INFLUENCE OF PHOTOPERIOD AND AIR TEMPERATURE ON THE GROWTH, FLOWERING AND MATURATION OF SOYBEAN (*Glycine max* (L.) Merrill)[1]

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ABSTRACT: With the purpose to evaluate the effect of short (12 hours) and long (13 and 14 hours) photoperiods and air temperature regimes (winter and summer growing seasons) on soybean behaviour, greenhouse experiments were installed at the Federal University of Viçosa, Brasil, from June 1984 to December 1985. In each experiment, under a completely randomized design with 12 treatments (soybean cultivars) and eight replicates: duration of vegetative period from emergency to stage R1 or flowering (DVP, in days); plant height (PH, m); number of nodes per plant at stage R1 (NNP); and duration of soybean cycle from emergency to stage R7 or physiological maturity point (DC, days), were evaluated. The results permit to conclude that: the vegetative period from emergency to flowering and the juvenile period are significantly affected by the photoperiod and temperature differences; shorter photoperiods or higher temperatures anticipate flowering; longer photoperiods under the same temperature regime or higher temperature under the same photoperiod regime result in higher plants.
Key words: phenology, plant height, photoperiodism

INFLUÊNCIA DO FOTOPERÍODO E DA TEMPERATURA DO AR NO CRESCIMENTO, FLORAÇÃO E MATURAÇÃO DA SOJA (*Glycine max* (L.) Merrill)

RESUMO: Experimentos em casa-de-vegetação visando estudar o comportamento de cultivares de soja perante fotoperíodo curto (12 horas) e longo (13 e 14 horas) e na presença de temperaturas variáveis em função de diferentes épocas de semeadura, foram instalados na Universidade Federal de Viçosa, MG, Brasil, durante o período de junho de 1984 a dezembro de 1985. Delineado inteiramente ao acaso, cada experimento contou com doze cultivares de soja repetidos oito vezes por época. Avaliaram-se as seguintes características: duração do subperíodo emergência - início do florescimento, altura de planta e número de nós vegetativos formados por planta e duração do subperíodo emergência - maturidade fisiológica. Concluiu-se que a fase fenológica da soja compreendida entre a emergência e o início do florescimento é significativamente influenciada pelas variações do fotoperíodo e da temperatura do ar; fotoperíodo e temperatura interferem com a duração fenológica do período juvenil da soja e acréscimos de fotoperíodo e de temperatura antecipam o florescimento da soja e aumentam a altura de suas plantas.
Descritores: fenologia, altura de planta, fotoperiodismo

INTRODUCTION

The photoperiod is defined as the time, within 24 hours of the terrestrial day, when there is light or sun bright (Ometto, 1981) also called daylength and defined as the time in hours between sunrise and sunset (Goudriaan & van Laar, 1994). Daylength, temperature and rainfall are the most important climatic factors to select a region for soybean cultivation and production (Câmara, 1991).

Latitude determines the daylength pattern. In soybean, a short-day plant , daylength affects the development rate from emergence to flower induction and particularly determines the time necessary for flowering (Marcos Filho *et al.*, s/d; Câmara, 1992). In what concerns the air temperature, it is well known that higher temperatures during the growing season favor faster development rates of this crop and reduce time for flowering (Major *et al.*, 1975a; Major *et al.*, 1975b; Miyasaka & Medina, 1970).

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Literature about the correlation between photoperiodic and temperature effects on soybean development is scarce. The objective of the present study was to evaluate the effects of these two climatic factors on growth and time for flowering and grain maturation of some soybean cultivars.

MATERIAL AND METHODS

Greenhouse experiments were installed at Federal University of Viçosa, state of Minas Gerais, Brazil (Latitude: 20° 45' South. Longitude: 42° 51' West. Altitude: 650 m). The experiments were conducted using twelve Brazilian cultivated varieties: Cristalina, Doko, IAC-6, IAC-7, IAC-8, Paraná, Primavera, Savana, Tropical, UFV-1, UFV-4, and UFV-5 (Sediyama *et al.*, 1981). The following combinations of growing period and photoperiod were studied:

- Winter season-1984: from June 18, 1984 until December 4, 1984 with short-days (photoperiod = 12 hours) and long-days (photoperiod = 13 hours).
- Summer season-1984/1985: from December 14, 1984 until May 26, 1985 with short-days (photoperiod = 12 hours) and long-days (photoperiod = 13 hours).
- Winter season-1985: from July 17, 1985 until December 23, 1985 with short-days (photoperiod = 12 hours) and long-days (photoperiod = 14 hours).

