International Journal of Agricultural Technology 2017 Vol. 13(7.1): 1371-1379
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Effects of Sulfometuron-methyl as the Ripener on Growth and Yield of Sweet Sorghum

Sommart Yoosukyingsataporn* **and Somyot Detpiratmongkol**

Department of Plant Production Technology, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520Thailand.

Yoosukyingsataporn S. and Detpiratmongkol S. (2017). Effects of sulfometuron-methyl as the ripener on growth and yield of sweet sorghum. International Journal of Agricultural Technology 13(7.1): 1371-1379.

The objective was to determine the effects of sulfometuron-methyl concentration application on growth, stem yield and juice extract yield of sweet sorghum. The field experiment was conducted during August to December 2015 at the research field of Faculty Agricultural Technology, King Mongkut's Institute of Technology Ladkabang, Ladkrabang district, Bangkok, Thailand. The experiment was arranged in a split plot design with four replications. Sweet sorghum cultivars such as Ethanol 2 , KKU 40 and Cowley were assigned to main plots and six sulfometuron-methyl concentration application treatments, 0 (control), 500, 1,000, 1,500, 2,000 and 2,500 ppm were allocated to the subplot. The results revealed that the interactions of sweet sorghum cultivars and sulfometuron-methyl concentration application on stalk yield and juice extract yield were not significantly different. Ethanol 2 cultivar produced higher stem growth, yield and juice extract than KKU 40 and Cowley cultivars, respectively. Sulfometuron-methyl concentrations affected on stem fresh weight and juice extract yields. Sulfometuron-methyl concentration at 1,000 ppm was found the best among different sulfometuron-methyl concentrations. The highest concentration of sulfometuron-methyl application (2,500 ppm) decreased not only brix value and stem fresh weight yield but also juice extract yield. However, optimum rate of sulfometuron-methyl concentration application (1,000 ppm) gave the highest brix degree of sweet sorghum. Based on these results, to have the highest brix value it may be suggested to apply sulfometuron-methyl concentration at 1,000 ppm in cultivar Ethanol 2.

Keywords: Sulfometuron-methyl, Sweet sorghum, Ripener, Yield

Introduction

Sweet sorghum (*Sorghum bicolor* L.Moench) is a C_4 plant characterized by a high photosynthetic efficiency (Bryan, 1990 and Billa *et al*., 1997). It is four months crop; relatively photoperiod sensitive, resistance to drought, tolerance of high salinity, soil grown under hot and dry climatic conditions. Sweet sorghum is consumed as feed. The juice of green stem of sweet sorghum can be used for ethanol production after removing ear heads at physiological

* **Corresponding Author:** Yoosukyingsataporn, S.; **E-mail:** teetechno30@gmail.com

maturity. Ethanol 2 is renewable source of energy and around the world known as biofuel which is ecofriendly. The productivity of sweet sorghum is depended upon fresh stem yield. In Thailand, many studies were carried out to evaluate genotype and cultivars for productivity and quality where a significant differentness among sweet sorghum cultivars. Stem yield and juice extract yield greatly affected by the application of chemical ripener on some sweet sorghum cultivars. The use of chemical ripener to increase the sucrose content of sweet sorghum crops enabling them to be harvested either earlier, or normal time with a higher sucrose content. Sulfometuron-methyl acts by inhibiting ALS enzyme (Acetolactate synthase), interfering with cellular metabolism, paralyzing the growth without killing the apical bud (Leite and Crusciol, 2008).

The introduction of sulfometuron-methyl (125 g ai lit^{-1}), which overcomes some of the disadvantages of other ripeners, is therefore timely. Sulfometuron-methyl is a grass herbicide that has shown promise as a chemical at low rates of application (Almodares *et al*., 2013). Many studies have reported that sulfometuron-methyl regarding its potential ripening effect in sugarcane varieties, causes no damage to sugarcane production (t ha^{-1}) or the agronomic characteristics of the culture (Silva *et al.*, 2007; Leite *et al.*, 2010). However, there was little information about the response of sweet sorghum cultivars to ripeners sulfometuron-methyl, commonly vessel. Therefore, the objectives of the present study were to investigate the effect of sulfometuron-methyl as the ripener on plant growth, stem fresh weight and juice extract yield of some sweet sorghum cultivars under field condition.

