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Chia flowering season prediction using day length data of 11 selected locations

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ABSTRACT

Chia (*Salvia hispanica* L.) is an annual herb of the Lamiaceae family. In pre-Columbian times, its seeds were one of the basic foods of Central American civilizations. Recently, chia seed has been given an important role in human health and nutrition, because its ω-3 fatty acid content promotes beneficial health effects. Efforts to incorporate chia into modern agriculture only began in 1990. However, a number of chia plantations have failed lately in Northwestern Argentina, Southeast Bolivia and South Paraguay, because the fact that chia shows a short-day response to flowering and is not a frost-resistant plant has been overlooked. This technical note aims to determine the photoperiod needed for chia flowering, apart from predicting its flowering season when there are not any chia production records. The results collectively indicate a relatively narrow set of conditions for optimal chia flowering, with optimal flowering considered to be the case of fast-developing plants with many flower buds and a satisfactory height. Chia plants were only able to flower when day length was shorter than 12:27 hours. This suggests a critical day length that ranges between 12 and 13 hours.

Key words: *Salvia hispanica* L., chia, flowering, photoperiod, length of day.

RESUMEN

Predicción de la época de floración utilizando los datos de duración del día en 11 localidades elegidas

La chía (*Salvia hispanica* L.) es una hierba anual de la familia Lamiaceae. En tiempos precolombinos, la semilla de chía era uno de los alimentos básicos de las civilizaciones centroamericanas.

Recientemente, las semillas de chía han adquirido un rol importante en la salud humana y la nutrición debido a que su contenido de ácidos grasos omega-3 produce efectos benéficos para la salud. Los esfuerzos para incorporar la chía a la agricultura moderna empezaron en 1990. Últimamente, sin embargo, algunas plantaciones de chía fracasaron en el noroeste de la Argentina, sudeste de Bolivia y sur de Paraguay, debido a que se ignoró el hecho de que con días cortos, la chía muestra una escasa respuesta a la floración y no es una planta resistente a las heladas. Esta nota técnica apunta a determinar el foto-período que necesita la chía para florecer y a predecir la época de floración, cuando no hay disponibles registros de producción de este cultivo. En conjunto, los resultados indican que son relativamente escasas las condiciones necesarias para que la planta de chía alcance una floración óptima, entendida como un rápido desarrollo de las plantas, una altura satisfactoria de estas y la emergencia de muchos pimpollos florales. Las plantas de chía solo pudieron florecer cuando la duración del día fue inferior a las 12:27 horas, lo que sugiere que la duración crítica del día oscila entre las 12 y 13 horas.

Palabras clave: *Salvia hispanica* L., chía, floración, foto-período, duración del día.

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INTRODUCTION

Chia (*Salvia hispanica* L.), an annual herb that belongs to the Lamiaceae family, constituted one of the basic foods in Central America before the Spanish conquest (Ayerza [h.] and Coates, 2005a). Together with corn, beans, and amaranth, chia seeds were daily consumed by more than 11 million people when Columbus arrived in America. Chia seeds were also part of holy ceremonies, as an offering to the Nahua gods (Sahagun, 1579).

Chia oil contains one of the highest known concentrations of α-linolenic fatty acid, namely up to 66.2% (Ayerza [h.], 1995, 2009). Its ω-3 fatty acid contents have beneficial effects on health (Ayerza [h.] and Coates, 2005b; Vuksan *et al*., 2007), so chia has come to be a greatly appreciated component of human nutrition.

Attempts to include chia as part of modern agriculture began in 1990, with the Northwestern Argentina Regional Project (Ayerza [h.], 1995; Ayerza [h.] and Coates, 1996). However, there have been reports of the failure of some chia plantations in Northwestern Argentina, Southeast Bolivia and South Paraguay, mainly because farmers have not considered the fact that chia shows a short-day response to flowering and is not a frost-resistant plant.

This technical note is based on studies which aimed to establish the photoperiod that chia requires for flowering, apart from predicting its flowering season where no chia production records are available.

MATERIALS AND METHODS

Chia flowering season was predicted using data from experimental and commercial fields in Salta (24°51' South latitude), a province in Argentina. Day seven is considered to be the earliest date at which chia flowers start blooming, and it is estimated using the average value calculated from observations made for a number of years.

Day length for each selected location was determined with data from the U.S. Naval Observatory of the Department of the Navy, Government of USA (Naval Observatory, 2012), and length of day seven of each month was used to characterize all the remaining days of the month. The same day length values were observed for the selected places when comparing these data.