The daylength of 12, 13 and 14 hours were used to simulate the natural photoperiodic conditions comparable to those of the Brazilian soybean growing regions of the Equator (Latitude=0°), and of the summer solstice in tropical latitudes of the central high-plains (Latitude=15° to 19° S) and of the South States (Latitude=30° to 32°S), respectively. The three photoperiods were kept constant inside of the greenhouses, during the entire growing season, by artificial lights. Sowing the crop in different seasons allowed to evaluate the effect of three different temperature regimes. Daily maximum and minimum temperature were monitored in all greenhouses during the three growing seasons.

We adopted for each photoperiod and growing season a completely randomized experimental design with 12 treatments (soybean cultivars) in eight replicates. Each replicate was represented by a pot with 3 kg of soil with two soybean plants. To compare the effect of different photoperiod within the same growing season or the temperature effect of different growing seasons with the same photoperiod, we adopted statistical analysis techniques for group of experiments. Significant differences were evaluated with test of Tukey at 5% probability level.

The phenological staging scale of Fehr & Caviness (1977) reviewed by Ritchie *et al.* (1994) was adopted to estimate: duration of vegetative period from emergency to stage R1 or flowering (DVP, in days); plant height (PH, m); number of nodes per plant at stage R1 (NNP); and duration of soybean cycle from emergency to stage R7 or physiological maturity point (DC, days).

RESULTS AND DISCUSSION

Long-day conditions of 13 and 14 hours daylength extended DVP, for al cultivars in every growing season, in average 28.6% to 48.8% in comparison to short-day conditions of 12 hours daylength (TABLES 1, 2 and 3). As a result of a larger vegetative period, soybean plants were higher (42.4% to 103%) and presented a larger number of nodes (33.8% to 57.3%). The duration of soybean cycle (DC) was also extended in average 2.3% to 4% under long-day conditions, although not as much as for the vegetative period.

Since the temperature in the same growing season was not significantly different between both daylength conditions, the extension the vegetative period under longer days was consequence of the daylength itself. Thus, the critical daylength at which flower formation is initiated varies according to photoperiodic conditions during juvenile phase or are dependent of the plant size.

The differences between the largest and lowest values of mean square error permitted to compare the results of the first and second growing season, to evaluate the temperature effect (TABLES 4 and 5).

TABLE 1 - Duration of vegetative period from emergency to flowering (DVP, days), plant height (PH, m), number of nodes per plant (NNP), and duration of soybean cycle from emergency to physiological maturity point (DC, days) for two photoperiods (12 and 13 hours) during winter season-1984. Federal University of Viçosa, Brazil.

Cultivated	12 hours				13 hours			
Varieties	DVP	PH	NNP	DC	DVP	PH	NNP	DC
Cristalina	72.1	0.754	9.1	152.9	92.7	1.003	12.6	157.6
Doko	81.9	0.687	9.4	152.2	100.1	1.025	13.0	157.2
IAC-6	72.9	0.651	7.6	143.9	91.8	1.013	10.8	148.6
IAC-7	81.3	0.644	9.8	148.6	94.6	0.872	12.3	152.6
IAC-8	79.0	0.681	8.7	148.8	85.6	1.084	11.9	154.6
Paraná	48.1	0.455	6.4	127.2	67.6	0.677	8.0	128.6
Primavera	48.9	0.486	6.9	120.7	65.5	0.711	8.4	122.9
Savana	73.3	0.657	8.4	144.4	93.5	0.827	11.5	146.4
Tropical	88.4	0.926	10.6	158.5	101.9	1.028	12.1	160.1
UFV-1	45.1	0.551	6.6	132.8	70.2	0.761	8.8	134.1
UFV-4	44.4	0.425	5.1	134.7	65.8	0.773	8.1	137.6
UFV-5	48.9	0.517	7.0	138.6	79.6	0.827	10.7	142.4
Mean	65.4	0.620	8.0	141.9	84.1	0.883	10.7	145.2
C.V.[1]	1.3	16.600	9.9	0.5	0.9	14.500	9.7	0.4
M.S.D.[2]	1.4	0.172	1.3	1.3	1.2	0.215	1.7	1.0

[1]Coefficient of variation (%)
[2]Minimum significant difference (Tukey test. Significance level 5%).

