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Potassium Fertilizer Increased Stalk Ethanol Production of Panicle Removed-Sweet Sorghum [Sorghum Bicolor (L.) Moench]

I G.A.M.S. Agung[1], I K. Sardiana[1], I W. Diara[1], I G.M.O. Nurjaya[2]
[1]*Department of Agroecotechnology, Faculty of Agriculture, Udayana University, Bali, Indonesia*
[2]*Department Biology, Faculty of Mathematics and Natural Sciences, Udayana University, Bali, Indonesia*

Abstract: *A field experiment was conducted to increase ethanol production of panicle removed-sweet sorgum stalks by applying potassium fertilizer. This experiment was designed as a randomized complete block with three replicates. The first factor was rate of potassium fertilizer (0, 50, 100 and 150 kg KCl ha^{-1}). The second factor was the variety of sweet sorghum (White Local Belu, Numbu, Kawali and Super). Variables measured were harvest age at the stage of 100% flowering, stalk length and diameter, stalk and leaf fresh weight, juice volume, ethanol content and ethanol production. Results showed that potassium fertilizer rates as well as variety significantly ($P<0.05$) affected all variables measured.There was no interaction effects of the two factors. Potassium fertilizer rate of 100 kg KCl ha^{-1} and Super variety resulted in the highest ethanol production of 13.29 KL ha^{-1} and 12.24 KL ha^{-1}of panicle removed-sweet sorghum stalk respectively. Increased rate to 150 kg KCl ha^{-1} did not increase ethanol production. Ethanol content of White Local Belu variety was significantly lower than that of Super variety but was not different from those of the other two improved varieties (Numbu and Kawali).*

Keywords: *Ethanol, Potassium, Sweet sorghum [Sorghum bicolor (L.) Moench], Varieties*

I. Introduction

Alternative sustainable sources of energy is an important issue considering the increasingly less availabile of fossel sources. Efforts have been made to find any sources that can be used sustainably for supplying the energy needed. Sweet sorghum is one of cereal crops with several function such as grain or sweet forage (Almodares et al., 2008a). Although it produces grain, the essence of the crop is from the stalk wich contains high sugar contents (Almodares et al., 2008b). The sugar content in the stalk generally reaches 54 - 69 t/ha (Almodares et al., 2008b). The sugar contents in the sweet soghum juices vary with varieties. Brix among sweet sorghum varieties ranges between 14.32–22.35% (Almodares et al., 2006). The juice could be converted into 85% ethanol (54.4 L ethanol per 100 kg fresh stalk) (Rains et al., 1993). Sweet sorghum could produce bioethanol of 4000-7000 L/ha/year therefore for producing 60 000 000 KL/year as many as 15 000 0000 land was needed (Yudiarto, 2005). Results of previous experiment indicated that three sweet sorghum varieties originated from Japan (FS501, FS902 dan KCS105) and one local variety (Red Local Belu) were adapted to dryland of Jimbaran, Badung regency, Bali provinsi of Indonesia (Agung et al., 2013). Besides, sweet sorghums are tolerant to dry environment and highly efficient in using water and has high photosynthesis efficiency compared to other crops. Like other biofuel resource crops, sweet sorghum results in bioethanol which will not increase CO2 emission to the atmosphere.

Efforts had been made to increase ethanol content and ethanol production of sweet sorghum stalk. Panicle removal before pollination and grain filling was reported to be able to influence sugar content of sweet sorghum due to photosynthates for grain set are able to store in the form of sugar in sorghum juices (Erickson et al., 2011). There are limited data available for supporting the hypothesis, but brix value was reported higher in sweet sorgum with panicle removed before grain setting (Broadhead, 1973). Rajendran et al. (2000) indicated that panicle removal increased sugar yields compared to non-panicle removal sweet sorghums. Agung et al. (2016) reported that panicle removal at stage of 100% flowering gave the highest ethanol production of sweet sorghum. Applying adequate potassium fertilizer could increase the yields compared to N fertilizer only (Pholsen and Sornsungnoen, 2004; Almodares et al., 2006; Almodares et al., 2008c). Taize and Tiger (2000) indicated that potassium has important role in efficient transformation of sunlight energy into chemical energy that could increase carbohydrates produced in leaves. Potassium also has significant function in assimilate translocation into sink-organs by influencing the electron transport in plant transport chains (Raja-Reddy and Zhao, 2005). Applying potassium fertilizer to sweet sorghum could increase the biomass production and will maintain high carbohydrates in the stalk, even when the panicles are removed, beacuse the carbohydrates will not be allocated to the grains (Broadhead, 1973; Erickson et al., 2011). Information on increasing stalk ethanol production of panicle removed-sweet sorghum by applying potassium fertilizer was limited particulaly of varieties grown in Indonesia. Therefore this research was needed to obtain high etanol production of sweet sorghum.

