularly in Experiment 1 (*c.* 18.0°C), and increased as planting time was delayed (*c.* LW—22.1°C; MS—24.2°C). The average temperature in the MA planting for the same period was 20.0°C.

Measurements

The leaf areas of three plants from each plot were recorded (not in MA planting) on light sensitive paper and the prints dried and weighed. Areas were then read from a standard graph which was based on known areas and weights of paper. Leaves were subsequently dried at 60°C and weighed. Weight per unit area was calculated by dividing the total dry weight of leaves by their total area. The average leaf area per plant for each planting time was found by dividing the total harvested leaf area per plant by its average commercial leaf number (Ferguson *et al.* 1984). Yield and leaf quality were assessed using 20 plants from each plot. After curing, the leaf from each plot was sorted and the weight of saleable and nondescript leaf recorded. Nondescript was leaf graded outside the range of quota grades. Total plot yield was calculated as the combined yield of saleable and nondescript leaf and was expressed per hectare on the basis of plant density (Ferguson *et al.* 1984). Saleable leaf was assigned a grade by a Leaf Appraisor of the Queensland Tobacco Leaf Marketing Board. The value of each grade was determined from the 1976 grade and price schedule.

A leaf sample was taken from the upper half of the plant (above acropetal leaf 8) from each plot for chemical analysis in Experiments 1 and 2. Lamina of each leaf was removed and dried at 60°C, ground and analysed for total alkaloid, total nitrogen and reducing sugar concentrations. Total alkaloids were determined by the method of Griffith (1957). Total nitrogen content was found by a modified semi-micro Kjeldahl method using selenium as a catalyst. The ammonia was recovered from the digest by alkaline distillation and trapped in boric acid solution, which was then titrated with hydrochloric acid. Reducing sugars were determined by an automated inverse colorimetric procedure adapted from that of Harvey, Starr and Smith (1969).

RESULTS

Leaf area and weight per unit area

The total harvested leaf area results (Table 1) showed a consistent increase in leaf area from EW to MS. The three year averages of leaf area per plant were 11 610, 18 670 and 23 134 cm^2 for EW, LW and MS respectively. Least leaf area was recorded from plants in the EW planting of Experiment 2 (9 764 cm^2). Based on average leaf numbers of 15.5 (EW), 20.3 (LW) and 22.8 (MS), average leaf areas were 747, 920 and 1 016 cm^2 respectively. Within the EW planting, leaf area was least in Experiment 2 (678 cm^2) and greatest in Experiment 1 (814 cm^2).

Highest leaf weight per unit area (Table 1) was produced in EW (13.1 mg/cm^2), which was 13% and 32% greater than the level found in LW and MS respectively. The differences arose because thicker leaves were produced in the upper half of the plant. For example, in Experiments 1 and 2 leaf weight per unit area ranged from 19.0 (EW) to 11.8 mg/cm^2 (MS) in upper leaf, but ranged from only 9.1 (EW) to 7.0 mg/cm^2 (MS) in lower leaf. There were no consistent differences recorded between varieties in either leaf area or weight per unit area.

Yield

The results for both dry weight yield of leaf per plant (Table 1) and total yield of cured leaf per hectare (Table 2) showed the same trends. Yields increased greatly between EW (152 g/plant; 2 472 kg/ha) and LW (213 g/plant; 3 197 kg/ha) plantings but a slight decrease in yield occurred between LW and MS (204 g/plant; 3 127 kg/ha). There were smaller differences in total yield between planting times in Experiment 3, with the lowest yield recorded in MS (3 095 kg/ha). This trend contrasted the larger differences in dry weight yields recorded between planting times in Experiment 3 (EW—163; LW—197 and MS—210 g/plant). Total yield in MA (3 383 kg/ha) was intermediate between EW and LW in this experiment.

Saleable yield (Table 2) in MS differed markedly from in EW and LW because of a large increase in the weight of nondescript leaf. The mean percentage of nondescript leaf produced over the three planting times was 10 (EW), 14 (LW) and 78 (MS). Nine percent nondescript leaf was produced in the MA planting of Experiment 3. Saleable yields in EW were low in Experiment 2 and high in Experiment 3. Leaf development may have been restricted in Experiment 2 because of the lower level of applied nitrogen. In each experiment there were no consistent differences in the yield data to indicate a varietal effect.

Leaf Quality

The results of the subjective leaf quality assessment (Table 2) indicated a decrease in leaf quality as planting time was delayed. However, the results within planting times were variable and inconsistent. The MA planting produced leaf of good quality (349 cents/kg) and of a similar standard to the LW (348 cents/kg) planting in the same experiment.