TABLE 2 - Duration of vegetative period from emergency to flowering (DVP, days), plant height (PH, m), number of nodes per plant (NNP), and duration of soybean cycle from emergency to physiological maturity point (DC, days) for two photoperiods (12 and 13 hours) during summer season-1984/1985. Federal University of Viçosa, Brazil.

Cultivated	12 hours				13 hours			
Varieties	DVP	PH	NNP	DC	DVP	PH	NNP	DC
Cristalina	43.3	0.808	7.4	147.3	65.3	1.433	12.2	148.6
Doko	50.6	0.778	8.9	138.4	70.3	1.581	13.1	142.6
IAC-6	46.1	0.829	7.3	133.1	65.7	1.671	12.1	135.7
IAC-7	44.1	0.807	8.0	138.4	62.6	1.396	11.9	139.2
IAC-8	47.4	0.877	7.5	141.3	64.4	1.696	11.4	144.2
Paraná	34.1	0.577	6.1	122.3	56.7	1.322	10.0	124.9
Primavera	36.5	0.618	7.2	117.9	58.4	1.475	11.4	125.6
Savana	43.1	0.708	7.4	140.4	63.1	1.246	11.6	142.9
Tropical	57.7	1.131	9.9	149.6	74.9	1.863	13.3	153.8
UFV-1	34.3	0.621	7.1	128.6	60.7	1.668	11.9	134.6
UFV-4	36.5	0.603	6.4	130.1	60.3	1.556	11.5	134.3
UFV-5	40.3	0.612	7.1	136.0	62.3	1.299	11.6	138.8
Mean	42.8	0.747	7.5	135.3	63.7	1.517	11.8	138.8
C.V.[1]	1.7	23.400	11.0	0.5	1.1	24.400	11.7	0.6
M.S.D.[2]	1.2	0.294	1.4	1.1	1.2	0.621	2.3	1.3

[1]Coefficient of variation (%)
[2]Minimum significant difference (Tukey test. Significance level 5%).

TABLE 3 - Duration of vegetative period from emergency to flowering (DVP, days), plant height (PH, m), number of nodes per plant (NNP), and duration of soybean cycle from emergency to physiological maturity point (DC, days) for two photoperiods (12 and 14 hours) during winter season-1985. Federal University of Viçosa, Brazil.

Cultivated	12 hours				14 hours			
Varieties	DVP	PH	NNP	DC	DVP	PH	NNP	DC
Cristalina	74.9	0.776	9.3	142.5	96.6	1.103	11.5	148.5
Doko	83.2	0.698	9.5	143.5	102.4	1.144	12.2	148.8
IAC-6	77.8	0.791	7.9	137.4	97.4	1.326	12.4	143.9
IAC-7	83.9	0.775	9.5	139.3	99.6	1.148	11.8	146.1
IAC-8	81.1	0.746	8.8	139.8	94.5	1.292	11.4	147.2
Paraná	54.6	0.526	6.6	127.6	78.9	0.848	9.4	132.7
Primavera	55.4	0.536	7.1	119.5	78.6	0.859	9.9	125.6
Savana	79.2	0.665	9.8	141.2	99.1	0.920	11.4	144.4
Tropical	89.9	0.978	10.5	147.2	103.6	1.259	12.6	149.8
UFV-1	53.8	0.563	7.2	129.3	79.7	0.858	9.8	135.3
UFV-4	51.1	0.498	5.6	130.6	80.0	0.933	10.1	135.8
UFV-5	55.3	0.528	7.3	132.2	92.7	0.923	10.6	138.5
Mean	70.0	0.673	8.2	135.8	91.9	1.051	11.1	141.4
C.V.[1]	1.0	5.600	5.4	0.3	0.5	5.200	3.6	0.3
M.S.D.[2]	1.1	0.063	0.7	0.7	0.8	0.092	0.7	0.7

[1] Coefficient of variation (%)
[2] Minimum significant difference (Tukey test. Significance level 5%).

TABLE 4 - Duration of soybean vegetative period from emergency to flowering (DVP, days) and plant height (PH, m) for two growing seasons (GS1 = Winter season 1984 and GS2 = Summer season 1984/1985) and respectively differences between growing seasons (GS1-GS2) at short photoperiod (12 hours). Federal University of Viçosa, Brazil.

