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Effect of Pretransplant Lighting on Post-transplant Growth and Development of Tobacco[1]

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ABSTRACT

Uniformity in time of flowering is desirable in tobacco *(Nicotiana tabacum* L.) production, especially when mechanization is involved. This study was initiated to determine methods of controlling premature floral induction without causing undesirable side-effects to the plants. Burley tobacco seedlings were treated with various combinations of illumination during the pretransplant period in controlled-environment chambers and outdoors in modified starting beds. Effectiveness of control was assayed under field conditions.

Early floral induction occurred in seedlings that received high intensity short days and cool temperatures, or low intensity natural day lengths coupled with cool temperatures. When 12-minute middle-of-night interruptions were used, white fluorescent light was more effective than white incandescent light in counteracting a florally inductive environment, while incandescent was slightly more effective than fluorescent when 240-minute interruptions were used. Twelve minutes of white incandescent light applied in 30-second increments repeated each 10 minutes during a 240-minute period were almost as effective as 240 minutes of continuous illumination from the same type of lamps. Night interruptions with white and yellow incandescent light were equally effective. Phytochrome involvement in counteraction of floral induction in tobacco was discussed.

Pretransplant treatments that showed most promise in the controlled-environments were tested over outdoor starting beds in 1970 and 1971. The first year had a period of cool overcast weather during the treatment period, and the middle-of-night supplemental lighting was effective in delaying floral induction. Bright, warm days predominated during the 1971 treatment period, and no premature flowering occurred among either the controls or the treated plants. There were no undesirable side-effects of the supplemental lighting during either year. In general, plants that flowered prematurely developed fewer leaves prior to flowering, produced several suckers per plant, were difficult to harvest, and yield of cured leaf was significantly reduced.

Additional index words: Nicotiana tabacum L., Photo-period, Temperature, Photomorphogenesis, Phytochrome, Floral induction.

NONUNIFORM ITY of flowering in field-grown tobacco *(Nicotiana tabacum* L.) can be caused by floral induction (a chemical change within the plant causing it to develop flowers instead of leaves) during the pretransplant period (10). The induction may vary in intensity depending on the physiological age of the plant and the environment to which it was exposed. Tobacco plants become increasingly more responsive to florally-inductive environments as they advance in age and size (10). A complete floral induction during the pretransplant period can result in flowering within 3 to 4 weeks after transplanting to the field, even though no macroscopic floral buds are detectable at time of transplanting. A partial induction during the pretransplant period can result in plants flowering from a few days to several weeks ahead of those that carry no floral induction when they are transplanted (10). Hence, a field that receives transplants with varying degrees of floral induction flowers unevenly, causing inconvenience in programming production procedures such as de-topping, sucker control, and harvesting.

Previous research has shown that 4 to 6 hours of low-intensity, middle-of-night illumination from white incandescent lamps is effective in delaying floral induction in burley tobacco (10), chrysanthemum (1), and corn (14). Some other short-day plants (2, 8, 12) are responsive to much shorter interruptions of the night. The effectiveness of supplemental lighting has been attributed to the phytochrome system (3). Thus, the ratio of red to far-red in the supplemental light may be influential in counteracting a florally inductive environment. This paper reports effectiveness of various combinations of duration, intensity, and quality of supplemental illumination on (1) delaying floral induction in tobacco during the pretransplant period, and (2) carry-over effects on growth and development under field conditions.

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MATERIALS AND METHODS

Tobacco (cv. Burley 21) seedlings were started in expanded peat pellets at 28 C under 14-hour, 1.6 x 10^4 lux photoperiods from cool-white fluorescent lamps. All plants were transferred to Maury silt loam in 200-ml peat pots about 3 weeks after seeding. Plants that received pretransplant, controlled environments were placed on treatment 4 weeks after seeding, and remained on treatment 3 weeks before being transplanted to field plots. Plants used in modified, outdoor starting beds also were started at 28 C under 14-hour, 1.6 **x** 10^4 lux photoperiods. They were transferred to the modified starting beds for the last 15 days of the pretranspiant period in 1970 and the last 18 days in 1971. During the pretransplant period all plants were sub-irrigated, as needed, with half-strength Hoagland's nutrient solution No. 1 (9).

