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Research Article
Prospect for Growing Sorghum (*Sorghum bicolor* L. Moench) at Marginal Dry Land in Coastal Area Retrieved with Organic Soil Amendments

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Abstract
Background and Objective: Sorghum is one of the cereal crops that can be used for food and feed. It has a wide adaptability and tolerant to environmental stress. The objective of this study was to introduce sorghum cultivation at dry land in coastal areas. **Materials and Methods:** Experiment was conducted in Bengkulu, Indonesia, from May-December, 2016. Sorghum varieties and organic soil amendments were evaluated in field experiment conducted in a split plot design with 3 replications. Sorghum varieties as main plots consisted of var. B-100, Kawali, Samurai and Super-2, while organic soil amendments as sub plots consisted of composted empty fruit bunch of palm oil (EFB), composted wedelia (*Wedelia trilobata*), chicken and cow manures. Physical and chemical properties of soil were analyzed before and after the experiments. Data of growth and yield parameters of sorghum were subjected to two-way analysis of variance and means of significant differences were separated by the least significant difference test at 5% level. **Results:** Initial soil analysis showed the pH, C-organic and electrical conductivity (EC) were 5.05, 1.48%, 8.01 dS m^{-1}, respectively. Chemical and physical properties of soil improved after one season treated with of organic soil amendments. Significant interaction of sorghum varieties and organic soil amendments was observed on plant height, number of leaves, yield and length of panicles. Composted EFB, Wedelia, chicken and cow manures increased sorghum yield of var. B-100 by 16.58, 13.51, 8.25 and 13.67%, respectively. Soil amendments of composted chicken and cow manures increased dry biomass weight by 25.44 and 21.12%, respectively. The heaviest 1000 seeds were produced by var. B-100, while the heaviest dry biomass was produced by var. Super-2. **Conclusion:** It was concluded that sorghum has a potential to be developed for seed and for biomass production at dry land of coastal areas after their retrieval by local organic soil amendments.

Key words: Empty fruit bunch (EFB), manure, marginal land, sorghum, *Wedelia trilobata*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is the fifth of the world's food crops after wheat, rice, corn and barley. Sorghum originated from Africa but the cultivation has spread over the world with current production in many countries including Africa, China, Central and South America, India and the USA[1,2]. In Indonesia, sorghum has been known for a long time but it was only cultivated in several dry regions such as North of Java, East and West of Nusa Tenggara[3]. Some benefits of sorghum are usefulness of grains as a source of human food, animal feed and the biomass can be directly used as a ruminant feed[4,5]. Sorghum grains are also used as raw materials for industry of beer, starch and liquid sugar[6]. In some countries like USA, India and China sorghum biomass have been processed to make paper, plastic and bioethanol[7,8].

Sorghum is known to have wide adaptability and tolerant to environmental stress such as low fertility, drought, salinity, acidic, as well as aluminum poisoning and even more tolerant to waterlogging[9,10,11]. Therefore, sorghum has a good prospect to be developed in marginal dry lands that are not yet managed. Now days, extensification of agriculture is intended to meet the needs of human food especially in developing countries[12]. Availability of suitable agricultural lands has been limited because of land conversion into residential housing and industries, thus agricultural extensification was directed to unmanaged dry lands such as the coastal areas[10,13]. Ecosystem of coastal areas is dry lands or peat swamp which has some limitations to be used for farming[13]. Thus, preparation of dry land for farming in coastal areas can be done by first improving soil qualities through the addition of soil amendments either organic or inorganic materials[12].

Manures from animals are often used as organic soil amendments. Using manures in farming can improve physical, chemical and biological properties of soil[14]. The average chemical content of nitrogen, phosphate and potassium from composted cow manures are 2.4, 0.7 and 2.1% of dry weight and from composted chicken manure are 2.3, 3.5 and 2.9% of dry weight, respectively[15]. Utilization of manure may substitute the need for inorganic fertilizers. It had been reported that manures can be used as an alternative fertilizer that can increase the growth and yield of crops for more than one growing season[14,16]. Researchers reported that application of 2 t ha^{-1} of chicken manure on maize could increase crop yield up to 60% in the first year and 40% in the second year.

