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Effects of rice husk mulch dosage on the growth and yield of corn

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Abstract

Drought significantly affects corn phenology and yield. Rice husk mulching is a technical cultural strategy to mitigate water stress caused by drought. This research aimed to determine the optimal dosage of rice husk mulch for the growth and yield of corn. Determining the optimal dosage of rice husk mulch is essential for agricultural efficiency, environmental sustainability, and plant health. A single-factor Randomized Complete Block Design was arranged for this research. The treatment consisted of varying dosages of rice husk mulch, namely 2; 4; 6; 8 kg.m^{-2} rice husk mulch and without rice husk mulch. The data were analyzed using Analysis of Variance and followed by the Post Hoc Tukey's HSD at α= 5%. The highest of plant height (185.99 cm), number of leaves (12.58), stem diameter (23.32 mm), stem dry weight (146.40 g), leaf dry weight (37.20 g), root dry weight (53.90 g), total dry weight (237.50 g), and suppressed weeds up to 234.47% were achieved in 6 kg.m^{-2} rice husk mulch. At this dosage, it impacts the optimal cob weight with cornhusk and the dry weight of the kernels. The optimal dosage of rice husk mulch was 5.9 kg.m^{-2}. This study shows that optimizing plant height and cob weight with cornhusk per plant are key indicators for achieving high corn yield. The study demonstrates that rice husk mulch can suppress weeds, and enhance corn growth and yield during drought, compared to conditions without rice husk mulch.

INTRODUCTION

Corn (*Zea mays* L., also known as maize) is cultivated mostly in America, China, and Brazil (FAO, 2022). Corn is a more versatile, multi-purpose crop than wheat and rice; in Asia it is consumed as human food, while in developed countries, it serves as a livestock feed crop and is used as an industrial and energy crop (Erenstein et al., 2022). According to FAOSTAT 2012–2016, Indonesia is the 8th world's largest corn-producing country (Aguss et al., 2019). Corn productivity in Indonesia from 2018 to 2022 fluctuated. In 2021, corn productivity decreased by 0.4% compared to 2020. Corn production has only reached 76% of the 33-million-ton target set for 2020–2024 (Suwandi, 2022). Corn productivity can be enhanced to meet the production target and achieve its potential yield of 12.83 tons.ha^{-1} (Aristya and Samijan, 2022).

Climate change is key factor contributing to fluctuation in corn yield, as it affects the physiological and biochemical processes during growth (Zhang et al., 2022). The agricultural sector in tropical belt countries, including those in Southeast Asian countries, is most affected by climate change (Dewi, 2009). Impacts include productivity loss, increased drought risk, fluctuating monsoon patterns, and shifting crop cycle (Sam et al., 2023). Climate change is intensifying and extending the duration of droughts and heat waves. These conditions exacerbate water scarcity. These

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also make increasingly difficult for plants to survive (Kim and Lee, 2023), and drought significantly reduces the grain-filling rate (Qi et al., 2022). Drought conditions are typically characterized by reduced soil moisture and precipitation deficits compared to average values (Park et al., 2023). The sensitivity analysis indicates that temperature and precipitation are the most crucial weather factors affecting yield changes when employing the direct differentiation method (Zhang et al., 2022).

Corn is classified as a C4 crop whose growth and yield are strongly influenced by environmental conditions (Hama and Mohammed, 2019). Corn phenology refers to leaf or leaf collar development during the vegetative stage and grain accumulation during the reproductive stage (Hatfield and Dold, 2018). Corn phenology generally consists of seedling, jointing, heading, milky, and harvest stage (Tian et al., 2023). Corn is often believed to tolerate drought stress by closing stomata to maintain leaf photosynthesis, but it is particularly vulnerable to drought during the heading stage, just before tassel flowering (Lopes et al., 2011). The vegetative phase of corn consists of germination and emergence (VE; six days after planting), first to second leaves (V1 to V2; one week after the plant emerges), third to fifth leaves (V3 to V5; two to three weeks after the plant emerges), sixth to tenth leaves (V6 to V10; three to five weeks after the plant emerges), eleventh to nth leaves (V11 to Vn; five to eight weeks after the plant emerges), tasseling stage (VT; two to three days before silking) (Ransom and Endres, 2020). The generative phase of corn consists of silking (R1; 55 to 66 days after emergence), blister (R2; 12 days after silking), milk (R3; 20 days after silking), dough (R4; 26 days after silking), dent (R5; 36 days after silking), physiological maturity (R6; 55 days after silking) (Ransom and Endres, 2020).

Drought stress from water deficit can significantly impact seedling development, early plant growth, photosynthesis, reproductive growth, and overall yield. Drought conditions accelerate phenological development because the number of thermal units required for leaf appearance remains relatively constant in the vegetative stage (Hatfield and Dold, 2018). Increasing temperatures due to drought stress can accelerate growth and shorten the growing season, potentially reducing productivity, so proper water management is critical to corn growth (Kim and Lee, 2023). Drought inhibits the growth of seedlings, crops' transpiration, stomatal conductance, leaf water potential, and root activities; all of which have an impact on the harvest index, vegetative growth, and generative yield (Dietz et al., 2021). High-temperature events during pollination reduce corn productivity, which is further exacerbated by water deficits during pollination and during the grain-filling period (Hatfield and Dold, 2018). Drought stress and high temperatures inhibit the transfer of assimilates to the grain, reducing the endosperm cell count and limiting the supply of assimilates, which in turn decreases grain or kernel weight (Qi et al., 2022). Water stress typically reduces a plant's ability for photosynthesis, which affects stomatal conductance and photosynthesis rate as well as matter production and plant yield (Shen et al., 2020).

