International Journal of Agricultural Technology 2019 Vol. 15(6):891-900
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Weed inhibition and sorghum yield as affected by organic mulch in tropical coastal environment

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Harsono, P., Setyowati, N., Qhoriyantoro, M. and Muktamar, Z. (2019). Weed inhibition and sorghum yield as affected by organic mulch in tropical coastal environment. International Journal of Agricultural Technology 15(6):891-900.

Abstract Weed control is a common practice in sorghum (*Sorghum bicolor*, L.) cultivation to prevent yield loss. The results showed that the most weed inhibition was observed in the treatment of rice straw mulch for 5 weeks after planting date (WAP) and at harvesting with a dry biomass weight of 13.49 g and 9.61 g, respectively. Nonetheless, the organic mulch had no prominent effect on sorghum yield. Keller variety had the highest biomass, but the yield was lower than the other two varieties. The result indicated that Keller variety was more suitable for animal feed, while Samurai and Super-2 varieties were prospective for human consumption. In addition, all tested sorghum varieties are potentially cultivated in the tropical coastal environment.

Keywords: coastal, sorghum, rice straw, rice husk, weed control

Introduction

Controlling weeds is an essential aspect of successful crop production. The lack of weed control can result in the total yield loss due to weed competition and weed role as a reservoir for pathogens through disease and insect damage. The multifaceted approach of weed management, such as crop rotation and herbicides, cover crops, mulches, and cultivation is more successful rather than relying solely on herbicides to control the weeds (Webber III *et al*., 2012). Weeds affect crop growth, health, and yield by competing for resources ie, light, nutrient, and growing space. Weeds can compete with sorghum and reduce the sorghum yield. The degree of crop-weed competition is determined by the weed species and density, duration of infestation, growth habit of crop plants, and environmental condition affecting the growth and development of the crop, leading to yield losses (Zimdahl, 2007).

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Weeds can compete with sorghum (*Sorghum bicolor*), reducing the sorghum yield (Fromme *et al.*, 2012). It was reported that yield loss of sorghum due to weeds ranges from 15 to 97 percent, depending on the nature and intensity of weeds. Sorghum is a crop used as a source of food, animal feed, and industrial raw materials. Sorghum is resistant to drought and a potential crop for suboptimal land. The crop prefers to grow in semi-arid regions with high temperature and water stress because of its drought adaptation capability (Paterson *et al*., 2009). Sorghum is also able to grow under low water conditions and tolerant to high temperatures (Prażak, 2016). Sorghum will play an essential role in food, feed, and fodder security, mainly in dryland areas.

The food security of many developing countries relies on sorghum production due to its low input requirements and the ability to endure extreme climatic stresses. This C_4 grass species is widely cultivated for grain, feed/fodder, and bio-fuel uses in tropical and semi-arid areas of the world. A high-efficiency water utilization mechanism and tolerance to drought and high temperatures favor it as an alternative crop to maize in areas with limited water availability (Paterson, 2009). Despite its potential, weed control for the crop has not been considered by most farmers. There are several methods for weed control, including mulch utilization.

Weeds can be controlled through preventive, cultural, chemical, biological as well as mechanical. Plastic and natural (dead or living) mulches are commonly used to control weeds (Upadhyaya and Blackshaw, 2007). Some researchers reported that organic mulching had a significant effect on soil moisture as well as grain yield (Teame *et al.*, 2017; Goitom, 2017; Setyowati *et al.*, 2017). Organic mulches such as straw, peat, wood chips, reduced weed germination. The growth of weeds such as black nightshade, redroot pigweed, barnyard grass, jimsonweed, and common purslane was sensitive to mulches (Jodaugienė *et al.*, 2006). Mulching combinations of the rice+sunflower+maize herbage was almost similar to herbicide s-metolachlor+atrazine application (Mahmood *et al*., 2016). Mulch materials of eucalyptus and rice straw could effectively control weeds in maize fields under rain-fed conditions. The research aims to determine the influence of selected organic mulch on the weed growth and yield of sorghum in the tropical coastal environment.