Materials and methods

Trial design

The experiment was conducted at the experimental farm, Faculty of Agricultural Technology, King's Mongkut Institute of Technology Ladkrabang, Bangkok, Thailand, during August to December 2015. The research experimental farm is located 13° 43′ 36.21″ N, 100° 46′ 48.45″ E at an altitude of 1.50 m above mean sea level. Three sweet sorghum cultivars including Ethanol 2, KKU 40 and Cowley and six sulfometuron-methyl concentration levels such as 0, 500, 1,000, 1,500, 2,000 and 2,500 ppm were assessed in a split-plot randomized complete block design with three replications. Sweet sorghum cultivars and sulfometuron-methyl treatments were assigned to main plot and sub-plot, respectively. The plot size was 3 m by 3 m (9 m^2). Soil at the experimental site is Bangkok series and clay in texture. The soil was pH 6.3 with slightly acidic.

Crop Husbandry

A seeding rate of 10 kg ha^{-1} and seed drill set to plant at a depth of 2.5 cm and thinned to 10 plant m^{-1} at 5 leaf stage. Plant spacing of 70 cm between the rows and 10 cm within the row was followed. Plots were fertilized with 90 kg ha^{-1} of N (urea), 45 kg ha^{-1} of triple superphosphate and 45 kg ha^{-1} of potassium sulphate as a broadcast application. The soil was mixed with these fertilizers before planting. Surface irrigation was applied in furrows to the crop to maintain proper growth. Herbicide atrazine (@ 1 kg ai ha^{-1}) and *s*-metolachlor (@ 2.1 kg ai ha^{-1}) was applied 1 day after sowing (pre-emergence) to control weeds. Recommended and need-based crop protection measures were taken to control pasts and diseases.

Data collection

At physiological maturity after 120 days after planting, growth parameters including plant height, stem diameter, stem fresh weight and brix degree were measured. After cutting the plants at ground level, the leaves along with sheath were stripped and panicle with last internode (peduncle) was separated; the fresh weight of stripped stem (hereafter referred as fresh stem yield) was then recorded. Plant height was measured on the 10 tagged plants as the height from the base of the plant to the collar of the highest leaf before the panicle. Stem diameter was measured by dividing the stem into three equal parts. Twenty representative plants from the three central rows of each plot were sampled in all three replications for measuring stem fresh weight yield. Juice extraction yield; Stem juice was extracted by passing the stems through a power-operated three-roller horizontal sugarcane machine miller soon after harvest. The extracted juice was filtered immediately with standard Whatman filter paper to remove large solids. The stripped stems were passed through the mill at least twice, and all extract juice was removed from stem and weighed immediately. Total soluble solids in terms of brix degree were measured using a digital refractometer (Model PAL-1, Atago Co. Ltd., Tokyo, Japan). Then 100 ml of the fresh juice was transferred to standard glass test tubes and processed immediately to estimate brix degree. Sulfometuron-methyl difference concentrations spraying on the stem of sweet sorghum was application 1 week before harvest.

Statistical analysis: Statistical analyses were performed using SAS program (SAS Institute, 2010). The data were analyzed using ANOVA following the procedure for split-plot design. Least significant different (LSD) values were calculated at 0.05 probability level whereas the F-test was significant.

Results

Plant height

In Table 1, three sweet sorghum cultivars, Ethanol 2 cultivar (with 2.83 m) produced more plant height than KKU40 (with 2.44 m) and Cowley cultivars (with 2.15 m). Stem height was decreased by increasing sulfometuron-methyl concentration application levels. While the highest stem height (2.83 m) was obtained in 0 ppm sulfometuron-methyl concentration, there was a significant difference in this parameter under 500, 1,000, 1,500, 2,000 and 2,500 ppm sulfometuron-methyl concentration treatments.

Table 1 Plant height (m), stem diameter (mm) and stem fresh weight (g $plant^{-1}$) at harvest of three sweet sorghum cultivars as affected by different sulfometuron-methyl concentrations application.

