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Growth, productivity, and harvest quality of Sorghum (*Sorghum Bicolor L.*) as food and bioethanol raw material with various treatments

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ABSTRACT

The purpose of this study was to investigate the different environmental factors that influence the growth, productivity, and quality results of harvest sorghum (*Sorghum bicolor L.*) as material food alternatives and materials raw bioethanol. The study consisted of 3 different treatments, where each treatment produced data to examine its effect on productivity, quality results. The experiment was designed using RAKF (factorial randomized block design) experimental design with one treatment factor, the usage of biofertilizer. The results show that liming at a dose of 2.5 tons/ha (Ca1) is sufficient to cultivate on acid soils with the red-yellow podzolic type and is more optimal if using a dosage of 5 tons per hectare depending on the results of soil analysis before planting. The best sugar quality is produced in the planting treatment during the dry season, with a total sugar value of about 14.5% and the highest reduction sugar of 2.4%. The addition of lime to acidic soil and the application of chemical and biofertileizers are crucial for optimal growth, enhancing both vegetative and generative development when applied in appropriate amounts. Furthermore, exploring the physiological mechanisms behind seasonal impacts on sugar content and assessing the economic viability of different planting seasons will provide valuable guidelines for farmers seeking to maximize food production and bioethanol raw materials.

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INTRODUCTION

After barley, rice, wheat, and maize, sorghum (*Sorghum bicolor L.*) is the most widely grown cereal crop. There are two varieties of sorghum plants: sweet sorghum (sweet sorghum) and sorghum seeds (grain sorghum). Sorghum seeds are used as a food source, sort of Compared to sorghum sweets, this has more sugar and yields larger seeds. In several countries on the continents of Africa and Asia, sorghum is the source of the main carbohydrates and proteins (Ortiz-Cruz et al., 2020). Consumption of sorghum is highly recommended Because sorghum contain compound bioactive compound phenols and antioxidants that provide benefit for health (Anunciação et al., 2017). Temporary sorghum sweet lots are used for feeding livestock, and raw materials liquid sugar, syrup, and jaggery, as well as can be utilized for the necessity bioethanol industry (Tang et al., 2018).

Sorghum crops come from dry areas such as Africa, so they have efficient use of water, are resistant to drought stress, and have nutrient-poor soil conditions (Karimuna et al., 2020). Sorghum adaptation environment plants are sufficiently broad to be able to be grown on a variety of land types and remain productive even when planted on marginal land. Nearly all of Indonesia's large prospective areas for sorghum crop development. Sorghum crops are relatively inexpensive to grow due to their high yield, ability to queen, and ability to be planted in monoculture or intercropping. At the moment, sorghum is produced in Indonesia in the Central Java, East Java, DIY, NTT, and NTB regions. Its productivity ranges from 0.4 to 1.5 tons of seeds per hectare. Indonesia's low sorghum yield is a result of the lack of suitable growing techniques.

The environment factors have significant influence in growth and production of sorghum plant; that factor also affects its potency as material food nor material raw bioethanol (Tang et al., 2018). Among other things, calcification, NPK fertilizer delivery, plant spacing, and planting time are all essential to the growth of sorghum plants. Because the majority of Indonesia's land has podzolic (acidic) soil, liming techniques are required to regulate the pH of the soil. High metal solubility, which results in inadequate nutritional availability, is another barrier on acidic soils. One endeavor that may be made to give plants nourishment is fertilization. The application of organic and inorganic fertilizers has a significant effect on the growth characteristics and production of several varieties of sorghum plants (Karimuna et al., 2020). The state of the plant population may have an impact on how well the roots of the plants absorb nutrients, therefore spacing becomes an important consideration while growing sorghum.

In addition to soil fertility, the planting period (wet season and dry season) is an environmental factor that also affects the growth and productivity of sorghum. During the dry season, low water availability and drought stress can delay flowering, inhibiting the addition of plant height, number of leaves, dry stover weight, and seed weight per panicle of sorghum plants (Samanhudi et al., 2021). While the rainy season with high rainfall can reduce the sugar content in the sap of sorghum plant stems.

Sorghum is not native to Indonesia, but in Indonesia this plant already has various varieties and some of them are superior varieties. The varieties that have been released include: Badik, EPL 1, Mandau, Numbu, Pahat, Samurai 1, Samurai 2, Genjah, Kawali, Hegari, KD4, Keris, Sungkur, and UPCA-S2. A national outstanding variety of seed sorghum (grain sorghum) is the Numbu variety. This cultivar has a lot of potential as a raw material for the bioethanol industry because of the high levels of sugar in the stem sap and starch in the seeds. The Numbu variety of sorghum may also be cultivated to make the best use of its biomass. Sorghum seeds can be utilized as a food source in addition to being a raw material for bioethanol. Given these contexts, the goal of this study was to investigate the different environmental elements that affect the best growing conditions for sorghum in acidic soils as a food source and bioethanol raw material.

The purpose of the study was to examine several environmental factors that influence growth, productivity, and quality results of harvest sorghum *(Sorghum bicolor L.)* as material food alternatives and materials raw bioethanol. The research contributes to the understanding of how various environmental factors affect the growth, productivity, and quality of sorghum (Sorghum bicolor L.), which is significant for both food alternatives and raw materials for bioethanol production. By identifying and analyzing these factors, the study provides valuable insights that could inform agricultural practices and policies aimed at enhancing sorghum cultivation. This knowledge is crucial for improving food security and promoting sustainable biofuel production, thereby addressing both nutritional and energy needs. Additionally, the findings may serve as a foundation for future research focused on optimizing sorghum production under varying environmental conditions, contributing to the broader field of agricultural science and sustainable development.