Strategies to mitigate water stress from drought include using drought-tolerant varieties, employing effective tillage practices, managing planting time, optimizing crop production systems and stand density, applying mulch, practicing stubble tillage, managing nutrients and irrigation, and inoculating soil with Arbuscular Mycorrhizal Fungi (AMF) and Plant Growth Promoting Rhizobacteria (PGPR) (Ray et al., 2020). Mulches are employed in agriculture in arid areas for a variety of reasons, but the two main ones are water conservation and erosion control. During seasons with extended periods of drought, mulching helps retain soil moisture (Islam et al., 2022). Mulching controls biological activity and helps protect soil moisture (Wróblewska et al., 2019). Additional justifications for mulch application include modifying soil temperature, conserving soil, adding nutrients, enhancing soil structure, managing weeds, and enhancing crop quality (Aung and Zar, 2023). Organic mulch is an effective strategy to overcome water stress caused by drought, as it improves the soil's physical environment. Organic mulch as a sustainable material is the best approach under conditions of water stress, resulting in improved yield, water productivity, and quality traits in an arid climatic region (Alhashimi et al., 2023). Organic mulch not only increases the growth of plant and soil organic matter contents but also improves the yield of corn (Asif et al., 2020).

Rice husk mulch is an organic mulch that is made from a rice husk of small size, solid but light. Applying mulch in cultivation aims to reduce evaporation, enhance soil structure, boost soil productivity, and prevent weed growth (Ramli, 2017). After one season, rice husk has improved the soil's organic matter, physical, and biological properties, resulting in a significant increase in plant height compared to no mulch treatment (Sharma et al., 2023). The application of rice husk mulch increases production per plant and saves cost-effective selection of mulching practices and commercial cultivation in the future (Sharma et al., 2023). Previous research indicates that rice husk mulch effectively controlled weeds in corn fields (Nurjanah et al., 2023).

Rice husk mulch applied at a rate of 5 ton.ha^{-1} increased the content of available soil N, P_2O_5, and K_2O compared to rice straw mulch and coir pith compost mulch in corn fields (Kumar et al., 2018). Applying rice husk mulch at a rate of 4 ton.ha^{-1} to corn fields improved water holding capacity, C-organic, P and K availability, and Cation Exchange Capacity, and yield of corn compared to without rice husk mulch (Riyanto et al., 2023). However, research by (Riyanto et al., 2023) and (Kumar et al., 2018) did not assess whether the dosage of rice husk mulch used was effective in mitigating drought stress. Since 1999, a 5 ton.ha^{-1} residue mulch rate was used, which was later increased to 10 ton.ha^{-1} for better soil coverage (Chiroma et al., 2006). According to (Eze et al., 2019), the application of rice husk mulch of 15 ton.ha^{-1} has been reported to ensure better corn performance; plant height, grain yield of corn, cob weight, and cob length compared to the without rice husk mulch. However, it was not significant compared to the application of rice husk mulch of 10 ton.ha^{-1}. Based on previous research, the problem is whether increasing the dosage of rice husk mulch can still support good growth and yield performance of corn under drought stress conditions, and what the optimal dosage might be. This research is crucial for determining the effective dosage of rice husk mulch to overcome drought stress and suppress weed growth in corn fields, as evidenced by the growth and yield of cultivated plants. This research aimed to determine the optimal dosage of rice husk mulch for enhancing corn growth and yield, and to identify important variables that are essential for achieving high corn production.

MATERIALS AND METHODS

Plant preparation

The research was conducted on agricultural land of Balai Pelaksana Penyuluhan (BPP) Simou, Labuan Toposo Village, Labuan District, Donggala Regency, Central Sulawesi Province, Indonesia, located at 0°38'03.5"S 119°51'01.6"E at an altitude 0f ±131 m above sea level (asl), from March to July 2023. The materials used were corn (*Zea mays* L.) NK6501 Super variety hybrid corn seeds, 300 kg.ha^{-1} NPK 16-16-16 fertilizer - 16% N, 16% P_2O_5, 16% K_2O (Mutiara, Indonesia), 200 kg.ha^{-1} Nitrogen fertilizer - 46% N (Urea Pupuk Indonesia, Indonesia), 75 kg.ha^{-1} KH_2PO_4 fertilizer - 52% P_2O_5, 34% K_2O (MKP Pak Tani, Indonesia), 20 kg.ha^{-1} PGPF (MycoGrow, Indonesia: Mycorrhiza contains 33 spores per gram, 300 active propagules per gram, 5 endomycorrhizas species), 1 ml.l^{-1} plant growth hormone (L-Top, Indonesia: gibberellic acid and cytokinin), herbicides pre-growth (Boral 480 SC, FMC Indonesia: Sulfentrazon 480 g.l^{-1}), insecticide (Sapporo 52 EC, Indonesia: Emamectin Benzoat 52 g.l^{-1}), and rice husk.

Research procedure

The research was conducted in paddy fields with no rainfall, which had been used for groundnut crops in the previous season. The soil was thoroughly plowed to loosen and rid the soil of weeds. A week's time separated the plowing operations for Plow 1 and Plow 2. Experimental plot units were made with a size of 2.8 m (length) x 2 m (width) for 25 experimental plot units. A pre-emergent herbicide with a dosage of 0.875 ml.l^{-1} was sprayed prior to planting. Planting holes were made in each experimental plot at a distance of 60 cm x 20 cm. Each hole was seeded with one corn seed, spaced 3–5 cm deep. Rice husk, used as organic mulch according to the treatment dosages, was applied above the soil surface before planting. The dosages of rice husk mulch used were 2; 4; 6; 8 kg.m^{-2} and without rice husk mulch. Using a drip irrigation system, irrigation was ideally completed every two days and adjusted to the local climate. Drip irrigation improved fertilizer utilization and reduced water consumption, especially during drought stress (Yang et al., 2023). The dosage of insecticide was 1.25 ml.l^{-1} to carry out the armyworms.