Materials and Methods

The study was conducted in Kandang Village, Subdistrict of Slebar, Bengkulu, Indonesia, in 2017. The experiment was a factorial arranged in a randomized complete block design (RCBD) consisting of two factors. The first factor was mulches treatment, *i.e.*, rice husk, rice straw, and control (no mulch), and the second factor was sorghum varieties, *i.e.*, Keller, Super-2, and Samurai. The treatment combination was replicated three times.

The experimental site was harrowed and 20 cm high soil beds of 4m x 2m in each block were constructed 3 days before planting. The experimental plots were separated by 75 cm between blocks and 50 cm within the blocks. Sorghum seeds were planted at a spacing of 20 cm x 15 cm, 4 seeds in each planting hole at 3 – 5 cm depth. Insecticide (Furadan 3G) was applied to prevent the seed from pest strike. Crop thinning was completed 2 weeks after planting.

Fertilizer application was carried out in accordance with the recommended dosage for sorghum, which was 200 kg urea/ha, 100 kg SP-36/ha, and 50 kg KCl/ha. Urea fertilizer was applied twice, 0.3 parts at planting date along with SP-36 and KCl fertilizers, and the rest was applied 4 weeks after planting. Fertilizer applied along the array, 10 cm from the planting hole.

Sorghum growth variables were measured on five randomly selected plant samples in each plot at 105 days after planting, included plant height (cm), stem diameter (cm), number of leaves, length of panicle (cm), panicle weight (g), panicle seed weight (g), time of flowering (DAP), harvest time (DAP), crop fresh and dry weight (g), seed weight (g), weed dry weight (g) and stalk sugar content (Brix).

Statistical analysis

Analysis of variance was calculated using SAS version 9.1.3 portable at $p < 0.05$. When there were significant differences, treatment means were separated using Duncan's Multiple Range Test.

Results

Analysis of variance showed that sorghum varieties exhibited no significant effects on the vegetative growth of sorghum and weed growth except on biomass fresh and dry weight at 5 weeks after planting (WAP). However, mulches affect the plant height, stem diameter, biomass weight as well as weed fresh and dry weight (Table 1.)

There were no significant effects of sorghum varieties on the generative growth of plants except the weight of 1000 sorghum seeds. Mulch types only affect the panicle length of sorghum. There was an interaction effect of sorghum varieties and mulches on stalk sugar content (Table 2).

Each sorghum variety controlled with mulch had higher stalk sugar content than their respective control. However, there was no different stalk content for each sorghum variety controlled by rice husk and rice straw. Keller variety without mulch exhibited the lowest stalk sugar content in comparison to the other varieties (Table 3).

Table 1. Analysis of variance for vegetative growth of sorghum and weed growth at P<5%

Variables	F-calculated		
	Varieties	Mulches	Interaction
Plant height			
• 30 DAP	1,02 ns	6,01*	1,53 ns
• 60 DAP	0,63 ns	0,12 ns	0,03 ns
• 90 DAP	0,76 ns	0,87 ns	1,39 ns
Stem diameter			
• 30 DAP	0,39 ns	6,76**	1,28 ns
• 60 DAP	0,93 ns	1,71 ns	2,14 ns
• 90 DAP	0,05 ns	5,36*	1,25 ns
Leaves number			
• 30 DAP	1,06 ns	0,18 ns	0,61 ns
• 60 DAP	2,26 ns	0,03 ns	1,27 ns
• 90 DAP	2,49 ns	0,08 ns	1,23 ns
Biomass fresh weight			
• 5 WAT	6,21*	2,69 ns	2,22 ns
• At harvest	1,88 ns	4,63*	2,15 ns
Biomass dry weight			
• 5 WAT	5,81*	2,96 ns	2,06 ns
• At harvest	1,91 ns	4,88 *	2,19 ns
Weed fresh weight			
• 5 WAT	2,54 ns	8,67**	1,22 ns
• At harvest	2,46 ns	6,91**	2,23 ns
Weed dry weight			
• 5 WAT	2,72 ns	9,26**	1,31 ns
• At harvest	2,62 ns	7,36**	2,38 ns