Other alternative organic amendments are biomass from green plants[15]. If manures are not available, materials from plants or crops are also used as alternative organic amendments such as forage of weed vegetations and green waste of crops[17,18]. Empty fruit bunches (EFB) of oil palms are agricultural waste that has been used as organic amendments[19]. Around 22-23% EFB were produced from waste processing of fresh fruit bunches. In large-scale plantations, the amount of EFB will be enormous but so far it's used only for landfills by open dumping. The chemical composition of EFB includes carbon, nitrogen, phosphate and potassium are 14.5, 2.15, 1.54 and 0.15%, respectively[19,20]. Another source of green organic amendment is weed based biomass[17,18]. Some weed species that have been tested as a source of organic compost were babadotan (*Ageratum conyzoides*), kirinyuh (*Chromolaena odorata*), ipil-ipil (*Leucaena leucocephala*), wild sunflower (*Tithonia diversifolia*) and wedelia (*Wedelia trilobata*). Wedelia has potential to be used as a source of organic amendment because it grows very fast and has succulent biomass. Composted wedelia contains organic carbon, nitrogen, phosphate and potassium of 4.8, 3.2, 0.38 and 4.33%, respectively[18]. Compost of wedelia improved the growth and yield of sweet corn, cabbages, peppers and cauliflowers[16,18].

This study was aimed to develop sorghum cultivation on marginal dry lands in coastal areas after retrieving soil marginalities using organic soil amendments from local resources such as composted EFB, composted wedelia, composted chicken and cow manures.

MATERIALS AND METHODS

Experimental preparation: The research was conducted to introduce sorghum cultivation in the coastal area in Bengkulu, Indonesia from May-December, 2016. Site of experimental field was located approximately 100 m from the shoreline of the Indian Ocean at a geographical position of 03°45' 27" South, 102°40' 03" East and the altitude of 3 m above the sea level. Soil texture was assessed following the methods in NSW Agriculture[21]. Soil analysis prior to land preparation was done in the Laboratory of Soil Sciences, University of Bengkulu to measured soil pH, C-organic and electrical conductivity (EC).

Local organic materials to be used as soil amendments were empty fruit bunches of oil palm (EFB), weed biomass of wedelia (*Wedelia trilobata*), composted chicken and cow manures. The EFB were collected from the waste of palm oil mill. Biomass of wedelia was collected in farm field of Bengkulu University. Green organic materials were chopped to a size of 5 mm and then sprayed evenly with bioactivator EM-4 0.2% (v/v) in sucrose solution 1% (w/v). Chopped organic materials were placed separately in 1 m^2 of wooden box covered with plastic tarps to prevent the materials from the rain. The organic materials were remixed every week for 4 weeks or up to form the ready to use compost. The composted chicken and cow manures were obtained from local farmers.

Field experiment was arranged in a split plot design with 3 replications as blocks. Four sorghum varieties were placed as main plots included var. B-100, Kawali, Samurai and Super-2. The subplots consisted of composted EFB, composted wedelia, composted chicken manure, composted cow manure and without compost as a control. Land was prepared by cutting weed vegetations and the soil was cultivated twice using hoes. The plots of 3 m x 2 m were formed for 60 plots in accordance with total treatment combinations. Each of composted organic soil amendments at a dose of 10 t ha^{-1} were applied by mixing evenly within the soil in each plot at a depth of 20 cm.

Sorghum seeds were planted a week after organic amendments applied. The planting was setting in rows where the distance between rows was 75 cm and the distance within a row was 20 cm. Three seeds/hole were planted with a dibble way with a depth of 3 cm and 5 pcs. of carbofuran granules were added to prevent seeds from insects.

Plants were fertilized with N, P_2O_5 and K_2O at a dose of 100 kg ha^{-1} each. N fertilizer was given twice, at planting time and at 30 days after planting with a half dose of each application, while P_2O_5 and K_2O were given once at the time of planting. Fertilizers were applied on an array of 5 cm apart from the crop rows.

