International Journal of Agricultural Technology 2018 Vol. 14(7): 1141-1146
Available online http://www.ijat-aatsea.com
ISSN: 2630-0613 (Print) 2630-0192 (Online)

Response of biomass and yield of Stevia (*Stevia rebaudiana* Bertoni.) to flower removal

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Chumthong, B. and Detpiratmongkol, S. (2018). Response of biomass and yield of Stevia (*Stevia rebaudiana* Bertoni.) to flower removal. International Journal of Agricultural Technology 14(7): 1141-1146.

Abstract It has never been reported on the effect of flower removal on the yield of Stevia plant. The effect of flower removal on growth and yield of Stevia was studied. Reesults revealed that flower removal produced significantly (P=0.05) greater number of leaves, dry biomass yield and leaf dry weight yield compared to the control. Four times of flower removal plant gave the highest number of leaves (1,318.50 plant^{-1}), total biomass dry weight (11.31 g plant^{1-}) and leaf dry weight yield (0.81 t ha^{-1}) compared to the control. Therefore, flower removal during the production of Stevia plant should be practiced in order to increase growth and leaf yield.

Keywords: Stevia, flower removal, growth, yield

Introduction

Stevia (*Stevia rebaudiana* Bertoni.) is a perennial herb belonging to the Asteraceae family. It is local plant to certain regions of South America, especially Paraguay and Brazil, is popularly for sweet savour and non-caloric diterpenoid steviol glycosides content in its leaves. The leaves of Stevia comprise more than 30 steviol glycosides have been identified with varying concentration (Wölwer-Rieck, 2012). The main of sweetening components in stevia dry leaf is stevioside (4 - 13 %), is about 250 - 300 times sweeter than saccharose and can be particularly beneficial to that sulfering from obesity, diabetes mellitus, heart disease and detal caries (Ghanta *et al*., 2007), and the next most abundant is rebaudioside A (2 - 4 %) with a sweetening power of 300 - 450. The other well known steviol glycoside are rebaudioside B, C (1 - 2 %), D and F, dulcoside A (0.3 %) and steriolbioside (Geuns, 2010; Tavarini and Angelini, 2013). Now Stevia cultivation has been extend to other regions of the world along with China, Brazil, Thailand and Argentina (Kim *et al*., 2011; Lemus - Mondaca *et al*., 2012). Many studies recommend that they have antioxidant, anti - diabetic, anti - hyperglycemic, anti - diarrheal, anti - tumour, anti - inflammatory, anti - hypertensive, diuretic and immunomodulatory effects (Puri *et al*., 2012; Shivanna *et al*., 2013). For this reason, there has been

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a large interest in Stevia although information respecting flower removal in Stevia and cause of growth unavailable.

However, the effects of flower removal on physiological of Stevia in Thailand have rarely been studied. Thus, the investigation of the present work was to determine the effect of flower removal on growth and yield of Stevia.

Materials and methods

The experimental site of location and climate, in glass-house conditions was conducted pot experiment during November 2015 to February 2016 at Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand. In this study was used soil Bangkok series, clay in texture with pH 6.12. The experiment was laid out in randomized complete block design with 3 replications. Treatments consisted of five flower removal were 1) control (no flower removal), 2) one time of flower removal at 30 days after transplanting, 3) two times of flower removal at 30 and 60 days after transplanting, 4) three times of flower removal at 30, 60 and 75 days after transplanting, and 5) four times of flower removal at 30, 60, 75 and 85 days after transplanting. The harvest of crop was done at 120 days after planting by cutting plant at 15 cm above ground level. Then, stem fresh weight, leaf fresh weight and root fresh weight were recorded. The flower, total biomass and leaf yield were dried at 40 ℃ in a hot air oven and flower dry weight, total dry biomass and leaf dry weight yield were recorded. The leaf area was measured using a LI-3100 leaf area meter (Licor Inc., Lincoln, USA) and leaf area index (LAI) was calculated.