Leaf quality was also measured by the level of three chemical constituents within the leaf (Table 3). Higher reducing sugar concentrations were found in EW (17.4%) than in LW (15.7%) and MS (10.7%).

Table 1. Total area, dry weight and dry weight per unit area of harvested leaf per plant from two varieties grown in an early winter (EW), late winter (LW) and mid spring (MS) planting in three experiments

Variety	Planting time											
	EW				LW				MS			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Area (cm^2)												
Hicks Q46	12 101	10 536	13 258		n.a.	17 009	19 171		25 922	19 651	21 771	
Sirone 2	11 757	8 991	13 015		20 259	16 710	18 610		26 987	19 356	25 115	
Mean	11 929	9 764	13 137	11 610	20 259	16 860	18 891	18 670	26 455	19 504	23 443	23 134
l.s.d (P=0.05)	1 419	1 842	1 872	n.a.	n.a.	2 735	2 289	n.a.	2 498	2 486	3 488	n.a.
Dry weight(g)												
Hicks Q46	172	142	168		n.a.	208	200		200	213	195	
Sirone 2	159	114	157		237	199	193		211	178	224	
Mean	166	128	163	152	237	204	197	213	206	196	210	204
(P=0.05)	25	29	28	n.a.	n.a.	35	29	n.a.	25	35	31	n.a.
Dry weight/unit area (mg/cm^2												
Hicks Q46	14.2	13.5	12.7		n.a.	12.2	10.4		7.7	10.9	8.9	
Sirone	13.5	12.7	12.1		11.7	12.0	10.4		7.8	9.1	9.0	
Mean	13.9	13.1	12.4	13.1	11.7	12.1	10.4	11.4	7.8	10.0	9.0	8.9
l.s.d. (P=0.05)	n.a.	1.9	1.2	n.a.	n.a.	0.7	0.9	n.a.	n.a.	1.0	1.0	n.a.

n.a.=not available

Table 2. Total and salable yield per hectare and average reserve price per kilogram of cured leaf from two varieties grown in an early winter (EW), late winter (LW) and mid spring (MS) planting in three experiments and in a mid autumn (MA) planting in Experiment 3

Variety	Planting time												
	MA	EW				LW				MS			
	3	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Total yield (kg/ha)													
Hicks Q46	3 628	2 517	1 699	3 452		2 812	3 126	3 489		3 054	2 951	3 069	
Sirone 2	3 138	2 269	1 804	3 089		3 621	2 634	3 498		3 512	3 053	3 120	
Mean	3 383	2 393	1 752	3 271	2 472	3 217	2 880	3 494	3 197	3 283	3 002	3 095	3 127
l.s.d. (P=0.05)	375	268	506	517	n.a.	371	314	327	n.a.	450	561	595	n.a.
Saleable yield (kg/ha)													
Hicks Q46	3 350	2 391	1 603	2 916		2 469	2 400	2 902		445	1 080	749	
Sirone 2	2 803	2 133	1 558	2 712		3 500	2 042	3 098		254	714	933	
Mean	3 077	2 262	1 581	2 814	2 219	2 985	2 221	3 000	2 735	350	897	841	696
l.s.d. (P=0.05)	385	285	479	870	n.a.	500	400	431	n.a.	284	300	658	n.a.
Average reserve price (cents/kg)													
Hicks Q46	353	336	315		329	307	279		347	288	302	337	
Sirone 2	345	323	306		307	299	271		348	244	317	339	
Mean	349	330	311	318	320	303	275	348	309	236	310	338	295
l.s.d. (P=0.05)	16	14	21	30	n.a.	15	22	20	n.a.	19	34	39	n.a.

n.a.=not available

Table 3. Percentage reducing sugars, total alkaloids and total nitrogen in cured lamina above cropetal leaf eight from two varieties grown in an early winter (EW), late winter (LW) and mid spring (MS) planting in Experiments 1 and 2

Variety	Planting time								
	EW			LW			MS		
	1	2	Mean	1	2	Mean	1	2	Mean
Reducing sugar									
Hicks Q46	18.8	18.9		17.4	14.1		6.6	16.2	
Sirone 2	17.3	14.3		18.2	13.0		6.6	13.2	
Mean	18.1	16.6	17.4	17.8	13.6	15.7	6.6	14.7	10.7
l.s.d. (P=0.05)	5.8	5.4	n.a.	4.8	3.0	n.a.	3.3	4.8	n.a.
Total alkaloids									
Hicks Q46	4.7	4.0		3.3	3.4		3.8	3.0	
Sirone 2	4.9	4.7		3.8	4.2		4.0	3.4	
Mean	4.8	4.4	4.6	3.6	3.8	3.7	3.9	3.2	3.6
l.s.d. (P=0.05)	1.0	1.2	n.a.	0.9	0.6	n.a.	0.8	0.5	n.a.
Total nitrogen									
Hicks Q46	2.4	2.0		2.5	2.2		2.8	2.2	
Sirone 2	2.4	2.4		2.0	2.4		2.7	2.3	
Mean	2.4	2.2	2.3	2.3	2.3	2.3	2.8	2.3	2.6
l.s.d. (P=0.05)	0.4	0.4	n.a.	0.4	0.2	n.a.	0.3	0.4	n.a.

