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Effect of Planting Patterns and Mulch Types on Weed Growth and Yield of Sweet Corn and Red Bean

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to determine the best cropping pattern and type of mulch in the intercropping system of sweet corn and red beans in organic farming systems. The research was conducted in Air Duku Village, Bengkulu at 1054 m above sea level. The experimental design was RCBD with two factors. The first factor was cropping patterns consisted of monocultures of sweet corn, monocultures red bean, and intercropping of sweet corn and red beans. The second factor was organic mulch types consisting of rice straw, coffee husk, rice husk mulch, and control (without mulch). Data were analyzed using an analysis of variance (ANOVA) (α= 5%). The treatment means were separated by LSD. Plant height, plant dry weight, husked cob weight, unhusked cob weight, cob husked weight per plot was measured for sweet corn plants, while red bean plants were assessed for plant height, the number of seeds, seed weight, seed weight per plot, and weeds were observed for weight dry. Study resulted intercropping can suppress weeds on red beans but

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not in sweet corn. Sweet corn-red bean intercropping suppressed weed growth, and mulch application of rice straw and rice husks effectively controlled weeds. The growth and yield of sweet corn planted in intercropping are equivalent to that grown in monoculture. Red-beans has higher yield in monoculture than intercropping even though the growth is not different between the two crops. This result is important in weed manejemen in organic farming practice.

Keywords: Intercropping; monoculture; organic mulch; organic farming.

1. INTRODUCTION

Organic farming is an agricultural system without using synthetic chemicals. Land management, seed and fertilizer use, insect and pest management, and the growing environment are factors to consider in organic farming [1]. Organic farming is also defined as a plant cultivation approach, using organically recycled nutrients such as plant waste, livestock manure, and other wastes to enhance soil fertility and structure [2]. The organic farming approach transfers nutrients from plant wastes, compost, and manure into soil biomass as quick as possible, which subsequently mineralizes nutrients in soil solution. However, because manure and compost contain weed seeds and vegetative growth organs, their usage in organic farming can induce weed growth.

Weeds are plants that cause discomfort or harm to humans. Weeds harm humans in many ways, including through agriculture, fisheries, aesthetics, and health [3]. Weeds in crop production are undesirable because they lower crop yields. The lower crop yield occurs due to competition for plant growth requirement, such as sunlight, nutrients, and space. Weeds can also lower crop quality due to contamination with weed parts [4]. According to the findings of [5], competition between weeds and sweet corn has a detrimental influence on the growth rate of corn plants. The sweet corn growth rate inhibition occurs due to competition for nutrients, which impacts vegetative plant growth. Weeds can significantly reduce sweet corn yield by 40-50%. Weeds are a critical issue in organic farming, and their presence substantially impacts crop production. Weed control in organic farming uses various methods, including technical culture with intercropping patterns and the application of organic mulch.

Intercropping is a method of plant cultivation by planting two or more crops on the same land area. This cropping systems can enhance crop yield and efficiency [6,7]. The findings of [8] and [9] showed that land usage and weed growth rate suppression by intercropping generate varying yields at different spacings. The highest corn yield was 9.02 tons/ha, obtained at a corn spacing of 80 cm x 20 cm, whereas the highest red bean yield was 1.49 tons/ha, obtained at a corn spacing of 100 cm × 20 cm with two rows of red beans. Intercropping with legume species offers more benefits than intercropping with other plants because legumes can fix nitrogen from the atmosphere. The intercropping also causes a shift in weeds [10].

Intercropping between corn and legume can influence corn plant height, the number of corn leaves, and fresh cob weight. Corn population increases fresh cob weight, dry cob weight, corn productivity, and yield [11,12] reported that intercropping corn-soybean had the most significant influence on the weight of dry corn kernels, which ranged between 5.77 - 7.34 tons/ha. In addition to intercropping, other method of controlling weed is the use of mulch.

Mulch can suppress weed growth, decrease water loss, keep the soil moist, keep soil temperature stable, and reduce evaporation. Mulch is classified into two types: organic mulch and inorganic mulch. Plant leftovers such as rice husks, straw, cogongrass, and coffee husks are souces of organic mulch [3]. Wheat straw mulch reduces weed dry weight up to 67.5% lower than control (without treatment) [13].

