Manipulation of the Annual Growth Cycle of Blueberry Using Photoperiod

M. Pilar Bañados and Bernadine Strik
Department of Horticulture, Oregon State University, ALS 4017 Corvallis, OR 97331 USA

Keywords: dormancy, flower buds, *Vaccinium*

Abstract

A controlled environment study was conducted using container-grown 'Duke', 'Bluecrop' and 'Elliott' from July to December 2002 in Corvallis, Oregon. Plants were placed in growth chambers (GC) under either short-day (SD, 8h of light) or long-day (LD, 16 h of light) photoperiod and constant temperature (22°C) for up to eight weeks. Every two weeks, a group of plants was moved from the GC to a greenhouse (16 h light, 22°C) to measure dormancy, growth, and percentage of flower buds. After eight weeks of SD, a group of dormant plants were moved from the GC to a cold room (4°C) for 900 hours, and then transferred back to the GC (LD and 25°C) to record days to bud break, bloom and fruit ripening. Plants under LD had three to six flushes of growth and did not initiate flower buds or enter endo-dormancy. Bud break occurred after 5 to 15 days in the greenhouse. Plants under SD had two flushes of growth and developed flower buds after two weeks of SD and dormancy after four weeks of SD. The number of flower buds and the degree of dormancy increased with time of exposure to SD. After cold storage, bud break and bloom occurred after 6 and 26 days, respectively, with little differences among cultivars. Fruit harvest started 65, 95, or 130 days after bud break in 'Duke', 'Bluecrop', or 'Elliott', respectively. Fruit set in the GC was reduced due to insufficient pollination.

INTRODUCTION

Photoperiod is an environmental factor that changes in a predictable manner year after year for a particular combination of latitude and day. Plants have evolved to sense these changes and adapt their physiology and metabolism to the oncoming season. Shortened photoperiods in the fall precede cold winters. This is especially important in deciduous woody perennial plants native to high latitudes, which alternate their annual growth cycle between a period of active growth in the spring and summer and one of dormancy in the fall and winter. Highbush blueberry (*Vaccinium corymbosum* L.) is native to latitudes 40 to 45°N, where the natural photoperiod ranges from 16 to 8 hr of light. The influence of short-day (SD) photoperiod on flower bud induction in blueberry is well documented (Darnell, 1991; Hall and Ludwig, 1961; Hall et al., 1963; Spann et al. 2003). Lowbush (*Vaccinium angustifoium* Ait.), highbush and rabbiteye (*V. ashei* Reade) blueberry develop flower buds under an 8 hr photoperiod but not under 16 hrs. However there is little or no information on the effect of photoperiod on the induction of dormancy and on the possibility to manipulating the annual growth cycle of highbush blueberry using a combination of SD and long-day (LD) photoperiod.

The objective of this work was to quantify the effect of SD and LD photoperiod on the growth, dormancy and flower bud development of three highbush blueberry cultivars under controlled environmental conditions, as well as to artificially manipulate the annual growth cycle of the plant in growth chambers (GC).

MATERIALS AND METHODS

Container grown blueberry (*Vaccinium corymbosum* L.) plants 'Duke', 'Bluecrop' and 'Elliott' were grown in the greenhouse from the end of March until the end of June 2002. Plants were then moved to controlled environment chambers (GC) (Conviron CMP 3023) and grown under either short-day (SD, 8h of light) or long-day (LD, 16 h of light)

Proc. VIII[th] IS on Vaccinium Culture
Eds.: L. Lopes da Fonseca et al.
Acta Hort. 715, ISHS 2006

photoperiod and constant temperature (22°C) for up to eight weeks. At "0" weeks (control plants), and every two weeks, three plants of each cultivar and treatment (SD or LD) were moved to a greenhouse (16 h light, 20°C) and completely defoliated by hand. Degree of dormancy and number of flower buds (FB) were recorded. Dormancy was measured as the number of days to first bud break and FB as the total number on the plant and expressed as a percentage of the total buds. After week eight for the SD plants, a group of dormant plants was moved to a cold room (4°C) for 900 hours, and then transferred back to the GC but under LD and 25°C. Days to bud break, bloom and first ripe fruit were recorded for each cultivar and compared to plants grown under natural conditions (NC).

Shoot length was measured weekly inside the chambers under SD or LD; three shoots on three plants per cultivar were randomly selected for measurements. At the end of the experiment plants from 8 weeks-SD and 8 weeks-LD treatment were destructively harvested to determine the final number of flushes of growth and the total biomass and partitioning in the plants.

Mean values for each measurement were compared using analysis of variance in S-plus.

