Response and Allelochemicals Content of Two Sorghum Varieties to Manure

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Abstract. Sweet sorghum can be used to support the needs of food, feed, and energy. The specific objectives are to determine the performance of different varieties of sorghum, to determine the best dose of manure for growing sorghum, and to study the interaction between combined fertilizer and varieties of sorghum in coastal land. Research was arranged in randomized factorial design with three replications. The first factor consisted of two varieties of sorghum includes Numbu, and Kawali, and the second factor is combination of fertilizers consisted of solid cow manure 10 ton ha\(^{-1}\) + ½ of recommended dose of mineral fertilizer, cow’s urine (200 ml urine in 15 L of water) + ½ dose of recommended dose of mineral fertilizer, and mineral fertilizers as recommended dose (120 kg ha\(^{-1}\) of Urea, 90 kg ha\(^{-1}\) of superphosphate, and 60 kg ha\(^{-1}\) of KCl). The results showed that the best performance on growth and yield was observed on Kawali with fertilization using solid cow manure 10 ton ha\(^{-1}\) + ½ of recommended dose of mineral fertilizer. Results of sorghum root analysis with GCMS showed results that Numbu and Kawali detected hydroquinone and resorcinol as intermediate compounds Sorgoleone potential as bioherbicides.

1. Introduction
Rural areas are generally identical to the area of coastal land which is limited for growing crops because of lacked of water resources. Activity on farm only rely on rainfall due to the lack of irrigation facilities. Therefore, availability of water is the main limiting factor for crop production. The symptoms of water deficiency were indicated by shrinking of assimilate storage organs such as stem, leaf, and cereal seeds [1]. Ability of photosynthesis was declined due to various environmental stresses such as drought, heat stress, and biotic disturbances on the leaves. One way to exploit the potency of the wide area coastal land is by planting crops that have low water consumption in order to keep the plant capable of producing.

Physical properties of coastal land are sticky when it is wet and hard when it is dry [2]. These characteristics make this type of soil become difficult to cultivate. Other properties such as less water content because of the high content of clay monmorillonite and high levels of calcium in the soil led to the low availability of phosphor. In addition, the availability of potassium is also low because it is adsorbed by clay minerals monmorillonite [3]. Soil aeration of coastal land gromosol is also unfavorable resulting in a low nitrogen content as a result of denitrification. Other characteristics of the gromosol soil of coastal land are low organic matter content and cation exchange capacity. Low of organic matter can reduce the variety...
of soil microbes. Addition of manure to the soil can stimulate aggregate granulation, improve the ability of soil to retain water, increase the adsorption ability and exchange cations capacity, increase soil nutrients such as N, P and K, and improve biological properties by increasing the population of soil microorganisms.

Manure fertilizer is an animal waste that can cause environmental and health problems and handling costly. Therefore, integrated farming system is the main pillar of agriculture because it can provide the actual feed and food in a sustainable agriculture. According to [4], integrated farming is a system that reuses and recycles of plants and animals wastes, creating an ecosystem that is tailor made just imitating nature. It is principally a farm that capable of maintaining ecosystem balance so that the flow of nutrients and energy occurs in a balanced manner.

Manure or organic material of animal waste that can be used to fix marginal land by improvement of the physical, chemical and biological properties of soil. Soil organic matter plays a role in stimulating aggregate granulation, improving the ability of soil to retain water, increasing the adsorption ability and exchange cations capacity of soil. Organic matter determines the physical properties of soil [5]. Organic matter also determine the value of cation exchange capacity, soil pH, mineralization of ions to become nutrients that required by crops and soil microbes.

One way to explore the potency of coastal land that has a low soil moisture is by growing the crops that require low water consumption in the life cycle and still capable of producing. [6] Stated that sorghum is one of the important crops capable to grow and produce in dry season with low rainfall. Sorghum is more tolerant to water deficit stress. The performance of sorghum are shown in terms of the dry matter accumulation and remobilization of assimilate in the suboptimal water conditions is the reason why sorghum can be cultivated in semiarid arid areas.

With broad adaptability, it can still produce despite sorghum grown in less fertile land, limited water conditions, and grown in the lowlands at an altitude of less than 500 m above sea level. In addition, it is adaptive to various types of soil, soil pH range of 4.3 to 8.7. The optimum growth and yield can be reached at the temperature of 23-30°C, relative humidity of 20-40 %, precipitation of 375-425 mm year⁻¹. Sorghum can adapt extensively on light soil (loam) and heavy soil, neutral period of sunlight and quite tolerant to saline soils [7].