Table 2. Analysis of Variance for sorghum generative growth at P<5%

Variables	F-calculated		
	Varieties	Mulches	Interaction
Flowering date	0,90 ns	0,06 ns	2,82 ns
Harvest time	0,85 ns	0,07 ns	2,85 ns
Plant seed weight	1,37 ns	2,52 ns	1,73 ns
Weight of 1000 seeds	43,90**	1,31 ns	2,15 ns
Panicle length	1,68 ns	3,79*	0,10 ns
Panicle weight/plant	2,52 ns	2,28 ns	1,73 ns
Panicle weight/plot	2,35 ns	2,60 ns	0,90 ns
Sugar content	2,27 ns	23,56**	3,62*

*=significantly different, **=highly significant different, ns=non significantly different

Table 3. Sorghum varieties and mulches interactions on stalk sugar content

Varieties, Mulches	Stalk sugar content (Brix)
Keller, rice husk	12,00 bc
Keller, rice straw	13,33 ab
Keller, no mulch	8,00 f
Super-2, rice husk	11,67 cd
Super-2, rice straw	12,00 bc
Super-2, no mulch	10,00 e
Samurai, rice husk	14,00 a
Samurai, rice straw	12,00 bc
Samurai, no mulch	10,33 de

Treatment means within the column, followed by the same letter are not significantly differences at DMRT 5%.

Table 4. Effect of varieties on sorghum vegetative growth

Variables	Sorghum varieties		
	Keller	Super-2	Samurai
Plant height (cm)			
30 DAP	119,96	117,23	111,54
60 DAP	258,54	279,4	256,89
90 DAP	327,67	321,33	314,22
Stem diameter (cm)			
30 DAP	6,19	5,99	6,12
60 DAP	6,02	6,23	6,37
90 DAP	5,76	5,78	5,84
Leaves number			
30 DAP	6,71	6,07	6,70
60 DAP	11,28	10,42	11,72
90 DAP	13,61	12,71	14,23
Biomass fresh weight (g)			
5 WAT	291,01 a	194,48 b	234,87 ab
At harvest	438,5	311,91	402,89
Biomass dry weight (g)			
5 WAT	59,39 a	39,69 b	47,93 ab
At harvest	89,49	63,66	82,22
Weed fresh weight			
5 WAT	84,11	79,95	66,45
At harvest	65,17	50,83	48,21
Weed dry weight			
5 WAT	17,52	16,66	13,84
At harvest	13,58	10,59	10,04

Treatment means between column followed by the same letter are not significantly differences at DMRT 5%.

Plants heights of sorghum at 90 DAP ranged from 314 cm - 327 cm; stem diameter at 60 DAP ranged from 6.02 cm - 6.37 cm, while the number of leaves was 12.71 - 14.23. Although there were no significant differences, var. Keller tended to have better growth than the other two. Keller variety was also exhibited higher plant weights. The results also showed no significant differences among varieties on weed fresh and dry weight (Table 4).

Plant height of rice husk and rice straw mulch treatments at 30 DAP was higher than that of no-mulch. Plant height in mulches treatments was more than 110 cm and less than 110 cm in no-mulch treatment (Table 6). However, there were no significant differences in plant height either at 60 or 90 DAP. Rice straw mulch resulted in higher stem diameter, biomass fresh and dry weight as reduced weed fresh dry, dry weight (Table 5).

Table 5. Effect of mulches on plant sorghum vegetative growth and weed fresh and dry weight

Variables	Mulches		
	Rice husk	Rice straw	No-mulch
Plant height (cm)			
30 DAP	115,84 a	113,91 a	106,06 b
60 DAP	263,09	264,24	260,53
90 DAP	324,00	326,67	312,89
Stem diameter (cm)			
30 DAP	5,87 b	5,90 a	5,84 b
60 DAP	6,25	5,99	5,95
90 DAP	5,50 b	6,34 a	5,53 b
Leaves number			
30 DAP	6,38	6,31	6,43
60 DAP	11,08	11,23	11,23
90 DAP	13,59	13,46	13,61
Biomass fresh weight (g)			
5 WAT	228,39	215,87	215,71
At harvest	370,98 ab	492,11 a	289,43 b
Biomass dry weight (g)			
5 WAT	46,61	44,06	44,02
At harvest	75,71 ab	100,58 a	59,07 b
Weed fresh weight			
5 WAT	69,33 b	64,75 b	96,32 a
At harvest	47,41 b	44,48 b	72,32a
Weed dry weight			
5 WAT	14,44 b	13,49 b	20,07 a
At harvest	9,88 b	9,61 b	15,07 a

Treatment means between column followed by the same letter are not significantly differences at DMRT 5%.

