Growth, Floral Induction and Reproductive Development in Selected Perennial Ryegrass *Lolium perenne* L. Cultivars [1]

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ABSTRACT

This research was designed to identify inductive requirements and floral initiation characteristics of three perennial ryegrass *Lolium perenne* cultivars. Information was also collected on growth and development differences in response to different low temperature exposures (0, 1, 2, 4, 8 weeks) and photoperiod treatments (12 and 20 hour) under growth chamber conditions. Response of imbibed seeds was compared with 1 and 4 weeks old seedlings exposed to low temperature to determine the effect of plant growth stage on response to floral inductive conditions.

Pennfine and Loretta cultivars were superior in tillering to Linn and Acclaim. Tiller number and dry matter production per plant were higher in the 20 hour than the 12 hour photoperiod.

More fertile tillers were produced when the low temperature exposure was given at the seedling stage rather than the imbibed seed stage. Inflorescence production increased as the exposure time increased.

The failure of many tillers to produce spikes may have been due to: 1. An obligate juvenile stage for these cultivars so they were insensitive to low temperataure and/or short days at time of exposure; 2. Insufficient duration of exposure. These cultivars may have requirements for low temperature exposure which exceeds the 8 weeks exposure treatment.

Additional key words: **floral initiation, photoperiod, temperature, spike production, growth chamber.**

INTRODUCTION

Perennial ryegrass (*Lolium perenne* L.) is used mainly for pastures with increasing use for turf due to development of acceptable turf types. The majority of the U.S. supply of perennial ryegrass seed is produced in the Willamette Valley of western Oregon of the U.S.A. Many perennial ryegrass cultivars are entering the market, but very little is known about environmental effects on growth or reproductive development. Knowledge of these requirements would help improve the management practices, such as fertilizer timing and rate for improved seed production.

Most investigators agree that there are three stages of development in grass tillers: juvenile, floral induction, and floral initiation stage, although the description of these stages differs (Cooper, 1960; Evans, 1960; Calder, 1964; and Calder, 1966).

The juvenile stage is the phase during which plants are insensitive to environmental conditions that later promote flowering, and its length depends on species (Calder, 1963; Calder, 1966). Induction is a physiological, chemical or hormonal change within the plant resulting from the fulfillment of certain thermophotoperiodic requirements (Gardner and Loomis, 1953; Canode, Maun and Teare, 1972; and Murray, Wilton and Powell, 1973). Conditions generally required for floral induction in most cool-season grasses are a period of short photoperiod and cool temperatures. The requirement of perennial ryegrass for short day and/or low temperature for flower induction has already been reported (Cooper, 1951; Cooper, 1957; Cooper 1960; and McCowan and Peterson, 1964). The response of plants to inductive conditions differs with the species, cultivar, and tillers within the plant (McCown and Peterson, 1964; and Canode, Maun and Teare, 1972).

Once the plant is fully induced, floral initiation can be triggered by the appropriate photoperiod and/or temperature exposure (Cooper, 1951; Chilcote, 1966; Calder, 1964, 1966; Canode, Maun and Teare, 1972; and Canode and Perkins, 1977). The elongation of the vegetative growing point is closely followed by clearly discernible morphological changes which have been carefully documented for several grasses (Gardner and Loomis, 1953; Barnard, 1964; and Calder, 1966).

Our research was designed to: 1) determine if juvenility exists in certain perennial ryegrass cultivars; 2) identify inductive requirements and floral initiation characteristics of these cultivars; and 3) determine growth and development differences among cultivars in response to different low temperature and photoperiod treatments.

MATERIALS AND METHODS

Four forage and turf type cultivars of perennial ryegrass were used, namely Linn, an early maturing cultivar, Pennfine and Acclaim, medium maturing cultivars, and Loretta, a late maturing cultivar. Two experiments were carried out in controlled environment chambers. The chambers were equipped with automatic light and temperature controls. The photosynthetic photon flux density (PPFD) at the plant level was 350 uE sed^{-1} m^{-2}.

