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Effect of Sowing Date on Growth and Development of Thai Hemp (*Cannabis sativa* L.)

Thitivara Sengloung[1]*, Lily Kaveeta[1] and Weerachai Nanakorn[2]

ABSTRACT

A field trial of Thai hemp was conducted at the Queen Sirikit Botanic Garden, Chiang Mai province, northern Thailand, with plantings at a density of 25 plants m^{-2} during July, August, September and October 2004 to determine the effect of sowing date on hemp growth and development. The flowering time of all treatments started in October the same year. Plant height declined (205, 180, 130 and 95 cm) and diameter declined (11.95, 8.17, 8.00 and 3.90 mm) from the earliest planting date, respectively. An earlier sowing date allowed a longer vegetative period, which in turn produced a longer stem. The commencement of flowering was a factor that ended plant height growth. Late planting reduced stem length and the time when plants ended their growth, with less time needed to change from the vegetative to the reproductive phase for the late planting. Phyllotaxis changed from 5.86 to 6.33 leaf pairs. The ratio of male to female plants was 57.68: 42.32. The results also indicated that the planting time for hemp in Thailand should be before July and August, to produce appropriate growth and development.

Key words: hemp, *Cannabis sativa* L., growth, development, phenology

INTRODUCTION

Hemp (*Cannabis sativa* L.) is a quantitative short day plant. The flowering is induced by short days and genetically controlled; the actual time of floral initiation is modified by weather, site conditions and management practices (Kozlowski and Pallardy, 1997; Lisson and Mendham, 2000). The photoperiod for hemp has been reported ranging from 9 h (Heslop-Harrison and Heslop-Harrison, 1969) to 14 h (Borthwich and Scully, 1954; Lisson *et al.*, 2000a; Lisson *et al.*, 2000b; Lisson *et al.*, 2000c). The photoperiod variation depends upon the hemp variety and the local climate.

Hemp fiber yield is from the stem bark. Thus, research has aimed to prolong the vegetative stage for high fiber yield production, before stem elongation terminates after flowering. The variation of hemp in phenological development and in stem elongation studied by de Meijer and Keizer (1994), found large variation in the day of anthesis and the day of seed maturity. The critical photoperiod for induction of flowering increases with altitude adaptation and the latitude where hemp is planted. Until now, most of the current hemp research has been in the temperate region where the seasons and climate differ from the tropical region.

[1] Department of Botany, Faculty of Science, Kasetsart University, Bangkok 10900, Thailand.
[2] Queen Sirikit Botanic Garden, Mae Rim, Chiang Mai 50180, Thailand.
* Corresponding author, e-mail: thitivara@hotmail.com

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Before flower initiation takes place, some vegetative growth must have occurred. The minimum leaf numbers that must form before floral initiation are different in each species (Vince-Prue, 1975). As hemp grows, the leaf orientation changes from opposite to alternate (Schaffner, 1926; Mediavilla *et al.*, 1998; Lisson and Mendham, 2000; van der Werf *et al.,* 1995). This phyllotaxis change in hemp was first reported by Schaffner (1926), who observed that plants in continuous light all changed from opposite to alternate phyllotaxis at the 7th, 8th or 9th leaf node, without any noticeable change in leaf character. Based on this classic work, hemp was described as having an alternate phyllotaxis, with later work using the term 'spiral' instead of 'alternate' (Allaby, 1992; Croft, 2005). This phenological character is a signal that reproductive growth had started. The number of opposite leaves in hemp refers to the minimal leaf number for the vegetative phase in this species.

Thai hemp cultivation is part of the history of the Hmong hill tribe people in northern Thailand. Although hemp was known to have good fiber quality (Nanakorn, 2002; Sengloung *et al.*, 2008), its physiology was limited due to a lack of scientific information on hemp cultivation in Thailand. The objective of this research was to provide information on the growth pattern of hemp under local climatic conditions, which will be useful in identifying the most suitable planting period for Thai hemp.

MATERIALS AND METHODS

Planting location and cultivation

Thai hemp was planted in an experimental field of the Queen Sirikit Botanic Garden (QSBG), Mae Rim district, Chiang Mai province, Thailand, located at 800 m above mean sea level. The planting site had a sandy, clay-loam soil texture, a soil pH of 5.63 and an organic matter content of 6.10%.

The experiment was based on four sowing dates in 2004. Hemp was sown on 27 July (S1), 21 August (S2), 13 September (S3) and 15 October (S4). The planting area was 5 × 5 m^2 for each sowing date, with the plant density of each treatment controlled at 25 plants m^{-2}. Each area was manually weeded and sprayed with insecticide (carbofuran) before planting.