Controlled-environment chambers were equipped with VH0 cool-white fluorescent lamps and maintained at a full intensity of about 2.2 x 10^4 lux. The basic florally-inductive environment consisted of 8-hour full-intensity photoperiods at a day/night temperature of 18/18 C. Treatments consisted of that basic environment plus various durations and intensities of supplemental lighting from cool-white fluorescent and white or yellow incandescent lamps. The supplemental lighting was given in the middle of each night during the treatment period.

The outdoor, modified starting beds were shaded with several layers of white cheesecloth and/or plastic mesh such that the plants received natural day lengths at about 10 to 20 percent of natural light intensity. Temperatures fluctuated during the period, but night temperatures usually ranged between 16 to 20 C. Overcast weather occurred during the treatment period in 1970, whereas bright, sunny days predominated during the 1971 treatment period. Thus, day time temperatures were higher in 1971 than in 1970. Supplemental lighting over these beds was from white and yellow incandescent lamps in 1970, and from white incandescent lamps in 1971. During both years the treatments were for 4 hours in the middle of each night. The light intensity was about 500 lux at plant level.

Effectiveness of the various pretransplant environments in delaying floral induction was assayed under field conditions. All experiments were programmed so that the plants were transplanted to field plots at the same time as those from conventional starting beds. The plants were set 45 cm apart in rows that were 100 cm apart, in Maury silt loam, on the South Farm of the Kentucky Agricultural Experiment Station near Lexington. Each plant was tagged at time of first flowering and allowed to continue growth. Plants that flowered prematurely usually developed several axillary branches (suckers) from the lower portion of the stem. Inflorescences and small upper leaves were removed from all plants, each year, at the same time as from conventionally started plants. Immediately after de-topping, the plants were sprayed with maleic hydrazide to retard growth of suckers. The plants were harvested about 3 weeks after detopping, and were air-cured according to standard burley procedures,

Data collected consisted of the date of first flowering of each plant, the number of leaves per plant at time of first flowering. and the average weight of conventionally air-cured leaf per plant. Flowering that occurred within the first 43 days after transplanting was considered "premature." Statistical evaluation of the data was done according to the procedure of Duncan (7).

RESULTS AND DISCUSSION

I. Pretransplant Period in Controlled-environments.

A. Incandescent vs Fluorescent Supplemental Lighting

Effectiveness of cool-white fluorescent and white incandescent lamps was compared because their radiation differs in ratio of red to far-red light. The ratio of red to far-red emitted by the fluorescent lamps was about 7:1, whereas that emitted by the incandescent lamps was about 1:1 (13).

Duration of night interruption. Twelve-minute interruptions in the middle of the night were about as effective in delaying floral induction as were 240-minute or 960-minute interruptions when all were from cool-white fluorescent lamps (Table 1, B). On the other hand, 12-minute interruptions with incandescent light were less effective than the 240- and 960-minute interruptions in delaying floral induction. Twelve minutes of incandescent light were less effective than 12 minutes of fluorescent light; whereas, 960 minutes of incandescent were more effective than 960 minutes of fluorescent.

Continuous vs cyclic night interruptions. Twelve minutes of incandescent light applied as 3-minute increments per 60 minutes over a 240-minute period were only slightly more effective than 12 minutes given at one time in the middle of the night (Table 1). However, 12 minutes of either fluorescent or incandescent light, applied in 30-second increments repeated each 10 minutes for 240 minutes, were as effective as 240 minutes of continuous illumination from cool-white fluorescent lamps. Delayed floral induction (Table 1, B) resulted in production of more leaves per plant between time of transplanting and first flowering (Table 1, C).