n.a.=not available

Total alkaloid results show a high concentration in EW leaf (4.6%) compared with leaf from LW (3.7%) and MS (3.6%). Sirone 2 had a higher concentration of total alkaloid in each experiment at each planting time. Total nitrogen concentration was similar in EW and LW leaf (2.3%) but was slightly higher in MS leaf (2.6%).

DISCUSSION

Yield

Between 1976 and 1979, the average saleable yield of cured leaf in north Queensland was 2 317 kg/ha (Anon. 1976, 1977 and 1978). A farm survey conducted during 1979 indicated that this average was derived principally from July and August plantings (Ferguson 1982). The saleable yield from the EW planting in Experiment 1 (Table 2) was similar to the district average, but the yields in Experiment 2 and 3 from the same planting were well below and above this average respectively. Climatic induced field disorders consistently reduced saleable yield in MS by an average of 78% which reflects the general unsuitability of this planting time. On the other hand, the results of the single MA experiment indicate the potential for higher productivity from this planting than from EW.

The mean leaf number of Hicks Q46 and Sirone 2 in the EW planting of Experiment 3 was 323 000 per hectare which was much greater than the mean of Experiment 1 and 2 (223 000 per hectare). This larger leaf number arose from a 20% increase in plant number and a greater number of leaves per plant (Ferguson *et al.* 1984). It also compared favourably with the figure (300 000 per hectare) proposed by several workers (Woltz and Mason 1966; Hawks 1970; Collins 1978) for the production of a high yield and good leaf quality. However, the higher plant number accounted for all of the increase in total yield (878 kg/ha; Table 2) between the EW plantings of Experiments 1 and 3 because the dry weight yield of harvested leaf per plant was similar (Table 1). In other words, the additional leaves produced per plant in EW Experiment 3 (*c.* 3 or 20% more) did not have a positive effect on yield even though leaf number had earlier been found to be strongly correlated with it (Woltz and Mason 1966). An explanation for the lack of a yield response to leaf number in EW Experiment 3 is that the plants were subjected to excessive irrigation (73 mm) one week before flowering which leached nutrients from the root zone at a time when the upper one-third of the plant was developing. The restricted nutrition of the plants was evident by the pale colour of the mature crop. Based on mean leaf numbers of 14.7 (Experiment 1) and 17.6 (Experiment 3) and the leaf dry weight results of Table 1, the mean leaf weights in these EW experiments were found to be 11.3 g (Experiment 1) and 9.3 g (Experiment 3). The lower figure in Experiment 3 was evidence of this restricted nutrition.

The increase in mean leaf area as planting time was delayed (747 (EW) to 1 016 cm^2 (MS)), most likely occurred in response to increase in air temperature. Raper *et al.* (1971) found that the area of leaves decreased as day/night temperature regimes decreased from 30/26° to 18/14°C. The potential area of a leaf is determined largely by the number of cells produced prior to the visual emergence of the leaf from the bud (Morton and Watson 1948; Hannam 1968). Low temperature can slow the rate of cell division (Evans and Savage 1959) as well as slow the rate of metabolism in expanding leaves.

Total leaf area per plant was 10% greater in the EW planting of Experiment 3 (Table 1) than in Experiment 1, and 35% greater than in Experiment 2. The 10% increase in leaf area over Experiment 1 arose from the extra leaves produced per plant (Ferguson *et al.* 1984) because mean leaf area per plant was greater in Experiment 1 (814 cm^2) than in Experiment 3 (749 cm^2. Temperatures were similar during the early winter plantings (*c.* 19°C) and yet the mean leaf area per plant in Experiment 2 (678 cm^2) was much less. Raper (1966) showed that a restricted nitrogen supply produced smaller narrower leaves. A low nitrogen application (25 kg/ha) was made to the EW planting of Experiment 2 and growth was attendant on adequate nitrogen being mineralised from the breakdown of a previous leguminous cover crop. The timing of this nitrogen release may not have occurred when the plant required it most to ensure maximum leaf expansion.

When commercial leaf number per plant was low in the EW plantings, the yield of cured leaf was compensated for, to some extent, by higher leaf weight per unit area (Table 1).