The hemp was grown under natural precipitation, with the rainy season usually lasting from May until September. During this season, the average temperature was 27-29°C. After October, both rainfall and temperature decreased. Precipitation in Chiang Mai province averaged 1208 mm in 2004. The photoperiod was 11-13 h.

Data collection and analysis

The number of visible leaves, leaf orientation, plant height, diameter at 10 cm above ground (D_{10}) and stage of development of 20 plants of each treatment were recorded on a weekly basis. The selected plants in each treatment were monitored for flower development and the appearance of sexual stages. Floral development was defined in four stages: vegetative growth, male flowering, female flowering and seed development. Vegetative growth was the period from the date of sowing to the appearance of the first male flower. Male flowering was the period from the appearance of the first male floret to 95% male flowering. Female flowering was the period from the appearance of the first female floret to 95% female flowering. Seed development was the period from the appearance of the first seed to seed maturity. These developmental stages were defined according to Mediavilla *et al.* (1998) and the detail of growth stages in this study is described in Table 1.

The growth curve of height and diameter was similar to the hypothetical curve studied by de Meijer and Keizer (1994). A logistic equation (Equation 1) for growth was fitted using the PlantPV software (Chuai-Aree *et al.*, 2006).

Table 1 Stages of development of hemp following Mediavilla *et al*. (1998).

Stage	Description	Mediavilla's code
Vegetative	From date of sowing to first flower appearance	0000 to 2001
Male flowering	First male flower appearance to end of pollination	2100 to 2103
Female flowering	First female flower appearance to stigma wilt	2200 to 95% stigma wilt
Seed development	Stigma wilt and ovule enlargement to seed maturity	95% stigma wilt to 2205

$$G(t) = U / (1 + e\,M\,(T - t)) \qquad (1)$$

Where G (t) = stem length(cm) or diameter (mm) at day t

U = maximum length or diameter of stem

M = slope coefficient (day^{-1}) at point T

T = curve inflexion point (day) at 50%

RESULTS AND DISCUSSION

Plant growth

Three days after the sowing date, the cotyledons appeared. At this time, the height of the hemp seedlings was less than 10 cm and thus, it was not possible to measure the diameter at 10 cm height until the second week. The plant height and diameter of hemp at maturity planted on the four sowing dates was different. The average plant height at maturity (Figure 1) declined (205, 180, 130 and 95 cm) and D_{10} (Figure 2) declined (11.95, 8.17, 8.00 and 3.90 mm) from S1 to S4, respectively. The growth chart showed that stem elongation was terminated at the flowering time when hemp growth changed from the vegetative to the reproductive phase.

After fitting the curves of height and diameter by a logistic equation, analysis showed that the growth parameter values of height and diameter (Figures 3 and 4) for the four sowing dates declined according to the lateness of sowing. According to the growth parameters, late planting: reduced maximum stem height (U), shortened the time until plants stopped growing (T), and reduced the time (M) plants spent to change their development from the vegetative to the reproductive phase. This meant that late planting would give reduced stem growth. The proper harvesting time was considered to be from the

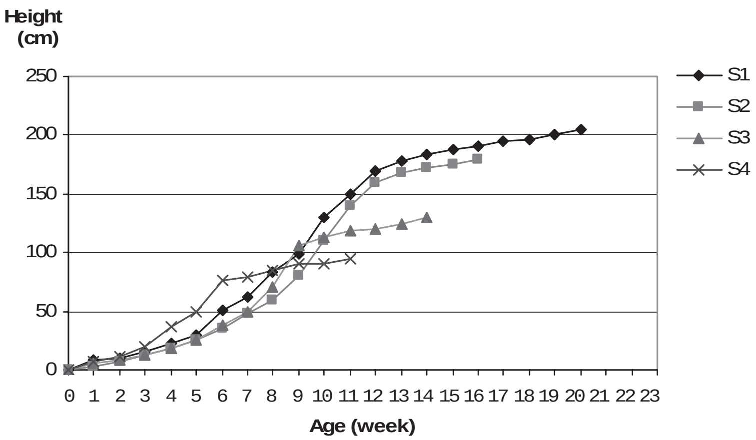

Figure 1 Plant height of hemp plant from four sowing dates (27 July, 21 August, 13 September and 15 October, 2004) grown at Queen Sirikit Botanic Garden.