The usage of organic mulch in polybags also benefits to plants. Straw mulch at 300 g/polybag effectively suppresses weed growth in soybean with a weed dry weight of 3.03 g/polybag. A dose of 300 g/polybag was more effective than a dose of 200 g/polybag in controlling weeds, resulting in a greater weed dry weight of 11.38 g/polybag. The higher the dose or thickness of the mulch surpressed more weed growth. Weed management effectiveness also has an impact on agricultural production. Straw mulch at a dose of 500 g/polybag generated the yield of soybean (50.2 pods per plant), whereas the untreated mulch was only 32.4 pods per plant [14].

Organic mulch and green manure can improve the soil's nutrient and water content. In comparison to its potential, the application of 9 cm of rice straw mulch and 20 tons/ha of green manure of Crotalaria juncea L. can increase the N content by 0.07%, increase the growth and yield of Tambin Kretek variety corn by 44.17%, and increase the seed weight by 0.88 tons/ha [15]. Compared to untreated mulch, organic rice husk mulch with a thickness of 8 cm can raise soil water content by 16.46% [16].

The research objectives were to determine the best combination of mulch types and cropping patterns for weed suppression, the best cropping pattern and type of organic mulch for weed suppression, and the best cropping pattern and type of mulch for plant growth and yield in sweet corn-red bean intercropping.

2. MATERIALS AND METHODS

2.1 Experimental Site and Design

The study was carried out at an altitude of 1054 m asl in Air Duku Village, Selupu Rejang District, Rejang Lebong Regency, Bengkulu, on dry land used for organic vegetable production since 2009. The study employed A Completely Randomized Block Design (RCBD) with two factors and three replications. The first factor was a cropping system including three treatment levels: sweet corn monoculture, red bean monoculture, and sweet corn-red bean intercropping. The second factor was the type of organic mulch, which was divided into four treatment levels: rice straw mulch, rice husk mulch, coffee husk mulch, and control (without mulch). There were 12 treatment combinations in total, and each treatment combination was repeated three times.

2.2 Field Experiment

Before planting, the land was divided into three blocks at spacing of with a 1 m. Experiment plots were 3 m × 3 m (l x w) in size and 50 cm apart in each block. The land was plowed using a hoe to the depth of 25 cm. As a basic fertilizer, 30 tonnes of vermicompost are spread evenly over the soil surface. Sweet corn was planted at a spacing of 25 cm × 75 cm while red bean intercrops were 25 cm × 37.5 cm between sweet corn rows. Five sample plants were randomly selected in each experimental unit for growth and yield variables. Mulch comprising rice straw, rice husk, and coffee husk waste was laid on land surface 4 weeks after planting (WAP) at a thickness of 5 cm. The mulch was distributed homogeneously over the soil surface.Pest and disease were sprayed using biopesticides from extract of Babandotan weed (Ageratum conyzoides L.) every week beginning at 2 weeks after planting to a week before harvesting.

Sweet corn was harvested in 95 DAP, indicated by shiny yellow seeds, yellowish green husks, blackish brown cob hairs, and drying. Red bean harvesting proceeded 88 DAP after the plants showed rough pod skin and dull pod color. At harvesting of each intercropped crop, weed was sampled from each plot by lifting up the weed. Weeds, then, were cleaned using tap water, rinsed, oven-dried at 65-70^{o}C, and weighed for weed dry weight. The sweet corn variables included plant height, shoot dry weight, husked cobs weight, unhusked cobs weight, and weight of husked cobs per plot. The variables for red beans were plant height, number of seeds, seed weight, and seed weight per plot, while the weed variable was the dry weight of weeds.

2.3 Data Analysis

Data were validated, normalized and analyzed using ANOVA at 5% level of probability. The LSD test at 5% was used to separate the treatment means.

3. RESULTS AND DISCUSSION

The homogeneity test revealed non-homogeneous data on the red bean variable. The √x method was then used to transform data of seed weight per plant, seed weight per plot, and number of seeds per plant. Furthermore, the data were statistically analyzed using the Analysis of Variance (ANOVA) at a level of α = 5%. The effect of cropping patterns and organic mulch on weed growth, sweet corn and red bean growth, and sweet corn and red bean yields is shown in Table 1. There was no interaction between the cropping pattern and the type of mulch for all observed variables.