Treatments		**Plant height** (m)	**Stem diameter** (mm)	**Stem FW** (g $plant^{-1}$)
Cultivars (A)	Ethanol 2	2.83	22.90	254.76
	KKU 40	2.44	19.80	221.59
	Cowley	2.15	17.63	210.48
Sulfometuron-methyl (Concentration) (B)				
	0 ppm	2.83	22.29	250.79
	500 ppm	2.64	21.56	237.09
	1,000 ppm	2.57	20.80	229.78
	1,500 ppm	2.40	19.43	224.30
	2,000 ppm	2.29	18.70	220.74
	2,500 ppm	2.15	17.91	210.94
LSD (0.05) (A)		0.44	4.77	42.13
LSD (0.05) (B)		0.36	2.85	29.67
LSD (0.05) (A x B)		ns	ns	ns
CV (%) (A)		10.15	13.50	10.48
CV (%) (B)		11.76	11.49	10.53

ns = no significant at the 0.05 probability level; FW= fresh weight.

Stem diameter

Data concerning stem diameter are present in Table 1. The influence of different cultivars was significant on stem diameter. The highest stem diameter (22.90 mm) was observed in Ethanol 2 cultivar followed by KKU 40 (19.80

mm) whereas the minimum stem diameter (17.63 mm) was recorded by Cowley cultivar. For five levels of sulfometuron-methyl concentration applications, stem diameter was 22.29 mm. in 0 ppm sulfometuron-methyl concentration and its lowest was 17.91 mm in 2,500 ppm sulfometuron-methyl concentration.

Stem fresh weight

Data regarding stem fresh weight are present in Table 1. The maximum stem fresh weight (254.76 g plant^{-1}) was observed in Ethanol 2 cultivar followed by KKU 40 (221.59 g plant^{-1}) and Cowley cultivars (210.48 g plant^{-1}), respectively. Stem fresh weight was significantly affected ($p \leq 0.05$) by sulfometuron-methyl concentration. The highest stem fresh weight (250.79 g plant^{-1}) was obtained with application of 0 ppm sulfometuron-methyl concentration and the lowest (210.94 g plant^{-1}) was recorded in 2,500 ppm sulfometuron-methyl concentration.

Table 2 Brix degree, stem fresh weight yield (t ha^{-1}) and juice extract yield (l ha^{-1}) at harvest of three sweet sorghum cultivars as affected by different sulfometuron-methyl concentrations application.

Treatments		**Brix degree**	**Stem FWY (t ha^{-1})**	**Juice extract yield (l ha^{-1})**
Cultivars (A)	Ethanol 2	23.56	20.85	2,144
	KKU 40	19.33	17.31	1,281
	Cowley	20.29	15.08	1,014
Sulfometuron-methyl Concentrations (B)				
	0 ppm	20.90	24.30	2,032
	500 ppm	21.00	20.89	1,739
	1,000 ppm	23.25	18.66	1,518
	1,500 ppm	21.33	16.25	1,312
	2,000 ppm	20.50	14.08	1,224
	2,500 ppm	18.38	12.28	1,054
LSD (0.05) (A)		0.68	7.11	745.50
LSD (0.05) (B)		2.82	6.11	527.70
LSD (0.05) (A x B)		ns	ns	ns
CV (%) (A)		12.47	13.18	28.67
CV (%) (B)		11.08	14.26	28.97

ns = no significant at the 0.05 probability level. ; FWY= fresh weight yield.

Brix degree

Data regarding brix degree are presented in Table 2. It was indicated that effects of different cultivars were significant. The highest brix degree (23.56) was in Ethanol 2 cultivar followed by KKU 40 (19.33) and Cowley cultivars (20.29), respectively. Sulfometuron-methyl concentrations influenced on brix degree. The maximum brix degree (23.25) was obtained in 1,000 ppm sulfometuron-methyl application and the minimum brix degree (18.38) was recorded in 2,500 ppm sulfometuron-methyl application. Leggio Nene *et al*. (2013) reported that under these conditions, ripeners restrict vegetative growth rates which results increased sucrose storage. Liao (2003) stated that chemical ripener increased sugar content per fruit more rapidly than control. They explained that such results may due to chemical ripener effect on sugar accumulation in fruit tissue, this is in agreement with our finding (Michael *et al.*, 2014).