II. Materials And Methods

2.1 Study area

The field experiment was conducted in village of Kemenuh, Gianyar regency, Bali province at ± 10 m above sea level from May to November 2016. Analysis indicated that before the experiment the soil pH of 6.8 (normal), organic-C of 2.18% (moderate), total-N of 0.14% (low), available-P of 117.25 ppm (very high), available-K of 169.18 ppm (moderate), soil misture content at field capacity of 48.84% and claily-loam texture (Laboratory of Soil Science Faculty of Agriculture Udayana University, 2016). The field experiment was arranged as randomized complete block design, in which two treatment factors were imposed. The first factor were four potassium fertilizer rates (0, 50, 100 and 150 kg KCl ha^{-1}) and the second factor were four sweet sorghum varieties (White Local Belu, Numbu, Kawali and Super).Whole treatments were randomly arranged and replicated three times.The stage of 100% flowering (full flowering of plants at middle row). The experiment was carried out for seven months (from May to November 2016).

The experiment consisted of 48 plots of 3.5 m x 1.5 m size. Fertilizers of 50 kg SP36 and 20 t ha^{-1} composts were applied a week before planting but KCl of 50, 100 and 150 kg ha^{-1} were applied seven days before planting. Urea of 100 kg was given twice i.e. seven days before planting and 30 days after planting (DAP). Five seeds were planted into a hole of 70 cm x 25 cm spacing and thinned at 14 DAP to keep one healthy seedling per hole or to maintain 30 plants per plot (population of 51.143 plants ha^{-1}). Spray-watering was given twice a day particularly at early plant growth until plants at 100% flowering Weeding was carried out once at 14 DAP. Panicles were removed at 100% flowering stage after which the plants were harvested. Observations and measurements were conducted to 100% flowering stage, stalk length and diameter, stalk and leaf fresh weights, juice volume, ethanol content and ethanol production after each harvest. Stalk and leaf fresh weights were determined from a quadran of 12 plants (1.26 m^2) in each plot, which was then converted into fresh weight per hectare. Juice volume was measured by crushing the stalk through the sugar cane crusher after which the juices were collected. The juice was then analyzed in the laboratory to determine ethanol content through fermentation and distillation process. Fermentation process was done for 60 hours and further continued with distillation process to primarily measured the ethanol content before the final content was determined using 3300 variant Gas Chromatography isothermally with stalk injector temperature of 150^{o}C, column temperature of 150^{o}C and detector temperature (FID) of 200^{o}C (Laboratory of Analytic Udayana University, 2016). The ethanol production was calculated from the ethanol content (%) multiplied by juice volume (L) per hectare.

2.2 Statistical analysis

Data were subjected to ANOVA Statistical analysis using Costat and MstatC computer software and comparation of means were calculated using Least Significant Different analysis at 5% level (Gomez and Gomez, 2007). Data were transformed where necessary.

III. Results And Discussion

3.1 Harvest age of each variety

All varieties were planted on 30 April 2016. Harvest was determined when plants were in the stage of 100% flowering (based on the results of previous experiment) (Agung et al., 2016). Plants were cut and then stalk, leaves and panicles were seperated. Each variety was harvested at different time based on their stage of 100% flowering. White Local Belu variety was the earliest to flower while Kawali was the latest (Table 1).

