Strawberry Flowering Induction by Artificially Low Temperature and Day Light

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***Abstract*—** Strawberry growing for tourist attraction is becoming popular in the Northeast of Thailand. However, the temperature in this area is normally too high for naturally flowering induction. The objective of this research is to induce flowering of strawberry by artificial light and low temperature. Three treatments of different temperature and day light conditions were compared: 1) natural conditions, 2) greenhouse conditions and 3) cold room conditions. It was found that 53% of strawberry plants induced under the cold room conditions flowered at 4 weeks, while none of strawberry plants from the natural and green house conditions flowered. At 8 weeks, cold room and natural conditions produced similar number of flowering plants (about 70 %), while green house conditions had lower number (about 30 %). After 11 weeks, almost strawberry plants from all conditions flowered. However, the number of flowers of strawberry induced under cold room conditions was much higher.

***Index terms*—** Strawberry cv. Prarachatan 80, Flowering induction, Temperature, Photoperiod

I. Introduction

Strawberry (*Fragaria x ananassa* Duch.) is popularly cultivated in many countries around the world. It is remarkable feature of the scent, bright red, sweet and juicy fruits [1]. It is an economic plant that can provide the returns in the short term [2]. In Thailand the major strawberry growing area is in the North [3] and on the highlands of some provinces in the West and North East [4]. The cold climate is an ideal condition for growth, flowering and productivity of strawberry. Temperature and photoperiod are very important factors for strawberry flowering. It can be characterized based on the responses to temperature and photoperiod into 3 groups: 1) Every bearing strawberries flower under a long day condition, 2) Day-neutral strawberries flower throughout the growing season as long as temperatures are optimal, and 3) June bearing cultivars require low temperature and short day length for flowering [5], [6]. When temperatures and day length are over their critical points, June bearing strawberry will not generate flower buds. The critical temperature and day length for flowering are dependent on cultivars. Florence, Frida and Koronaare are June bearing cultivars. However, Florence and Koronaare flower under the night temperature between 9-18 ˚C, while Frida flower at 15 ˚C [7]. When Strawberry was grown under night temperature of 9, 12, 15 and 18 ˚C with 12 hours of day length for a period of 3 and 5 weeks, it was found that all temperatures could induce strawberry flowering in 3 weeks, but in 5 weeks, temperature of 9 ˚C interrupted strawberry flower bud initiation. It was also found that Tokoyoka and Tioga grown under average night temperatures of 15-17 ˚C with 16 hours day length for 25 days flowered 100% and 63.3% respectively [2].

Prarachatan 80 is a June bearing cultivar which is currently the most popular growing cultivar in Thailand due to its large fruits and good quality i.e. juicy, less fiber, soft skin, good smell and test [3], [8] as well as its widely adaptability to various environmental conditions. Further than cultivation for fresh consumption and industrial processing, this cultivar is also cultivated for the tourist attraction in many areas including the Northeast. The growing period of strawberry in the Northeast is in winter (November - January). Due to the very short winter season in this area, strawberry flowering bud induction has to be done during the seedling stage (September to October) before transplanting in November in order to flower and produce fruits in December and January. However, the temperature in this area during September to October is too high for flowering bud induction. The average maximum and minimum temperatures during this period, which are well above the temperature required to induce strawberry flowering, are 33 and 30 ˚C respectively. Most of strawberry growers in this area have to buy the seedlings from the North of Thailand where the temperature is lower during the same period. The average minimum and maximum temperature from a major seedling production area such as Chiang Mai are 23.6 ˚C and 30.1 ˚C. In some areas of the North, seedlings were produced on the high lands where temperature is lower than low land areas. Therefore, the quality of runner plants is very different depending on the production areas and weather conditions. The production on the highlands with lower temperature usually yields better quality of seedlings than that in the lower plain areas. However, the cost and damage from transportation are major drawbacks of high land seedling production. In order to produce the good quality seedlings with readily flowering bud induction in the lowland areas of the Northeast, artificially cold temperature and light would be required.

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II. Material And Mathods

2.1 Plant material

The seedlings of Strawberry cv. Pharachatan 80 were produced during August - September in 2015, under the greenhouse (Evaporative cooling system) with the temperature of 25-30 ˚C.