Stem fresh weight yield

Data regarding stem fresh weight yield are presented in Table 2. Among three sweet sorghum cultivars, the maximum stem fresh weight yield (20.85 t ha^{-1}) was recorded in Ethanol 2 cultivar, followed by KKU 40 cultivar (17.31 t ha^{-1}) whereas the minimum stem fresh weight yield (15.08 t ha^{-1}) was produced in Cowley cultivar. Stem fresh weight yield decreased with the inverse in sulfometuron-methyl concentration levels. Maximum stem fresh weight yield (24.30 t ha^{-1}) was recorded in control 0 ppm sulfometuron-methyl concentration and minimum (12.28 t ha^{-1}) was noted in 2,500 ppm sulfometuron-methyl concentration. The decrease in plant growth of sweet sorghum may be due to increasing sulfometuron-methyl concentration levels.

Juice extract yield

The different about juice extract yield was significant among three sweet sorghum cultivars Ethanol 2 cultivar (with 2,144 l ha^{-1}) also produced more juice extract yield than KKU 40 (with 1,281 l ha^{-1}) and Cowley, cultivars (with 1,014 ha^{-1}), respectively in Table 2. Juice extract yield ranged from 1,054 to 2,032 l ha^{-1}. Juice extract yield significant difference at all sulfometuron-methyl concentrations. The highest (2,032 ha^{-1}) and the lowest (1,054 l ha^{-1}) juice extract yield were obtained at control (0 ppm sulfometuron-methyl concentration) and 1,000 ppm sulfometuron-methyl concentration, respectively.

Among three sweet sorghum cultivars, Ethanol 2, KKU 40 and Cowley cultivars had significant differences in these five characteristics with each other. The maximum plant height (2.83 m), stem fresh weight (254.76 g $plant^{-1}$), brix degree (23.56), stem fresh weight yield (20.85 t ha^{-1}) and juice extract yield (2,144 l ha^{-1}) were recorded in Ethanol 2 cultivar followed by KKU 40 and Cowley cultivars, respectively. Sandeep *et al.* (2009) also reported that genotypes have significantly different effect on plant height, brix percentage, and stem yield. Indhubata *et al.* (2010) noted that hybrids of sweet sorghum had the significant influence on plant height, stem fresh weight yield, total sugar and brix degree. Almodares *et al.* (2013) and Thakare *et al.* (2005) also concluded that sweet sorghum can grow well and produce high biomass and sugar in the stem. Yoosukyingsataporn *et al.* (2016) reported that the amount of sucrose percentage and brix degree depended upon the type of sweet sorghum and line.

Sulfometuron-methyl concentrations affected on stem fresh weight and juice extract yield. The highest (24.30 t ha^{-1} and 2,032 l ha^{-1}) and the lowest (12.28 t ha^{-1} and 1,054 l ha^{-1}) were obtained at 0 and 2,500 ppm sulfometuron-methyl concentrations application, respectively. The result explained that it was decreased by increasing sulfometuron-methyl concentration from 0 to 2,500 ppm. Also, the highest brix degree (23.25) was obtained at 1,000 ppm in Table 2. Sulfometuron-methyl is systemic herbicide that translocates apoplectically, focusing on the growing point of plant and causing growth and inhibiting cell division after absorption by the plant. Paralyzed development of the apical meristem causes a reduction in the internodes formed at the time of application. Then, sucrose is stored in the stalk in place of the production of new leaves. Which results a reduction in the rate of the pith process stem growth is restrict and the unwanted, immature top of some stem may eventually break off. This will not result in a reduction in the stem, compared with unseated. However, it may also be used as a ripener in sweet sorghum when applied at lower doses (from 500 to 1,000 ppm). These results are agreement with the finding of Rostron (1977) stated that ripener produces consistent improvements sucrose percent cane fresh mass and juice purity in ten of the experiments. Morgan *et al.* (2007) reported that ripener can increase the sucrose content in the stem of many cultivars. Silva and Caputo (2014) reported the recommended dose of the product to hasten ripening of sugarcane is 15 g ha^{-1} of the active ingredient or 20 g ha^{-1} of the commercial product. After application, the treated area can be harvested in 25 to 45 days.

Conclusion

Our study demonstrated that the maximum plant height, stem fresh weight yield, and juice extract yield were recorded in Ethanol 2 cultivar followed by KKU 40 cultivar whereas the minimum was Cowley cultivar. For different concentrations of sulfometuron-methyl foliar application rate, the maximum of stem fresh weight yield and juice extract yield were obtained with an application rate of 0 ppm (control treatment) while the minimum effective dose for maximum brix value in the stem was achieved with an application rate of 1,000 ppm. However, the interaction between sweet sorghum cultivar and chemical concentration (sulfometuron-methyl concentration) was not significant in growth parameter.

