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Effects of sulfometuron-methyl as chemical ripener on growth and yield of three sweet sorghum cultivars

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Abstract The effect of sulfometuron-methyl as chemical ripener on growth and yield of three sweet sorghum cultivars was investigated. The results revealed that for three sweet sorghumcultivars, growth and yield of Ethanol 2 cultivar were largest and followed by KKU 40 and Cowley cultivars, respectively. Sulfometuron-methyl mainly affected on growth and yield of sweet sorghum. As different sulfometuron-methyl concentration levels, the increasing doses of sulfometuron-methyl concentration were decreased the growth and yield of sweet sorghum. Juice extract yield, brix degree and stem fresh weight yield of sweet sorghum were the largest at 1,000 mg lit^{-1} sulfometuron-methyl concentration when compared to the other concentration and control treatment. However, it was recommended that the most suitable application of sulfometuron-methyl was 1,000 mg lit^{-1} concentration with Ethanol 2 cultivar. In addition, all of the growth parameters, It was not found the interaction between sulfometuron-methyl concentrations and sweet sorghum cultivars.

Keywords: sweet sorghum, sulfometuron-methyl, chemical ripener

Introduction

Sweet sorghum belonging to *Sorghum bicolor* (L.) Moench. is a multipurpose crop (viz. food, feed, fodder, and fuel) that has the high potential as an alternative biofuel feedstock. The Juice extractsof sweet sorghum were high concentrations of soluble sugars (10–15%) in the stalk. The juice extract from sugar-rich stalks can be used for the production of products syrup and ethanol (Ratnavathi *et al.*, 2011). The leaves and stalks can be used for sugar, syrup, alcohol, chewing, fodder, fuel (Ratnavathi *et al.*, 2011) and bagasse for animal feed or paper products (Whitfield *et al.*, 2012). Sweet sorghum can be adapted most of the tropical and subtropical of the world. It has a very short growing season (4 months), only 120 days, on average. It isfourth cultivated per year. Sweet sorghum has potential growing to be water deficit stress and

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waterlogging (Regassa and Wortmann, 2014), tolerance of high salinity, grown under hot and dry climatic conditions (Woods, 2000). The studies in Thailand, of sweet sorghum response to breeding and crop husbandry. Hybrid sweet sorghum was promising for plant height, stem diameter, juice extract yield and ethanol yield (Pothisoong and Jaisil, 2011). It has not studied chemical ripening in sweet sorghum.

Sulfometuron-methyl is a chemical herbicide as an organic compound used in agriculture (Silva and Caputo, 2012). It is a sulfonylurea herbicides group are characterized as inhibition of ALS enzyme (Acetolactate synthase enzyme) (Zhou *et al.,* 2007). ALS enzyme is not a protein found in animals but is found in plant (Cox, 2002). The ALS enzyme is a first step in the amino acid synthesis (Zhou *et al.*, 2007), It is building of the branched-chain amino acids (valine, leucine, and isoleucine) (Silva and Caputo, 2012). Effects of sulfonylurea herbicides group on stopping division cells and particularly cells in the apical meristem and root of plant (Cox, 2002), inhibitors DNA synthesis and inhibitors potent synthesis of plant growth (Silva and Caputo, 2012). However, chemical herbicide of sulfometuron methyl applied has been many studies with sugar cane (Silva and Caputo, 2012) Caputo *et al* (2008) and Silva and Caputo (2012) reported, the spraying sulfometuron-methyl used on dose rates at 10-20 g ha^{-1} of sugar cane. After application, sugarcane can be physiological maturity in 20-45 days, can be not killing of apical buds and internodes is normal growth (Leite *et al.*, 2010).

The objectives of this work were to evaluate the effect of different concentration levels of sulfometuron-methylis chemical ripeneron some growth parameters and sugar contentof three sweet sorghum cultivars under field condition.

Materials and methods

Field experiment was conducted during March to August 2018 at the agricultural research station farm, Faculty of Agricultural Technology, King's Mongkut Institute of Technology Ladkrabang, Bangkok, Thailand. The research experimental farm is located 13°43′36.21″N, 100°46′48.45″ E an altitude of 1.50 m above mean sea level. The soil at the planting site was Bangkok series and clay in texture. The soil was slightly acidic with pH 6.10. The mean annual rainfall for five years from the year of 2013 to 2017 was 1,827.30 mm. The mean daily temperature is 30.46 degree centigrade.

The experiment was arranged in a split plot design with three replications. The main plot was the three sweet sorghum cultivars (Ethanol 2, KKU40 and Cowley) and the subplot was six sulfometuron-methyl concentration levelssuch as 0, 500, 1,000, 1,500, 2,000 and 2,500 mg lit^{-1}, respectively. The plot size was 3 m by 3 m (9 m^2).