Plant maintenances included watering every day during germination period in the first week after planting (WAP), thinning by leaving one plant/planting hole at 2 WAP, weeding at 3 WAP, controlling insects and diseases as needed using Deltamethrin 25 EC and Dithane M-45 at recommended doses. Sorghum was harvested at 100 days or by considering criteria of maturity seeds.

Data collection: Data collected included plant height, leaf areas, number of leaves, yield, length of panicle, weight of 1000 seeds and sorghum biomass. Measurement of plant height, leaf areas and number of leaves were done when 50% of plants were flowering. Plant height was measured from the base of the stem to the tip of the highest leaf. Leaf areas were measured by gravimetric method[9], as in Eq. 1. Number of leaves was counted all leaves of one plant from the bottom to the top of stem. Yield was harvested from sample crops and presented as dried weight of grains/plant. Length of panicle was measured from the base to the tip of panicle. Weight of 1,000 seeds of sorghum obtained from 1,000 cleaned seeds[9]:

$$LA = \frac{DWL}{DWPL} \times LAPL \quad (1)$$

Where:

LA = Leaf areas of observed leaf
DWL = Dry weight of observed leaf
DWPL = Dry weight of pattern leaf
LAPL = Leaf areas of pattern leaf

Soil analysis observed soil pH, C-organic and electric conductivity (EC) was done at the end of the experiment. Precipitation and number of rainy days were recorded during the experiments.

Statistical analysis: Data of sorghum parameters were subjected to two-way classification of analysis of variance (ANOVA) using statistical software of CoStat 6.4. Means of each variable that were influenced significantly by F-test were further separated by Fisher's LSD test at 5% level.

RESULTS AND DISCUSSION

Experimental site characteristics: Soil analysis prior to land preparation showed the pH, EC and C-organic were 5.05, 8.31 dS m^{-1} and 1.48%, respectively (Table 1). Soil texture is loamy sand which consisted of >90% fine sand. Based on soil quality indicators[21], the experimental site was acidic, moderately saline and low of C-organic contents. Improvement of soil qualities was indicated after one season of growing sorghum treated with organic amendments. Soil pH increased from 5.05-5.93 and to 6.13 with the treatment of cow and chicken manures, respectively. Electrical conductivity (EC) which was used to determine the level of salinity remained in moderately saline. C-organic increased by all treatments of organic amendments and the highest C-organic (2.65%) was measured in the treatment of cow manure compost. Monthly precipitation and number of rainy days from May-October, 2016 were provided in Table 2. Sorghum was planted in June, 2016 in which monthly precipitation was 181 mm with 7 days of rain. This precipitation was relatively low and categorized dry season. Thus, sorghum seedlings were watered daily during germination periods.

Overall, there were no barriers for growing sorghum in marginal dry land of coastal areas. Sorghum is known to have

Table 1: Physical and chemical properties of soil at the experimental site

		Final analysis (end of the research)*				
Soil properties	Initial analysis	Control	EFB	Wedelia	Chicken manure	Cow manure
pH (1:2.5/Soil:Water)	5.05	5.33	5.33	5.43	6.13	5.93
Electrical conductivity (dSm^{-1})	8.31	8.54	9.67	8.65	9.50	9.95
C-organic (%)	1.48	1.36	1.74	1.99	1.83	2.65

*Average of four soil samples collected by composite method

Table 2: Number of rainy days and total precipitation during the experiments*

Months	Number of rainy days (days)	Monthly precipitation (mm)
May	14	432.3
June	7	181.0
July	6	202.0
August	15	496.7
September	17	466.0
October	9	243.4

*Soil Science Laboratory, University of Bengkulu

a wide adaptability and tolerant to environmental stress such as drought, saline, acidity and low fertility[9-11]. Soil characteristics in the experimental site were categorized marginal indicated by low precipitation, high EC, acidic pH (less than 5.5) and low C-organic content, respectively.