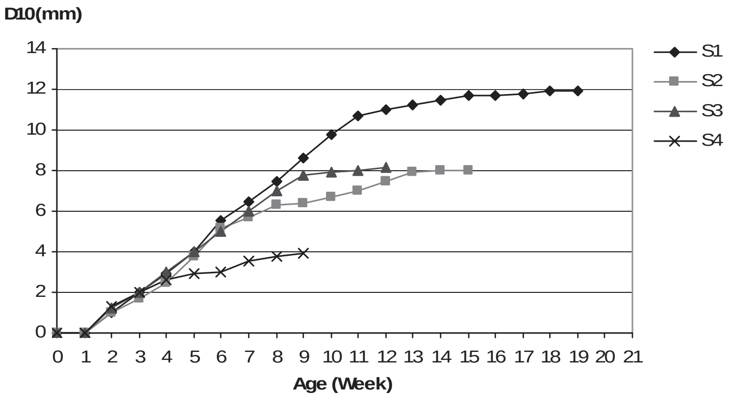

Figure 2 Diameter at 10 cm above ground (D_{10}) of hemp from four sowing dates (27 July, 21 August, 13 September and 15 October, 2004) grown at Queen Sirikit Botanic Garden.

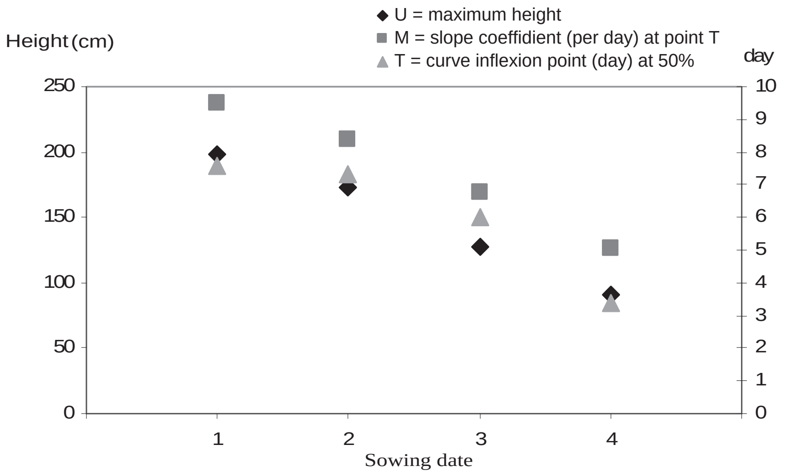

Figure 3 Parameters of plant height from the calculations based on four sowing dates for hemp grown in 2004 at Queen Sirikit Botanic Garden.

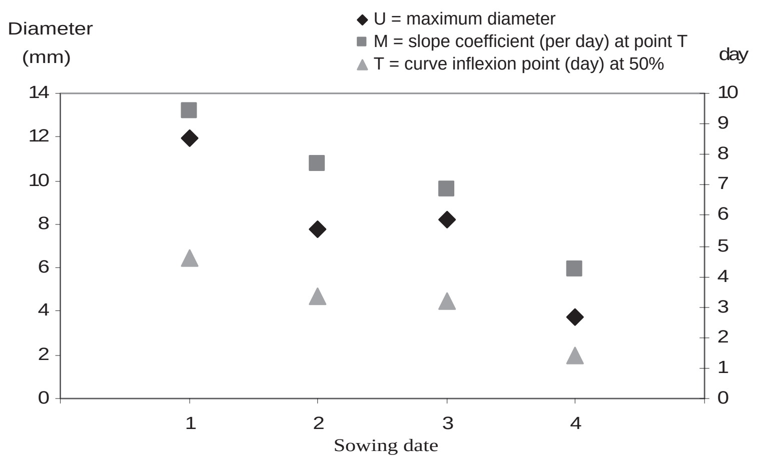

Figure 4 Parameters of plant diameter from the calculations based on four sowing dates for hemp grown in 2004 at Queen Sirikit Botanic Garden.

flowering stage (Mediavilla *et al*., 2001) to the seed maturity stage (Keller *et al*., 2001), thus, an early sowing date would allow a long vegetative period, which would give a positive result in increased stem growth.

Number of leaf appearance

The phyllotaxis change occurred at 5.86 to 6.33 leaf pairs but the leaf orientation of S4 changed from opposite decussate to spiral immediately at inflorescence. Plants changing into the flowering period had dense and short internodes instead of opposite leaves at the terminal shoot. The results from this experiment agreed with the result reported by Schaffner (1926) that the changes in phyllotaxis were induced after the fourth leaf node. However, the degree of changing might be different due to climatic variation during the growing season and the sensitivity of each variety.