2.2 Experimental design

The experimental design was completely randomize design (CRD) with 3 replications, each with 20 seedlings. Treatments consisted of 3 different flowering induction conditions: 1) Natural conditions, 2) Greenhouse conditions with day/night temperature of 30/25 ˚C and 3) Cold room conditions with day/night temperature of 20/15 ˚C. Both natural and green house conditions received the sun light of about11 hrs./day while controlled room conditions received light from the fluorescent lamp with the light intensity of 160 $\mu mol.m^{-2}.s^{-1}$ at 10 hrs./day.

In October, sixty uniform seedlings were selected and placed in different conditions for a period of 20 days. Water and complete plant nutrient solution were applied daily. After 20 days of induction, all seedlings were transplanted in the 6x6 inch pots filled with coir dust and grown in the greenhouse with day/night temperatures of 25/20 ˚C, which is similar to the average temperature during that period. Complete plant nutrients were applied through drip irrigation every day.

2.3 Data collection

The growth parameters including plant height, leaf number and leaf area at 4 weeks after transplanting were recorded. Plant height was measured from the base to the end of the leaf canopy. Leaf area was calculated as follows;

$$LA = LI \times LN \quad (1)$$

$$LI = MBA \times 3 \quad (2)$$

$$MBA = (W \times L) \times 0.75 \quad (3)$$

Where LA is mean of leaf area

LI is mean of leaf index

LN is leaf number

MBA is mean of middle blade area of small third leaf from the top

W is width of leaf blade

L is length of leaf blade

Flowering response was recorded on day to flowering, number of flowering plants, number of flowers per plant and the length of flower truss. All characters were measured at 4, 8 and 11 weeks after transplanting except the length of flower truss were recorded only 11 weeks. All data were subjected to analysis of variance by SPSS for Window (version 16.0) and means were compared by Least Significant Difference (LSD).

III. Results

3.1 Growth

At 4 weeks after transplanting, leaf number was not significantly different between treatments but plant height was the greatest under cold room conditions. Both leaf index and leaf area per plant were greater under cold room and greenhouse than under natural conditions (Table 1).

Table I: Effects of different induction conditions on plant height, leaf number, leaf index and leaf area at 4 weeks after transplanting

Induced conditions	Plant height (cm)	Leaf number	Leaf index	Leaf area (cm^3/plant)
Natural	17.3b	6.0	29.6b	170b
Greenhouse	18.5b	6.0	79.8a	483a
Cold room	22.0a	5.6	105.8a	586a
CV(%)	4.41	22.6	33.5	33.6

Means in the same column followed by the common letters are not significantly different at p <0.5 by LSD.

3.2 Flowering

At 4 weeks after transplanting, induction under cold room conditions resulted in 50 % of flowering plants while under the natural and green house conditions, none of the plants flowered (Fig. 1a). At 8 weeks, cold room and natural conditions produced similar number of flowering plants (about 70 %), while green house conditions had lower number of flowering plants (about 30 %). At 11 weeks all conditions produced about 80-90 % of flowering plants.

The number of flowers per plant was recorded and averaged only on the plants with flowering. It showed that number of flowers per plant was more in the plants induced by the cold room conditions in all recorded periods than under other conditions. (Fig. 1b).

Table 2 showed days to flowering and the length of flower truss. Induction under cold room condition, the plants flowered 50 % within 48 days after transplanting, while it took 62 days for the plants to flower 50 % when they were induced under green house and natural conditions. The flower truss was significantly longer in plants induced under cold room than under greenhouse and natural conditions.

Table II: Effects of different induction conditions on day to 50 % flowing and length of flower truss

Induced conditions	Days to 50% flowering	Length of flower truss (cm)
Natural	62a	8.4b
Greenhouse	62a	7.9b
Cold room	48b	11.2a
CV(%)	25.4	36.2

Means in the same column followed by the common letters are not significantly different at p. <0.5 by LSD

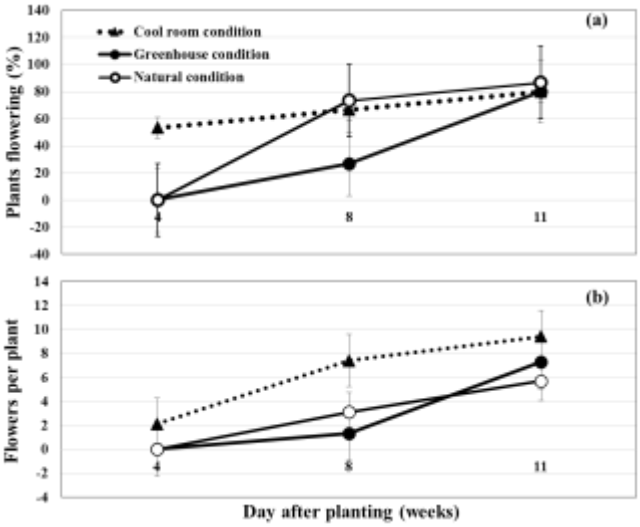

Fig. 1. Effects of different induced conditions on number of flowering plants (a), and flowers per plant (b). Vertical bars denote S.E.