Cultivated	DVP			PH		
Varieties	GS1	GS2	GS1-GS2	GS1	GS2	GS1-GS2
Cristalina	72.1	43.3	28.8	0.754	0.808	-0.054
Doko	81.9	50.6	31.3	0.687	0.778	-0.091
IAC-6	72.9	46.1	26.8	0.651	0.829	-0.178
IAC-7	81.3	44.1	37.2	0.644	0.807	-0.163
IAC-8	79.0	47.4	31.6	0.681	0.877	-0.196
Paraná	48.1	34.1	14.0	0.455	0.577	-0.122
Primavera	48.9	36.5	12.4	0.486	0.618	-0.132
Savana	73.3	43.1	30.2	0.657	0.708	-0.051
Tropical	88.4	57.7	30.7	0.926	1.131	-0.205
UFV-1	45.1	34.3	10.8	0.551	0.621	-0.070
UFV-4	44.4	36.5	7.9	0.425	0.603	-0.178
UFV-5	48.9	40.3	8.6	0.517	0.612	-0.095
Mean	65.4	42.8	22.6	0.620	0.747	-0.127
C.V.[1]	1.3	1.7	-	16.600	23.400	-
M.S.D.[2]	1.4	1.2	-	0.172	0.294	-

[1] Coefficient of variation (%)
[2] Minimum significant difference (Tukey test. Significance level 5%).

TABLE 5 - Duration of soybean vegetative period from emergency to flowering (DVP, days) and plant height (PH, m) for two growing seasons (GS1 = Winter season 1984 and GS2 = Summer season 1984/1985) and respectively differences between growing seasons (GS1-GS2) at long photoperiod (13 hours). Federal University of Viçosa, Brazil.

Cultivated	DVP			PH		
Varieties	GS1	GS2	GS1-GS2	GS1	GS2	GS1-GS2
Cristalina	92.7	65.3	27.4	1.003	1.433	- 0.430
Doko	100.1	70.3	29.8	1.025	1.581	- 0.556
IAC-6	91.8	65.7	26.1	1.013	1.671	- 0.658
IAC-7	94.6	62.6	32.0	0.872	1.396	- 0.524
IAC-8	85.6	64.4	21.2	1.084	1.696	- 0.612
Paraná	67.6	56.7	10.9	0.677	1.322	- 0.645
Primavera	65.5	58.4	7.1	0.711	1.475	- 0.764
Savana	93.5	63.1	30.4	0.827	1.246	- 0.419
Tropical	101.9	74.9	27.0	1.028	1.863	- 0.835
UFV-1	70.2	60.7	9.5	0.761	1.668	- 0.907
UFV-4	65.8	60.3	5.5	0.773	1.556	- 0.783
UFV-5	79.6	62.3	17.3	0.827	1.299	- 0.472
Mean	84.1	63.7	20.4	0.883	1.517	- 0.634
C.V.[1]	0.9	1.1	-	14.500	24.400	-
M.S.D.[2]	1.2	1.2	-	0.215	0.621	-

[1] Coefficient of variation (%)
[2] Minimum significant difference (Tukey test. Significance level 5%)

The duration of vegetative period was reduced from the winter to the summer growing seasons, independently of photoperiodic conditions. The enhancement of development rate reducing the juvenile period and anticipating flowering under summer growing season was probably result of the warmer temperatures. Despite the shorter juvenile and vegetative periods of summer growing season compared to winter growing seasons, higher temperatures favored growth of soybean resulting in higher plants in summer.

Under 12 hours daylength conditions during the first (Winter season 1984) and second (Summer 1984/1985) growing season, the average for the maximum, minimum and daily average temperature were 31.8°C, 15.0°C and 23.4°C, and 33.1°C, 22.1°C e 27.6°C. respectively. The differences between growing seasons for vegetative period and daily average temperature were 22.6 days and 4.2°C. The ration of both values indicates that a increase in 1.0°C resulted in 5.4 days anticipation for flowering under short-day conditions.

Under 13 hours daylength conditions during the first (Winter season 1984) and second (Summer 1984/1985) growing season, the average for the maximum, minimum and daily average temperature were 31.0°C, 15.2°C and 23.1°C, and 34.0°C, 22.3°C e 28.2°C. respectively. The differences between growing seasons for vegetative period and daily average temperature were 20.4 days and 5.1°C. The ration of both values indicates that a increase in 1.0°C resulted in 4 days anticipation for flowe-ring under short-day conditions (12 hours).

CONCLUSIONS

- The vegetative period from emergency to flowering and the juvenile period are significantly affected by the photoperiod and temperature differences. Shorter photoperiods or higher temperatures anticipate flowering.

- Longer photoperiods under the same temperature regime or higher temperature under the same photoperiod regime result in higher plants.

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