The difference in effectiveness of delaying floral induction with 12 minutes of continuous fluorescent and 12 minutes of continuous incandescent illumination (Table 1) can be attributed to the relative levels of red and far-red that these sources emit. The amount of phytochrome in the biologically active form at the end of an irradiation period depends upon the amount of red relative to far-red light received (4, 12), Also, the level of active phytochrome diminishes in darkness at a temperature-dependent rate, while the level of inactive form increases (5). Thus, the level of active phytochrome in the plants should be higher after a brief illumination from fluorescent rather than from incandescent lamps. Intermittent lighting should have the effect of repeatedly building up the level of active phytochrome and allowing its level to slowly diminish in darkness. Hence, if one can assume that active phytochrome must be maintained above a critical minimum level for a certain period of time to delay floral induction in tobacco, one can explain greater effectiveness of: (1) a 12-minute exposure to fluorescent vs a 12-minute exposure to incandescent light; and (2) the greater effect of 12 minutes of incandescent light applied intermittently in repeated cycles vs a single continuous exposure.

Table 1. Carry-over effects of continuous and cyclic interruptions of the night with low-intensity (500 lux) light during the pretransplant period on post-transplant growth and development of burley tobacco m the field.

Pretransplant Supplemental light source (White)	Duration of pretransplant night interruption† None (Control)	12 min, continuous	12 min, cyclic 240 min ‡	12 min, cyclic 240 min§	240 min, continuous	960 min, continuous
(A) Premature flowering (% of plants)						
Incandescent	95	82	76	3	0	0
Fluorescent	95	10	—	3	19	15
(B) Avg. no. of days from transplanting to first flowering .						
Incandescent	32.8 a*	35.7 ab	37.2 b	50.4 c	56.9 de	57.9 e
Fluorescent	32.8 a	52.1 c	—	52.7 cd	51.4 c	53.3 cd
(C) Avg. leaves developed per plant between transplanting and first flowering .						
Incandescent	15.7 a	16.3 a	17.6 a	27.2 b	30.l cd	30.5d
Fluorescent	15.7 a	27.8 bc	—	28.0 bc	27.9 bc	28.2bc

* Within each sub-table, entries followed by the name letter do not differ significantly at the 5% level by Duncan's multiple range tent. Also, plants that received 8-hr. full intensity photoperiods alternated with uninterrupted 16-hr nights at 28 C had no premature flowering and flowered in 57 days with an average of 29. 5 leaves per plant.
† All plants received a basic 8-hr. full-intensity photoperiod and constant 18 C temperature in addition to the indicated night interruptions during the treatment period. Entries are averages for 72 plants per treatment (i.e. 3 replications of 24 plants each).
‡ 3 min/hr repeated for 240 min. § 30 sec/1O min repeated for 240 min

Table 2. Carry-over effects of duration, color and intensity of middle-of-night pretransplant supplemental incandescent light on floral induction and yield of cured leaf of burley tobacco.

Illumination during pretransplant, night interruption			Effectiveness In delaying floral induction*			Yield of cured leaf		
Dura-tion, min.	inten-sity, lux	Color	Pre-mature flow-ering, % of plants	Avg. days from trans-planting to lst flowering, no.	Avg. leaves devel. per plant between trans-planting & 1st flowering, no.	Avg. leaves harvested per plant, no.	Avg. wt. per plant, g	kg/ha
0, control	--	--	100	23.4 a‡	12.9 a	41.8 a	111.8 a	2,484 a
15	600	White	92	27.4 b	13.1 a	35.5 b	111.4 a	2,476 a
		Yellow†	88	29.7 b	13.9 a	33.3 b	113.8 a	2,529 a
60	600	White	2	57.3 cdef	29.0 c	27.5 c	150.0 b	3,333 b
		Yellow	0	57.7 def	29.1 c	27.l c	148.3 b	3,296 b
60	150	White	13	54.9 c	28.4 bc	26.1 cd	144.4 k	3,209 b
		Yellow	15	53.8 c	27.4 b	25.8 cd	142.4 b	3,164 b
240	600	White	0	60.6 f	29.8 c	25.6 cd	152.2 b	3,382 b
		Yellow	0	60.3 ef	29.4 c	24.6 d	144.7 b	3,216 b
240	150	White	2	58.9 ef	29.2 c	24.3 d	145.6 b	3,236 b
		Yellow	4	56.5 cde	28.4 bc	26.6 cd	145.6 b	3,236 b