Sorghum has a great chance to be developed in Indonesia because it can grow on marginal land, degraded land, drought tolerant, and low input production requirements. Sorghum is an efficient plants in water consumption and needs only small amount of water in life cycle [8]. To produce 1 kg of dry matter, sorghum requires only 322 kg of water, while corn, barley and wheat requires 368,434, and 434 kg of water, respectively. According to [8], One of the Program of Indonesian Ministry of Research and Technology is to develop sorghum as the fourth rank commodity after rice, corn, and soybeans.

Sorghum (Sorghum bicolor L.) is the fifth rank commodity as a food crops after rice, wheat, corn, and barley [9]. Nutrient content such as protein, potassium, iron and vitamin B are higher in sorghum compare to other staple foods (Table 1). Besides food, feed and forage, sorghum is also used as raw materials to produce starch, fiber, dextrose syrup, biofuels, and alcohol.

Based on the potency of human resources, natural resources, infrastructure, land use and availability of labors, sorghum is one of crop commodity that potential to be developed in the coastal land. Derivative products of sorghum can be used for diversification of various foods such as porridge, rice, cakes and pop-sorghum. Sorghum can also be used as feed for cattle, goats in form of forage or silage and feed for poultry such as chicken, quail or birds [9].
Table 1. Comparison of the nutritional value of sorghum, rice, corn and soybeans (per 100 g)\(^1\).

| Nutrient       | Sorgum | Rice | Corn | Soybean |
|----------------|--------|------|------|---------|
| Calori (cal)   | 342.0  | 360.0| 361.0| 286.0   |
| Protein (g)    | 10.0   | 6.8  | 8.7  | 30.2    |
| Fat (g)        | 3.7    | 0.7  | 4.5  | 15.6    |
| Carbohydrate (g)| 72.7  | 78.9 | 72.4 | 30.1    |
| Potassium (mg) | 22.0   | 6.0  | 9.0  | 196.0   |
| Iron (mg)      | 3.8    | 0.8  | 4.6  | 6.9     |
| Phosphor (mg)  | 242.0  | 140.0| 380.0| 506.0   |

\(^1\) Source: Supriyanto, 2011.

The general objective of this study is to optimize the utilization of coastal land to support food security and to increase farmers’ incomes through sustainable integrated farming and sorghum-based livestock. The specific objective are (1) to determine the performance of different varieties of sorghum in coastal land, (2) to compare different combination of manure and mineral fertilizers for growing sorghum in coastal land, and (3) to study the effect of the interaction between a fertilizer combinations and sorghum varieties in coastal land.

2. Materials and Methods

The research was conducted in the coastal land village of Kandang Mas, District of Bengkulu, Province of Bengkulu. The altitude of field experiment is 5 m above sea level, and the soil type is ultisol. Two factor of experiment was arranged factorial in completely randomized block design with three replications. The first factor is the sorghum varieties namely Numbu (V1), and Kawali (V2). The second factor is combination of fertilizers included solid manure fertilizer at 10 ton ha\(^{-1}\) + ½ of recommended dose of mineral fertilizer (P1), cow’s urine at 200 ml in 15 L of water (Nikus et al., 2004) + ½ of recommended dose of mineral fertilizer (P2), and (P0) was mineral fertilizer (120 kg ha\(^{-1}\) of Urea, 90 kg ha\(^{-1}\) of superphosphate, and 60 kg ha\(^{-1}\) of KCl) as recommended for sorghum by Supriyanto (2011).

Experiment was started with soil cultivation and preparation for experiment plot sized of 2 m x 10 m. Three sorghum seeds were planted with the drill hole in planting distance between was 60 cm x 25 cm. Solid manure fertilizer in P1 treatment was given once at planting time by immersion with 10 cm deep extending between rows of plants. Cow’s urine fertilizer in P2 treatment was given by spraying the urine solution to the surface of soil. Mineral fertilizers in P1, P2, and P3 were applied in a hole located between the two plants in a row. Mineral fertilizers were applied twice at 15 and 45 days after planting (DAP) with a dose of 50 % for each application. Thinning of sorghum seedlings were done at 15 days after planting. One of the best vigor plants was maintained in one hole. Basic maintenances were done as the regular practices in cropping system of sorghum such as insect and pest controls, weed controls.

Observations were made on variables of growth and yield included plant height, rod diameter, leaf area, length of panicle, dry weight of panicle, grain yield and allelochemicals in sorghum root analysis were carried out at the Organic Chemistry Laboratory of the Faculty of Mathematics and Natural Sciences, Gadjah Mada University, Yogyakarta using the Gas Spectrophotometer Gas Cromatography. Analysis of variance (ANOVA) were performed on data collected with statistical software CoStat 6.4. Means of observed data which showed a significant effect on ANOVA were separated by Duncan’s multiple range test (BNT) at P = 5%.
3. Results and Discussions

The results of ANOVA showed the interaction of the variety and fertilizer combination is not significantly affected all variables observed (Table 2). Plant height, rod diameter, and length of panicles were significantly affected by sorghum variety. On the other hand, fertilizer combination significantly influenced on dry weight of panicle and grain yield. Further test of the different effect on varieties of sorghum on plant height, rod diameter, and length of panicle can be seen in Table 3, as well as the influence the fertilization combination on sorghum in coastal land is presented in Table 4.