Acknowledgement

We wish to extend my cordial thanks to the National Research Council of Thailand, Bangkok, Thailand, for providing the financial support.

References

Almodares, A., Usofzadeh, M. and Daneshvar, M. (2013). Effect of nitrogen and ethephon on growth parameters, carbohydrate contents and bioethanol production from sweet sorghum. Sugar Technology. 15(3) : 300-304.

Bryan, W. L. (1990). Solid state fermentation of sugars in sweet sorghum. Enzyme and Microbial Technology. 12: 437-442.

Billa, E. Koullas, D. P., Monties, B. and Koukios, E. G. (1997). Structure and composition of sweet sorghum stalk components. Industrial Crops and Products. 6 : 297-302.

Leggio-Nene, M. F., Fajre, S., Romero, E. R., Alonso, L. G. and Ducca, A. S. (2013). Chemical ripening advances in Tucuman Argentina. Revista industrialy agricola de Tucuman. 90(1) : 57-59.

Leite, G. H. P., Crusciol, C. A. C. (2008). Plant regulators in development and productivity of sugarcane. Pesqui. Pesquisa Agropecuaria Brasileira journal. 43(8) : 995-1001.

Leite, G. H. P., Crusciol, C. A. C., Siqueira, G. F. and Silva, M. A. (2010). Qualidade tecnológica em diferentes porções do colmo e produtividade da cana-de-açúcar sob efeito de maturadores. Bragantia. 69(4) : 861-870.

Liao, W. Z., Li, Y. R., Lin, Y. K., Nong, Y. Y., Liu, Y. and Yang, L. T. (2003). Effects of ethephon applied at different times of late growth stage on ripening of sugarcane Southwest China. Journal of Agricultural Sciences. 16(4) : 60-64.

Michael, L., Schwieterman, T. A., Colquhoun, E. A., Jaworski, L. M., Bartoshuk, J. L., Gilbert, D. M., Tieman, A. Z., Odabasi, H. R., Moskowitz, K. M., Folta, H. J., Klee, C. A., Sims, V. M. and Whitaker, D. G. C. (2014). Strawberry flavor : diverse chemical compositions, a seasonal influence, and effects on sensory perception. Plos One. 9(2) : 1-12.

Morgan, T., Jackson, P., McDonald, L. and Holtum, J. (2007). Chemical ripeners increase early season sugar content in a range of sugarcane varieties. Australian Journal of Agricultural Research. 58: 233-241.

Rostron, H. (1977). Results of recent experiments on chemical ripening of sugarcane. Sasta Congress Proceedings. 51: 30-35.

SAS Institute. (2010). SAS system for windows releases 9.3. SAS Institute, Cary, North Carolina, USA.

Sandeep, R. G., Gururaja-Rao, M. R. and Chikkalingaiah, S. H. (2009). Assessment of variability for grain yield, ethanol yield and their attributing characters in germplasm accessions of sweet sorghum (*Sorghum bicolor* (L.) Moench). Journal of Agricultural Sciences. 43(3) : 472-476.

Silva, M. A., Gava, G. J. C., Caputo, M. M., Pincelli, R. P., Jerônimo, E. M. and Cruz, J. C. S. (2007). Uso de reguladores de crescimento como potencializadores do perfilhamento e da produtividade em cana-soca. Bragantia. 66(4) : 545-552.

Silva, M. A. and Caputo, M. M. (2014). Ripening and the use of ripeners for better sugarcane management. In Crop management: Cases and tools for higher yield and sustainability, ed. Fabio R. Marin, 2–24. Rijeka: InTech.

Yoosukyingsataporn, S., Detpiratmongkol, S. and Liphan, S. (2016). Influence of ethephon hormone applied at different concentrations on growth and juice extract yields of sweet sorghum. Conference proceeding. Asia-Pacific Conference on Engineering and Applied Science. August 25-27, 2016. Tokyo, Japan. 29-34.

Thakare, R., Bhongle, S. A. and Somani, R. B. (2005). Biochemical properties of some elite sweet sorghum cultivars. Journal of Soils and Crops. 15(1) : 136-138.

(Received: 20 October 2017; accepted: 25 November 2017)