METHOD

This study consisted of 3 different treatments, where each treatment produced data to examine its effect on the productivity and quality of sorghum. The method used in this research is as follows.

The Influence of Liming, NPK Fertilizer, and Planting Spacing

The Center for Starch Technology (BPPT) Experimental Garden in Kampung Negara Bumi Ilir, Anak Tuha District, Central Lampung Regency, Lampung, Indonesia, served as the site of the study. September through December was when the trial started. The Numbu type of sorghum seeds were utilized. Three factors were included in the RAKF (factorial randomized block design) experimental design. The first component is the application of lime, which is done following field preparation and is dosed according to the soil's Al-DD value. Dolomite is the lime that is used. Three liming doses—Ca0 (0 tons/ha), Ca1 (2.5 tons/ha), and Ca2 (5 tons/ha)—were used in the experiments. The second treatment involved applying NPK fertilizer in doses of D1 (100 kg/ha of urea (N), SP36 (P), and KCl (K)), D2 (200 kg/ha, SP36 (P), and KCl (K) 100 kg/ha), and D3 (300 kg/ha of urea (N), SP36 (P), and KCl (K) 100 kg/ha). The distance between J1 (70 cm x 20 cm) and J2 (50 cm x 30 cm) is the third factor. In this experiment, 36 plots of 500 m2 each were created because there were 18 treatment combinations with two replications. Ten plants were selected from each plot to serve as samples.

At 30, 45, 60, and 90 days after seedling (DAS), plant growth metrics such as height and stem circumference were measured. At harvest, which occurred 90 DAS, plant productivity was measured, taking into account the weight of the leaves, stems, stover, and seeds. The results of calculating the average value arising from each observation parameter are then compared in order to examine the growth and productivity measurement findings.

Application of Biofertilizer in Sorghum Plants var. Numbu

The Center for Starch Technology (BPPT) Experimental Garden in Kampung Negara Bumi Ilir, Anak Tuha District, Central Lampung Regency, Lampung, Indonesia, served as the site of the study. The study was carried out in 2014 between March and November. The Numbu variety of sorghum seeds were utilized, and the experiment was designed using RAK (Randomized Block Design) with one treatment factor—the usage of biofertilizer. The Center for Bioindustry Technology, Deputy for Agro-industry Technology and Biotechnology, BPPT, evaluated and developed the biofertilizer used in this study. Application of biofertilizer is done using doses of B0 (100% recommended dose of inorganic fertilizer: KCl 150 kg/Ha, SP-36 100 kg/Ha, and Urea 200 kg/Ha), B1 (100% recommended dose of inorganic fertilizer + Organic Fertilizer 2.5 tons/Ha), B2 (70% recommended dose of inorganic fertilizer + 6 kg/ha bioorganic fertilizer), and B3 (70% recommended dose of inorganic fertilizer + 2.5 tons/ha organic fertilizer + 6 kg/ha bioorganic fertilizer).

The treatment combination was 4×1 with 3 replications; thus the number of plots in this experiment were 12 plots measuring 756 m2/plot. Each plot was taken 10 plants used as samples. The plot plan in this experiment is presented in Figure 1.

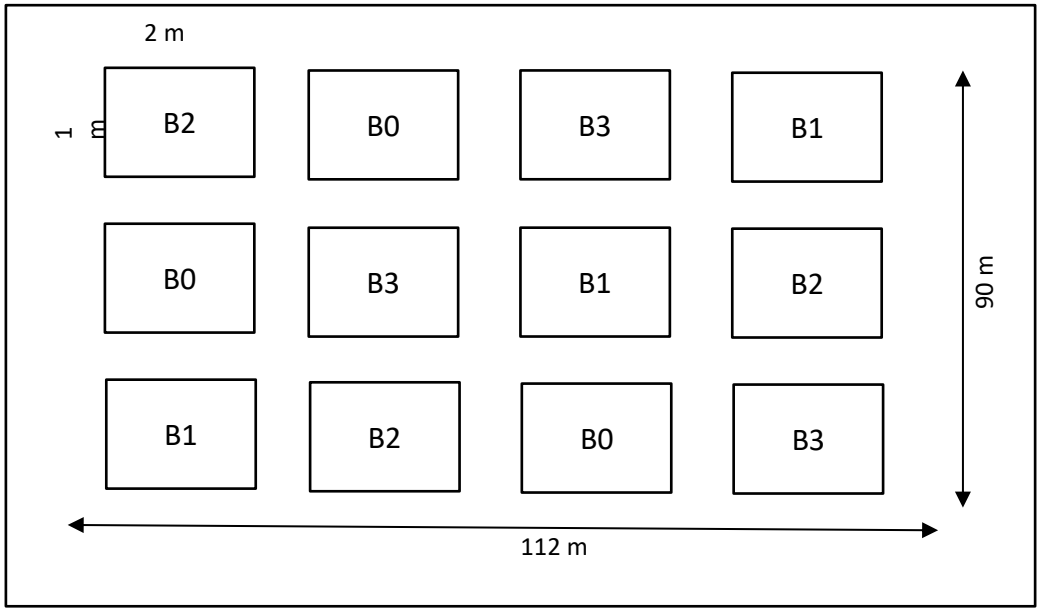


Figure 1. Experimental plot plans the cultivation sorghum var. Numbu with application biofertilizers

Growth of sorghum was measured by growth in height and stem diameter while productivity was seen by the number of leaves at 40, 60, 80 and 90 days after seedling (DAS). The measurement results are then analyzed by comparing the results of calculating the average value resulting from each observation parameter.

