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Effect of Intercropping with Mungbean on Growth, Yield and Seed Protein Content of White and Purple Waxy Corn

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ABSTRACT: This study aimed to determine the effect of intercropping with mungbeans on growth, yield, and protein content of waxy corn. The experiment was conducted on rainfed land in Rembitan village (Central Lombok, Indonesia) during the rainy season from December 2023 to March 2024, which was arranged using a Split Plot Design with three blocks and two treatment factors: intercropping (T0= no intercropping, T1= intercropping with mungbeans) as the main plots, and waxy corn varieties (J1= white, J2= purple waxy corn) as subplots. Observation variables included growth, yield components and seed protein content, and data were analyzed with analysis of variance (ANOVA) and Tukey's HSD using CoStat for Windows. The results showed that based on the main effect, intercropping significantly increased green leaf number at 28, 42 and 56 DAP (days after planting), weight of dry cobs per plant and protein content of the seeds. Both varieties of waxy corn were also significantly different in terms of green leaf number at 28, 42 and 56 DAP, cob length, weight of dry cob per plant and protein content of the seeds, which were on average higher in purple than in white waxy corn. However, there was an interaction effect of the treatment factors on green leaf number at 42 and 56 DAP, cob length, cob diameter, number of seed rows, weight of 100 seeds and weight of dry cob per plant, in which the effects of intercropping with mungbean were more significant on white than on the purple waxy corn. So it can be concluded that white waxy corn is more responsive than purple waxy corn to intercropping with mungbeans.

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KEYWORDS: intercropping; purple waxy corn; white waxy corn; mungbean; seed protein

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1. INTRODUCTION

The area planted with corn in Indonesia in 2020 was 3.82 million hectares, while the area harvested for corn was 3.74 million hectares with a production of 2.81 million tons [1]. In 2023, the West Nusa Tenggara (NTB) region in Indonesia produced 1.28 tons of dry corn kernels with a water content of 14%. The area harvested for corn decreased to 8.69% compared to 2022 [2]. This decline in yield and harvest area is very unfortunate if it continues to occur, even though corn has the potential to be a source of functional food, especially since the Indonesian indigenous functional market is increasingly open due to changes in people's lifestyles, and changes in eating patterns toward healthy living [3, 4]. Corn has various types, one of which is waxy corn (*Zea mays ceratina*) which consists of purple waxy corn and white waxy corn [5, 4].

Purple waxy corn, which is categorized as specialty corn, is one of the varieties widely developed in Thailand and America. This corn has its own uniqueness because it has purple seeds caused by the high anthocyanin content of 290 - 1323 mg / 100 g dry weight [6]. Unlike purple waxy corn, white waxy corn has lower anthocyanin content, but contains 90% amylopectin so that this corn has a delicious, savory and soft taste [7]. The characteristics of waxy corn are that it is early maturing and physiologically ripe at the age of 80 days [4]. Waxy corn is usually consumed in an easy way, namely grilled or boiled [8]. Waxy corn has a lower starch digestibility compared to other corn. Therefore, waxy corn is very suitable for consumption by diabetics who need carbohydrates but are low in glucose. Waxy corn also contains around 9.20 g / 100 g of protein. This shows that waxy corn has the potential as a food diversification or as an industrial material with a high economic level [3].

The disadvantages of waxy corn, especially the local varieties, are the small size of the cobs, susceptible to downy mildew, and the productivity level is still relatively low, namely less than 2 tons/ha [9]. The numbers of genetic diversity studies on waxy corn are also still relatively low [11]. Considering the advantages and disadvantages of waxy corn, it is necessary to grow them using cultivation techniques that can increase productivity, one of which is intercropping with legumes. The intercropping system makes a major contribution to crop production through effective utilization of resources, compared to monoculture [12, 13, 14]. In Indonesia, dryland farmers usually grow corn in intercropping with legume crops [15]. The advantage intercropping corn with legumes is the increase in nitrogen (N) supply from legumes to corn (non-legumes) [7, 16]. The results of intercropping research between corn and various types of legumes show that corn plants intercropped with mungbeans have the highest grain yield and N uptake [17]. The amount of nitrogen is thought to influence the total protein content, because nitrogen is an important element in protein formation [18].

Mungbeans are classified as C3 plants with low crowns, causing the rate of photosynthesis to occur at relatively low light intensity and temperature compared to C4 plants (corn) so that mungbean plants can tolerate shading [19]. The results of research by Polnaya and Patty (20) showed that corn and mungbean varieties in the intercropping system had a significant effect on the growth and yield components of both plants, in which the crop combination resulted in the highest yield of corn seed weight of 7.63 tons/ha and mungbeans of 0.73 tons/ha. However, that research was not involving the cultivation of waxy corn. This study was conducted to examine the effect of intercropping with mungbeans on growth, yield, yield components and seed protein content of white and purple waxy corn varieties.