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Experiment One

Seeds of certified perennial ryegrass cultivars Linn, Pennfine, and Loretta were exposed to different cold treatments in moist perlite in a dark cold room at 4-6 C, after free imbibition for 24 hours at 20 C (Salisbury, 1965). Once a week, air was circulated through the dishes to prevent accumulation of carbon dioxide with water added at the same time if needed. Cold exposure treatments of 0, 1, 2, 4, and 8 weeks were arranged so that all treatments were completed simultaneously and plants moved to a chamber at 21 C constant temperature on the same date, 6 January, 1978, for floral initiation treatments. Four seedlings were transplanted into 10 x 10 cm plastic pots filled with thoroughly mixed combination of sandy loan soil and greenhouse peat. The pots were placed in the chamber according to a completely randomized design under 12- and 20-hour photoperiods.

Experiment two

Acclaim cultivar was included in this experiment instead of the Linn cultivar because it is a better known turf type cultivar. Seeds were sown in 10 x 10 cm plastic pots. Four plants were grown in each pot in the greenhouse at a constant 18 C and 14-hour photoperiod for different periods of time, during the period from 19 April to 19 May, 1979. Plants were transferred to the coldroom at three different stages (Table 1).

Table 1. Growth stage, age and description of plants at time of exposure to inductive conditions.

Growth stage	Age of plants (weeks)	Description
I	4	Two-three leaf stage with 2-3 tillers/plant
II	1	Single leaf stage
III	0	Imbibed seeds

Sowing dates were arranged so that all three stages were completed simultaneously and moved to the cold room at 4-6 C and 8 hrs photoperiod at the same time. The plants were exposed to cold treatments for durations of 0, 1, 2, 4, or 8 weeks, as in experiment one. After the end of the cold exposure, plants were preconditioned for a week in a chamber at 15 C and 8-hour photoperiods and were then transferred to the growth chamber. The chamber constant temperature was 21 C and two photoperiods (12 and 20 hours) were used.

In both experiments, newly exerted heads were logged daily to record time to head exertion. When experiments were discontinued, number of plants per pot, number of tillers per plant, total number of spikes appearing at the same date, number of heads per plant, number of leaves at heading, and number of spikelets per spike were recorded. Dry weights were determined after the samples were oven-dried for 48 hours at 60 C. The data from both experiments were analyzed as a completely randomized design and the means that were statistically significant were separated by Duncan's multiple range test.

RESULTS AND DISCUSSION

Vegetative growth

In the first experiment, significant differences were found among cultivars and between photoperiods in number of tillers produced per plant (Figure 1). These differences are

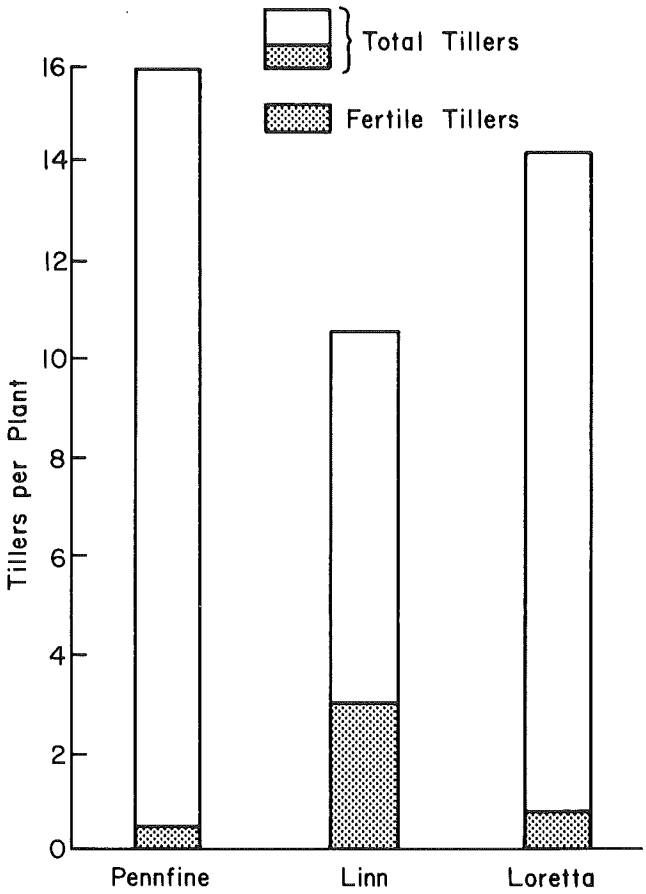


Fig. 1. Total and fertile tiller production for three ryegrass cultivars grown under long day conditions following exposure of the imbibed seed to low temperature (4-6 C).