Table 1. Average of harvest age of four sweet sorghum variety

Average harvest age	Variety	No
58	Lokal Belu putih	1
62	Numbu	2
75	Kawali	3
73	Super	4

Notes: Data were not statistically analysed

3.2 Stalk length and diameter

Increased rates of potassium fertilizer from 0 to 150 kg KCl ha^{-1} significantly ($P<0.05$) increased stalk length of sweet sorghum by 4.63 cm compared to control (0 kg KCl ha^{-1}). There was no different effect between rate of 150 kg KCl ha^{-1} and 100 kg KCl ha^{-1} (Table 2). Variety of White Local Belu had the longest stalk than the other two varieties, but still shorter than Super variety. The rate of 150 kg KCl ha^{-1} significantly ($P<0.05$) increased stalk diameter by 3.48 cm compared to control. Kawali variety had bigger diameter than those of the other two varieties and 4.68 cm bigger than White Local Belu (Table 2). The increased in stalk length and diameter of sweet sorghum were probably due to the efficiency in energy transformation into chemical energy in the leaves, which contributed to carbohydrate content (Taize and Ziger, 2000). Additionally, potassium also has important role in assimilate translocation to sinks by influencing plant transport chains (Raja-Reddy and Zhao, 2005).Therefore, applying potassium fertilizer could increase biomass production and hence increased carbohydrate content in the stalks which will remain high after panicles were removed as reported by Rajendran et al. (2000), Bitzer (2009) and Erickson et al. (2011).

Table.2. Effects of potassium fertilizer (KCl) rates on stalk length, stalk diameter, stalk and leaf fresh weights of four varieties of sweet sorghum

Leaf fresh weight (ton ha^{-1})	Stalk fresh weight (ton ha^{-1})	Stalk diameter (cm)	Stalk length cm)	Treatments
KCl rates (kg ha^{-1})				
10.87^{c}	37.38^{c}	20.81^{c}	187.19^{b}	0
11.91^{bc}	42.22^{b}	21.58^{c}	194.82^{b}	50
13.33^{b}	46.11^{ab}	22.85^{b}	198.80^{ab}	100
15.56^{a}	50.24^{a}	24.29^{a}	214.82^{a}	150
1.595	4.262	0.826	16.571	5% LSD
Variety				
13.02^{b}	45.00^{a}	20.13^{d}	180.70^{b}	White Local Belu
11.59^{b}	36.67^{b}	21.87^{c}	152.41^{c}	Numbu
15.64^{a}	48.89^{a}	24.81^{a}	164.61^{bc}	Kawali
11.51^{b}	45.64^{a}	22.72^{b}	297.91^{a}	Super
1.595	4.262	0.826	16.571	5% LSD

Notes: Means followed by the same letters at the same columns are not significantly different at 5% level of LSD.

3.3 Stalk and leaf fresh weights

Increased rate of potassium fertilizer up to 150 kg KCl ha^{-1} significantly ($P<0.05$) increased stalk freh weights by 25.60% and 15.96% in comparison to control and to the rate of 50 kg ha^{-1} respectively (Table 2). The fresh weight of Kawali variety was not different from those of White Local Belu and Super, however was 24.99% higher than Numbu variety (Table 2). The application of potassium of 150 kg KCl ha^{-1} also significantly ($P<0.05$) increased leaf fresh weights by 30.14% and 14.33% respectively compared to control and rate of 100 kg KCl ha^{-1} (Table 2). The highest leaf fresh weight was given by Kawali variety, which was 16.75% and 26.41% higher than White Local Belu and Super respectively. This was due to high stalk diameter more than stalk length of Kawali (Table 2), which was associted with the longer time to reach 100% flowering stage (Table 1), indicating the longer time to stored assimilates in the stalk. The important role of potassium in increasing biomass production was shown also by increasing stalk length and diameter (Table 2).Kawali and Super varieties. After panicles were removed the assimilates that already stored in the stalk did not change because there was little possibility to translocate into the panicles as explained by Taize and Ziger, 2000; Raja-Reddy and Zhao, 2005). The benefits of panicle removals were also reported by Broadhead (1973), Rajendran et al. (2000), Bitzer (2009) and Erickson et al. (2011).

3.4 Juice volume

Increased the rate of potassium fertilizer to 100 kg ha^{-1} significantly ($P<0.05$) produced the highest juice volume of sweet sorghum (Tabel 3). The rate of 100 kg ha^{-1} gave 20.20% and 27.57% increament in juice volume compared to control and rate of 150 kg ha^{-1} respectively. Super variety produced the highest juice volume in comparison to the other varieties. Compared to White Local Belu and Kawali varieties, Super variety had 12.94% and 42.64% higher juice volume respectively (Tabel 3). High leaf and stalk fresh weights due to potassium fertilizer application (Tabel 2) might have contibuted to the high juice volume of sweet sorghum. The important role of potassium in enhancing assimilate production in the leaves and in contributing its transportation to and finally stored in the stalk (Raja-Reddy and Zhao (2005).