The accuracy of this day length assumption was checked against the field data collected at each place. Locations for this study are mentioned in Table 1.

RESULTS

Predictions of both flowering season and planting season are presented in Table 1.

Flowering season

Depending on individual yearly characteristics, including number of cloudy, sunny and rainy days, flowers can start to bloom as early as March 30, when day length is 11:42 hours (limit of tolerance: up to 12:27 hours of light) (Table 1). This does not apply between 04° 00' North and

Table 1. Chia flowering season prediction table.

Site	Latitude	Elev.	Jan. 7	Feb. 7	Mar. 7	Apr. 7	May-07	Jun. 7	Jul. 7	Aug. 7	Sep. 7	Oct. 7	Nov. 7	Dec. 7
		m	Hours and minutes[3,4]											
Salta[2], Arg.	24°51' S	1170	13:38	13:06	12:27	***11:42***	***11:03***	***10:39***	10:39	11:05	11:45	12:28	13:10	13:37
Perico[2], Arg.	24°13' S	936	13:34	13:04	12:26	***11:42***	***11:05***	***10:41***	10:42	11:07	11:45	12:27	13:08	13:35
Anta M[1], Arg.	22°50' S	400	13:28	13:00	12:25	***11:43***	***11:08***	***10:47***	10:47	11:11	11:47	12:27	13:03	13:28
Acatic[2], Mex.	20°40' N	1680	10:57	11:20	11:51	12:28	13:00	13:21	13:20	12:58	12:25	***11:50***	***11:17***	***10:56***
S. Cruz[2], Bol.	17°48' S	437	13:09	12:48	12:20	***11:49***	***11:23***	***11:06***	11:06	11:24	11:51	12:21	12:51	13:09
Atitlan[2], Gua.	14°34' N	1600	11:19	11:35	11:56	12:21	12:43	12:58	12:57	12:42	12:19	***11:55***	***11:32***	***11:18***
Ica[2], Peru	13°01' S	396	12:52	12:40	12:33	***11:53***	***11:34***	***11:23***	11:23	11:36	11:55	12:17	12:39	12:52
Managua[2], Nic.	12°07' N	300	11:27	11:40	11:58	12:19	12:37	12:49	12:48	12:36	12:17	***11:57***	***11:38***	***11:27***
Maracay[1],Ven.	10°15' N	436	11:33	11:44	11:59	12:17	12:32	12:42	12:42	12:31	12:15	***11:59***	***11:43***	***11:33***
Cali[2], Col.	03°22' N	920	***11:56***	***12:00***	***12:04***	***12:10***	***12:15***	***12:19***	***12:19***	***12:15***	***12:09***	***12:04***	***11:59***	***11:56***
S. Dom.[1], Ecu.	00°07' S	1200	***12:08***	***12:07***	***12:07***	***12:06***	***12:07***	***12:07***	***12:07***	***12:07***	***12:06***	***12:07***	***12:07***	***12:08***

[1]: chia is (or was) under experimental cultivation; [2]: chia is (or was) under commercial cultivation; [3]: underlined values indicate month when sown; [4]: italic-bold numbers indicate flowering months, and those with slashed cells indicate a risk of frost before the crop matures.

04° 00' South latitude, where flowers open all year round, as confirmed in both experimental and commercial plantations in Cauca Valley, Colombia.

Sowing months were selected according to the predicted flowering season (Table 1). This season corresponded with day length, but this did not imply that no frosts occurred in the period. There could have been some days when there was a risk of frosts taking place.

In general, when the apical meristem of the plant is committed to flowering, its fate becomes irreversible (Bernier, 1988), although flower or inflorescence reversion to vegetative growth can also occur spontaneously in some species, as is the case of the chia plant. This can happen when plants are subjected to certain specific photoperiod or temperature regimes which favor vegetative development (Battey and Lyndon, 1990).

In chia, as in other crops such as soybean, photoperiod is the environmental factor that most influences floral development rate. Accurately predicting days to flowering is important, because time between emergence and flowering determines plant size, thus affecting dry matter production and final crop yields (Coates and Ayerza [h.], 1996; Wang *et al*., 1997).

CONCLUSIONS

These results showed that chia plants could only bloom when day length was shorter than 12:27 hours, thus suggesting a critical day length for chia flowering that stretched from 12 to 13 hours. They also showed that a narrow set of conditions allowed having fast-developing plants with several flower buds and a satisfactory height.

Multi-location and multi-year trials are required to confirm these results, understand the biochemical bases for these phenomena, and generate more information. Meanwhile, the results presented in this note can be considered as a guide to identify potential areas for growing chia crops.

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