Fertilization of NPK 16-16-16 at a dosage of 300 kg.ha^{-1} was applied 3 times, i.e. 105 kg.ha^{-1} at 2 WAP (Weeks After Planting), 135 kg.ha^{-1} at 5 WAP, 60 kg.ha^{-1} at 7 WAP (Pusparini et al., 2018). Three applications of 200 kg.ha^{-1} Nitrogen fertilization were made, i.e. 50 kg.ha^{-1} at 2 WAP, 70 kg.ha^{-1} at 5 WAP, and 80 kg.ha^{-1} at 7 WAP (Tabrani and Saiful, 2023). Fertilization of KH_2PO_4 was applied 3 times, i.e. 18.75 kg.ha^{-1} at 5

WAP, 26.25 kg.ha^{-1} at 7 WAP, and 30 kg.ha^{-1} at 8 WAP. Two applications of plant growth hormone were made, one at 2 WAP and the other at 7 WAP, with each dosage of 0.5 ml.l^{-1}. Mycorrhiza was applied once at 2 WAP at a dosage of 20 kg.ha^{-1} (4 g.plant^{-1}) with a spot placement technique. Corn was harvested at 15 WAP, characterized by brown and hardened corn cobs, dried corn silks, and shriveled, brown silks.

Variables of observation

The research variables observed were plant growth components and yields. Plant height (cm) was measured with a ruler (the distance from the soil surface excluding the first 2 cm which represented the planting depth) from the soil surface to the highest point of the arch of the uppermost leaf, tip pointing down every two weeks (2–14 WAP) (Mota et al., 2024). The number of leaves was determined using the Leaf Collar Method, which involved counting the visible leaf collars on a plant every two weeks (2–14 WAP), starting with the lowest lead (the coleoptile leaf with a rounded tip) and continuing to the highest leaf with a visible collar (Nielsen, 2019). Stem diameter (mm) was measured using a digital vernier caliper with an accuracy of ±0.02 mm during the vegetative phase, at 5 cm above the ground or the lowest point of the stem. Stem diameter was measured at 2 WAP (V3–V5 phase; the growth stage occurs when 3–5 leaves are fully developed and have visible leaf collars), 4 WAP (V6–V10 phase; the growth stage occurs when 6–10 leaves are fully developed and have visible leaf collars), and 6 WAP (V11–Vn phase; the growth stage occurs when 11– "n" leaves are fully developed and have visible leaf collars).

Stem dry weight (g.plant^{-1}), leaf dry weight (g.plant^{-1}), root dry weight (g.plant^{-1}), and total dry weight (g.plant^{-1}) were oven-dried at 80°C to a constant weight. At 16 WAP, the dry weight was measured using a digital scale. Weed dry weight (g.m^{-2}) was oven-dried at 80°C until it reached a constant weight, and then the dry weight was measured using a digital scale. Weeds were collected directly on the sample plots using the square method, which measured 0.4 m x 0.4 m at 16 WAP. The sample plots were diagonally arranged, with a raffia string separating each plot (Marpaung et al., 2022). At 15 WAP, the weight of the cob with cornhusk (g.plant^{-1}) was measured using a digital scale. After the kernels were removed from the cobs and dried in the sun for two days, the kernel dry weight (g.plant^{-1}) was calculated using a digital scale at 16 WAP. The yield of corn was calculated from the production of cobs with cornhusk per hectare (ton.ha^{-1}).

Experimental design

A single-factor Randomized Complete Block Design (RCBD) was employed for the research, with five treatments and five replications within each block. Two sample plants for periodic observation and thirty sample plants for production observation were included in each replication. The size of the experimental plot unit was 2.8 m (length) x 2 m (width) or 5.6 m² per experimental plot unit. The dosages of rice husk mulch used were 2; 4; 6; 8 kg.m^{-2} and without rice husk mulch.

Data analysis

The data were analyzed using Analysis of Variance (ANOVA) and then the Post Hoc Tukey's Honestly Significant Difference/HSD Test at the 5% significance level. The growth curve used sigmoidal growth curve (Ukalska and Jastrzębowski, 2019). The polynomial orthogonal test was used in the analysis of variance to identify trends between independent treatments (Berry, 1993). The strength to which two variables have a linear relationship was determined using the correlation analysis. The Pearson correlation coefficient is commonly used for interpretation. A value of -1 indicates a total negative linear correlation, 0 indicates no correlation, and +1 indicates a total positive correlation. This coefficient is a dimensionless measure of the covariance and is scaled (Schober et al., 2018). One method to divide the correlation coefficients into direct and indirect effects is to use path coefficient analysis. The study's variables were divided into independent and dependent categories (Wamanrao et al., 2020). The dependent variable in path analysis is kernel dry weight. The total dry weight is used as the intervening variable (mediator) in path analysis, while the other variables are used as the independent variables. SAS 9.4 and RStudio 3.6.0 were used to carry out the statistical analysis.

RESULTS AND DISCUSSION

Plant height of corn

Plant height is a key component of a plant's ecological strategy, strongly correlated with life span, seed mass, time to maturity, above-ground biomass, plant fitness, and leaf photosynthesis, and it is a major determinant of a species' ability to compete for light (Wang et al., 2019). Figure 1 illustrates the growth of corn from 2 to 14 WAP. Based on a sigmoid curve in Figure 1, the application of the rice husk mulch showed a positive effect on the plant height of corn compared to the without rice husk mulch. At the 14 WAP, the application of rice husk mulch effected the plant height higher than without rice husk mulch. The plant height of 2, 4, 6, 8 kg.m^{-2} and without rick husk mulch were 171.77; 183.41; 185.99; 173.70; and 149.21 cm respectively. Rice husk mulch outperforms no mulch by enhancing water storage (Salahudeen and Sadeeq, 2018) and reducing soil temperature (Sharma et al., 2023).