Growth of sorghum: Interaction effects of organic soil amendments and sorghum varieties observed on growth variables included plant height and number of leaves, while single effect of organic amendments was observed on leaf areas dry biomass weight (Table 3). Plant height was significantly increased by organic amendment treatments in the main plot of var. Super-2 (Table 4). The tallest plant was 334.10 cm found in the subplot of composted chicken manure, followed by composted EFB, cow manure and wedelia for 309.67, 305.37 and 297.83 cm, respectively. Among the varieties of sorghum in all subplots, var. Super-2 was the tallest and var. Kawali was the shortest.

Similar to plant height, number of leaves was influenced significantly by organic soil amendments in main-plot of var. Super-2 (Table 5). The highest number of leaves was observed in the treatment of composted chicken manures (11.83 sheets/plant). Leaf areas was affected singly by organic soil amendments and the widest leaf areas was 720.89 cm^2/leaf found in the plot of composted chicken manure, followed by 710.51, 616.76 and 557.31 cm^2/leaf in the plot of composted cow manure, EFB and wedelia, respectively (Table 6).

Significant enhancements of sorghum growth found on plant height and number of leaves was caused by the treatment of organic soil amendments. The growth of crops increased due to improvement of soil qualities after treated with organic amendments[11,22]. The growth was performed better with composted manures than with composted green materials[15]. The main reason is because chicken and cow manures were easily decomposed and some nutrients such as nitrogen, phosphate, potassium, calcium and magnesium were available for crop[14,15]. The ratio of C/N was determined availability of nutrients. The lower the ratio of C/N the faster decomposition process of organic amendments, thus performed better effects on plant growth[17,22].

Numerous studies have been successfully showing the benefits of using organic amendments at marginal soil, such as increased soil pH, C-organic and enhanced availability of nutrients to plants[11,14]. Application of organic soil amendments improved not only chemical but also physical properties of soil, thus enhanced water holding capacity of soil in coastal areas[15]. Previous report described that the improvement of soil qualities enhanced the growth parameters of some crops[22]. On the other hand, growth improvements varied among sorghum varieties which were the tallest and the highest number of leaves observed on var. Super-2. The main explanation of different response of sorghum varieties to organic soil amendments were caused by genetic variations of sorghum[2,23].

Yield and yield components: Interaction effect of organic soil amendments and sorghum varieties was found on grain yield of sorghum (Table 3, 7). In the main-plot of var. B-100, soil amendments of EFB, wedelia, chicken manure and cow manure increased grain yield production of sorghum from 99.72-116.26, 113.23, 107.95 and 113.49 g/plant or 16.58, 13.51, 8.25 and 13.67%, respectively. In the main plot of var. Kawali, only chicken manure increased grain yield significantly from 88.77-104.60 g/plant or 17.83%. In the main plot of var. Samurai, grain yield increased significantly with composted chicken and cow manures from 56.86-82.11 and 91.59 g/plant or 44.40 and 61.08%, respectively. In main plot of var. Super-2, grain yield increased significantly with organic amendments of composted EFB, wedelia, chicken manure and cow manure from 54.64-84.94, 74.31, 93.58 and 89.55 g/plant or 55.45,

Table 3: Recapitulation of F-test from analysis of variance (ANOVA) of the growth and yield variables of sorghum

Observed parameters	F-test Sorghum variety (main plot)	Organic soil amendments (sub plot)	Interaction
Plant height (cm)	38.61*	1.73^{ns}	3.39*
Number of leaves (sheets/leaf)	3.91^{ns}	1.75^{ns}	2.21*
Leaf areas (cm^2/leaf)	2.07^{ns}	4.74*	0.44^{ns}
Yield (g/plant)	92.76*	8.46*	2.59*
Length of panicle (cm)	28.06*	4.15*	2.68*
Weight of 1000 seeds (g)	86.31*	1.82^{ns}	0.77^{ns}
Dry Biomass (g/plant)	56.33*	2.88*	1.76^{ns}
F-table ($p \leq 0.05$)	4.67	2.67	2.07
F-table ($p \leq 0.01$)	9.78	3.98	2.81

*Significant effect with analysis of variance (ANOVA) at 5% level, ns: No significant effect

Table 4: Interaction effect of sorghum varieties and organic amendments on plant height (cm)