- Entries are averages for 48 plants per treatment, i.e. 4 replicates of 12 plants each. All plants received basic 8-hour days alternated with 16-hour nights at a day/night temperature of 18/18C in controlled environment chambers. † Yellow lamps of the same wattage as the white ones were substituted in the same position after intensity of white light was determined. ‡ Within each column, entries followed by the same letter do not differ significantly at the 5% level kg Duncan's multiple range test.

The fact that, under prolonged (960-minute) exposures, fluorescent was less effective than incandescent lighting in delaying floral induction seems to contradict the apparent simplicity of phytochrome control indicated in the previous paragraph. This paradox has been reported and discussed in previous papers (6, 10). Nevertheless, the critical findings in this report are that: (I) under brief illumination periods, middle-of-night supplemental illumination from fluorescent lamps is more effective than that from incandescent lamps; (2) a short total duration of middle-of-night illumination from incandescent lamps is more effective if given in short increments repeated over several hours rather than as one continuous exposure; and (3) under prolonged exposures, supplemental illumination from incandescent lamps is more effective than that from fluorescent lamps in delaying floral induction. However, excessive exposure to incandescent light during the pretransplant period can result in long-stemmed plants (11) that are difficult to transplant with conventional equipment. Thus, the 4-hour middle-of-night exposure to incandescent light seems to be potentially most useful because it is easy to apply, effective in counteracting a florally inductive environment, and produces transplants that are easy to handle.

B. White vs Yellow Incandescent Supplemental Lighting

The effectiveness of white vs yellow incandescent lighting was compared. White and yellow incandescent lamps emit about the same ratio of red to far-red light, but radiation from the yellow lamps should be less attractive to insects when used out of doors because the insect-attracting wavelengths are filtered out by the yellow lamp envelop. White and yellow light of approximately the same red and far-red energy levels did not differ in effectiveness of delaying floral induction (Table 2). Fifteen minutes of either color had only a small influence on delaying floral induction. However, the same total energy, applied at ¼ the intensity for four times the duration (i.e. 60 instead of 15 minutes) was much more effective, indicating the low energy requirement of the photoreceptor system . Another 4-fold increase in duration from 60 to 240 minutes resulted in slight additional delay in floral induction.

Plants that flowered prematurely had more, but smaller leaves at time of harvest (Table 2) because they had developed several suckers per plant. Nevertheless, their yields of cured leaf were substantially lower than those that did not flower prematurely. Furthermore, the multi-suckered plants were difficult to cut and spear (harvest), and hard to hang in the curing barn. Also, an excessive amount of time was required to strip and tie the numerous small leaves prior to marketing them.

II. Pretransplant Period in Modified, Outdoor Starting Beds

1970 Experiments. Time of flowering and number of leaves per plant were observed in plants that attained or surpassed the 6-leaf stage in a non-inductive growth chamber before being transferred outdoors to low-intensity, natural photoperiods with or without supplemental lighting. Plants that received 240 minutes of supplemental light in the middle of each night for 15 consecutive nights in the modified, outdoor starting bed flowered later and produced more leaves per plant than did the controls (Table 3). Growth and developmental responses of plants that received yellow light were not significantly different from those that received supplemental white light during the pretransplant period (data not presented). Table 3 shows that supplemental lighting was effective in counteracting a florally-inductive environment that occurred during at least a part of those 15 diurnal cycles. Earlier flowering of the 1970 control plants that did not receive supplemental lighting is evidence that the low-intensity, natural photoperiods were florally inductive, although the induction was not as intense as that obtained in the control plants that were treated with short, cool days in controlled environment chambers (Table 3).