According to (Ukalska and Jastrzębowski, 2019), the growth curve had various growth patterns. In the initial or lag phase (2 – 4 WAP), growth was relatively slow but accelerated thereafter (6 – 10 WAP) and decreased in the final or stationary phase (12 – 14 WAP), approaching the upper asymptote. Rice husk as a mulching material significantly affected plant height from 2 – 14 WAP or during the vegetative and generative phases of corn. The application of 2 kg.m^{-2} rice mulch did not significantly differ from the application of 4, 6, and 8 kg.m^{-2} in terms of plant height from 2 to 14 WAP. This is consistent with (Riyanto et al., 2023), which stated that rice husk enhances the corn growth compared to no mulch. According to (Sharma et al., 2023), mulching material limit the amount of radiation that reaches the soil surface due to their higher albedo and lower thermal conductivity compared to no mulch soil, which reduces both the radiation reaching the soil and the interfacial heat available to warm the root system. The application of rice husk mulch reduces soil temperature by more than 10°C compared to bare soil, thereby maintaining soil moisture, minimizing soil evaporation rates, and reducing soil water loss, especially during drought (Demo and Bogale, 2024), as well as maintaining the photosynthesis process and transpiration (Kusbiantoro et al., 2023), so that plant height growth is not inhibited (Gupta et al., 2023).

Number of leaves

The number of leaves can indicate whether the plants are in good condition. According to (Nasution et al., 2021), one of the primary plant components needed to produce biomass through photosynthesis is its leaves. Similar to plant height, the number of leaves also reflects corn growth from 2 to 14 WAP (Figure 2). Based on a sigmoid curve in Figure 2, rice husk mulch showed a positive effect on the number of corn leaves compared to no mulch. Application of rice husk mulch 6 kg.m^{-2} significantly increased the number of leaves compared to no mulch. At the 12 WAP, the application of rice husk mulch resulted in a higher number of leaves compared to no mulch. The number of leaves of 2, 4, 6, 8 kg.m^{-2} and without rick husk mulch were 11.37; 12; 12.58; 12.35; and 11.36 respectively. In addition to overcoming water stress due to droughts, rice husk mulch can enhance nutrient availability and improve the corn growth corn (Saranya et al., 2018). Rice husk mulch has a considerable impact on increasing the number of

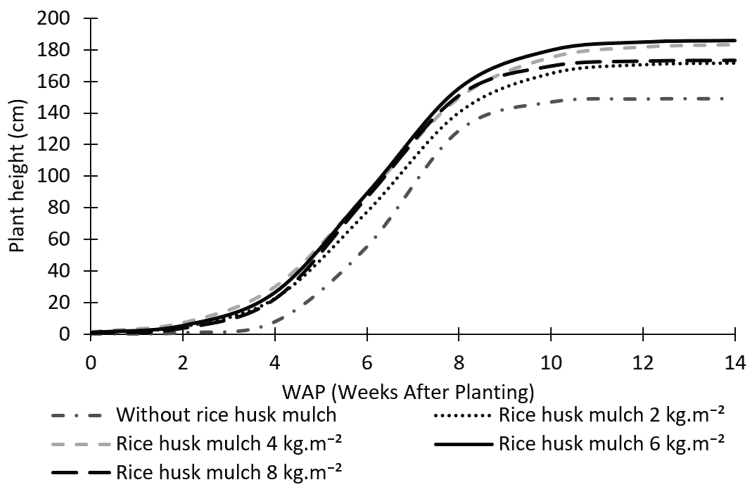

Figure 1. The sigmoid curve of corn plant height at 2–14 WAP on the different dosages of rice husk mulch

leaves compared to no mulch (Sharma et al., 2023).

During the stationary phase (12 – 14 WAP), the number of leaves decreased because the plants entered the generative phase, with assimilates being redirected towards the corn development. Rice husk as a mulching material had a significant effect on the number of leaves during the vegetative and generative phases of corn. The application of rice mulch 2 kg.m^{-2} was not significant with the application of 4, 6, and 8 kg.m^{-2} rice mulch on the number of leaves during 2 – 14 WAP. In addition to increasing organic matter, crop yield, and water productivity, using organic mulch can save up to 50% on energy consumption and lessen water stress in the root zone (Alhashimi et al., 2023).

Stem diameter of corn

Stem diameter is one of the most common measurements commonly taken to assess plant growth (Paul et al., 2017) and is the parameter used for predicting field survival (Gallegos-Cedillo et al., 2021). The agronomic traits were assessed by measuring the stem diameter. A larger stem diameter indicates greater reserves and accumulation of assimilates, which improves kernel filling (Irmak et al., 2022). Stem diameter reflects corn growth from 2 – 6 WAP, as shown in Figure 3. Stem diameter was measured during the vegetative phase. The quality of plants depends on their ability to rapidly generate a large stem diameter (Gallegos-Cedillo et al., 2021).

Based on a sigmoid curve in Figure 3, rice husk mulch showed a positive effect on the stem diameter of corn compared to no mulch. Application of rice husk mulch 2, 4, and 6 kg.m^{-2} significantly increased the stem diameter compared to no mulch at 2 – 4 WAP. Application of rice husk mulch 4, 6, and 8 kg.m^{-2} significantly increased the stem diameter compared to no mulch at 6 WAP. At 6 WAP, the application of rice husk mulch affected the stem diameter higher compared to no mulch. At 6 WAP, stem diameters with 2, 4, 6, 8 kg.m^{-2} or rice husk mulch and with no mulch were 20.67; 22.24; 23.32; 22.99; and 18.77 mm respectively. According to (Sharma et al., 2023), the application of rice husk increases the stem diameter in corn during the growth phase compared to no mulch. The application of rice husk mulch overcomes drought stress by restraining irrigation water evaporation. Organic mulch from rice cultivation waste improved the stem diameter in corn (Khan et al., 2022). Supported by drip irrigation, it can improve the stem diameter in corn (Yang et al., 2023).

Stem dry weight, lead dry weight, root dry weight, and total dry weight of corn

Plant growth is an irreversible increase in size and is mostly described as net primary production (Hilty et al., 2021). Dry weight gain, or the accumulation of plant biomass, is a crucial measure of growth as it reflects how a plant responds to various factors, including photosynthetic activity, CO_2 concentration, and, to a lesser extent temperature (Gallegos-Cedillo et al., 2021). There was a significant difference between the treatments on the stem dry weight, leaf dry weight, root dry weight, and total dry weight of corn at the 16 WAP (Table 1).