3.1 The Effect of Cropping Patterns and Organic Mulch on Weed Growth

Table 2 shows the effect of the cropping pattern on total weed dry weight in sweet corn and red bean.

Table 1. Results of the analysis of the variation in the effect of cropping patterns and types of organic mulch on the growth of weeds, and sweet corn-red beans growth and yield

Variables	F-calc.			CV (%)
	Cropping Patterns	Organic Mulch	Interaction	
Weed dry weight on sweet corn	1.17 ns	8.07 **	2.42 ns	2.90
Weed dry weight on red beans	10.08 **	5.60 **	0.32 ns	4.96
Sweet corn plant height	1.14 ns	0.37 ns	0.28 ns	5.81
Sweet corn top crop dry weight	0.70 ns	4.11 *	0.62 ns	22.96
Husked cob weight per plant	0.21 ns	0.16 ns	1.80 ns	18.05
Unhusked cob weight per plant	0.13 ns	1.12 ns	3.12 ns	14.84
Husked cob weight per plot	0.004 ns	0.22 ns	2.17 ns	15.61
Red beans height	3.01 ns	6.41 **	0.37 ns	7.10
Red bean seed weight per plant #	3.79 ns	3.41 *	0.04 ns	21.08
Red bean number of seed per plant #	6.03 *	6.21 **	0.32 ns	16.26
Red bean seed weight per plot @	28.89**	2.57 ns	0.02 ns	29.90

*Note: ns: non significantly different, *= significantly different (5%); **= highly significant different (1%); F-table cropping patterns = 4.6; F-table organic mulch = 3.34*

Table 2. Effect of cropping patern on weed dry weight

Cropping Patterns	Weed dry weight (g/0,5 m^2)	
	Sweet corn	Red beans
Monoculture	225.91	237.86 a
Intercropping	223.03	223.03 b

Note: numbers followed by different letters in the same column are significantly different.

Weed dry weight in sweet corn did not differ between monoculture and intercropping patterns. The result is associated with that the sweet corn consistently grew well, rapidly covering underneath space with their canopy, leading the inhibition of weed growth [12] confirmed that the height and area among plant canopies in intercropping can affect the reception of sunlight in intercrops and weeds. The quantity of sunlight received affects plant growth and overall crop yield.

The dry weight of weeds in the red bean monoculture cropping pattern was higher than in the sweet corn - red bean intercropping (Table 2). Weed growth is more suppressed in the intercropping cropping pattern because the space for weed growth is covered by the intercropping canopy, causing the weed growth to be inhibited. Weeds also receive less sunlight since they are shaded by the corn and red bean canopies. This finding is in-line with that by [17], who concluded that intercropping resulted in lower weed dry weight compared to monoculture. Aside from mulch, cropping pattern affects weed growth. Table 3 shows the effect of mulch type on weed dry weight.

The use of much from rice straw and husks inhibits weed growth. The dry weight of the weeds produced by the rice straw mulch treatment in sweet corn cropping was lower, at 217.41 g/plot than coffee husk mulch (226.47 g/plot) and without mulch (234.2 g/plot). Similar pattern was observed on the dry weight of weeds in red bean cropping (Table 3). As a result, rice straw mulch is equally effective as rice husk mulch at controlling weeds in sweet corn plants. On the other hand, coffee husk mulch is less effective at reducing weeds in sweet corn and red bean.

Mulch has an impact on the environment in which plants thrive. Mulch can prevent the sunlight required for weed germination, inhibiting weed germination. Organic mulch can prevent weeds from receiving essential elements such as growing areas, sunlight, and nutrients. The use of organic mulch can also assist in preventing the growth of weeds [18].

Table 3. Effect of mulch type on weed dry weight in sweet corn and red beans

Mulch type	Weed dry weight (g/0,5 m2)	
	Sweet corn	**Red beans**
Control	234.20 c	241.33 c
Rice straw	217.41 a	216.68 a
Rice husk	219.79 ab	226.66 ab
Coffee husk	226.47 bc	237.11 bc

Note: numbers followed by different letters in the same column are significantly different.