Effect of Planting Time on Sorghum Cultivation

The Center for Starch Technology (BPPT) Experimental Garden in Kampung Negara Bumi Ilir, Anak Tuha District, Central Lampung Regency, Lampung, Indonesia, served as the site of the study. The study used sorghum seed varieties Keller, Wray, and Numbu and ran from April to October 2014. RAK (Randomized Block Design) was used to conduct the experiment, and the planting time variation served as the sole treatment element. Periods T1 (end of the rainy season/March), T2 (beginning of the dry season/May), and T3 (dry season/July) are the three different planting times. There were 27 plots in this experiment, each measuring 756 m2, because the treatments were combined in a 3x3 configuration with three replications. Ten plants were selected from each plot to serve as samples.

Stem height and diameter at 30, 60, 90, and 120 DAS were assessed as growth parameters, and the weight of the stem and seeds at harvest (120 HST) was used to compute productivity. The Analysis Laboratory, B2TP-BPPT, tests the sap content, total sugar content, and percentage of reduced sugar to determine the quality of sorghum. Additionally, the calculation results of the average value of each observation parameter were compared in order to examine the measurement data.

RESULTS AND DISCUSSION

The Effect of Liming, NPK Fertilizer, and Planting Spacing

Lime treatment on acid soils aims to improve soil pH so that nutrient availability increases, suppresses Al and Mn poisoning, and improves plant growth. The application of liming to acid soils reduces soil Al solubility thereby stimulating root development and P uptake by plants (Silveira et al., 2018). In addition to adding Ca, the type of dolomite lime used also adds Mg which is important for plant growth and development. Ca enhances plant development by regulating hormonal activity (Pathak et al., 2020), while Mg plays a role in the transportation of carbohydrates. Mg is also a molecule that forms plant chlorophyll (Alrashidi et al., 2022).

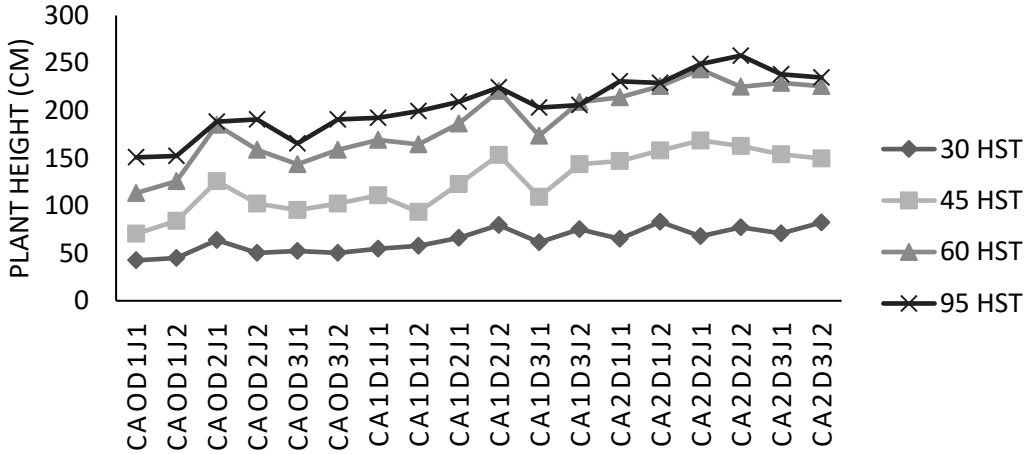


Figure 2. The height of sorghum var. Numbu at different planting ages (30, 45, 60, and 95 days after seedling/DAS) to the combination of liming doses (CA0, CA1, CA2), NPK fertilizer (D1, D2, D3), and plant spacing (J1 and J2)

Observations of plant height and stem circumference showed that liming had a positive effect on plant growth (Figure 2). This can be seen since the plants are 30 DSA. Liming up to a dose of 5 tons/ha (Ca2) produces high growth more than a lime dose of 2.5 tons/ha (Ca1) and plants that are not limed (Ca0). This shows that liming (Ca1 and Ca2) increases the growth rate of plant height compared to without liming (Ca0). The same thing also happened to the circumference of the plant stem (Figure 3).

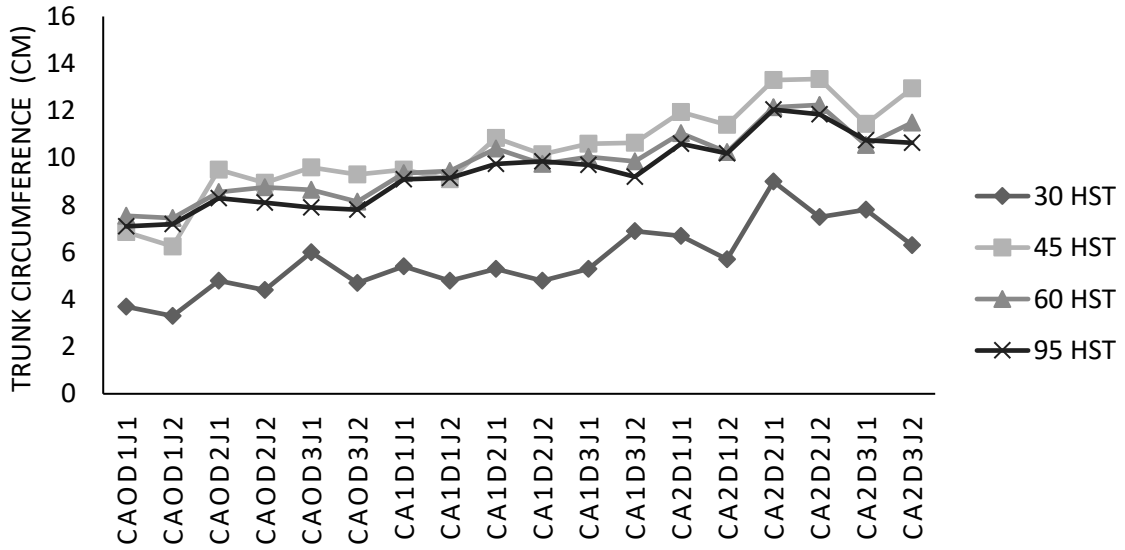


Figure 3. Stem circumference of sorghum variety Numbu at different planting ages (30, 45, 60, and 95 days after seedling/DAS) against combinations of liming doses (CA0, CA1, CA2), NPK fertilizer (D1, D2, D3), and plant spacing (J1 and J2)