Two seeds were hand-planted at 3 cm soil depth and then thinned to 10 plants m^{-1} at 5 leaf stages. A seeding rate of 10 kg ha^{-1} and plant spacing of 10 cm with the row and 70 cm between the rows was followed. Herbicide atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1, 3, 5-triazine) at 1 kg ha^{-1} was applied 2 days after sowing (pre-emergence) to control the weed. Plots were fertilized with 95 kg ha^{-1} of N (Urea), 140 kg ha^{-1} of triple superphosphate and 70 kg ha^{-1} of potassium sulphate as a broadcast application. The soil was mixed with these fertilizers before planting. Recommended and need-based crop protection measures were taken to control pests and diseases. Surface irrigation was applied in furrows to the crop to maintain proper growth. Sulfometuron-methyl difference concentrations spraying on the stem of sweet sorghum was application 2 weeks before harvest.

Days to 50 % flowering (anthesis) was measured on 5 tagged plants in each treatment plot as the time from date of the seedling to the time that 50% of plants in a plot extended anthers in the mid-section of the panicle. At physiological maturity (120 days after planting), plant height was recorded on the 10 tagged plants by measuring the height from the base of the plant to the tip of the panicle (Tsuchihashi and Goto, 2005). Stem diameter was measured by dividing the stem into three equal parts. Grain yield was estimated from the 15 tagged plants (panicle). The panicles were dried, threshed, weighed and grain yield (kg ha^{-1}) computed, yield was adjusted to 14.5% moisture content. Twenty representative plants from the three central rows of each plot were sampled in all three replications for measuring stem fresh weight yield. After cutting the plants at ground level, the leaved 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.

Stem juice was extracted by passing the stems through a power-operated three-roller horizontal sugarcane machine miller soon after harvest. The stripped stems were passed through the mill at least twice, and all extract juice was removedfrom stem and weighed immediately. The extracted juice was filtered through Whatman filterpaper to removed large solids. Then 100 ml of the fresh juice was transferred to standardglass test tubes and processed immediately to estimate brix degee. Juice brix (a measure of mass ratio of total soluble solids to water) of the extracted juice was determined using a digital hand-held refractometer (Atago digital hand-held pocket refractometer n, pal-1, Tokyo, Japan). This is referenced as juice brix hereafter.

Total soluble sugar content (lit ha^{-1}) was estimated using (Liu *et al*., 2008).

$$y=0.8111x-0.37285$$

Where, y = total soluble sugar content, %; x = brix degree of stalk juice, brix degree (%)

Ethanol yield (lit ha^{-1}) was estimated using

Ethanol yield (lit ha^{-1})=5:324xTotal sugars%xJuice yield (lit ha^{-1})/1000

Statistical analyses were performed using SAS program (SAS, 2012). The data were analyzed using ANOVA following the procedure for Split-plot design. Least significant different (LSD) values were used to compared treatment means at P = 0.05.

Results

The number of days until 50 % of flowering was not significantly differed among three sweet sorghum cultivars (Ethanol 2, KKU40 and Cowley) and it was ranged from 63.74 to 74.00 days. In addition, there was not significantly different in number of days until 50% of flowering under 0, 500, 1,000, 1,500, 2,000 and 2,500 mg lit^{-1} sulfometuron–methyl concentration treatments (Table 1). The plant height are presented as three sweet sorghum cultivars, Ethanol 2 (with 295.59 cm) produced more plant height than KKU40 (with 182.43 cm) and Cowley cultivars (with 143.52 cm). Stem height was decreased by increasing sulfometuron–methyl concentration levels. While the highest stem height (242.59 cm) was observed in 0 mg lit^{-1} sulfometuron–methyl concentration, there was significant difference in this parameter under 500, 1,000, 1,500, 2,000 and 2,500 mg lit^{-1} sulfometuron–methyl concentration treatments.

The highest stem diameter (2.22 cm) was recorded in Ethanol 2 cultivar followed by KKU 40 (1.78 cm) whereas the minimum stem diameter (1.21 cm) was observed by Cowley cultivars. For five levels of sulfometuron–methyl concentration application, the highest stem diameter (2.05 cm) was in 0 mg lit^{-1} sulfometuron–methyl concentration and followed by 500, 1,000, 1,500 and 2,500 mg lit^{-1} sulfometuron–methyl concentrations, respectively while its lowest was 1.41 cm in 2,500 mg lit^{-1}sulfometuron–methyl concentration. It was indicated that Ethanol 2 produced significantly ($P \leq 0.05$) more (9.21 percent and 29.09 percent) stem fresh weight over KKU 40 and Cowley respectively. Similar to stem fresh weight the highest (230.58 g $plant^{-1}$) was in 0 mg lit^{-1} sulfometuron–methyl concentration and its lowest was 159.47 g $plant^{-1}$in 2,500 mg lit^{-1} sulfometuron–methyl concentration.