Table 2. F - values from analysis of variance (ANOVA) of some variables of growth and yield of sorghum.

| Variable                    | Sorghum Variety | Manure Fertilizer | Interaction |
|-----------------------------|-----------------|-------------------|-------------|
| Plant height (cm)           | 0.002**         | 0.090 ns          | 0.786 ns    |
| Leaf area (cm²)             | 0.312 ns        | 0.195 ns          | 0.762 ns    |
| Rod diameter (cm)           | 0.005**         | 0.641 ns          | 0.539 ns    |
| Dry weight of stover (g)    | 0.895 ns        | 0.268 ns          | 0.872 ns    |
| Lenght of panicle (cm)      | 0.001**         | 0.872 ns          | 0.908 ns    |
| Dry weight of panicle (g. plant⁻¹) | 0.055 ns   | 0.028 *           | 0.157 ns    |
| Grain yield (g. plant⁻¹)    | 0.072 ns        | 3.210 *           | 0.446 ns    |

*: significantly difference at 5%, **: very significantly different at 1%, ns: no significantly difference

3.1. Growth of Sorghum Varieties

Results of BNT test on the growth component of sorghum varieties is presented in Table 3. Sorghum var. Kawali has shorter than var. Numbu. But rod diameter Numbu has bigger and significantly different from var. Kawali, then Sorghum var. Numbu has length of panicle of is longer compare to var. Kawali (Table 3). According to [10], plant height and rod diameter can provided information of crop ability to distribute the assimilate from photosynthesis process. Soil organic matter in the field is 1.06 %, relatively low and may influenced to growth of sorghum. Sorghum will grow very slow as a consequence of low organic matter in the soil, because organic matter is one of the main component to sorghum productivity [11]. [12] Stated that if soil organic matter less that 2%, sorghum is not growing optimum, because nutrients in the soil are not sufficient for growth development of plants.

Table 3. BNT test on the means of growth variables of three sorghum varieties.

| Varietas  | Plant height (cm) | Rod diameter (cm) | Lenght of panicle (cm) |
|-----------|-------------------|-------------------|------------------------|
| Numbu     | 397.22 a          | 2.93 a            | 21.86 a                |
| Kawali    | 376.30 b          | 2.76 b            | 18.13 b                |

Means of each variable followed by the same letter are not significantly different by BNT test at P = 5%.

Soil acidity (pH) before and after planting were respectively 5.0 and 5.10. However, sorghum can grow well with soil acidity ranging from 5.5-7.5. In general, nutrients are absorbed by plant roots on neutral pH because the nutrient is easily soluble in water. [2] Reported that soil conditions thereby affect soil biota that
may decrease nitrogen fixation ability. Evaporation of nutrients can decrease due to non coverage of soil surface by the plants so that sunlight can be directly reached on the ground surface. According to [13] soil texture conditions desired by plants is a medium texture.

Sorghum var. Kawali has the shorter panicle compared from var. Numbu and var. Kawali. Lenght of panicle is correlate to grain yield. [14] Reported that lenght of sorghum panicle is a main component of yield because panicle is the place for grain sorghum to grow. Genetic diversity of panicle is one component in developing a new variety of sorghum.

3.2. The Effect of Fertilization on Sorghum

Results of ANOVA (Table 2) shows that the fertilizer combination treatment was significanly affecting the panicle weight and grain yield of sorghum, but no effect was observed on plant height, leaf area, rod diameter, dry weight of stover, and length of panicle. BNT test on panicle weight and grain yield are shown in Table 4. Manure fertilizer at 10 ton ha⁻¹ + ½ of recommended dose of mineral fertilizer (P1) produced the highest panicle weight and grain yield which are respectively 198.17 and 193.59 g plant⁻¹ compared to other types of fertilizer combination. This P1 treatment can increase the weight of panicle by 40.96 %, while the grain yield can increase by 44.85 % compared to cow’s urine fertilizer and mineral fertilizer.

| No | Fertilization | Dry weight of panicle (g plant⁻¹) | Grain yield (g plant⁻¹) |
|----|---------------|-----------------------------------|------------------------|
| P0 | Manure (10 ton ha⁻¹ + ½ dose of mineral fertilizer) | 198.17 a | 193.59 a |
| P1 | Cow’s urine (200 ml in 15 L of water) + ½ dose of mineral fertilizer) | 189.42 ab | 186.89 a |
| P2 | Mineral Fertilizers (120 kg ha⁻¹ of Urea, 90 kg ha⁻¹ superphosphate, and 60 kg ha⁻¹ KCl) | 169.64 b | 162.54 b |

Means of each variable followed by the same letter are not significantly different by BNT test at P = 5%.