There were no significant differences among varieties on the yield of sorghum except on 1000 seed weight. Super-2 variety has a higher 1000 seed weight (30.66 g) compare to that of Keller (21.06 g). This result indicates that Keller variety has smaller seed size compared to the others (Table 6).

Table 6. Effect of varieties on sorghum yield

Variables	Varieties		
	Keller	Super-2	Samurai
Flowering date (DAP)	55,67	54,67	56,93
Harvest time (DAP)	111,33	109,33	113,87
Seed weight (g/plant)	20,21	28,1	29,69
1000 seed weight (g)	21,06 b	30,86 a	30,78 a
Panicle length (cm)	23,89	21,76	22,20
Panicle weight (g/plant)	48,5	67,44	71,24
Panicle weight (g/plot)	1877,78	2611,11	2411,11

Treatment means between column followed by the same letter are not significantly differences at DMRT 5%.

There was no significant effect of mulch types on the sorghum vegetative growth except on panicle length. Panicle length of sorghum treated with rice straw was higher than that of rice husk mulch; however, mulch treatments resulted in no different on the date of flowering, harvest time, as well as seed weight of sorghum (Table 7).

Table 7. Effect of mulches on the flowering date, harvest time, seed weight and panicle length and weight

Variables	Mulches		
	Rice husk	Rice straw	Control
Flowering date (DAP)	55,58	53,82	55,56
Harvest time (DAP)	111,16	107,64	111,11
Seed weight (g/plant)	24,79	23,26	21,89
1000 seed weight (g)	27,02	27,14	26,98
Panicle length (cm)	20,77 b	24,07 a	23,00 ab
Panicle weight (g/plant)	59,50	55,82	52,54
Panicle weight (g/plot)	2261,11	2211,11	1922,22

Treatment means between column followed by the same letter are not significantly differences at DMRT 5%. ⌘= no mulch

Discussion

The stalk sugar content of sorghum stems with no mulch was lower than that of mulches treatment. Rice husk and rice straw mulch increased the sugar content of sorghum var. Keller 50% dan 66.6%, var. Super-2 Keller 16.7% and 9.1%, and var. Samurai 35.5% dan 16.2% respectively. Keller has the highest sugar content, 13.33 Brix, while var. Samurai 14.00 Brix is the lowest. In this experiment, The sugar content of sorghum varieties treated with mulches is higher than those of other varieties such as var. Numbu = 10.81 Brix, Lokal Selayar Hitam = 11.85 and Lokal Sorgum Hitam = 12.18. Gamawati Adinurani *et al.* (2018) reported var. Suri-3 has higher sugar content compared to that of Kawali, Super-2, and Suri-4 varieties. Related to the finding, (Alhajturki *et al.*, 2012) reported that Genotype ICSSH 30 was superior to other varieties in terms of drought-tolerance, associated traits and high sugar and bio-ethanol potential yield under both well-watered and low moisture stress. According to (Ekefre *et al.,* 2017), the sugar content in the stalk of the sorghum plant varies among the varieties, depending on the environmental conditions, the position of the stem segment, and the stages of the harvest time. The sugar content of the three varieties varied between (8.00 to 14.00 Brix) with the highest on the Samurai with rice husk mulch. This study validated previous researches, showing sorghum as a drought-tolerant crop and demonstrates that there is high genetic variation among sweet sorghum varieties.