Three sweet sorghum cultivars, Ethanol 2 cultivar (with 292.76 g $plant^{-1}$) produced more total dry weight than KKU40 (with 211.05 g $plant^{-1}$) and Cowley cultivars (with 111.89 g $plant^{-1}$). Total dry weight was decreased by increasing sulfometuron-methyl concentration application levels. The highest of total dry weight (238.66 g plant^{-1}) was obtained in 0 mg lit^{-1} sulfometuron-methyl concentrationfollowed by 500, 1,000, 1,500, 2,000 and 2,500 mg lit^{-1} sulfometuron-methyl concentration treatments, respectively.

Grain yields of sweet sorghum were 34.89 t ha^{-1}, 33.99 t ha^{-1}, and 25.14 t ha^{-1} in cultivar Ethanol 2, KKU 40 and Cowley cultivars, respectively. Grain yield decreased with the inverse in sulfometuron–methyl concentration levels. Maximum grain yield was presented in control (35.74 t ha^{-1}) and minimum (28.29 t ha^{-1}) was noted in 2,500 mg lit^{-1} sulfometuron–methyl concentration.

Stem fresh weight yield was significantly differed vamong three sweet sorghum cultivars.Ethanol 2 (20.85 t ha^{-1}) produced more stem fresh weight yield than KKU 40 (17.31 t ha^{-1}) and Cowley cultivars (15.08 t ha^{-1}). Stem fresh weight yield was decreased significantly by increasing sulfometuron–methyl concentration levels. The highest (24.30 t ha^{-1}) was observed in control (0 mg lit^{-1} sulfometuron–methyl concentration) and the lowest (12.28 t ha^{-1}) was at 2,500 mg lit^{-1} sulfometuron–methyl concentration.

The juice extract yield was significant differed among three sweet sorghum cultivars. Ethanol 2 (with 1,793 l ha^{-1}) also produced more juice extract yield than KKU 40 with 1,522 l ha^{-1} and Cowley with 1,291 1 ha^{-1}, respectively. Juice extract yield ranged from 1,027 to 2,063 l ha^{-1}. Juice extract yield significant difference at all sulfometuron–methyl concentrations. The highest (2,063 ha^{-1}) and the lowest (1,027 l ha^{-1}) juice extract yield here obtained at control (0 mg lit^{-1} sulfometuron–methyl concentration) and 2,500 mg lit^{-1} sulfometuron–methyl concentration, respectively.

It was indicated that the effects of different cultivars were significantly differed. The highest brix degree (23.33) was in Ethanol 2 cultivar followed by KKU 40 (19.25) and Cowley cultivars (16.58), respectively. Sulfometuron-methyl concentrations influenced on brix degree. The maximum brix degree (23.33) was obtained in 1,000 mg lit^{-1} sulfometuron-methyl application and the minimum brix degree (16.16) was recorded in 2,500 mg lit^{-1} sulfometuron-methyl application (Table 2).

The maximum total soluble sugar content (18.55%) was recorded in Ethanol 2 cultivar followed by KKU40 (15.24%) and Cowley cultivars (13.08%), respectively. Total soluble sugar content was significantly affected ($p \leq 0.05$) by sulfometuron–methyl concentrations. The highest total soluble sugar content (18.55%) was obtained with 1,000 mg lit^{-1} sulfometuron–methyl concentration followed by 1,500, 500, 2,000 and 2,500 mg lit^{-1} sulfometuron–methyl concentrations, respectively while the lowest (12.74%) was observed in 0 mg lit^{-1} sulfometuron–methyl concentrations.