RESULTS AND DISCUSSION

Growth

Shoot growth cessation and terminal bud set in SD treated plants occurred after 2 weeks in 'Elliott' and 'Bluecrop' and after three weeks in 'Duke'. Plants grown under LD photoperiod grew until the end of the experiment (week 8; Fig 1). Plants under LD were taller than SD (Fig. 1). Plants grown under LD photoperiod had 4.3 to 5 flushes of growth compared with 2 to 2.7 on plants grown under SD (Table 1). 'Duke' was the cultivar that grew the most under LD conditions. Total plant dry weight was doubled in LD treated plants compared to SD plants (Table 1). Shoot growth cessation due to SD photoperiod has been shown in different plant species such as *Vitis sp* (Fennel and Hoover, 1991; Wacke and Fennell, 2000), poplar (Bañados, 1992; Zhu and Coleman, 2001), birch (Welling et al., 1997), and willow (Barros and Neil, 1987). In this study, SD photoperiod was a very powerful environmental clue./Even under optimal temperature for growth plants under SD set buds after 2 or 3 weeks.

Dormancy

Non-dormant control plant (week 0) took between 7 to 10 days after defoliation to break buds in a greenhouse. Plants exposed to SD photoperiod developed endo-dormancy after 4 weeks with an increasing number of days to first bud break. Plants were evaluated for up to 4 months after defoliation. Plants treated for 6 or 8 weeks of SD photoperiod did not break bud within that time (Fig. 2).

Long-day treated plants broke buds 7 to 25 days after defoliation for week 2 to 6. Plant treated for 8 week of LD took longer to broke buds (40 to 60 days). In those plants the apical meristems of plants subjected to LD were actively growing when moved to the greenhouse. However the complete defoliation of the plant apparently stressed the pants, delaying the regrowth or budbreak. Dormancy induction due to SD photoperiod has been reported in deciduous woody species. In poplar, 8hr- SD induced dormancy under natural and controlled environmental conditions (Bañados, 1992; Jecknic and Chen, 1999). In many studies, however the effect of photoperiod and temperature is not clearly separated. In this study blueberry plants entered dormancy after 4 weeks of 8hr-SD photoperiod and 22°C.

Flower Bud Formation

Bud set was observed after two weeks of SD in 'Bluecrop' and 'Elliott' and after 3 weeks in 'Duke' but never under LD. Flower buds were formed only under SD photoperiod and progressed in a quantitative manner with time of exposure (Fig. 3).

Flower bud number per plant increased in 'Bluecrop' plants from 2 after 2 weeks in SD to 28 after 8 weeks in SD conditions.

The influence of SD in the flower bud formation of blueberries is well documented (Darnell, 1991; Hall and Ludwig, 1961; Hall et al., 1963; Spann et al., 2003) but this is the first report that compares the effect of photoperiod in three different highbush blueberry cultivars, an early, mid season and late season.

Phenological Stages

Plants treated for 8 weeks of SD plus 900 chilling hours broke buds 7 to 10 days after being placed in a GC under LD and 25°C. Bloom occurred within one month and first mature fruit for 'Duke' was observed on December 20, 180 days before it occurred under natural conditions. 'Bluecrop' and 'Elliott' did not differ from 'Duke' in the time of budbreak or bloom, but the first mature fruit on these cultivars was observed on January 22 and February 25 respectively. These results corresponded to 155 to 170 days before plants grown under natural environment conditions (Table 3).

CONCLUSIONS

Short-day photoperiod stopped shoot growth of highbush blueberry after two or three weeks of treatment. Terminal bud formation was observed in the plants at the time of growth cessation and precedes flower bud formation. In contrast LD plants grew continuously in the growth chambers until the end of the experiment.

Plants treated with SD for 4 or more weeks developed endo-dormancy and did not break buds after four months (end of the experiment) under greenhouse conditions. Long-day plants did not show endo-dormancy and broke buds 7 to 40 days after defoliation in the greenhouse.

Flower bud formation occurred only under SD photoperiod.

ACKNOWLEDGEMENTS

We thank the EPA and USDA in Corvallis, Oregon for allowing us to use their controlled environment chambers for this study, and to the Oregon Blueberry farms for donating the plants for this study**.**

Literature Cited

Bañados, M.P. 1992. Nitrogen and environmental factors affect bark storage protein gene expression in poplar. M.S Thesis, Oregon State University, Corvallis, Or, USA.

Barros, R.S. and Neil, S.J. 1987. Shoot growth in willow (*Salix viminalis*) in relation to abscisic acid, plant water status and photoperiod. Physiol. Plantarum 70: 708-712.