The rice straw mulch treatment produced the lowest weed weight, although it was not significantly different from the rice husk mulch treatment (Table 3). This result is attributed to that rice straw mulch can cover plant area more effectively than coffee husk mulch. Rice straw and rice husk mulch have a higher volume than coffee husk mulch, which can suppress weed growth. Because of the high lignin content of rice straw mulch, it decomposes slowly, allowing rice straw mulch to protect the soil surface for a more extended time. Coffee husk mulch, on the other hand, can still be lifted up by growing weeds, allowing weeds to continue to grow and proliferate [19].

Beside suppressing weed development, rice husk mulch can also affect the soil physical, chemical, and biological characteristics. Rice husk can reduce soil crust, improve infiltration, moisture content, aeration, temperature, microbial activity, and plant root penetration [1]. Rice husk treatment may enhance soil water content [16] On the other hand, the coffee husk mulch was ineffective at suppressing weed growth, since the weeds can still grow among interspaces of husk particles.The decomposed coffee husk will then enriched the soil with nutrients for weed growth.

3.2 The Effect of Cropping Patterns and Organic Mulch on the Growth and Yield of Sweet Corn

Table 4 shows the influence of the cropping pattern on plant height, dry weight, husked cob weight, unhusked cob weight, and cob weight per plot of sweet corn.

Differences in cropping patternsdid not affect sweet corn growth and yield (Table 4) whether in monoculture or intercropped with red beans since sweet corn is easily adapted to various environment. Study by [20] suggests that intercropping of corn and legumes favors the previous growth and development because legume supplies N to the soil through rhizobium fixation. In addition, corn is a C4 plant, so, it can grow effectively in an intercropping system with red beans. C4 plants are more tolerant to heat and drought than C3 plants. Furthermore, CO_2 is bound by PEP (CO_2 binding enzyme in C4 plants), which does not bind O_2, so there is no competition between CO_2 and O_2 [21].

Except for shoot dry weight, the types of organic mulch treatments did not affect any of observed variables (Tables 1 and 5). Mulch application, in general, can enhance sweet corn growth and yield compared to treatment without mulch since it can adapt effectively to the growing environment of rice straw, rice husk, and coffee husk mulch. According to [22], using organic mulch creates good soil environmental conditions for the growth and development of soil microorganisms, saves water, and facilitates the development of root hairs. Furthermore, minerilized organic mulch could enrich soil nutrients. Plant height, shoot dry weight, husked cob weight, unhusked cob weight, and cob weight per plot of sweet corn in the organic mulch treatment produced higher yields than the control/no mulch treatment.

Table 4. Effect of cropping pattern on growth and yield of sweet corn

Variable	Cropping pattern	
	Monoculture	**Intercropping**
Plant height (cm)	214.36	219.88
Crop dry weight (g)	149.68	138.36
Husked cob weight per plant (g)	364.65	377.13
Unhusked cob weight per plant (g)	285.53	291.95
Husked cob weight per plot (kg)	7.50	7.53

Table 5. Effect of organic mulch on growth and yield of sweet corn

Mulch type	Variable				
	PH (cm)	CTDW (g)	CWP (g)	UCW (g)	CWT (kg)
Control	212.80	112.60b	364.43	282.26	7.21
Rice straw	218.86	178.82a	387.46	315.49	7.76
Coffee husk	219.90	137.48b	365.76	272.36	7.51
Rice husk	216.90	147.17ab	365.90	284.93	7.56

Note: PH: plant height, CTDW: corn top dry weight, CWP: cobs weight per plant, UCW: unhusked cob weight per plant, CWT: cobs weight per plot. Numbers followed by different letters in the same column are significantly different

Rice straw mulch treatment resulted in a higher dry weight of sweet corn shoots than coffee husk mulch or without mulch. The shoot dry weight produced by rice straw mulch was 178.82 g, higher than that produced by coffee husk mulch (137.48 g) and without mulch (112.60 g). This result is associated with that straw mulch could slow the growth rate of weeds (Table 3). [23] reported that the application of rice straw mulch produced better plant growth than no mulch.

3.3 The Effect of Cropping Patterns and Organic Mulch on the Growth and Yield of Red Beans

The cropping pattern treatments did not influence red bean plant height or seed weight, but it significantly affected the number of seeds per plant and seed weight per plot. Table 6 shows the effect of the cropping pattern on plant height, seed weight, number of seeds, and seed weight per red bean plot.