Table 1. Number of days until 50% of flowering, plant height (cm), stem diameter (cm), stem fresh weight (g plant^{-1}), total dry weight (g Plant^{-1}) and grain yield (t ha^{-1}) of 3 sweet sorghum cultivars as affected by different sulfometuron-methyl concentration application

Treatments	Number of days until 50% of flowering	Plant height (cm)		Stem diameter (cm)		Stem FW (g plant^{-1})		Total DW (g plant^{-1})		Grain yield (t ha^{-1})	
Cultivars (A)											
Ethanol 2	66.32	295.59	A	2.22	A	224.62	A	292.76	A	34.89	A
KKU 40	63.74	182.43	B	1.78	AB	203.93	AB	211.05	AB	33.99	A
Cowley	74.00	143.52	B	1.21	B	159.28	B	111.89	B	25.14	B
Sulfometuron-Methyl (B)											
0 mg lit^{-1}	69.40	242.59	a	2.05	a	230.58	a	238.66	a	35.74	a
500 mg lit^{-1}	69.82	231.08	a	1.89	ab	217.90	ab	217.01	ab	33.32	ab
1,000 mg lit^{-1}	67.99	226.08	ab	1.79	bc	204.54	abc	207.61	bc	31.74	ab
1,500 mg lit^{-1}	66.63	216.81	ab	1.70	bc	189.12	abc	200.56	bc	29.49	ab
2,000 mg lit^{-1}	66.57	174.50	bc	1.58	cd	174.06	bc	190.11	cd	29.45	ab
2,500 mg lit^{-1}	67.70	151.86	c	1.41	d	159.47	c	177.45	d	28.29	b
Mean	68.02	207.15		17.37		195.94		205.32		31.34	
LSD (0.05)(A)	ns	71.67		0.58		54.68		43.17		7.10	
LSD (0.05) (B)	ns	53.33		0.23		48.11		48.22		4.83	
LSD (0.05) (AxB)	ns	ns		ns		ns		ns		ns	
CV (%) (A)	16.48	19.71		19.02		15.89		11.98		19.97	
CV (%) (B)	10.22	20.92		11.03		19.95		19.09		17.73	

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

Table 2. Stem fresh weight yield (t ha^{-1}), juice extract yield (l ha^{-1}), brix degree (%) and total soluble sugar content (l ha^{-1}) of 3 sweet sorghum cultivars as affected by different sulfometuron-methyl concentration application

Treatments	Stem FWY (t ha^{-1})	Juice extract yield (l ha^{-1})	Brix degree (%)	Total soluble sugar content (%)	Ethanol yield (l ha^{-1})
Cultivars (A)					
Ethanol 2	20.85 A	1,793 A	23.33 A	18.55 A	351.50 A
KKU 40	17.31 AB	1,522 AB	19.25 AB	15.24 AB	243.07 B
Cowley	15.08 B	1,291 B	16.58 B	13.08 B	148.71 C
Sulfometuron-Methyl (B)					
0 mg lit^{-1}	24.30 a	2,063 a	16.16 c	12.74 c	263.92 a
500 mg lit^{-1}	20.89 b	1,822 ab	20.00 b	15.85 b	313.02 a
1,000 mg lit^{-1}	18.66 bc	1,666 bc	23.33 a	18.55 a	313.56 a
1,500 mg lit^{-1}	16.25 cd	1,425 cd	21.00 ab	16.66 ab	254.29 ab
2,000 mg lit^{-1}	14.08 ed	1,208 de	19.50 b	15.44 b	196.85 bc
2,500 mg lit^{-1}	12.28 e	1,027 e	18.33 bc	14.50 bc	144.92 c
Mean	208.15	1,535	19.72	15.62	247.76
LSD (0.05)(A)	4.11	291	5.56	4.51	69.13
LSD (0.05) (B)	3.11	275	2.98	2.41	62.82
LSD (0.05) (AxB)	ns	ns	ns	ns	ns
CV (%) (A)	13.18	10.82	16.06	16.43	15.89
CV (%) (B)	14.26	14.56	12.27	12.56	20.61

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

Statistical analysis showed that sweet sorghum cultivars had a significant effect on ethanol yield. Ethanol 2 cultivar produced maximum ethanol yield (351.50 l ha^{-1}) followed by KKU 40 and Cowley, respectively. It is obvious from the results that the different concentrations of sulfometuron–methyl application significantly affected ethanol yield. The maximum ethanol yield (313.56 l ha^{-1}) producedwith 1,000 mg lit^{-1} sulfometuron–methyl concentration closely followed by 500, 1,000, 1,500 and 2,000 mg lit^{-1} sulfometuron–methyl concentrations whereas the minimum ethanol yield (144.92 l ha^{-1}) was in 2,500 mg lit^{-1} sulfometuron–methyl concentration.