The addition of cow manure as a soil amendment can improve soil nutrients, both macro and micro nutrients, although it took a long time for decomposition and mineralization processes until it is used by plants. According [3] manure can also increase organic matter content, and improve the physical, chemical and biological properties of soil. Soil analysis showed that organic matter increased from 1.02 to 12.20 % by addition of manure fertilizer at 1.5 ton ha⁻¹, 14.27 % by addition of manure fertilizer at 3 ton ha⁻¹, and 12.36 % by additions of manure fertilizer at 4.5 ton ha⁻¹. Similarly, the concentration of total N also increases from 0.10 % to 0.20 % by addition of manure fertilizer at 1.5 ton ha⁻¹, 0.32 % by addition of manure fertilizer at 3 ton ha⁻¹, and 0.28 % by addition of manure fertilizer at 4.5 ton ha⁻¹.

According to [15] sorghum var. Numbu showed the best response to treatment of manure at a dose of 6.5 ton ha⁻¹ which was observed on grain yield of 185.16 g plant⁻¹ or equivalent to 5.45 ton ha⁻¹. [16] also reported that the sorghum grain yield production was 162.67 g plant⁻¹ if treated with cow manure at 5 ton ha⁻¹. The addition of cow’s urine (200 ml in 15 L water) + ½ of recommended dose of mineral fertilizer produced the higer grain yield (186.89 g plant⁻¹) compared from treatment of mineral fertilizer (120 kg ha⁻¹ of Urea, 90 kg ha⁻¹ of superphosphate and 60 kg ha⁻¹ KCl). These probably caused by availability of nitrogen, phosphor and auxin hormone from cows’ urine which were needed by plants to incresed grain yield [17]. The nutrients of cow’s urine are 1.21, 0.01, and 1.35 of N, P2O5 and K2O, respectively [18];
The presence of nitrogen in the soil can increase soil microorganism. Explained that phosphor from cow’s urine can stimulate flowering and ripening of seeds and also be used to build up lipids and protein. The results of BNT test showed the effect of mineral fertilizers (120 kg ha\(^{-1}\) of Urea, 90 kg ha\(^{-1}\) of superphosphate, and 60 kg ha\(^{-1}\) of KCl) on weight of panicle and grain yield was the lowest compare to the combination of manure 10 ton ha\(^{-1}\) + \(\frac{1}{2}\) of recommended dose of mineral fertilizer and cow’s urine solution which are respectively 169.64 and 162.54 g plant\(^{-1}\). The absent of any macro and micro nutrients in the soil may end up in low production of sorghum.

### 3.3. The Effect of Manure Fertilization on Allelochemicals Content of Sorghum

The results of sorghum root analysis were carried out at the Organic Chemistry Laboratory of the Faculty of Mathematics and Natural Sciences, Gadjah Mada University, Yogyakarta using the Gas Spectrophotometer Gas Cromatography with Abdel column 5MS, 30 meters long, ID 0.25 mm, 0.35 micro micron film, Helium carrier gas, ionizing EI 70 Ev shows the results that Sorghum varieties of Numbu and Kawali detected hydroquinone and resorcinol as intermediate compounds Sorgoleone has potential as bioherbicides.

Sorgoleone interferes with several molecular target site, including inhibition of photosynthesis in germination seedlings of weed. It is not translocated acropetally in older plants, but can be absorbed through the hypocotyl and cotyledon tissues. Therefore, the mode of action of sorgoleone may be the result of inhibition of photosynthesis in young seedlings in concert with inhibition of its other molecular target sites in older plants. The mechanisms of its phytotoxic activity focus on the inhibition of photosynthetic apparatus in lower plants by interfering with the uptake of solutes and water molecules. Further it is also a potent inhibitor of electron transport in chloroplast and mitochondria. The effectiveness of the herbicidal activity of sorgoleone is comparable to that of the synthetic herbicides in commercial use.

![Figure 1. Results that Numbu and Kawali detected hydroquinone and resorcinol by GCMS](image)

### 4. Conclusions

The conclusions from the current research are (1) sorghum var. Kawali has better growth and yield compares to var. Numbu and var. Kawali, which were observed on rod diameter and length of panicle of sorghum as
well as weight of panicle and grain yield, (2) fertilization with combination of cow manure at 10 ton ha$^{-1}$ + $\frac{1}{2}$ of recommended dose of mineral fertilizer produced the highest dry weight of panicle and grain yield of sorghum, (3) Sorgoleone is an allelopathic chemical released from the root exudates of the coastal land cereal crop as a potent bioherbicide.

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