3.5 Stalk ethanol content

Stalk ethanol content was also increased as resulted from potassium fertilizer application. Rates of 100 KCl ha^{-1} dan 150 kg KCl ha^{-1} significantly ($P<0.05$) gave higher ethanol content compared to control and rate of 50 KCl ha^{-1} (Table 3). An increament of 1.11% ethanol content was given by the rate of 150 kg KCl ha^{-1} in comparison to control. Rate of 50 kg KCl ha^{-1} apparently had not been able to increase the stalk ethanol content of sweet sorghum. Kawali and Super varieties had higher ethanol content compared to Numbu and White Local Belu varieties (Table 3). Super variety had 0.97% higher ethanol content than White Local Belu. Increased ethanol content resulted from the application of potassium fertilizer was associated with increased juice volume (might be in carbohydrate and sugar content also).

3.6 Stalk ethanol production

The application of potassium fertilizer signifcantly increased stalk ethanol production of sweet sorghum. The rate of 100 kg KCl ha^{-1} increased 20.92% (or 2.87KLha^{-1}) ethanol production in comparison to control or 27.93% (or 3.64 KLha^{-1}) higher than the rate of 150 kg KCl ha^{-1} (Table 3). Apparently the rate of 150 kg KCl ha^{-1} could not increase ethanol production more. This was due to the lowest juice volume produced by the rate of potassium fertilizer applied although the stalk ethanol content was high (Table 3). Super variety resulted in the highest (12.24 $KLha^{-1}$) ethanol production among all varieties, which was 13.48% and 9.48% higher compared to White Local Belu and Kawali varieties respectively (Table 3). This findings could help farmers to apply potassium fertilizer up to 100 kg KCl ha^{-1} or to use Super variety with panicle removal at 100% flowering stage to obtain high stalk ethanol production.

Table 3. Effects of potassium fertilizer (KCl) rates on ethanol content, juice volume and ethanol production of four varieties of sweet sorghum

Produksi etanol ($KLha^{-1}$)	Juice volume (Lha^{-1})	Ethanol content (%)	Treatments
KCl rates (kg ha^{-1})			
10.51^{c}	110.86^{c}	94.81^{b}	0
11.92^{b}	125.28^{b}	95.12^{b}	50
13.29^{a}	138.85^{a}	95.72^{a}	100
9.65^{c}	100.57^{d}	95.92^{a}	150
0.546	8.290	0.412	5% LSD
Variety			
10.59^{b}	111.56^{b}	94.92^{b}	White Local Belu
11.02^{b}	118.92^{b}	92.64^{a}	Numbu
11.08^{b}	116.14^{b}	95.44^{a}	Kawali
12.24^{a}	128.14^{a}	95.55^{a}	Super
0.546	8.290	0.412	5% LSD

Notes: Means followed by the same letters in the same coloumn are not sinificantly different at 5% LSD.

IV. Conclusion

Application of potassium fertilizer significantly increased biomass production, stalk juice volume, ethanol content and ethanol production of sweet sorghum. The rate of 100 KCl ha^{-1} resulted in the highest juice volume, ethanol content and ethanol production. Higher rates than that could not increase stalk ethanol production. Super variety gave the highest juice volume, ethanol content and ethanol production among varieties. Farmers are suggested to apply 100 KCl ha^{-1} or to use Super variety with panicle removal at 100% flowering stage to obtain high stalk ethanol production of sweet sorghum. Research on increasing plant population combined with nitrogen fertilizer application will have the potential benefits to increase biomass and ethanol production of sweet sorghum.

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References

[1] A. Almodares, R. Taheri, and S. Adeli, Categorization of sweet sorghum cultivars and lines as sweet, dual purpose and grain sorghum. *Journal of Tropical Agriculture, 46*, 2008a, 62–63.

[2] A. Almodares, R. Taheri, and S. Adeli, Stalk yield and carbohydrate composition of sweet sorghum [*Sorghum bicolor* (L.) Moench] cultivars and lines at different growth stages. *Journal of Malaysian Applied Biology, 37*, 2008b, 31-36.