Discussion

Among three sweet sorghum cultivars, Ethanol 2, KKU 40 and Cowley cultivars had significant differences in these ten characteristics with each other. The maximum plant height (295.59cm), stem diameter (2.22 cm), stem fresh weight (224.62 g plant^{-1}), total dry weight (292.76 g plant), grain yield (34.89 t ha^{-1}), stem fresh weight yield (20.85 t ha^{-1}), juice extract yield (1,793 l ha^{-1}), brix degree (23.33), total soluble sugar content (18.55%) and ethanol yield (351.50 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 a 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 soluble sugar content, 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 2,063 l ha^{-1}) and the lowest (12.28 t ha^{-1} and 1,027 l ha^{-1}) were obtained at 0 and 2,500 mg lit^{-1} sulfometuron-methyl concentrations application, respectively. The result explained that it was decreased by increasing sulfometuron-methyl concentration from 0 to 2,500 mg lit^{-1}. Also, the highest brix degree (23.33), total soluble sugar content (18.55%) and ethanol yield (313.56 l ha^{-1}) were obtained at 1,000 mg lit^{-1} sulfometuron-methyl concentrationin Table 2. Sulfometuron-methyl is systemic herbicide that translocates apoplectically (Caputo *et al*., 2008), 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 (Silva and Caputo, 2012). 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 mg lit^{-1} sulfometuron-methyl concentration). 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 (2012) 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.

It concluded that the highest plant height, stem diameter, stem fresh weight, total dry weight, grain yield, stem fresh weight yield, juice extract yield, brix degree, total soluble sugar content and ethanol yield were recorded in Ethanol2 cultivar followed by KKU40 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 mg lit^{-1} (control treatment) while the minimum effectivedose for maximum brix value in the stem was achieved with an application rate of 1,000 mg lit^{-1} sulfometuron–methyl concentration. However, the interaction between sweet sorghum cultivar and chemical concentration (sulfometuron-methyl concentration) was not significant differed in all growth parameters.

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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. 15:300-304.

Cox, C. (2002). Herbicide factsheet Sulfometuron-methyl. Journal of pesticide reform winter. 22:15-20.

Caputo, M. M., Beauclair, E. G. F., Silva, M. A. and Piedade, S. M. S. (2008). Resposta de genótipos de cana-de-açúcar à aplicação de indutores de maturação. Bragantia. 6:15-23.

Indhubala, M., Ganesamurthy, K. and Punitha, D. (2010). Combining ability studies for qualitytraits in sweet sorghum (*Sorghum bicolor* (L.) Moench). The Madras Agricultural Journal. 97:17-20.

Leite, G. H. P., Crusciol, C. A. C., Siqueira, G. F. and Silva, M. A. (2010). Qualidade tecnológicaemdiferentespor ções do colmo e produtividade da cana-de-a çúcar sob efeito de maturadores. Bragantia. 69:861-870.

Liua, R., Li, J. and Shen, F. (2008). Refining bioethanol from stalk juice of sweet sorghum by immobilized yeast fermentation. Renewable Energy. 33:1130-1135.

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.

Pothisoong, T., and Jaisil, P. (2011). Yield potential, heterosis and ethanol production in F1 hybrids of sweet sorghum (*Sorghum bicolor* L. Moench). KMITL Science and Technology Journal. 11:17-24.

Regassa, T. H. and Wortmann, C. S. (2014). Sweet sorghum as a bioenergy crop : Literature review. Biomass and Bioenergy. 64:348-355.

Ratnavathi, C. V., Chakravarthy, S. K., Komala, V. V., Chavan, U. D. and Patil, J. V. (2011). Sweet Sorghum as Feedstock for Biofuel Production: A Review. Sugar Tech. 13:399-407.

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

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. 43:472-476.

SAS. (2012). SAS/STATUser' s guide version 9.4 SAS Institute Inc., Cary, NC.

Silva, M.A., and Caputo, M.M. (2012). Ripening and the use of ripener for better sugarcane management. In: Fabio R. M. ed. Crop Management-Cases and Tools for Higher Yield and Sustainability, InTechJanezaTrdine 9, Rijeka, Croatia.

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

Tsuchihashi, N. and Goto, Y. (2005). Internode characteristics of sweet sorghum (*Sorghum bicolor* (L.) Moench) during dry land and rainy seasons in Indonesia. Plant Production Science. 8:601-607.

Whitfield, M. B., Chinn, M. S. and Veal, M. W. (2012). Processing of materials derived from sweet sorghum for biobased products. Industrial Crops and Products. 37:362-375.

Woods, J. (2000). Integrating sweet sorghum and sugarcane for bioenergy: Modeling the potential for electricity and ethanol production in SE Zimbabwe. (PhD Thesis) King's College, London, United Kingdom.

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.

Zhou, Q., Liu, W., Zhang, Y. and Liu, K. K. (2007). Action mechanisms of acetolactate synthase-inhibiting herbicides. Pesticide Biochemistry and Physiology. 89:89-96.

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