Darnell, R.L. 1991. Photoperiod, carbon partitioning, and reproductive development in rabbiteye blueberry. J. Amer. Soc. Hort. Sci. 116(5):856-860.

Fennel, A. and Hoover, E. 1991. Photoperiod influences growth, bud dormancy, and cold acclimation in *Vitis labruscana* and *V. riparia*. J. Amer. Soc. Hort. Sci. 116 (2): 270-273.

Hall, I.V. and Ludwig, R.A. 1961. The effects of photoperiod, temperature, and light intensity on the growth of the lowbush blueberry (*Vaccinium corymbosum* Ait). Can. J. Botany 39:1733-1739.

Hall, I.V., Craig, D.L. and Aalders, L.E. 1963. The effect of photoperiod on the growth and flowering of the highbush blueberry (*Vaccinium corymbosum* L.) Proc. Amer. Soc. Hort. Science.

Jecknick, Z and Chen, T.H.H. 1999. Changes in protein profiles of poplar tissues during the induction of bud dormancy by short-day photoperiods. Plant Cell Physiol. 40(1):25-35.

Spann, T.M., Williamsom J.G and Darnell, R.L. 2003. Photoperiodic effects on vegetative and reproductive growth of *Vaccinium darrowi* and *V.corymbosum*. HortScience 38:192-195.

Wacke, C.M. and Fennel, A. 2000. Morphological, physiological and dormancy responses of three Vitis genotypes to short photoperiod. Physiologia Plantarum 109:203-210.
Welling, A., Kaikuranta, P. and Rinne, P. 1997. Photoperiodic induction of dormancy and freezing tolerance in Betula pubescens. Involvement of ABA and dehydrins. Physiol. Plantarum. 100:119-125.
Zhu, B. and Coleman, G.D. 2001. Phytochrome-mediated photoperiod perception, shoot growth, glutamine, calcium, and protein phosphorylation influence the activity of the bark storage protein gene promoter. Plant Physiol. 126:342-351.

Tables

Table 1. Flushes of growth and biomass partitioning in container grown blueberry plants 'Bluecrop', 'Duke' and 'Elliott under long-day (LD) or short-day (SD) photoperiod.

		Flushes of growth	Leaves (g)	shoots (g)	1-year-wood (g)	Crown (g)	Roots (g)	Total DW (g)
Bluecrop	LD	4.3	37.60	36.79	13.77	11.81	64.61	164.57
	SD	2.7	13.80	16.20	11.70	5.71	27.82	75.23
		*****	**NS**	*****	**NS**	*****	*****	*****
Duke	LD	5.0	24.79	39.87	16.27	24.32	60.99	166.24
	SD	2.3	12.07	7.70	10.24	9.24	28.56	67.80
		*	*	*	*	ns	**	**
Elliott	LD	4.3	38.55	40.38	17.20	17.19	81.89	195.20
	SD	2.0	15.87	18.07	14.93	11.40	44.83	105.10
		*****	******	******	**NS**	**NS**	*****	******

NS, *, **, ***: non-significant, or significant at $p < 0.05$, $p < 0.01$ or $p < 0.001$ respectively

Table 2. Number of flower buds in containergrown blueberry plants 'Bluecrop', 'Duke' and 'Elliott' grown under long-day (LD) or short-day (SD) photoperiod.

		Weeks under treatment				
		0	2	4	6	8
Bluecrop	LD	0	0	0	0	0
	SD	0	2	18	25	28
		NS	*	***	***	***
Duke	LD	0	0	0	0	0
	SD	0	2	12	12	14
		NS	*	***	***	***
Elliott	LD	0	0	0	0	0
	SD	0	0	20	28	22
		NS	NS	***	***	***

Table 3. Dates to budbreak, bloom and first mature fruit in containergrown blueberry plants 'Bluecrop', 'Duke' and 'Elliott in growth chamber (GC) or natural conditions (NC) in Corvallis, Oregon, USA.