Sorghum varieties (main plot)	Organic soil amendments (sub-plot)* Control	EFB	Wedelia	Chiken manure	Cow manure
B-100	249.10^{aA}	257.27^{bA}	257.23^{bA}	251.30^{bA}	257.37^{bA}
Kawali	204.43^{bA}	197.67^{cA}	195.17^{cA}	189.83^{cA}	187.77^{cA}
Samurai	253.77^{aA}	258.67^{bA}	250.40^{bA}	236.43^{bA}	257.53^{bA}
Super-2	251.50^{aC}	309.67^{aA}	297.83^{aB}	334.10^{aA}	305.37^{aAB}

*Means followed by the same lowercase and uppercase letters are not significantly different by LSD test at 5% level within a column and a row, respectively

Table 5: Interaction effect of sorghum varieties and organic amendments on number of leaves (sheets/plant)

Sorghum varieties (main plot)	Organic soil amendments (sub-plot)* Control	EFB	Wedelia	Chicken manure	Cow manure
B-100	11.03^{aA}	9.93^{bA}	10.03^{bA}	10.17^{bA}	10.40^{bA}
Kawali	11.07^{aA}	11.60^{aA}	11.43^{aA}	11.40^{aA}	10.47^{abA}
Samurai	10.47^{abAB}	9.93^{bB}	10.30^{bAB}	11.23^{aA}	11.40^{aA}
Super-2	9.43^{bC}	10.60^{abBC}	10.47^{abBC}	11.83^{aA}	11.30^{aAB}

*Means followed by the same lowercase and uppercase letters are not significantly different by LSD test at 5% level within a column and a row, respectively

Table 6: Effect of organic amendment on leaf areas and dry biomass of sorghum

Soil amendments	Leaf areas (cm^2/leaf)*	Dry biomass weight* (g/plant)
Control	557.31^c	117.16^b
EFB	616.76^b	129.16^{ab}
Wedelia	605.29^{bc}	116.83^b
Chicken manure	710.51^a	146.97^a
Cows manure	720.89^a	141.91^a

*Means followed by the same letters are not significantly different by LSD test at 5% level

34.16, 71.26 and 63.89%, respectively. Overall, the highest improvement due to treatment of soil amendments were observed in var. Super-2 treated with chicken and cow manures for 71.26 and 63.89%, respectively and var. Samurai treated with cow manure for 61.08%. However, in all main plots, var. B-100 produced the highest yield which was significantly different from var. Kawali, Samurai and Super-2.

Interaction between organic soil amendments and sorghum varieties also appeared on length of panicles (Table 3, 8). Panicle length increased due to the organic amendments only in var. Samurai and Super-2. The longest panicle was observed in chicken manure of 27.94 and 28.26 cm, respectively. Weight of 1,000 seeds were also influenced by sorghum varieties (Table 9), which var. B-100 had the heaviest of 1000 seeds weight (41.10 g), while var. Kawali, Samurai and Super-2 had 1,000 seeds weight ranged from 31.81-30.8 g. So far, yield improvement was not associated to the weight of 1,000 seeds and length of panicle.

The yields of sorghum grown in marginal dry land of coastal areas improved after retrieving soil marginalities with organic soil amendments. Treatment of composted green organic and manures improved soil qualities and soil nutrients availability to sorghum. Soil amendments from manures enhanced the grain yield production better than composted green plants. The main reasons were similar to previously explained, because animal manures were easily decomposed in the soil and faster availability of nutrients to crop needs[14,15]. The improvement of grain yield did not associated with yield component such as length of panicle and weight of 1,000 seeds. The improvements of yield due to organic amendments were found in all 4 varieties tested. Different

Table 7: Interaction effect of sorghum varieties and organic amendments on yield of sorghum (g/plant)