IV. Discussion

The cold condition during vegetative period is required for floral induction and/or early flowering in many floriculture species. Cold requiring species usually need several days, weeks and months at temperature of 1-6 ˚C [9]. However, flowering can be induced by higher temperatures at 15-20 ˚C in species such as strawberry [2].

The experimental results clearly illustrated that strawberry plants flowered faster and produced more flowers when the seedlings were pre-induced under cold room conditions. The results also showed that seedlings induced under natural conditions flowered faster (8 weeks) than under greenhouse conditions (11 weeks) (Fig. 1a). Pharatchatan 80 is the June bearing type strawberry which requires low temperature and short day length for flowering induction. However, in all conditions of this experiment, photoperiods (11 hrs./day for natural and greenhouse and 10 hrs./day for cold room) were shorter than 12 hrs./day i.e. the critical day length for this variety. Therefore the temperature difference among the three conditions is the only factor responsible for the variation in flowering patterns.

The day/night temperature under natural conditions during the experimental period was fluctuated with the average of about 35/29 ˚C. However, the lowest night temperature was recorded at 20 ˚C in some nights while the temperature was more constant with lower average under greenhouse conditions (about 30/25 ˚C). The temperature under cold room condition was constant at 20/15 ˚C. The result showed that the temperature of cold room was suitable for flowering induction in cv. Pharachatan 80 as it could induce faster flowering and produce more flowers. This result is in agreement with the previous study which reported that cv. Prarachatan 80 required temperatures at 16-20 ˚C for 30 days to flowering [8].

Even though the average temperature under greenhouse condition was lower than under natural condition, strawberry induced under natural condition flowered more than under greenhouse conditions at 8 weeks after transplanting (Fig. 1a). This might be due to the fact that the lowest temperature of natural conditions which occurred in some nights (20 ˚C) was lower than the lowest temperature of greenhouse condition (about 25 ˚C). The lowest temperature of natural conditions (20 ˚C) is close to the critical temperature for flowering of this cultivar [8].

At 11 weeks, in all conditions, strawberry flowers more than 90 %. This was because strawberry plants already accumulated enough low temperature from the current growing conditions to stimulate their flowering. Even though at 11 weeks, almost strawberry plants from all conditions flowered, the number of flowers of strawberry induced under cold room conditions was much higher (Fig. 1b). Not only the flowering responded best to cold room conditions, growth characters including plant height and leaf area were also promoted with the cold room conditions (Table 1). These results are consistent with the results of other studies with the same genus plants [10]. Growth and the number of flowers are usually directly correlated with productivity. The strawberry yield could not be determined in this study because it was done under controlled greenhouse condition without cross pollination from natural insects. However, the results implied that the cold room conditions would induce strawberry seedlings to produce faster and higher berry yield than other conditions.

It was observed that strawberry seedlings from the North, grown under the same conditions of this experiment, flowered about 30 % at 4 weeks after transplanting while strawberry seedlings induced under cold room flowered 53 % at the same time. The lower flowering of strawberry from the North might be due to the damage from transportation (Fig. 2) or incomplete flowering induction. Whatever the reason, it showed that cold room induction produced better seedlings than those produced in natural conditions of the main production areas and transported to the Northeast. The other advantage of producing seedlings in the growing area of the Northeast is the low transportation cost. However, induction with cold temperature involves the once time investment of the cold room facilities and the varied cost of power supply. This must be further evaluated in terms of costs and returns at the commercial scale.

Fig. 2 - The damage of strawberry seedlings transported from the high land areas of the North.

V. Conclusion

The current research indicated that strawberry cv. Prarachatan 80 flowered faster and produced more flowers when the seedlings were induced under cold room conditions than those induced under natural or greenhouse conditions. The strawberry plants induced under the cold room conditions were also taller and had more leaf areas. To produce good quality strawberry seedlings with readily flowering bud induction in the lowland areas of the Northeast, artificially cold temperature and light is required.

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