		Budbreak		First Bloom		First mature fruit	
Duke	GC	November 1, 2002	(-125 days)	November 16,	(-130	December 23, 2002	(-175 days)
	NC	March 5, 2003		March 30, 2003		June 20, 2003	
Bluecrop	GC	November 1, 2002	(-125	November 16,	(-131	January 22, 2003	(-160 days)
	NC	March 5, 2003		April 1, 2003		July 7, 2004	
Elliott	GC	November 5, 2002	-123 days)	November 18,	(-132	February 25, 2003	(-155 days)
	NC	March 8, 2003		April 4, 2003		July 30, 2003	

Figures

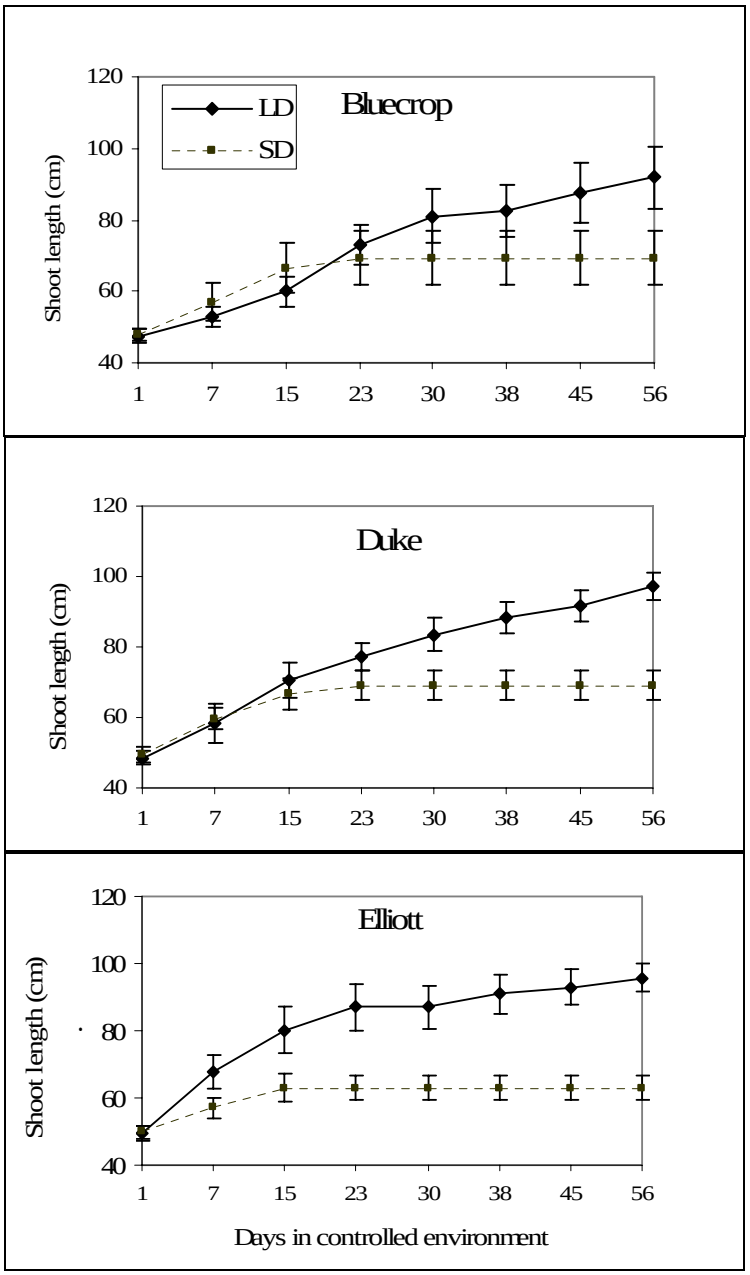

Fig. 1. Shoot length of three blueberry cultivars grown in a growth chamber under long days (LD) or short-days (SD) photoperiod. Means ± SE (n=3).