The dose of Ca1 calcification was still sufficient but did not show a significant difference with the Ca2 calcification dose. However, excess doses of liming in acid soils will stimulate the Ca element to bind the P element resulting in the unavailability of P nutrients for plants or better known as the high rate of liming (Wijaya, 2011). The calcification of acid soils in the tropics does not have to neutralize the soil to a pH of 6–7, enough that a pH of 5.5 is sufficient to support plant growth. Based on observations of the vegetative characters in this experiment (Figures 1 and 2), the level of liming at a dose of 2.5 tons/ha (Ca1) is sufficient for sorghum cultivation on acid soils with the red-yellow podzolic type and is more optimal if using a dose of 5 tons per hectare depending on the the results of soil analysis before planting, if the soil has a pH of less than or equal to 5, then a dose of 5 tons per hectare is the most optimal. In line with resarch by Getachew et al. (2017) liming at a dose of 5 tons per hectare and 7.5 tons/ha gave results that were not too much different in the height growth of wheat plants in Africa.

Application of Biofertilizer in Plants Sorghum var. Numbu

Biofertilizer is a type of fertilizer that contains a microbial consortium that functions to increase soil fertility. The types of microbes contained in the biofertilizer include: *Agrobacterium* sp. is able to fix nitrogen from the air and at the same time produces growth hormones; *Pseudomonas putida* has the ability to dissolve phosphates as well as degrade organophosphates pesticides; *Eupenicillium javanicum* is dissolving potassium and can protect roots (Bhardwaj et al., 2014). The results showed that from 40 DAS to 90 DAS the vegetative growth of sorghum plants did not show significant differences from each treatment plot, but the stem height up to 60 HST in the treatment of dose B1 had the highest value, namely 175.8 cm, while at 90 DAS in B2 it reached a height 231.1 cm and for the stem diameter parameter from 40 DAS to 90 DAS dose B1 has the highest value (Figure 4).

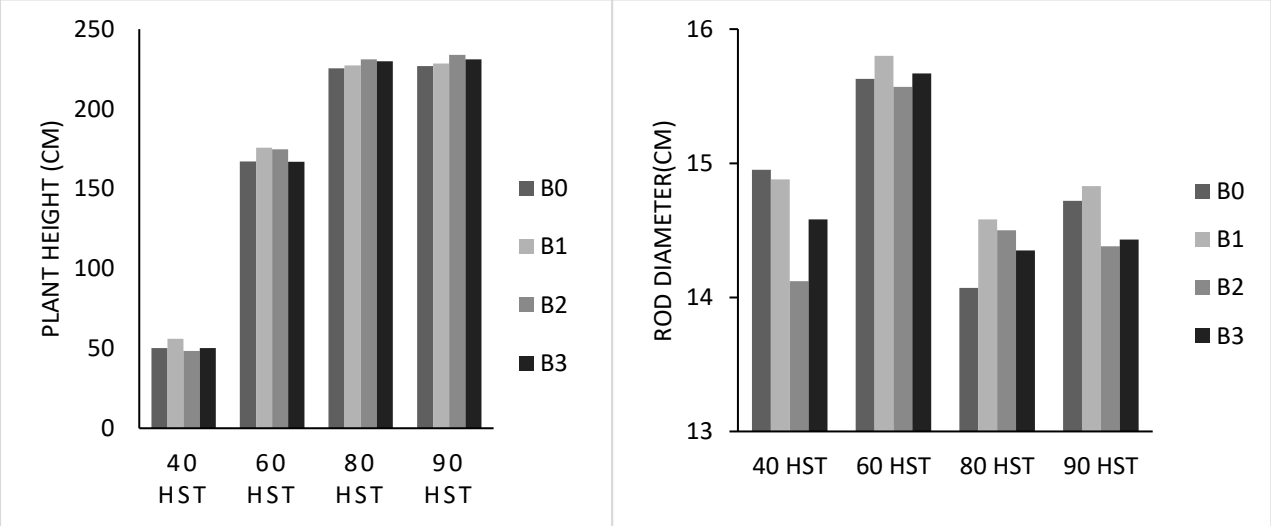


Figure 4. Height and diameter of sorghum var. Numbu at age different (40, 60, 80, and 90 days after seedling/ DAS) against biofertilizer application dose B0 (Fertilizer inorganic 100%), B1 (Fertilizer inorganic 100% + Fertilizer Organic 2.5 tons/Ha), B2 (Fertilizer inorganic 70% + Fertilizer Bioorganic 6 kg/ha), and B3 (Fertilizer inorganic 70% + Fertilizer Organic 2.5 ton/ha + Fertilizer Bioorganic 6 kg/ha)

The availability of nutrients for plants is intimately linked to the mix of fertilizer application methods. This efficiency is attained when plants optimally absorb the amount of nutrients in the applied fertilizer rather than losing them. Because the nutrients are utilized for tissue cell division and multiplication, sorghum will develop more optimally if the plant absorbs more and more components well. When applied in the proper amount, biofertilizer can lower the dosage of inorganic fertilizers to a predetermined level. This will prevent soil damage from inorganic fertilizer and save production expenses. However, the advantages of inorganic fertilizers as a whole cannot be replaced by the usage of biofertilizers. Thus, it is crucial to utilize integrated and prudent biofertilizers or inorganic and organic fertilizer sources to promote optimal development and preserve the environment. Even Bakrie et al. (2010) claimed that using biofertilizers might cut the amount of inorganic fertilizer used to rice plants by as much as 50%.