likely due to the genetic background of these cultivars. Loretta (late maturing) and Pennfine (medium maturing) are turf types, whereas, Linn is a forage type and early maturing. Higher tiller number was produced in the 20-hour photoperiod in both experiments because of greater light energy in the 20-hour photoperiod which favors tillering. In the second experiment, significant differences were noted among cultivars (Figure 2) and plant growth stages (Table 2) in tiller number per plant. Pennfine again had the highest tiller number, followed by Acclaim and Loretta. The observed difference in tiller number per plant noted among growth stages (Table 2) is understandable since the plants exposed at growth stage I (4 weeks) which has the highest tiller number are four and three weeks older than growth stage III (0 week) and growth stage II (one week) plants, respectively. Higher numbers of tillers and larger size are

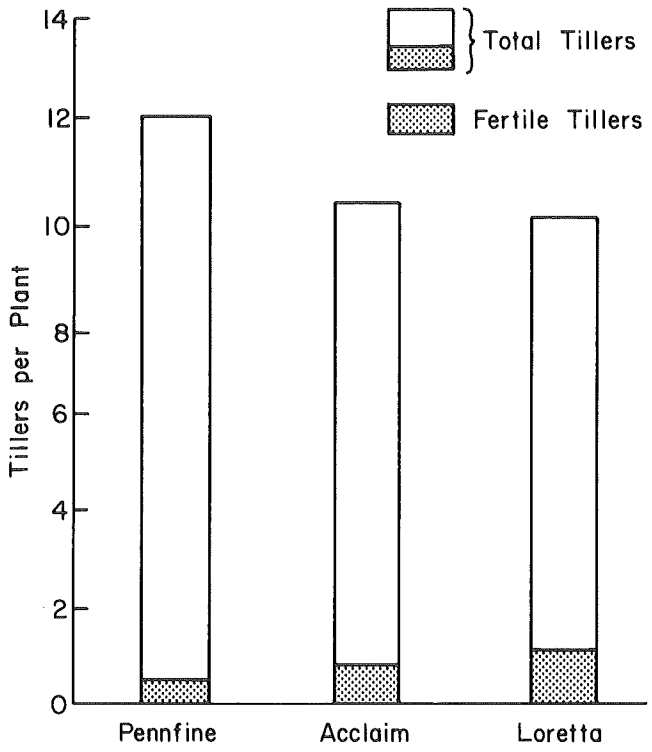


Fig. 2. Total and fertile tiller production of three ryegrass cultivars exposed at the seedling stage to different low temperature 4-6 C durations and grown under different photoperiods.

Table 2. Response of three turf type perennial ryegrass cultivars exposed to low temperature at different ages and grown under 12 and 20 hour photoperiods.

Growth stage	Plant age at time of cold exposure (weeks)	Tillers* per plant	Days to Heading
I	4	11.4 a	51.4
II	1	10.9 a	60.1
III	0	7.6 b	60.6

*Figures with different letters are significantly different at 5% level of probability

the prerequisites for good seed production.

Dry Matter Production

Dry weight per plant is a function of number of tillers per plant and tiller weight which depends, in part, on number of leaves per tiller, their expansion and duration of growth. The dry weight per plant was higher for the 20-hour photoperiod than the 12-hour photoperiod following the same trend of tiller number per plant. This was due to the higher total energy in the 20-hour photoperiod.

In experiment one, a variety x photoperiod interaction for dry weight per plant was significant due to variation among cultivars within the 20-hour photoperiod (Figure 3). This small but significant difference appears to be due to the reduced response of the Linn cultivar (forage type) to the 20-hour photoperiod. The advanced plant growth stages