Application of rice husk mulch 4, 6, and 8 kg.m^{-2}

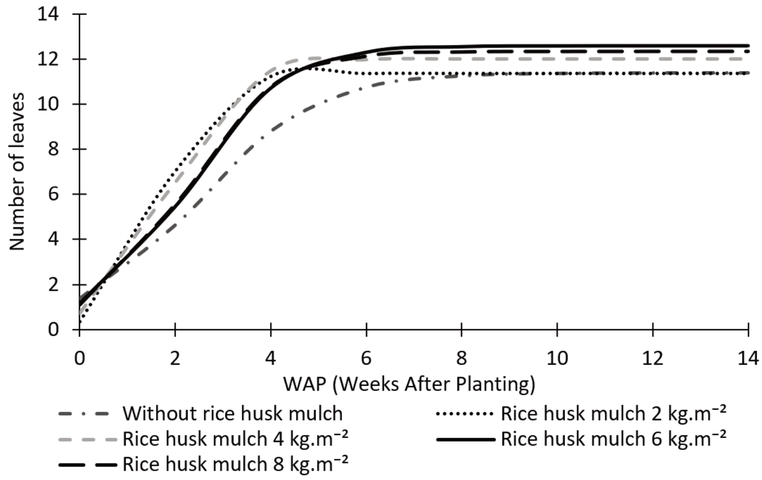

Figure 2. Number of leaves of corn at 2–14 WAP on the different dosages of rice husk mulch

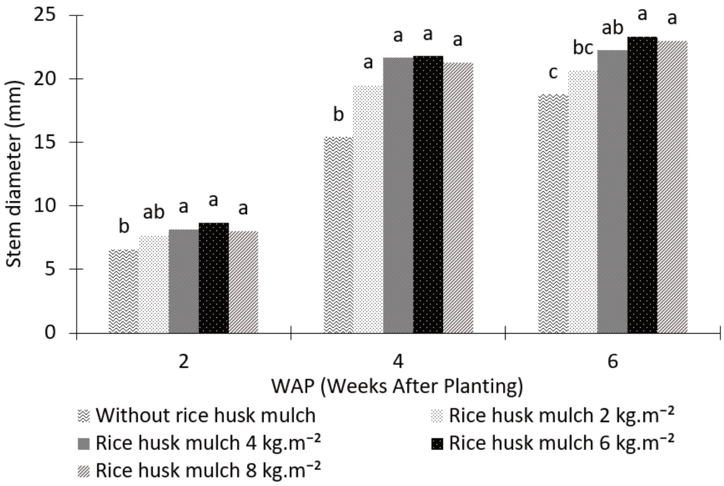

Figure 3. Stem diameter of corn at 2–6 WAP on the different dosages of rice husk mulch

Remarks: The different letters are significantly different at the 5% probability level by Tukey's test.

Table 1. Stem dry weight, leaf dry weight, root dry weight, and total dry weight of corn at 16 WAP on the different dosages of rice husk mulch

Treatments	Stem dry weight (g.plant^{-1})	Leaf dry weight (g.plant^{-1})	Root dry weight (g.plant^{-1})	Total dry weight (g.plant^{-1})
Without rice husk mulch	47.00 b	18.20 b	37.10 b	102.30 b
Rice husk mulch 2 kg.m^{-2}	75.38 b	27.90 ab	41.50 ab	144.78 b
Rice husk mulch 4 kg.m^{-2}	129.50 a	35.10 a	46.90 ab	211.50 a
Rice husk mulch 6 kg.m^{-2}	146.40 a	37.20 a	53.90 a	237.50 a
Rice husk mulch 8 kg.m^{-2}	119.30 a	35.70 a	45.00 ab	200.00 a
Coefficient of variation (%)	17.75	19.88	17.54	12.75

Remarks: Means followed by the different letters in the same column are significantly different at the 5% probability level by Tukey's test. WAP = Weeks After Planting.

significantly increased the stem dry weight compared to no mulch at 16 WAP. The significant results were influenced by the significantly larger stem diameter compared to no mulch at 6 WAP. Rice husk mulch 6 kg.m^{-2} showed the highest significant effect on stem dry weight than the other treatments of rice husk mulch. The same result also happened to the leaf dry weight and root dry weight of corn. Total dry weight (the stem, leaf, root) reflects the accumulation of organic compounds. The total dry weight was most significantly affected by rice husk mulch at a rate of 6 kg.m^{-2}, followed by rice husk mulch at a rate of 2 kg.m^{-2} and without rice husk.

Total dry weight is the result of the photosynthesis process which is influenced by the amount of nutrients and water absorbed by plants' roots (Padafani, 2022). Given the changing climate, including prolonged drought, it is crucial to understand how environmental factors affect and interact with plants (Qaderi et al., 2019). Rice husk application in dry land affects the availability of soil moisture content thereby affecting the growth and productivity of corn (Riyanto et al., 2023). Rice husk was added to the soil, enhancing its water-holding capacity and improving irrigation efficiency, leading to better plant growth and higher dry weight compared to plants without rice husk mulch (Nurjanah et al., 2021). Mulch altered the soil energy balance by reducing soil water evaporation, which affected the uptake and transfer of essential nutrients and consequently had an effect on shoot and root biomass (Sharma et al., 2023).