Sorghum varieties (main plot)	Organic soil amendments (Sub-plot)*				
	Control	EFB	Wedelia	Chiken manure	Cow manure
B-100	99.72^{aB}	116.26^{aA}	113.23^{aA}	107.95^{aAB}	113.39^{aA}
Kawali	88.77^{aB}	99.65^{bAB}	98.46^{bAB}	104.60^{abA}	94.13^{bAB}
Samurai	56.86^{bC}	70.66^{cBC}	66.83^{cC}	82.11^{cAB}	91.59^{bA}
Super-2	54.64^{bC}	84.94^{cAB}	74.31^{cB}	93.58^{bcA}	89.55^{bA}

*Means followed by the same lowercase and uppercase letters are not significantly different by LSD test at 5% level within a column and a row, respectively

Table 8: Interaction effect of sorghum varieties and organic amendments on length of panicle (cm)

Sorghum varieties (main plot)	Organic soil amendments (Sub-plot)*				
	Control	EFB	Wedelia	Chiken manure	Cow manure
B-100	20.63^{dA}	20.56^{bA}	20.19^{cA}	20.73^{cA}	19.72^{cA}
Kawali	27.11^{aA}	26.39^{aA}	26.31^{aA}	26.61^{bA}	23.99^{bB}
Samurai	25.65^{bB}	26.11^{aAB}	25.94^{bB}	27.94^{aA}	27.46^{aAB}
Super-2	22.21^{cC}	25.53^{aB}	25.86^{bB}	28.26^{aA}	24.79^{bB}

*Means followed by the same lowercase and uppercase letters are not significantly different by LSD test at 5% level within a column and a row, respectively

Table 9: Difference of 1000 seeds weight and dry biomass weight of sorghum varieties

Sorghum varieties	1000 seeds weight* (g)	Dry biomass weight* (g/plant)
B-100	41.10^{a}	127.04^{b}
Kawali	31.81^{b}	100.17^{c}
Samurai	30.31^{b}	133.61^{b}
Super-2	30 08^{b}	160.81^{a}

*Means followed by the same letters are not significantly different by LSD test at 5% level

yield of sorghum varieties to soil organic amendments was caused by genetics variations of sorghum, where var. B-100 produced the highest grain yield production[2,23].

Biomass production: No interaction was found between organic amendments and sorghum varieties but singly organic amendments and sorghum varieties influenced dry biomass production (Table 6, 9). The heaviest dry biomass was produced by composted chicken manure and cow manures of 146.97 and 141.91 g/plant, respectively (Table 6). Dry biomass weight varied among sorghum varieties which ranked from the highest to the lowest were Super-2, Samurai, B-100 and Kawali (Table 9).

Retrieving soil quality with organic soil amendments will increase the potential rate of photosynthesis and the amount of carbon sequestered by plants[9]. Application of organic amendments on marginal dry land of coastal area improved soil qualities which provided favorable conditions for metabolic process of the plant, because more nutrients and water available, as well as better biological, physical and chemical properties of soil for growing crops[14,22]. The results of this research described that organic amendment of manure is better to enhance growth, yield and biomass production of sorghum in marginal dry land of coastal areas but organic amendment of green plants can be used as an alternative if animal manure is in shortage conditions.

CONCLUSION

Sorghum has a potential to be developed at dry lands in coastal areas after retrieving their soil marginalities using local organic soil amendments. The highest plant height and number of leaves were found in var. Super-2 treated with composted chicken manure. Sorghum yield of var. B-100 increased by 16.58, 13.51, 8.25 and 13.67% with composted EFB, wedelia, chicken and cow manures, respectively. Singly, var. Super-2 produced the heaviest biomass of sorghum. Soil amendments by animal manures were better in retrieving soil marginalities of dry land in coastal areas but green manure of plants can be used as an alternative soil amendments.

SIGNIFICANCE STATEMENTS

This study discovered the potential of wide dry land of coastal zones to be developed for crop cultivation. Sorghum, which has enormous benefits, wide adaptability and high tolerant to environmental stress, has an excellent prospect to be cultivated at marginal dry land in coastal areas after retrieving soil marginalities with local organic soil amendments, such as forage of green organic materials from plants or agricultural wastes and animal manures. Sorghum var. B-100 produced the highest grain yield, while var. Super-2 produced the heaviest dry biomass weight. Green organic materials can be used as soil amendments if animal manures are not available.

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