The number of leaf appearance increased at the time of flowering, when the stem height growth changed to its stationary phase. This effect was influenced by the change in the growth pattern from the vegetative to the reproductive phase; the energy from photosynthesis was focused on the reproductive organs (Kozlowski and Pallardy, 1997). At the end of plant height growth, the number of leaves increased immediately (Figure 6).

Effect of sowing date on development of hemp

The period of vegetative growth lasted from the sowing date to the first appearance of a male floret, the male flowering period was from the first appearance of a male floret to end of pollination, and the female flowering period was from the first detection of a female floret to stigma wilt. The seed development period was from stigma wilt to seed maturity. The stage of development considered in this study was a field stage, which focused on the development of the hemp fiber.

The flowering period was a time when the height changed from a lag phase to a stationary phase. This relationship between plant height and flower development occurred in all treatments (Figure 7). The maximum stem height from S1 to S4 declined dramatically. The relationship between longevity of each development stage and stem height was revealed for the vegetative period, male flowering, female flowering and seed development as the area under the height curve. The longevity of vegetative period depended on how early the sowing date was, for harvesting carried out at flowering, which was recommended as the stage of fiber maturity (Bennett *et al*., 2006; Sengloung, 2009).

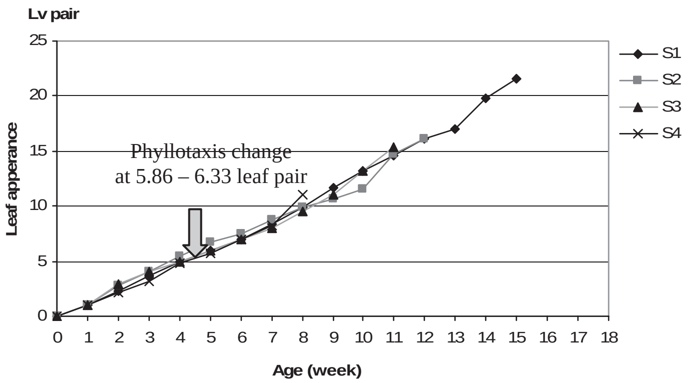

Figure 5 Phyllotaxis change and number leaf appearance of hemp from four sowing dates grown in 2004 at Queen Sirikit Botanic Garden.

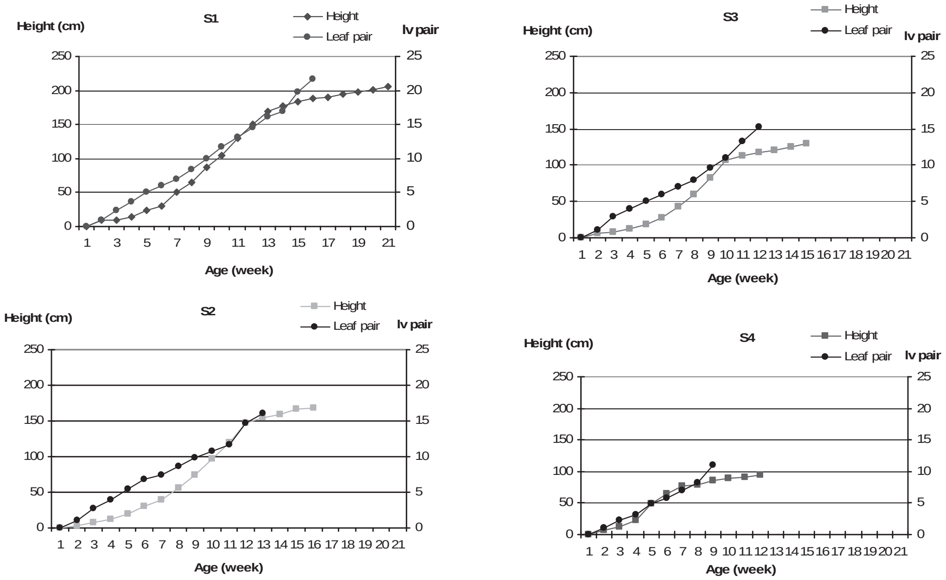

Figure 6 The relationship between number of leaf pairs and height of hemp from four sowing dates grown in 2004 at Queen Sirikit Botanic Garden.