Effect of Planting Time on Cultivation Sorghum

Environmental factors greatly affect the growth, productivity, and quality of sorghum yields which are classified as dry land cultivation plants. Environmental factors, especially rainfall, play a very large role in

the production and quality of the crops produced. Rainfall that exceeds the limit will result in an increase in the volume of water on the soil surface so that it can affect the ability of roots to absorb oxygen, and conversely if the rainfall is low it will cause drought stress which will inhibit growth (Herlina & Prasetyorini, 2020). *Sorghum bicolor* with the characteristics of a fairly thick waxy layer on the leaves, a deep and deep root system, as well as a physiological response to osmotic pressure regulation; This cereal plant is the most drought tolerant (Fracasso et al., 2016). Even so, in the first 21 days of growth, sorghum must still receive enough water. If in the later growth phase water is limited, this plant can still grow well because the anatomical development that supports drought tolerance has already been formed (Sriagtulaa et al., 2016).

Likewise with the results of the study which showed that there was not a significant difference in the growth of sorghum stem height and diameter due to the influence of rainfall. Due to the different planting time treatments still meet the basic needs of sorghum to grow. But with regard to the value of the distribution of rainfall at the sorghum cultivation location in Central Lampung, T1, that is, planting was carried out in March which is the end of the rainy season which has the highest rainfall of up to 270 mm with a total of 17 rain days (Table 1).

Table 1. Distribution of rainfall period January until with December in 2014 Padang Ratu Sub District, Central Lampung, Lampung

Rainfall Distribution				
Month	***(mm)***	***(Day)***	***Max. (mm)***	***Min. (mm)***
January	299	17	55	2
February	168	10	45	2
March	270.5	17	42	3
April	80.5	7	32	2
May	32.5	4	16.5	3.5
June	25	3	15	2
July	27.5	4	18	2
August	8.5	2	5	3.5
September	16	2	11	5
October	50	6	17	2
November	188.5	12	58	4
December	201	14	61	2

According to the test findings, plot T1 (planting at the conclusion of the rainy season) had the best vegetative development of sorghum when compared to plots T2 and T3 (planting at the start of the dry season till the dry season). The growth of sorghum varieties of Warka, Babel, and Rabeh varied depending on when they were planted in March and April; plants sown in March had the highest average plant height compared to those grown in April, which is consistent with studies by Ajaj et al. (2021). Furthermore, there are 17, 7, and 4 rainy days in March, April, and May. While Aqil (2011) reported that in the early growth phase to the late vegetative phase, sorghum requires at least 15 rainy days. The flowering phase until seed filling requires 20 rainy days and the seed filling phase before the ripening phase requires 40 rainy days from the start of this phase.

The weight of the stem and panicle at harvest, which is the next productivity metric, is very different. Sorghum, which is planted at the end of the rainy season and harvested in July with 27.5 mm of rainfall, produces the best yields. Sorghum stems weigh between 4700 and 6000 kg, with the maximum panicle and seed output weighing between 215 and 615 kg. Sorghum, which was planted during the dry season and harvested in September with only 16 mm of rainfall, had the lowest yield. Sorghum stalks weigh between 1700 and 6300 kg, whereas panicles and seeds weigh between 171 and 537 kg. As a result, the output of seeds, panicles, and stems decreased by about 30%. This outcome is consistent with Sriagtulaa et al. (2016)'s study on sorghum mutant variants. Water deficits throughout the panicle's blooming phase and seed filling were shown to result in the worst production reduction. Crop yields might drop by as much as 50% under dry weather. This is due to the fact that pollination does not take place and that most panicles will dry out even if it does. In contrast, sorghum yields just around 15% less if it is dehydrated during the last vegetative stage.

Discussion

Stover weight, stem weight, and seed weight are all impacted by liming in terms of productivity. The weight of the stover, stems, and seeds were shown to be impacted by the liming treatment, according to the experimental data. Without liming, the weight yield of stover per plant (Ca0) varied between 287.5 and 327.5 g; for the Ca1 treatment, it ranged between 262.5 and 337.5 g; and for the Ca2 treatment, it reached between

304 and 342.5 g. Here, it is evident that increasing the liming dosage also improved stover yield, whereas the Ca2 treatment produced better outcomes for seed production. However, stem productivity was not too affected, namely without liming, it ranged from 520 kg – 617 kg, Ca1 treatment ranged from 595 kg -680 kg and Ca2 treatment ranged from 555 kg -672 kg (Table 2).