Results

Stem, leaf and root fresh weight

Stem, leaf and root fresh weight at different flower removal times (Table 1). The data disclosed that the effect of flower removal on stem, leaf and root fresh weight at harvest was significant and the highest values were recorded with flower removal four times (15.08, 16.04 and 7.32 g plant^{-1}), respectively, compared with control (Table 1).

Number of leaves and leaf area index (LAI)

The number of leaves and LAI were significantly affected by varied with flower removal times (Table 1). Flower removal four times were recorded significantly the highest number of leaves (1,318.50 leaves plant^{-1}) and LAI (0.88) which were statistically at par with flower removal three times, flower removal two times, flower removal one time and control, respectively.

Table 1. Effects of flower removal on stem, leaf, and root fresh weight, number of leaves and leaf area index (LAI) of *Stevia rebaudiana* Bertoni. at 120 days after transplanting

Treatments	Stem FW. (g plant^{-1})	Leaf FW. (g plant^{-1})	Root FW. (g plant^{-1})	Number of leaves (leaves plant^{-1})	LAI
Flower removal					
30 DAT	7.69 CD	8.52 CD	2.70 CD	700.25 CD	0.49 CD
30, 60 DAT	9.08 BC	10.56 BC	3.58 BC	830.25 BC	0.57 BC
30, 60, 75 DAT	11.91 B	12.51 B	4.76 B	1,041.50 B	0.71 B
30, 60, 75, 85 DAT	15.08 A	16.04 A	7.32 A	1,318.50 A	0.88 A
Control	5.175 D	6.22 D	1.98 D	463.00D	0.40 D
Mean	9.78	10.77	4.07	870.70	0.61
F-test	15.61	11.80	19.58	14.61	12.68
LSD (0.05)	2.98	3.37	1.45	263.27	0.16
C.V. (%)	19.82	20.33	23.25	19.63	17.43

FW = fresh weight; DAT = days after transplanting; In a column figures with the same letter did not different significantly at the 0.05 probability level; ns = non significantly at the 0.05 probability level.

Table 2. Effects of flower removal on flower dry weight, total biomass dry weight, harvest index (HI) and leaf dry weight yield of *Stevia rebaudiana* Bertoni. at 120 days after transplanting

Treatments	Flower DW. (g plant^{-1})	Total biomass dry weight (g plant^{-1})	HI	LDW Yield (t ha^{-1})
Flower removal				
30 DAT	1.15 B	6.03 CD	0.40 A	0.38 CD
30, 60 DAT	1.05 BC	7.30 BC	0.42 A	0.48 BC
30, 60, 75 DAT	0.82 CD	8.52 B	0.45 A	0.62 B
30, 60, 75, 85 DAT	0.64 D	11.31 A	0.42 A	0.81 A
Control	1.45 A	4.99 D	0.40 A	0.30 D
Mean	1.02	7.63	0.42	0.52
F-test	12.17	27.98	0.95	15.33
LSD (0.05)	0.27	1.42	0.07	0.15
C.V. (%)	17.30	12.13	10.79	19.68

DW = dry weight; LDW = leaf dry weight; LAI = leaf area index; HI = harvest index;
DAT = days after transplanting; In a column figures with the same letter did not different significantly at the 0.05 probability level; ns = non significantly at the 0.05 probability level.
the 0.05 probability level.

Flower dry weight, total biomass dry weight and harvest index

Flower dry weight in control were significantly highest flower dry weight (1.45 g plant $^{-1}$) higher than in flower removal one time, flower removal two times and flower removal three times (1.15, 1.05 and 0.82 g plant $^{-1}$), respectively. The lowest flowering dry weight was recorded in flower removal four times (0.64 g plant $^{-1}$) as seen in Table 2. Total biomass dry weight revealed the flower removal four times recorded significantly higher total biomass dry weight (11.31 g plant $^{-1}$), followed by flower removal three times (8.52 g plant $^{-1}$), flower removal two times (7.30 g plant $^{-1}$), flower removal one time (6.03 g plant $^{-1}$) and lowest total biomass dry weight was recorded with control (4.99 g plant $^{-1}$). Harvest index was not significantly affected by different flower removal times.