Quality

Barnard (1960) found lamina weight per unit area to be positively correlated with leaf thickness, which is a component of quality associated with manufacturing economy (Akehurst 1981). McNee *et al.* (1978) found that leaf of lamina weight per unit area greater than 8.0 mg/cm^2 was representative of heavy bodied leaf of only fair quality. However, in the present EW experiments, lamina weight per unit area of Hicks Q46 was higher (9.6 mg/cm^2) than this figure. The estimate was based on the results of a separate study which found lamina to account for 71% of the leaf weight of the Hicks Q46 plant. Sirone 2 could not be measured but the percentage was expected to be similar to Hicks Q46.

Raper *et al.* (1971) found that lamina weight per unit area increased progressively from 7.2 to 10.2 mg/cm^2 as day/night temperatures decreased from 30/26° to 18/14°C. Ferguson (1982) demonstrated that if the productive capacity of the plant was increased by increasing its leaf area, whilst the level of nutrition was held constant, a reduction in weight per unit area occurred. Such a decrease occurred in the EW planting of Experiment 3 because of greater leaf area per plant (Table 1).

The decline in leaf quality in the EW planting as indicated by increased leaf thickness, was not evident in the subjectively assessed leaf quality (reserve price; Table 2). Leaf quality was better from this planting than from LW and MS plantings but the lowering of quality by environmental factors in several experiments made the overall result inconclusive.

Cured leaf had a more desirable level of reducing sugar (Table 3) in EW (17.4%) and LW (15.7%) experiments than in MS (10.7%). Harlan and Mosely (1955) describe a leaf with too much sugar as being dense, 'soggy' and having an unpleasant smoke. Abdallah (1970) considered a level of 26% reducing sugar an upper acceptable limit.

Nitrogen concentration was higher in MS leaf (2.6%) than in leaf from the other experiments (2.3%). The previously reported inverse relationship between nitrogen and reducing sugar concentrations (Pearse 1960; Raper and McCauts 1970) was not clearly evident in the results.

Abdallah (1970) described the upper acceptable limit for nicotine as 3.5% which is equivalent to a total alkaloid concentration of about 3.8%. In EW, the total alkaloid concentration in cured leaf was too high but that in LW and MS leaf was acceptable. Most alkaloids are produced in the roots. Bush and Saunders (1977) reported that a topped *Nicotiana tabacum* plant produced 8% of its alkaloid content in the stalk and 3% in the leaves, and that the primary alkaloid, nicotine, was produced in the growing root tip. Since alkaloids accumulate in the leaves, their concentration depends on final leaf area. Walker and Vickery (1959) and Jones and Kenyon (1961) noted decreased alkaloid concentrations in leaf when yield increased, and both Chaplin (1963) and Ferguson (1981) recorded a dilution in alkaloid concentration with increased leaf area. The decrease in total alkaloid concentration as planting time was delayed in these experiments also occurred because of increased leaf area per plant.

Conclusions

Total yield needs to be stabilized at the level recorded in EW Experiment 3, if June planting is to gain commercial acceptance. The much higher yield found in EW Experiment 3 compared with the mean yield from Experiments 1 and 2, occurred because of a greater number of leaves per plant (*c.* 3; Ferguson *et al.* 1984) and a 20% increase in plant number per hectare. In all, this amounted to a 45% increase in the total leaf area per hectare.

Leaf quality, or its component parts, has been stated to be the balance between total leaf area per hectare and the productive capacity of the crop under given conditions (Carr 1959). We feel that the weight per unit area recorded in EW Experiment 3 was still too high to consider acceptable. On the basis of Carr's principle, a still greater total leaf area per hectare than that recorded in this experiment is required.

We suggest that further increase in total leaf area per hectare over the level recorded in Experiment 3 is achievable in an early planting. Plant density could be increased through changes to both plant and row spacings. In similar experiments other varieties exhibited superior leaf area charactertistics. Transplanting by mid May and applying a period of water stress immediately after transplanting, would have the net effect of increasing leaf number per plant (Ferguson *et al.* 1984). The former would achieve this through the beneficial response to leaf initiation from higher temperature, and the latter, by prolonging the period of vegetative growth during which leaves are initiated. In addition, Ferguson (1982) has found that the period of water stress increases the final area of leaves initiated during the stress, supposedly by increased cell number.

Field planting before the middle of May would contravene the Tobacco Industry Protection Act (1965) which is concerned with the maintenance of a disease free period. Earlier field plantings would no doubt give higher returns but the potential loss from erosion associated with land preparation towards the end of the monsoon wet season is too great for it to be given consideration.

From the consistently poor saleable yields from the spring field plantings (MS), we conclude that unless there are extenuating circumstances, field planting should not be contemplated after August.

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