[3] A. Almodares, R. Taheri, M. Hadi and M. Fathi. The effect of nitrogen and potassium fertilizers on the growth parameters and yield components of two sweet sorghum cultivars. Pakistan Journal of biological Sciences 9 (12), 2006, 2350-2353.

[4] G.C. Rains, J.S, Cundiff, and G.E.Welbaum, Sweet sorghum for a piedmont ethanol industry, in J. Janick and J. E.Simon (Eds), *New crops*, (New York: John Wiley and Sons, 1993), 394-395.

[5] M.A. Yudiarto, The use of sorghum as raw materials of bioethanol: *Paper presented in Focus Group Discussion "Prospects of Sorghum to Support Food and Energy Security"*. Department of Research and Technology-BATAN, Serpong, Indonesia, 5 September 2006.

[6] IG.A.M.S. Agung, I.K. Sardiana, I.W. Diara, and IG.M.O. Nurjaya, Adaptation, biomass and ethanol yields of sweet sorghum [*Sorghum bicolor* (L.) Moench] varieties at dryland farming areas of Jimbaran Bali, Indonesia. *Journal of Biology, Agriculture and Healthcare, 3 (17)*, 2013, 110-115.

[7] E. Erickson, K.R. Woodard, L.E. Sollenberger, Optimizing sweet sorghum production for biofuel in the southern USA through nitrogen fertilization and panicle removal, *Bioenergy Research*, DOI.10.1007/s12155-011-929-3. Published online: 26 May 2011.

[8] D.M. Broadhead, Effects of Panicle removal on stalk yield and juice quality of Rio sweet sorghum, *Crop Science 13*, 1973, 395-396.

[9] C. Rajendran, K. Ramamoorthy, and S. Backiyarani, Effect of panicle removal on juice quality characteristics and sugar yield of sweet sorghum. *Journal of Agronomy and Crop Science*, 185, 2000, 23-26.

[10] IG.A.M.S. Agung, I.K. Sardiana, I.W. Diara, and IG.M.O. Nurjaya, Panicle removal increased ethanol production of sweet sorghum [*Sorghum bicolor* (L.) Moench]. *Journal of Agriculture and Veterinary Science,* 9 *(11) Ver.II*, 2016, 46-50.

[11] S. Pholsen and N. Sornsungnoen. Effects of nitrogen and potassium rates and planting distances on growth, yield and fodder quality of forage sorghum (*Sorghum bicolor* L. Moench). Pakistan Journal of Biological Sciences, 7, 2004, 1793-1800.

[12] A. Almodares, R. Taheri, M. Chung and M. Fathi. The effect of nitrogen and potassium fertilizers on growth parameters and carbohydrate content of sweet sorghum cultivars. Journal of Environmental Biology, 29, 2008c, 849-852.

[13] Laboratory of Soil Science Faculty of Agriculture Udayana University. 2016. Results of soil analysis of dryland area in Biaung village, Badung, Bali.

[14] Laboratory of Analytic Udayana University. 2016. Results of ethanol content of sweet sorghum stalk.
[15] K.A Gomez and A.A Gomez, *Statistical Procedures for Agricultural Research* (University of Indonesia Press, Jakarta, 2007)..
[16] L. Taize and E. Zeiger, E. *Plant Physiology*. Sinauer Associates. USA.,2000.
[17] K. Raja-Reddy and D. Zhao. Interactive effects of elevated CO2 and potassium deficiency on photosynthesis, growth and biomass partitioning of cotton. Field Crop Res., 04, 2005, 201-213.
[18] T.V. Balole, *Strategies to involve yields and quality of sweet sorghum as a cash crop for small scale farmers in Botswana, doctoral diss*., University of Pretoria, Pretoria, 2001.
[19] R. Humbert, P. Mario, M. Zamora, and T.B. Fraser, Ripening and maturity control progress at Ingenio Los Mochis Mexico: *Proc. 12 th Congress ISSCT*, Amsterdam: Netherlands, 1967, 446 – 452.
[20] G.G. McBee and F.R. Miller, Carbohydrates in sorghum culms as influenced by cultivars, spacing and maturity over a diurnal period. *Crop Science, 22*, 1982, 381 – 385.
[21] M. Bitzer, *Early deheading of sweet sorghum*, Research report, National Sweet Sorghum Producers and Processors Association, 2009. http://nssppa.org/.