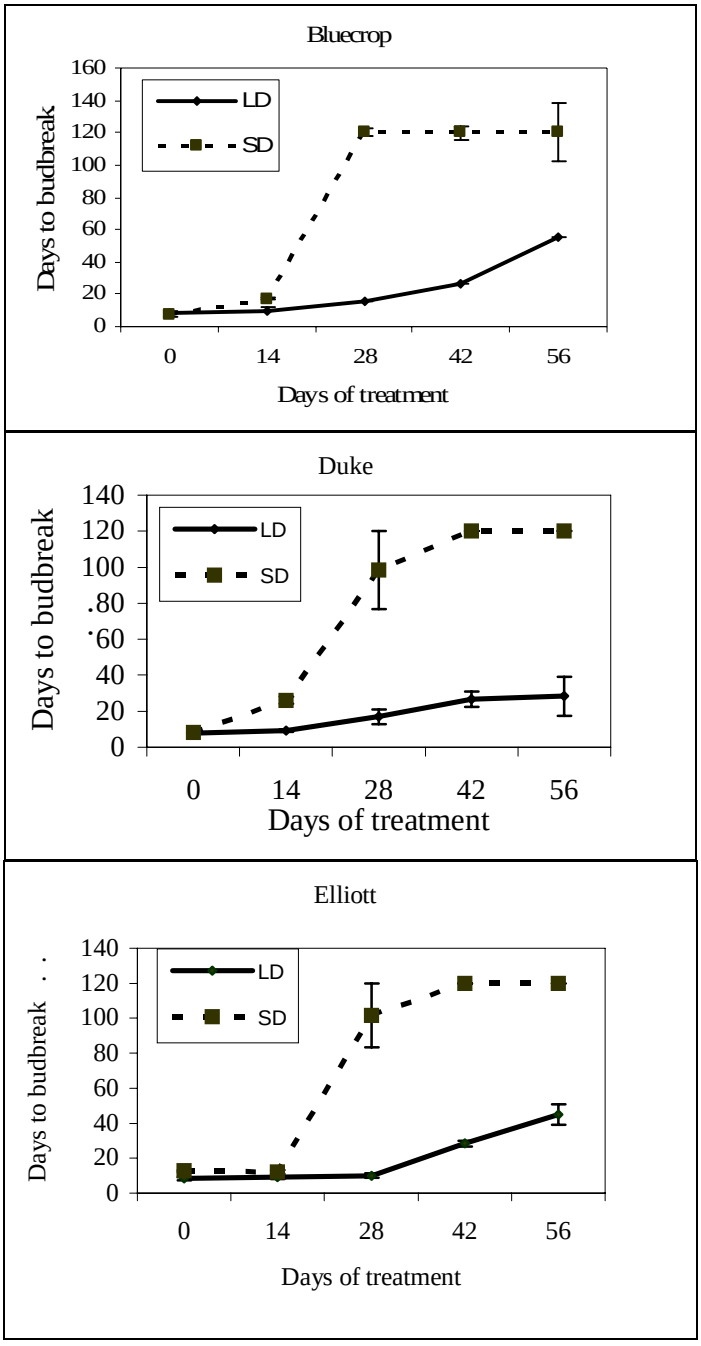

Fig. 2. Days to budbreak in ‘Bluecrop’, ’Duke’ and ’Elliott’ plants treated with SD or LD photoperiod. Means ± SE (n=3).

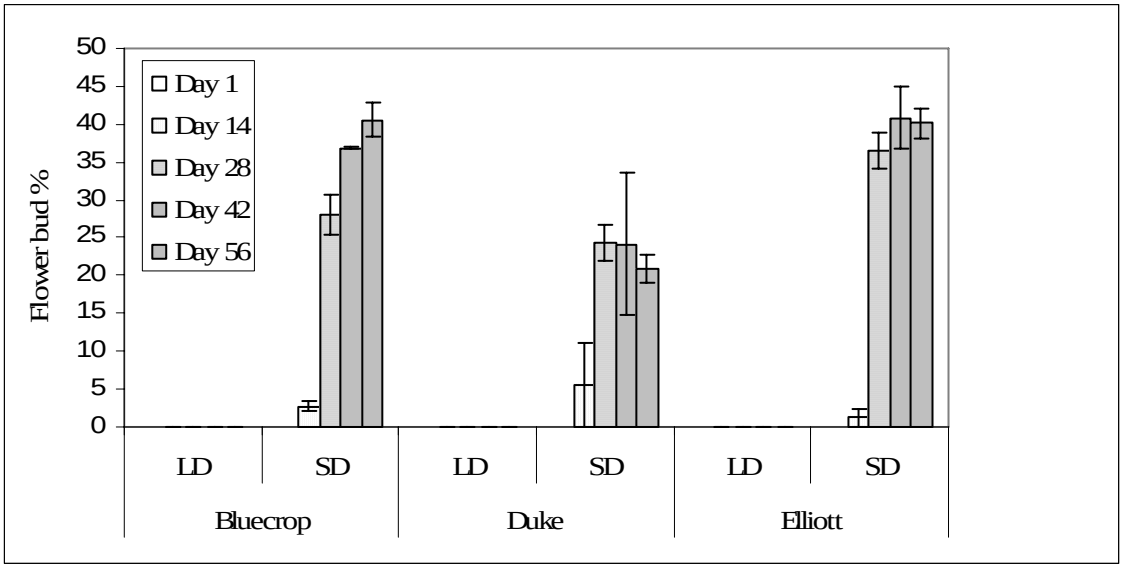

Fig. 3. Percent flower bud (%) in blueberry plants ‘Bluecrop’, ‘Duke’ and ‘Elliott under long-day (LD) or short-day (SD) photoperiod. Values are mean of three plants. Bars indicate SE.