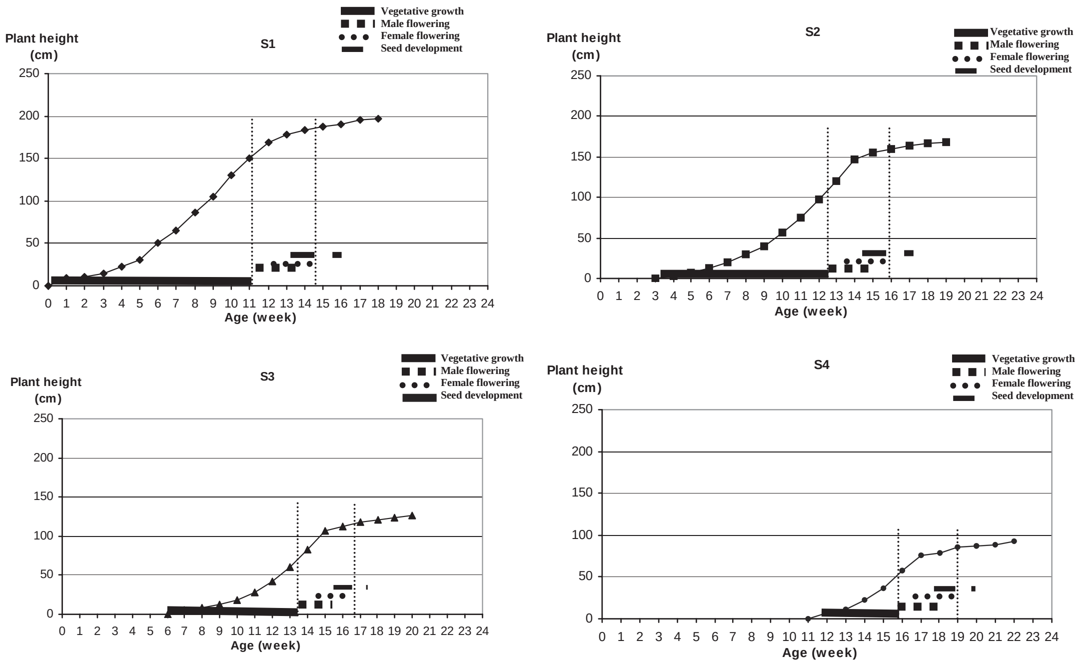

Figure 7 The relationship among plant height and field development of hemp from 4 sowing date at ueen Sirikit Botanic Garden. Week 1 started on 27 July, 2004

When plants have a long vegetative phase, the energy available to produce reproductive organs will increase (Kozlowski and Pallardy, 1997). Although the number of florets, seed and fiber yield were not recorded in this experiment, the numbers of visible seed and florets of the S1 plants were much higher than for S4 (data not shown). Minimal flowering was observed when the time from emergence to flowering was short. This was related to low yields (Amaducci *et al*., 1998, 2008; Cromack, 1998; Sankari, 2000; Struik *et al*., 2000). At the seed-ripening stage, the final sex ratio of male to female plants was 57.68 to 42.32 and there were no monoecious plants in the population.

The different sowing date had an effect on both the vegetative and reproductive growth of Thai hemp. Late planting reduced the vegetative period and induced a faster reproductive phase. Photoperiod that induced the flowering of Thai hemp was approximately 11 to 12 h. When the planting time was delayed over the four-month period, the vegetative period from sowing date to inflexion point was reduced by 12, 11, 9 and 6 weeks, respectively (Table 2). This result was similar to the experiment by Amaducci *et al*. (2008) who pointed out that a large variation in flowering duration was influenced by the time of emergence in monoecious and dioecious hemp. Time from emergence to 50% flowering decreased when sowing was postponed. This was in accord with a long basic vegetative phase (BVP) and the high sensitivity to the photoperiod.

The study of flowering response to photoperiod in the Kompolti and Futura 77 hemp hybrids produced results typical for a quantitative short-day plant (Heslop-Herrison and Heslop-Herrison, 1969). Lisson *et al*. (2000a) pointed that the sensitivity of flowering in hemp to photoperiod has a number of implications in the cultivation of this crop, especially at low latitudes. Future research could cultivate Thai hemp in the highlands and cooler areas of Thailand in order to study plant adaptation and the response to the photoperiod.

CONCLUSION

The results of the study of Thai hemp grown under natural conditions clearly showed that the critical photoperiod of Thai hemp was between 11 and 12 h. Late sowing after July would reduce the plant height of hemp. Longer vegetative periods allow greater stem elongation. Planting early in July is recommended for hemp cultivation in Thailand with natural precipitation.

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Table 2 Photoperiod during the experiment at Queen Sirikit Botanic Garden.

Sowing date	Photoperiod at the beginning (h)	Photoperiod at inflexion point (h)	Vegetative period* (week)
S1	13.01	11.42	12
S2	12.46	11.27	11
S3	12.26	11.21	9
S4	11.59	11.10	6

* The vegetative period lasted from the planting date to the date of the inflexion point.

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