Table 2. Productivity of sorghum var. Numbu on the combination of liming doses (CA0, CA1, CA2), NPK fertilizer (D1, D2, D3), and spacing (J1 and J2). Note: BBr/t (stuff/plant weight), BB/t (stem/plant weight), BBj/t (seed/plant weight), PB/p (stem production/plot), PBj/p (seed production/plot), and BBj 100 (seed weight of 100 grains)

Treatment	Bbr /t (g)	weight/h (g)	BBh /t (g)	PB/p (Kg)	PBj /p (Kg)	BBj 100 (g)
CaOD1J1	275.5	178.5	18,42	520.5	54.5	2.45
CaOD1J2	324	215	21,8	610.6	61.9	2.63
CaOD2J1	327.5	212.5	21.39	603.5	60,7	2.54
CaOD2J2	322.5	217,5	22.35	617,7	63.5	2,5
CaOD3J1	287.5	182.5	18.89	545.8	57,8	2.49
CaOD3J2	314	190.5	20.45	552.5	58,1	2.55
Ca1D1J1	317,5	207.5	21.55	595.6	61,2	2.65
Ca1D1J2	330	237.5	22,19	654.7	63,1	2,7
Ca1D2J1	262.5	217	20.98	616.3	59,6	2.65
Ca1D2J2	**337,5**	**240**	25.97	**682.6**	70,2	2.58
Ca1D3J1	295.5	227.5	21.05	664,2	59,9	2.56
Ca1D3J2	320.5	232.5	22.38	660.3	63,6	2.48
Ca2D1J1	342.5	237.5	**29.85**	672.5	**72.5**	2.64
Ca2D1J2	305	207.5	26,17	605,2	70,3	2.62
Ca2D2J1	312.5	200.5	22.59	575.4	64,2	2.68
Ca2D2J2	332.5	222.5	21,32	631.9	60.5	**2.78**
Ca2D3J1	315.5	195.5	21,29	555,2	61.8	2.52
Ca2D3J2	304	205.5	21,28	612.6	66,2	2.25

It is believed that the best way to turn acidic soil into healthy soil for growth is to apply 2.5 to 5 tons of lime. A dose of 3.5 tons of lime per hectare is the most effective way to prepare land for bean cultivation, according to Buni (2014). This is because the dose can raise the pH to 5.5, which can increase the value of cation exchange capacity and the availability of internal elements needed by plants, particularly nitrogen, phosphorus, and potassium.

A material called fertilizer is applied to the soil to promote plant growth. NPK is found in inorganic fertilizers that are often used in horticulture. The N ingredient in NPK fertilizer helps plants produce amino acids (proteins), nucleic acids, nucleotides, and chlorophyll. These substances are particularly helpful for promoting vegetative development in plants, including the formation of leaves, stem height, and stem diameter. Plant biomass, such as stem and leaf weight, can be increased by activating specific enzymes and proteins, promoting root growth, initiating cell division, and fortifying plant uprights. Meanwhile, element P in NPK fertilizer serves as an energy storage and transfer agent. As an enzyme activator, element K in NPK fertilizer facilitates the transfer of assimilation results from leaves to plant tissues, increasing its contribution to fruit and seed development.

Plant height is positively impacted by the application of N fertilizer up to a level of 300 kg Urea/ha (D3). From the start of growth till harvest, element N is required. This was demonstrated by the notable variation in plant height between treatments D2 and D3 at 30 DAP and 60 HST, which ranged from 178 cm to 153 cm, whereas treatment D1 only achieved 153 cm. However, at 95 HST, no discernible difference existed between the D2 and D3 administrations (Figure 2). As is well known, the element N plays a critical role in vegetative development, particularly in relation to stem height, stem breadth, and leaf count, which occur from the start of plant growth until shortly before harvest. P and K elements will have an impact on further development after sorghum reaches its maximum age and vegetative growth is at its best. Furthermore, the production of sorghum seeds is not considerably impacted by urea dosage treatment. According to research on the sorghum cultivars Benny and Saif by Muflahi & Basuaid (2017), a N fertilizer dose of 165 kg per hectare tends to yield higher production than doses of 100 kg and 55 kg per hectare, although the efficiency value is lower.

Sorghum's vegetative development was not much impacted by plant spacing, however productivity at J2 spacing (50 cm x 30 cm) was often higher than J1 spacing (70 cm x 20 cm). The intrapopulation competition for sunlight or the roots' capacity to get water and nutrients is linked to this spacing. Establishing

the spacing goals to allow the plants to benefit as much as possible from their surroundings. While too-narrow spacing that closes together results in conflicts in nutrient absorption, tenuous spacing that is too far apart can enhance the growth of individual plants but also creates a chance for weed growth. Additionally, some of the light that falls on the soil surface and nutrients will be lost through evaporation and leaching. Sorghum experimental spacing started to show up 45 days after planting; while not very noticeable, there was a little difference: 50 cm by 30 cm spacing improved stem circumference, while 70 cm by 20 cm spacing improved stem height. According to research by Tufa & Kumbi (2019), spacing planting on wheat plants is more effective at 20 cm wide than at 15 or 25 cm. This is consistent with findings from Kartika (2019)'s study on maize plants, which showed the effect of spacing was observed after 28 days after planting, where a spacing of 60 cm x 20 cm had lower stover yields than 80 cm x 20 cm.

According to observations, B1—100% inorganic fertilizer plus 2.5 tons/ha of organic fertilizer—or B2—70% inorganic fertilizer plus 6 kg/ha of bioorganic fertilizer—is the most effective dose for the growth of sorghum of this Numbu type. It is believed that this has to do with the best possible mix of doses. The struggle between bacteria for food increases if the dosage of bioorganic fertilizer is excessively high or if the mixture of bioorganic and organic fertilizer contains germs as well. This results in the bacteria' nutritional demands not being met, which makes them function less well and has a less than ideal impact on plant development (Simnadis et al., 2016). On the other hand, plants that only utilize inorganic fertilizer will eventually harm the ecosystem and reduce soil fertility. Sorghum var. Mahabeej-Bhagyalaxmi grows best when 100% inorganic fertilizer and 14 kg of biofertilizer are combined. This is true for stem height, stem diameter, and leaf count. Furthermore, it was shown that applying biofertilizer to wheat plants increased lateral root formation by 51% (Talboys et al., 2014).