Weed dry weight on the different dosages of rice husk mulch

Weed is the main problem in cultivation. In addition to maintaining water availability, the application of rice husk mulch also serves as a cover crop. Mulching with organic mulch has proved to be an effective technique for controlling weed control, building organic matter, and increasing corn yield (Asif et al., 2020). Based on a histogram in Figure 4, rice husk mulch treatments significantly reduced weed dry weight compared to no mulch. Application of 2 kg.m^{-2} of rice husk mulch significantly reduced weed dry weight by 109.17 g.m^{-2}, which was 196.17% lower compared to no mulch. Applying 8 kg.m^{-2} of rice husk mulch resulted in the greatest reduction in weed dry weight compared to other dosages, with a decrease of 492.40% compared to no mulch. Although applying more rice generally reduced weeds growth, this research found that the different dosages of rice husk mulch did not significantly differ in their effectiveness at suppressing weeds. The application of rice husk mulch effectively inhibited the growth of weeds (Nurjanah et al., 2021), evaporation reduction, and other environmental modifications (Salahudeen and Sadeeq, 2018). Weed growth is restricted by rice husk mulch because light penetration into the soil is reduced (Sharma et al., 2023). Organic mulch can defend weeds from the sunlight, which is necessary for weed germination, and from other important elements such as growing areas, sunlight, and nutrients (Nurjanah et al., 2023).

Weight of cob with cornhusk, kernel dry weight, and yield of corn

The weight of cob with cornhusk and kernel dry weight is a result of corn per plant, which contributes to the yield (Asif et al., 2020). Table 2 illustrates the mean comparison results for the weight of cob with cornhusk and kernel dry weight throughout various treatments. Application of rice husk mulch 4, 6, and 8 kg.m^{-2} significantly increased the weight of cob with cornhusk and kernel dry weight at 16 WAP compared to no mulch. Rice husk mulch at 6 kg.m^{-2} had the most significant effect on the weight of cob with cornhusk compared to the other treatments (244.30 g.plant^{-1}), but it did not differ significantly from the 4 and 8 kg.m^{-2} rice husk mulch treatments. For kernel dry weight variable, rice husk mulch at 4 kg.m^{-2} had the most significant effect (114.20 g.plant^{-1}), but it did not differ significantly from the 2, 6, and 8 kg.m^{-2} rice husk mulch treatments. The application of rice husk can increase soil organic matter content in the soil (Riyanto et al., 2023), and maintain water availability and nutrient uptake for plant growth (Irmak et al., 2022), so high plant growth typically results in greater corn yield components (Nurjanah et al., 2021).

Yield is the main reason the farming community cultivates the corn crop (Asif et al., 2020). Application of rice husk mulch significantly increased the corn yield at 16 WAP compared to no mulch, but there was no significant difference between rice husk mulch treatments (2, 4, 6, and 8 kg.m^{-2}). Rice husk mulch 6 kg.m^{-2} had the most significant effect on the yield of corn compared to the other treatments of rice husk mulch (7.34 ton.ha^{-1}), where this result was directly proportional to the weight of cob with cornhusk per plant. In the growth variables, i.e. rice husk mulch 6 kg.m^{-2} showed the optimal growth of the plant, but it did not significantly differ from the 4 kg.m^{-2} treatment of rice husk mulch. The optimized growth resulted in the highest yield. These results indicated that organic mulch can influence the environment by retaining soil moisture and suppressing weed growth (Figure 4).

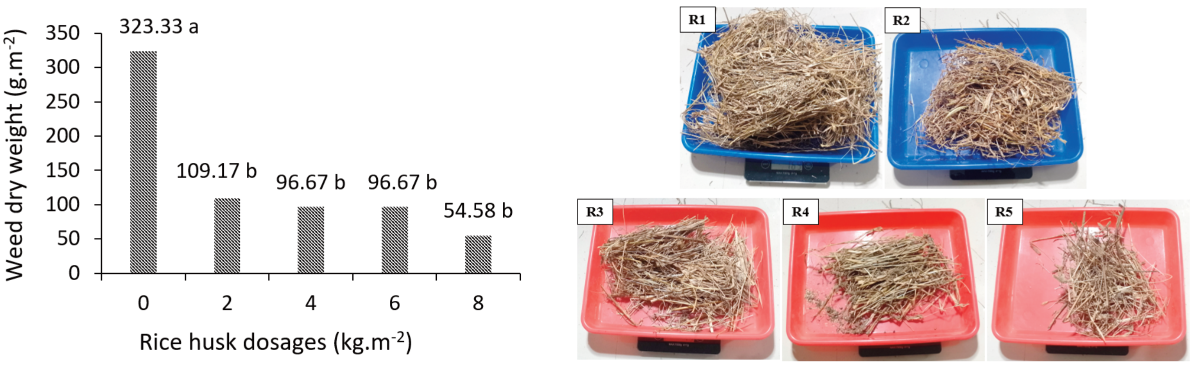

Figure 4. Weed dry weight on the different dosages of rice husk mulch

Remarks: Means followed by the different letters are significantly different at the 5% probability level by Tukey's test. R1 = without rice husk mulch, R2 = rice husk mulch 2 kg.m^{-2}, R3 = rice husk mulch 4 kg.m^{-2}, R4 = rice husk mulch 6 kg.m^{-2}, R5 = rice husk mulch 8 kg.m^{-2}.

Table 2. Weight of cob with cornhusk, kernel dry weight, and yield of corn at harvest period 16 WAP

Treatments	Weight of cob with cornhusk ($g.plant^{-1}$)	Kernel dry weight* ($g.plant^{-1}$)	Yield of corn ($ton.ha^{-1}$)
Without rice husk mulch	130.30 c	60.00 b	4.04 b
Rice husk mulch 2 $kg.m^{-2}$	165.60 bc	87.80 ab	5.99 a
Rice husk mulch 4 $kg.m^{-2}$	206.50 ab	114.20 a	7.15 a
Rice husk mulch 6 $kg.m^{-2}$	244.30 a	111.70 a	7.34 a
Rice husk mulch 8 $kg.m^{-2}$	226.30 ab	109.10 a	7.05 a
Coefficient of variation (%)	18.59	11.42	14.83

Remarks: Means followed by the different letters in the same column are significantly different at the 5% probability level by Tukey's test. WAP = Weeks After Planting. * = results of data transformation √x.