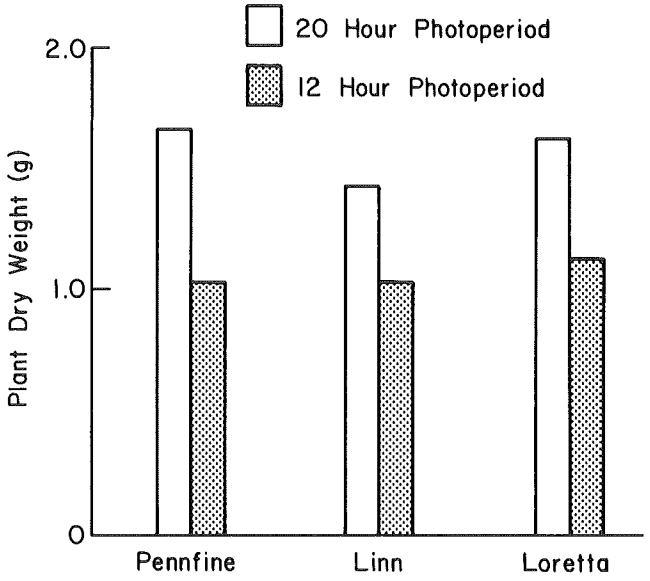


Fig. 3. Effect of photoperiod and cultivar on dry matter production in perennial ryegrass cultivars exposed as imbibed seeds to low temperature conditions.

(second experiment) resulted in significantly increased plant dry weight. Since tiller production for these stages is different (Table 2), the higher tiller number for older plants allowed greater leaf area, more light interception, thus higher dry matter production through the photosynthetic process. Cold treatments did not affect dry matter production, which is in contrast to findings by Salisbury (1965) who noted that low temperature exposure increased tillering and dry weight per plant in *Lolium*. High dry matter production is also important in obtaining high seed yield if it is partitioned to economic yield (seed).

Reproductive Development

Seed production depends not only on growth and development of tillers (shoots), but these tillers must be receptive and the environmental conditions necessary for induction and initiation must be favorable for fertile tiller production. In this study, flowering response of plants, even when exposed to 8 weeks of low temperature treatment, was less than expected. The percentage of plants which succeeded in producing spikes under growth chamber conditions was quite low (10%) compared to that usually occurring under field conditions. Since plants were started from seeds and the species is cross pollinated, variability may be the result of genetic variation within the plant population. Fertile tiller production was poor in both experiments (Figures 1, 2). The percentage of fertile tillers produced in experiment one was 2, 32 and 4 for Pennfine, Linn, and Loretta cultivars, respectively. Linn (the forage type) was the only cultivar where spike production increased as the duration of cold treatment increased (Table 3). This is in agreement with Murray, et al., (1973), who found that the number of panicles per plant increased and days to heading decreased with increasing exposure to low

Table 3. Response of Linn perennial ryegrass after different cold duration exposures in the imbibed seed stage.

Cold Duration (weeks)	Total Tillers	Fertile Tillers	Fertile Tiller (%)	Leaves to Heading	Spikelet/ Spike
8	190	82	43	2.65	10.0
4	162	64	40	2.20	9.1
2	157	43	28	2.60	8.2
1	200	26	13	3.77	14.8
0	172	17	10	3.62	12.1

temperature. Evans (1960), Canode, Maun and Teare (1972) and Canode and Perkins (1977) drew similar conclusions. However, in the other cultivars, e.g. Pennfine and Loretta (turf types), the "no cold treatment" was sometimes as effective as the eight-week cold treatment. This may suggest induction due to short days which can be independent of low temperature induction (Cooper, 1960). Cultivars differed in spike production despite the low response to floral induction conditions (Figure 4). Linn (forage type)

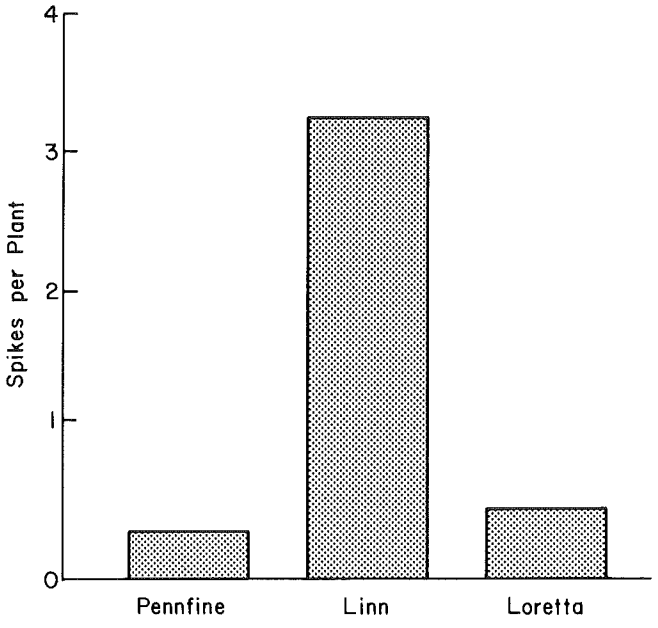


Fig. 4. Spike production in three ryegrass cultivars after low temperature 4-6 C treatment in the imbibed seed stage and grown under long days.