Fresh and dry biomass var. Keller was higher than Super-2 even though no significant difference in plant height, stem diameter, and leaves number. However, the fresh and dry weight were related to plant height, stem diameter as well as leaves number — plant height of var. Keller tends to be higher (327. 67 cm) than that of var. Super-2 (321.33 cm) and var. Samurai (314.22 cm); stem diameter of var. Keller (5.76 cm), var. Super-2 (5.78 cm) while var. Samurai (5.84 cm) whereas the leaf number of var. Keller was 13.61, var. Super-2 (12.71) and var. Samurai (14.23) at 90 DAP (Table 4). These results indicate that all tested sorghum varieties well-adapted to the coastal area since the plant growth variables were close to the description of the varieties. A similar result was reported by (Simarmata *et al*., 2017) that sorghum var. B-100, Kawali, Samurai, and Super-2 have the potential for the production of seed and biomass in the dry land of the coastal area. In addition, weed fresh and dry weight was lower at harvest time in all varieties compared to that at 5 WAT, indicating that the weed growth was suppressed since the sunlight could not penetrate the canopy and resulted in weed growth suppression.

Sorghum treated with no-mulch has lower plant height and stem diameter at 30 DAP and no significant difference in leaf number either in 30, 60 or 90 DAP. Rice straw treatment resulted in higher (6.34 cm) stem diameter compared to that of no-mulch (5.53 cm). Fresh and dry biomass at harvest was also higher in rice straw mulch treatment compared to that of no-mulch. No significant difference between rice straw and rice husk mulch on the biomass weight, indicating both mulches have a similar effect on sorghum growth.

Weeds growth was suppressed by the existence of both rice husk and rice straw mulches. Rice husk and rice straw suppressed weed fresh weight as much as 34.4% and 38.50% and weed dry weight of 34.4% and 36.23% compared to that of control treatment or with no-mulch at harvest time. These results indicated that both rice husk and rice straw mulch had a positive impact on sorghum growth. A similar finding was reported by Mahmood *et al*. (2016) on maize (Teame *et al*., 2017), and on sesame (*Sesamum indicum* L.). Organic mulching increased soil moisture content up to 0.6 m depth (Teame *et al*., 2017). Accordingly, soil moisture correlated to plant growth and development. Therefore, organic mulch, such as rice husk and rice straw, is an option for weed control of sorghum in the coastal area.

There were no significant differences among varieties on sorghum date of flowering, harvest time, seed weight, panicle length, and weight but 1000 seeds weight. The 1000 seeds weight of var. Keller was lower (21.06 g) than that of Super-2 (30.86 g) and Samurai (30.78 g), indicating that var. Keller had a smaller seed size compare to other varieties. This finding was comparable to their variety description where Super-2 1000 seeds weight is 30.1 g. Since sorghum varieties tested in this experiment had resulted in no difference in panicle length, and weight as well as seed weight, the varieties (Keller, Super-2, and Samurai) were prospective for their productions in the coastal area of Bengkulu. Other findings such as var. B-100 and Kawali also had the potential for seed and biomass production in dryland of the coastal area (Simarmata *et al*., 2017) and var. Numbu, Kawali, Padjadjaran University-1, Padjadjaran-2, Batari, Keller as well as Taomitsu was well-adapted to dry land in Kudat District, West Java Province (Sutrisna *et al*., 2013). Weed existence during plant growth and development did not affect sorghum yield. Sorghum is known to express adaptability and tolerant to environmental stress such as drought, salinity, acidic, low fertility as well as aluminum poisoning (Saberi and Aishah, 2013; Sutrisna *et al.*, 2013). Sorghum is a C4 plant and well adapted on dry land with high air temperature. Therefore, sorghum is a prospective crop on marginal dry land such as the coastal region in Bengkulu. It was concluded that in general, rice husk, as well as rice straw, had no effect on the growth and yield of sorghum; however, both mulches suppressed weed growth. Sorghum var. Samurai with rice husk has the highest stalk sugar content.

Acknowledgment

Highly appreciation goes to the Directorate General of Research and Extension, The Ministry of Research, Technology and Higher Education, Republic of Indonesia, for providing financial support through the Postgraduate Research project in 2019.

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(Received: 26 July 2019, accepted: 30 October 2019)