Less competition between weeds and crops resulted in better plant growth and higher yield (Nurjanah et al., 2021).

Regression between kernel dry weight and weight of cob with cornhusk on the different dosages of rice husk mulch

Since many of the factors studied in agricultural sciences are quantitative, regression analysis is highly relevant to the field. Generally, researchers used polynomial models to explain their experimental results (Shimizu and Gonçalves, 2023). Regression analysis on the results of this study used quadratic polynomial regression (order 2). Regression analysis aimed to find the relationship between the x variable (independent variable) and the y variable (dependent variable), where in this study the x variable was rice husk dosages, namely 2; 4; 6; 8 $kg.m^{-2}$ rice husk mulch and without rice husk mulch. The y variables were kernel dry weight per plant and corn yield. Figure 5 shows a regression graph depicting the relationship between rice husk mulch dosages and both kernel dry weight per plant and corn yield. The relationship between rice husk mulch dosages and kernel dry weight per plant was quadratic. The polynomial regression equation was $Y = -1.6018x^2 + 18.919x + 59.326$ with $R^2 = 0.9785$. This result showed that the relationship between the two variables was close (97.85%), and statistically significantly different ($P < 0.05$). The relationship between rice husk mulch dosages and the corn yield was quadratic. The polynomial regression equation was $Y = -0.0973x^2 + 1.1472x + 4.0607$ with $R^2 = 0.9979$. This result showed that the relationship between the two variables was very close (99.79%), but statistically not significantly different ($P < 0.05$).

From this study, the optimal dosage to produce the highest yield was a rice husk mulch dosage of 5.9 $kg.m^{-2}$. The application of rice husk mulch at a dosage of 5.9 $kg.m^{-2}$ produced the highest kernel dry weight per plant of 115.19 $g.plant^{-1}$ and corn yield of 7.44 $ton.ha^{-1}$. When we applied rice husk mulch beyond the optimal dosage, the kernel dry weight per plant and corn yield will decrease. The application of excessive dosages of organic mulch makes the soil too moist, limiting oxygen in the root zone of the soil (Naresh, 2022). Hypoxia may occur in the plant if there is a lack of oxygen in the root zone. Root hypoxia causes a decrease in root respiration, which in turn causes a shift from aerobic to anaerobic respiration; this causes root growth to stop, and ion transport to slow down. This leads to rapid increases in phytohormones, such as ethylene and abscisic acid (ABA), which causes leaf stomata to close and a decrease in the net photosynthetic rate, consequently affecting crop growth and yield (Ouyang et al., 2021).

Correlation coefficient of growth components and yield of corn

Information about the relationships between traits and yield suggests how important each trait is in terms of selection for increased yield. One commonly used method to assess the degree of relationship between different traits is correlation analysis (Rachana et al., 2021). The plant growth components are not only individually correlated with the corn yield, but they are also correlated with the others (Wamanrao et al., 2020). The value of Karl Pearson's correlation coefficient helps in finding the correlation between two characters or components (Wamanrao et al., 2020). A value of -1 indicates a total negative linear correlation, 0 indicates no correlation, and +1 indicates a total positive correlation. The stratification of correlation was categorized as negligible (0.00 – 0.10), weak (0.10 – 0.39), moderate (0.40 – 0.69), strong (0.70 – 0.89), and very strong (0.90 – 1.00) (Schober

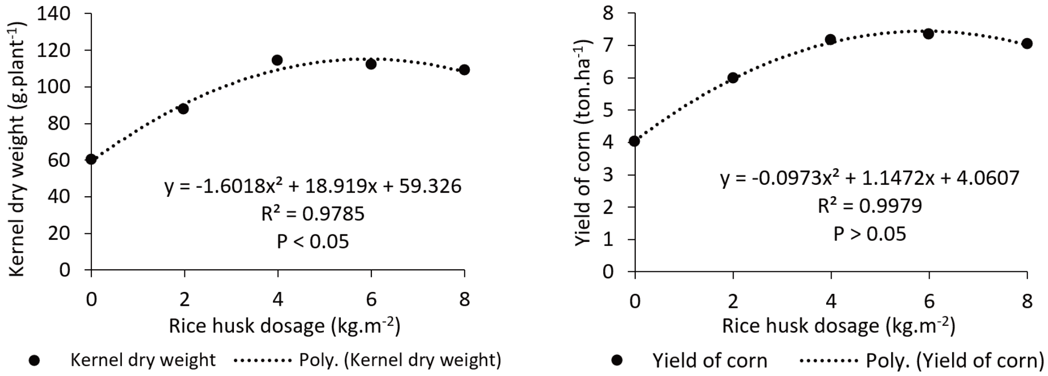

Figure 5. Kernel dry weight per plant and yield of corn on the different dosages of rice husk mulch

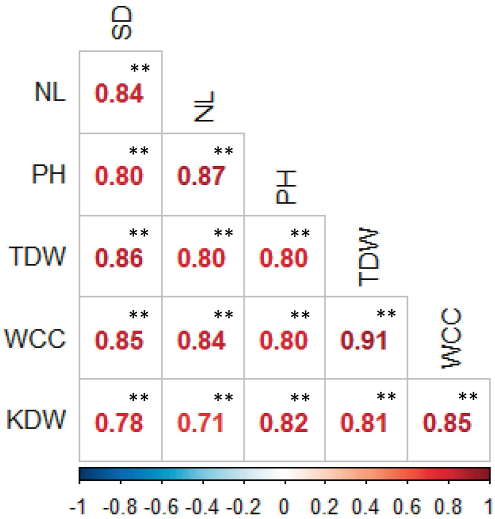

Figure 6. Correlogram of the relationship between growth components and yield of corn

Remarks: SD = Stem Diameter, NL = Number of Leaves, PH = Plant height, TDW = Total Dry Weight, WCC = Weight of Cob with Cornhusk, KDW = Kernel Dry Weight. Red numbers indicate a positive correlation, sign * = significant different at 5% and sign ** = significant different at 1%.