showed a moderate or intermediate flowering response, averaging more than three spikes per plant, whereas Pennfine and Loretta averaged less than one spike per plant. These differences may be due to the different genetic background which effect control of reproductive development.

Low temperature duration effects

Despite the poor fertile tiller production, a greater percent of tillers become reproductive in the 8-week cold treatment (15%) than in the "no-cold" treatment (6%). However, the number of leaves to heading did not differ (3-4) excluding any evidence for an optimum quantitative response.

The number of spikes produced per plant was different for different durations of cold treatments in both experiments. The number of spikes produced per plant exposed at the seedling stage was always higher than for similar treatments in the imbibed seed stage. This may be due to the fact that plants in the advanced seedling stage had already surpassed the juvenile stage and became sensitive to low temperature and/or short days that promote flowering. Failure of plants to respond favorably to low temperature treatment may have been due to the fact that cultivars examined have a threshold higher than the 8-week cold treatments used. Such a threshold has been documented for other grasses, e.g., tall fescue (*Festuca arundinacea*, Schreb) (Templeton, Mott and Bula, 1961), Kentucky bluegrass (*Poa pratensis*) (Lindsey and Peterson, 1962; Canode, Maun and Teare, 1972; Canode and Perkins, 1977).

Growth stage effects

It is generally known that seedlings are more responsive to low temperature induction than seeds. Evans (1960) found that more rapid low temperature induction occurred in four-week-old plants than seeds at 10 C in *Lolium* and *Poa pratensis*. In these experiments, fertile tiller production increased only slightly where seedlings were exposed to inductive conditions. Percent fertile tillers increased from 1.5 to 2% in Pennfine and from 3.5 to 7% in Loretta cultivars. Plants exposed to low temperature induction when they were 4 weeks old produced spikes at earlier dates than those exposed as imbibed seeds (Table 2). The earlier heading may be because the 4-week-old plants either were more responsive to low temperature or the more advanced stage allowed them to have more leaf area for photosynthate production. Maintenance of an optimum tiller population in the fall is not enough to guarantee good seed yield. These tillers must also be adequate in size or age to respond to inductive conditions during the winter.

The number of spikelets per spike are higher for the "no cold" and imbibed seed cold exposure throughout the experiments. This indicates less competition for dry matter. Since fewer spikes were produced, compensation between yield components likely occurred.

CONCLUSIONS

Pennfine and Loretta cultivars (turf type) were superior in tillering to Linn (forage type) and Acclaim (turf type). This characteristic of high tiller production may be desirable in forages because of the need for high dry matter production and in turf, together with horizontal growth habit, to maintain cover. However, in growing high tillering cultivars for seed production, the seeding rate may need to be reduced to avoid a super optimum tiller population which can lead to competition among tillers resulting in higher tiller mortality and reduced efficiency in seed yield.

More fertile tillers were produced when the low temperature exposure was at the seedling stage rather than

imbibed seeds. This suggests that maintenance of adequate tiller number and size is a prerequisite for high seed yield.

The failure of many tillers to produce spikes in these studies showed some of the problems of greenhouse research. Results may not relate to field conditions because of the artificial light and temperature regime present in the growth chamber. This failure to produce spikes may also be due to:

1. An obligate juvenile stage for these cultivars so they were insensitive to inductive low temperatures and/or short days at time of exposure.
2. Insufficient duration of exposure for floral induction. These cultivars may have requirements for low temperature exposure which exceeds the 8 weeks used.

The results stress the fact that different cultivars of perennial ryegrass have different requirements for vegetative and reproductive growth and development and specific management systems for cultivars needs to be better identified.

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