Leaf dry weight yield

Leaf dry weight yield was significantly affected by different flower removal times. The highest of leaf dry weight yield (0.81 t ha^{-1}) was recorded at flower removal four times followed by flower removal three times (0.62 t ha^{-1}), flower removal two times (0.48 t ha^{-1}), flower removal one time (0.38 t ha^{-1}) and control (0.30 t ha^{-1}) as seen in Table 2.

Discussion

The results were shown that flower removal significantly affected on growth and leaf yield of stevia. Flower removal treatments resulted in stem, leaf and root fresh weight, total biomass dry weight and leaf dry weight yield compared to control. Bazzaz *et al*. (1987) and Kriedemann *et al*. (2014) reported that an increase in plant height due to flower removal should be expected because when plant begins to lower and fruiting bodies, drawing energy away from vegetative growth. By removing this resource sink, energy and resources continue to supply leaves and shoot. This extends vegetative stage, resulting in taller plants. Mondol *et al*. (1978) and Crafts Brandner *et al*. (1984) reported that longer leaf area duration brought about by flower and pod removal did not cause increased photosynthetic rate. Mavengahama (2013) reported that the extraction of flowers of plants resulted in a 46% increase fresh and dry weight of leaves and the continuous extraction of the flowers leads to increase utilizable leaf yield. Thus, the continuous extraction of the flowers leads to increased total dry weight and leaf dry weight yield. In stevia plant Rakesh *et al*. (2014) reported that flower removal treatments significantly reduced the number of flower per plant (40.2), as compared with the control (95.6) at 45 days after transplanting. A similar finding was observed by Salama (2008) and Lokesh *et al*. (2018) reported that in stevia manual flower removal recorded highest fresh leaf yield per ha, while the minimum fresh leaf yield per ha was observed in control.

Plants which were deflowered had the highest number of primary branches compared to those which were not deflowered. Removal of flower encourages vegetative growth *C. gynandra* (Masinde and Agong, 2011). In *Bidens pilosa* flowering was liable for lessening of leaf and stem growth and flower removal decreased senescence, hence retaining vegetative growth (Zobolo and Van Staden, 1999). Similarly, flower removal increased the leaf yield of *Solanung nigrum* by 40% with deflowered plants giving a leaf yield of 2,154 kg ha^{-1} continuous removal of the flowers leads to increased utilizable leaf yield of *C. gynandra* (Mavengahama, 2013). The results according to Mavengahama (2013); Masinde and Agong (2011); Zobolo and Van Staden (1999) are in agreement without finding that flower removal in erases the vegetative phase of the vegetable $plant^{-1}$. According to Kriedemann *et al*. (2014) flower removal could cause increased shoot growth due to maintaining resources available for vegetative growth. A study on spider plant by Oluoch *et al*. (2009) collaborates these findings, with harvesting techniques that flower removal resulting in significantly greater biomass yield (329.0 g $plant^{-1}$) than those where flowers remained (70.0 g $plant^{-1}$).

It is concluded that the plant growth and leaf dry weight yield from the results of present investigation that the flower removal four times gave the significantly higher stem fresh weight, leaf fresh weight, root fresh weight, total biomass dry weight and leaf dry weight yield compared with flower removal. In addition, it is recommended that flower removal four times should be practiced in the production of stevia plant to increase leaf yield.

Acknowledgment

The authors gratefully acknowledge the financial support of the Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL) and National Research Council of Thailand, Bangkok, Thailand. Additionally, the authors are grateful to laboratory staffs of the Plant Production Technology Section, KMITL, for their assistance in an analysis.

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(Received: 12 September 2018, accepted: 4 November 2018)