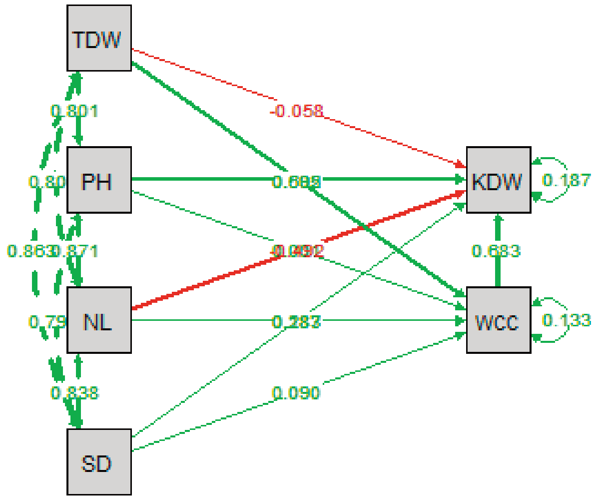

Figure 7. Path analysis diagram of growth components on corn crop yield

Remarks: SD = Stem Diameter, NL = Number of Leaves, PH = Plant height, TDW = Total Dry Weight, WCC = Weight of Cob with Cornhusk, KDW = Kernel Dry Weight. R21 = 0.87 and R22 = 0.81. Residual effect of path 1 (e1) = 0.36, residual effect of path 2 (e2) = 0.44.

et al., 2018).

The relationship between the growth components, i.e. stem diameter, number of leaves, plant height, total dry weight, weight of cob with cornhusk, and kernel dry weight was confirmed by the correlogram, as illustrated in Figure 6. The growth components had a significantly strong correlation and positive value with the others (r = >0.80**, p-value ≤ 0.01), especially total dry weight had a positive and significantly very strong correlation with the weight of cob with cornhusk (r = 0.91**, p-value ≤ 0.01). Thus crop yield components can be increased by increasing the total dry weight accumulation (Rachana et al., 2021). The stem diameter (r = 0.78**, p-value ≤ 0.01), number of leaves (r = 0.71**, p-value ≤ 0.01), plant height (r = 0.82**, p-value ≤ 0.01), total dry weight (r = 0.81**, p-value ≤ 0.01), weight of cob with cornhusk (r = 0.85**, p-value ≤ 0.01) were positive and significantly strong correlated with kernel dry weight. Among the causal components, the weight of cob with cornhusk exhibits the strongest correlation with kernel dry weight. A highly significant correlation was found between the growth components and kernel dry weight, indicating that an increase in one component corresponds to a proportional increase in the related components.

Path analysis of growth components and yield of corn

Path coefficient analysis is a method used to divide the correlation coefficients into direct and indirect effects. The path coefficient is calculated by simultaneously solving the following set of equations that represent the fundamental relationship between path coefficients and correlation (Wamanrao et al., 2020). The dependent variable (kernel dry weight) is supposed to be influenced by the other characters called independent variables (growth components). Figure 7 illustrates the path coefficient analysis results for all growth components to yields. The dependent variable was the amount of kernel dry weight per plant, while the independent variables were the total dry weight, plant height, number of leaves, and stem diameter. The weight of the cob with cornhusk per plant served as a mediating variable between the independent variables and the dependent variable, kernel dry weight.

Kernel dry weight, as a yield variable, is a complex quantitative trait; therefore, multiple traits need to be considered for its improvement (Rachana et al., 2021). Concerning kernel dry weight, plant height had the most direct positive effect (β = 0.592, p-value ≤ 0.05). This is followed by stem diameter (β = 0.187). Kernel dry weight was directly and negatively affected by both the total dry weight (β = -0.058) and the number of leaves (β = -0.492). Compared to other casual variables, the weight of cob with cornhusk as an intervening variable had the most indirect positive effect on kernel dry weight (β = 0.683, p-value ≤ 0.05). The indirect effects of stem diameter (β = 0.09), the number of leaves (β = 0.283), plant height (β = 0.001), and total dry weight (β = 0.605, p-value ≤ 0.05) on kernel dry weight were observed to be positive. The total dry weight had a strong significant effect on the weight of cob with cornhusk per plant. The results from correlation and path coefficient analysis strongly indicated that plant height and the weight of cob with cornhusk per plant should be considered and optimized as key indicators for achieving high corn yield. The studies have reported that plant height and biological yield had a positive effect on yield indicating the relationship between these traits as good contributors to improved kernel dry weight per plant (Aman et al., 2020); (Rachana et al., 2021).

In general, rice husk mulching benefits plants by suppressing soil water loss, decreasing soil temperature, and increasing nutrient availability, which later affects soil microbial activities in the rhizosphere (Sharma et al., 2023). This condition reduces photorespiration and enhances carbon use efficiency (Lara and Andreo, 2011), while increasing the photosynthetic rate (Lopes et al., 2011). Applying rice husk mulch in corn fields minimizes competition between corn and weeds, leading to changes morphology such as increased plant height, number of leaves, and stem diameter, as well as greater dry biomass weight of corn. These conditions affect yield components such as kernel dry weight and weight of cob with cornhusk, as well as corn yield. This study shows that applying rice husk mulch can suppress weeds and produce high corn growth. Therefore, it is recommended for use under drought stress conditions, as it enhances corn yield compared to no mulch.

CONCLUSIONS

The highest of plant height, number of leaves, stem diameter, dry weight of biomass (stem, leaf, root), and suppressed weed were achieved with 6 kg.m^{-2} of rice husk mulch. In this dosage, it impacts the optimal weight of cob with cornhusk and kernel dry weight. The optimal dosage of rice husk mulch to get the highest yield was 5.9 kg.m^{-2}. This study reveals that plant height and the weight of cob with cornhusk per plant should be optimized as key indicators for producing high corn yield.

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