On wheat var. Numbu, the number of leaves in the second month was typically 6–10 and did not significantly vary across treatments. The increase in leaves on var. Pahat and Kawali is likewise not substantial, according to another research. The variations in leaf growth, such as weight, area, and length, are undoubtedly not the same even when there are an equal number of leaves. Water availability has an impact on leaf appearance in addition to nutritional considerations. Increased leaf display rates, delayed plant vigor, or smaller canopy diameters are probably all intended to boost grain yields, particularly in arid environments (Kholová et al., 2014).

One way to determine a sorghum's quality is to look at how much sap is generated and what proportion of sugar is present at harvest. The best sugar quality is produced in the planting treatment during the dry season, with a total sugar value of about 14.5% and the highest reduction sugar of 2.4%. Plant stem sap production in T1, T2, and T3 treatments tends not to differ, but the growers at the end of the rainy season have the highest results with a value of 0.54 ml/g. These data show that water requirements have a significant impact on increasing stem production while decreasing sugar quality; conversely, drought conditions tend to decrease plant stem production while increasing the percentage of sugar content; the average sugar content in rainy season crops ranges from 12.9% to 16.5%, while in dry season crops it is approximately 16.5% (Kolo & Sine, 2019). While drought stress can result in more reduced sugar sap as a kind of adaptation, low rainfall causes low plant growth, which is reflected in decreased biomass output (Zubair, 2017). Pabendon et al. (2017) also found that Sorghum Super-1 and Super-2 cultivars with a greater sugar content were planted in the dry season as opposed to the rainy season, but they also produced less biomass. The best practices for sorghum planting include watering when the seeds begin to fill up to maximize seed productivity and ensuring that there is enough rainfall at the beginning of the planting period until the plant is two months old. After that, the conditions become drier until harvest time.

The availability of water for plants is linked to the high sugar content of sorghum stems grown during the dry season with little rainfall (Figure 5). Plants experience stress when there is a shortage of water. Osmosis power and assimilate production are lowered as a result. Moreover, not every component of a plant's body can get photosynthates. One of the plant processes for sustaining photosynthetic transport is the buildup of sugar in the leaves, which raises the concentration of sugar and the ratio of sugar to starch. In contrast, there is a negative correlation between sugar concentration and panicle and seed weight per panicle during the dry season. This happened because the state of stress development makes it difficult for the photosynthates that are created to be distributed equally among all sinks, including seeds and panicles. As a result, that area displays a less than ideal plant look (Zubair, 2017).