Table 6 shows that the number of red bean seeds per plant and seed weight per plot was higher in the monoculture treatment than in the intercropping treatment. The red bean received more growing space and sunlight in the monoculture cropping because there is no coverage of sweet corn canopy. In contrast, in the intercropping, the height and width of the sweet corn canopy covered the distribution of sunlight, so the red beans received limited sunlight. This condition interferes with photosynthesis, resulting in a lower yield of red beans.

The plant canopy influences the supply of sunlight received by plants in intercropping. According to [12], the height and area of intercropped space between plant canopy lowered the supply of sunlight, affecting overall plant growth and yield. Intercropped plants will interact with one another because each plant requires sufficient space to maximize interaction and minimize competition. Thus, in intercropping system, it is necessary to consider plant spacing, plant population, harvesting age of each plant, and plant morphology.

The sweet corn canopy restricts sunlight and narrows the space for red beans growth in intercropping system. The sweet corn canopy coverage also increases soil moisture which promotes pathogens to infest the red bean pods. The disease has caused the red bean pods to decay. Narrow growth space also has an impact on plant flowering and pollination. In addition, low light that reaches the plant also influences seed development.

A lack of sunlight hinders plant development and seed formation. The growth and yield of red beans intercropped with sweet corn in this study were still below the yield potential. Weeds, in addition to sunlight, significantly impact the growth of intercropped plants. Weed growth was so rapid that plant height and seed weight per plant of red beans in monoculture and intercropping did not differ significantly. Weeds inhibit red bean growth because plants cannot compete for nutrients, water, and sunlight.

Aside from cropping patterns, the usage of organic mulch influences the growth and yield of red bean (Table 7). When rice straw, coffee husk, and rice husk were applied as mulch, plant height increased (26.13 cm, 24.17 cm, and 25.18 cm, respectively) compared to the control (21.97 cm). These findings suggest that mulch can promote plants' growth faster than control (without mulch). According to [24], organic mulch can reduce soil temperature fluctuations, benefiting root growth and soil microbes. Mulch can also stabilize soil temperature and moisture, allowing plants to flourish [3]. The findings of this study also demonstrate that using organic mulch can reduce weed growth (Table 3).

Table 6. Effect of cropping pattern on the growth and yield of red beans

Variable	Cropping patterns	
	Monoculture	**Intercropping**
Plant height (cm)	23.75	24.98
Seed weight/plant (g)	1.67	1.41
Number of seed/plant	2.02 a	1.72 b
Seed weight/plot (g)	14.85 a	7.50 b

Note: numbers followed by different letters in the same row are significantly different

Table 7. Effect of the type of organic mulch on the growth and yield of red beans

Mulch type	Plant height (cm)	Seed weight per plant (g)	Seed weight per plot (g)	Number of seeds/plant
Control	21.97 b	1.36 b	9.51 b	1.65 b
Rice straw	26.13 a	1.88 a	14.12 a	2.30 a
Coffee husk	24.17 a	1.59 ab	9.50 b	1.64 b
Rice husk	25.18 a	1.36 b	11.58 ab	1.88 b

Note: numbers followed by different letters in the same column are significantly different

Compared to control and rice husk mulch, rice straw mulch resulted in higher seed weight per plant (1.88 g). Compared to the control and coffee husk mulch treatments, the rice straw mulch treatment resulted in a higher seed weight per plot (14.12 g). The rice straw treatment yielded the highest amount of seeds (Table 7). According to the findings of this study, straw mulch can suppress weed growth rates more than other treatments, resulting in less competition for light, growing space, and nutrients between red bean plants and weeds. According to [19], straw mulch can control weed growth while also increasing soil nutrients. Weed dry weight is also affected when straw mulch is applied.

4. CONCLUSIONS

There is no combination effect between cropping pattern and type of organic mulch on the growth of weeds, sweet corn, and red beans and yields of sweet corn and red beans. Weed dry weight in sweet corn-red bean intercropping was lower than in red bean monoculture and did not differ significantly from sweet corn monoculture. In organic farming systems, rice straw and husk mulches effectively control weeds on sweet corn and red beans. The growth and yield of intercropped sweet corn are comparable to monoculture. The yield of red-beans is higher in monoculture than intercropping even though its growth is comparable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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