1971 Experiment. Plants that received supplemental light in the middle of the night flowered uniformly late and produced about the same number of leaves as those that received the same treatment in 1970. However, plants that received uninterrupted nights in 1971 (Table 3) did not flower as soon after transplanting as did their counterparts in 1970

Table 3. Carry-over effects of middle-of-night pretransplant lighting over outdoor tobacco plant beds on post-transplant growth and development under field conditions. The chamber pretransplant treatments are included as controls.

Pretransplant environment*				Effectiveness in delaying floral induction					Effectiveness in delaying floral induction				
Location	Day-length, hr	Temp., C	Night interruption white incand.	Premature flowering, % of plants	Avg no. days from transplant to 1st flowering	Avg no. leaves devel. btw, transplant and 1st flowering	Yield of air-cured leaf: Avg wt per plant, g	Yield of air-cured leaf: kg/ha	Premature flowering, % of plants	Avg no. days from transplant to 1st flowering	Avg no. leaves devel. btw, transplant and 1st flowering	Yield of air-cured leaf: Avg wt. per plant, g	Yield of air-cured leaf: kg/ha
				1970 experiment**					1971 experiment**				
Field bed	Nat. †	Nat.	None	15	56.0 b	27.6 b	126.4 b	2,809 b	0	62.7 a	29.6 a	144.4 a	3,209 a
	Nat.	Nat.	4-hr	0	64.6 a	30.2 a	146.4 a	3,253 a	0	65.0 a	29.8 a	146.2 a	3,249 a
Chamber	8	18	None	100	24.4 c	12.8 c	116.0 c	2,578 c	98	28.0 b	10.7 b	107.2 b	2,382 b
	8	18	4-hr	0	63.5 a	30.5 a	147.4 a	3,276 a	0	67.0 a	30.8 a	150.2 a	3,338 a
	8	28	None	0	63.4 a	29.9 a	145.0 a	3,222 a	0	65.9 a	30.1 a	148.7 a	3,304 a

*All plants, in both years, were started and grown to the 6-leaf stage (10) under 16-hr, 28 C days alternated with 8-hr, 28 C nights prior to being placed in the above-described pre-transplant environment for the last weeks prior to transplant field plots. **Values are averages for 21 plants in 1970 and for 60 plants in 1971; those in the same column, within each year followed by the same letter do not differ significantly at the 5% level according in Duncan's multiple range test. † Field location received natural photoperiods and temperatures. Field temperatures rose above 30 C during part of each day for the last 12 days before transplanting to 1971. Supplemental lighting in both locations and years was at about 500 lux from white incandescent-filament lamps.

Some differences in response to this treatment in the field may be expected because early florally inductive environments are more prevalent in some years than in others (15). In 1970, there was a period of cool, overcast weather just prior to transplanting. However, in 1971 the reduction in light intensity over the experimental plants was obtained with shading cloth. Thus, while light intensity was reduced, temperatures rose to more than 30 C during part of each day for the last 12 days prior to transplanting. It is possible that the high temperature during part of the diurnal cycle was effective in counteracting the inductive effects of low light intensity. This would be consistent with our controlled-environment treatments in which 8-hour (or low-intensity, natural length) days alternated with uninterrupted nights are florally inductive at 18-20 C, but are not inductive at 28-30 C (10) (also, see chamber-treated plants in Table 3).

In both 1970 and 1971, plants exposed to supplemental illumination in the field did not differ in time from transplanting to first flowering or in number of leaves per plant relative to those exposed to supplemental illumination in the controlled-environment laboratory. In general, plants that flowered early produced lower yield of cured leaf than did those that did not flower prematurely (Table 3). Thus, it appears from these data that low-intensity, supplemental middle-of-night illumination from standard incandescent lamps can be effective in delaying floral induction during adverse (florally-inductive) pretransplanting seasons, without causing undesirable developmental sequences during years with non-inductive pretransplant environments. It may be desirable to have relatively inexpensive lamps positioned over conventional starting beds such that middle-of-night supplemental lighting could be applied during periods of cool, overcast weather, but not during periods in which warm, sunny conditions predominate.

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