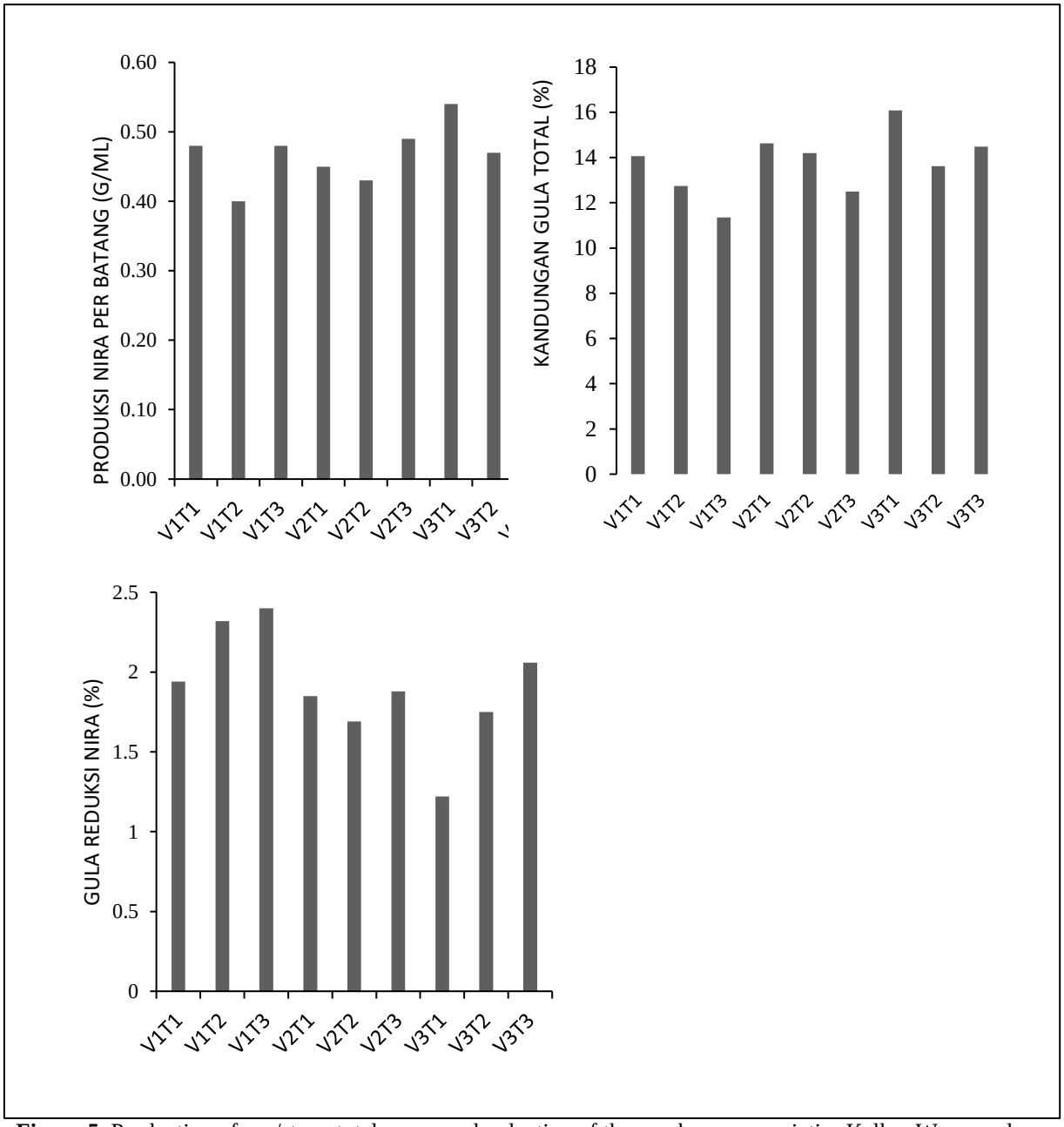


Figure 5. Production of sap/stem, total sugar, and reduction of the sorghum sap varieties Keller, Wray, and Numbu (V1, V2, V3) at planting age 120 days after seedlingDAS) on differences in planting time at the end of the rainy season, the beginning of the dry season, and the dry season (T1, T2, T3)

Plant varieties also differ in terms of quality, production, and growth patterns. The var. wray has the highest stem output when compared to other kinds. In terms of sap content, total sugar, and reduction sugar, numbu cultivars are the best for seed production. This was demonstrated by Bhya et al. (2013), who discovered that each variety responded differently to the observation variables due to both environmental and genetic factors. Different responses to sorghum development are caused by adaptation to various growing environments, as seen by variations in diameters, leaf count, and yield productivity (Regassa & Wortmann, 2014). As a result, the planting location can influence the choice of sorghum type. There are wray types of sorghum that can be planted for bioethanol, livestock feed, and fodder. Numbu variants can be used if you wish to use the seeds and sap as food. The Numbu varieties were chosen in accordance with the government's suggestion that one of the sorghum types be grown in Indonesia as a rice alternative since 2001. To achieve the best outcomes, it is extremely possible to use different planting kinds (Mullet et al., 2014).

Sorghum is a food source because of its high percentage of resistant starch (RS) and good carbohydrate content. Customers feel fuller for longer when sorghum contains a higher percentage of RS.

Therefore, there is a chance to lower the frequency of snacking and excessive calorie consumption, which could lower glycemic levels and lower the risk of diabetes and obesity (Simnadis et al., 2016). Moreover, a comparatively high phytochemical content—such as polycosanols, flavonoids, phytosterols, and phenolic compounds—is advantageous to health. The predominant phytochemicals in sorghum are phenolic compounds, such as flavonoids and phenolic acids, which function as anti-trade agents and antioxidants while also potentially improving other health outcomes (Girard & Awika, 2018).

Sorghum biomass can be used economically for the production of bioenergy, including as raw materials for briquettes and pellets, in addition to being a food source. Due to their high heat values, these products are effective solid biofuels. Furthermore, sorghum seeds and stems can be a good substrate for the manufacture of bioethanol, and the leftover biomass processing waste can be used to make biogas (Windpassinger et al., 2015). The majority of research explains that tropical and subtropical locations produce the most sorghum biomass. The most well-known biomass in the world is cellulose lignin, which is present in plant leaves, skin, and branches. As a result, bioethanol lignocellulose has been produced recently as a substitute for the still widely used bioethanol starch. In addition to not competing with food production for raw resources, bioethanol and lignocellulose also significantly lower greenhouse gas emissions. This kind of bioethanol is ideal for nations that employ forestry and agricultural waste as an input.

Sorghum is used to produce bioethanol by converting carbohydrates into alcohol. Hydrolysis, sacrifice, and fermentation are steps in the process of turning carbohydrates into bioethanol. This procedure turns simple sugar into bioethanol, which may be used as a fuel substitute for gasoline. First, biomass is ground and then subjected to physicochemical treatment to create stems and stances. By decreasing the size of the substrate and facilitating bioactive compounds' access to the surface, this preparation seeks to lessen polymerization and the degree of lignocellulose crystallization. Additionally, acid and base treatment are part of the chemical process (Kumar & Sharma, 2017). The lignocellulose complex undergoes different alterations depending on the technique. For instance, base and neutral delignification occurs, whereas acid and vapor treatment dissolves the majority of the hemicellulose. Using enzymatic preparations, the second stage is enzymatic hydrolysis, which releases fermentable sugar. The last step, known as ethanol fermentation, is when different microbes, such as the Saccharomyces cerevisiae yeast, transform monosaccharides into ethanol (Rosales-Calderon & Arantes, 2019). Compared to sugar cane sap, which has a total sugar content of 10–18% and sucrose of 9–17%, sorghum sap has a relatively high total sugar content of 11–16% and sucrose of 10.0%–14.4%. Thus, one of the possible and promising sources of bioethanol is sorghum agricultural waste in the form of sorghum stems.

CONCLUSION

The addition of lime to acidic soil and the application of chemical and biofertilizers are crucial for optimizing sorghum growth, enhancing both vegetative and generative development when applied in appropriate amounts. Seasonal variations significantly affect sugar content, with planting during the dry season being preferable for higher sugar yields. Future research should investigate the long-term effects of lime and various fertilizers on sorghum across different soil types and climates, as well as the optimal timing and combinations of these inputs. Additionally, exploring the physiological mechanisms behind seasonal impacts on sugar content and assessing the economic viability of different planting seasons will provide valuable guidelines for farmers seeking to maximize food production and bioethanol raw materials.

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