II. MATERIALS AND METHODS

This study used an experimental method by conducting a field experiment in rainfed land in Rembitan village (Central Lombok, Indonesia), during the rainy season, from December 2023 to March 2024. The experiment was arranged using a Split Plot Design with three blocks and two treatment factors, namely: intercropping (T0 = without intercropping (monocrop), T1 = intercropping with mungbeans) as the main plots, and waxy corn varieties (J1 = white waxy corn (WC), J2 = purple WC) as subplots. Each treatment factor was combined to obtain 4 treatment combinations, namely T0J1, T0J2, T1J1, T2J2, and each treatment combination was made in three blocks to produce 12 experimental units.

After finishing soil tillage, four treatment plots were made which were replicated thee times (thee blocks) to produce 12 experimental plots. Waxy corn seeds were dibbled with a planting distance of 75 cm between rows and 20 cm within rows, but mungbeans were planted first, which was 10 days before seeding the waxy corn varieties. Mungbean seeds were planted 2 rows between rows of corn with a planting distance of 25 cm between rows and 20 within rows. Fertilization was done by dibbling the fertilizers 3-5 cm next to the base of the plant, then covered with soil. Mungbean plants were fertilized at the age of 15 days after seeding (DAS) with NPK (16-16-16) fertilizer at a dose of 200 kg/ha, while corn fertilization was done at the age of 10 and 35 DAS with NPK (16-16-16) fertilizer at a dose of 200 kg/ha, and at 49 DAS with Urea fertilizer at a dose of 50 kg/ha. Pest control was done using Bassazinon 750 EC for corn and Curracron 500 EC for mungbeans. Mungbean harvest was started at 65 DAS while corn was harvested at 80 DAS.

Observation variables include growth variables (plant height and green leaf number), and yield components of waxy corn (weight of dry cobs without husk, diameter and length of cobs, weight of 100 seeds, and protein content of seeds). The samples observed were three sample corn plants per plot. Data were analyzed with ANOVA (Analysis of Variance) and Tukey's HSD using the statistical program "CoStat for Windows ver. 6.303". The interaction patterns between the treatment factors are presented in the form of a bar graph accompanied by error bars using the mean & standard error (SE) values.

III. RESULTS

The summary of ANOVA results showed that intercropping with mungbeans significantly increased the number of green leaves at 28, 42 and 56 DAS (Table 1), and dry cob weight and seed protein content (Table 2), while differences in the waxy corn varieties only affected the number of green leaves at 28, 42 and 56 HST (Table 1), cob length, dry cob weight and seed protein content (Table 2). However, there was an interaction effect between intercropping and the waxy corn varieties on the number of green leaves at 42 and 56 DAS (Table 1), as well as cob length, cob diameter, number of seed rows, 100-grain weight, and dry cob weight per plant (Table 2).

Table 1. Effect of intercropping with mungbean on the growth of two waxy corn species

Treatments	Plant height (cm) at								Green leaf number per plant at							
	14 DAS		28 DAS		42 DAS		56 DAS		14 DAS		28 DAS		42 DAS		56 DAS	
J1: White corn	12.82	a	41.84	a	77.23	a	105.87	a	5.22	a	7.45	b	9.84	b	12.78	b
J2: Purple corn	12.42	a	42.69	a	76.50	a	106.67	a	5.17	a	8.06	a	10.61	a	13.00	a
HSD0.05	1.22		1.22		1.88		3.94		0.22		0.16		0.15		0.22	
T0: monocrop	12.13	a	42.43	a	77.69	a	106.07	a	5.22	a	7.28	b	9.28	b	11.78	b
T1: intercropping	13.11	a	42.10	a	76.04	a	106.47	a	5.17	a	8.22	a	11.17	a	14.00	a
HSD0.05	8.18		3.64		5.33		5.50		0.87		0.24		0.24		0.85	
Interaction	ns		ns		ns		ns		ns		ns		*		***	

Table 2. Effect of intercropping with mungbean on yield components, and seed protein contents of two waxy corn species

Treatments	Cob length (cm)		Cob diameter (mm)		Number of seed rows per cob		Weight of 100 dry grains (g)		Weight of dry cobs (g/plant)		Seed protein content (%)	
J1	17.75	b	47.50	a	13.72	a	22.52	a	126.72	b	4.79	a
J2	17.96	a	47.85	a	13.94	a	22.56	a	130.30	a	4.52	b
HSD0.05	0.20		0.36		0.56		0.46		2.91		0.20	
T0: monocrop	17.54	a	47.53	a	13.50	a	22.26	a	121.07	b	4.56	b
T1: intercropping	18.17	a	47.82	a	14.17	a	22.82	a	135.95	a	4.75	a
HSD0.05	0.66		0.98		1.10		0.86		3.78		0.15	
Interaction	*		*		*		*		***		ns	

[1)] Mean values followed by the same letter are not significantly different between treatments of each factor

However, there was an interaction effect of the treatment factors on green leaf number at 42 (Figure 1) and 56 DAP (Figure 2), cob length (Figure 3), cob diameter (Figure 4), number of seed rows (Figure 5), weight of 100 seeds (Figure 6) and weight of dry cob per plant (Figure 7), in which the effects of intercropping with mungbean were more significant on white than on the purple waxy corn.

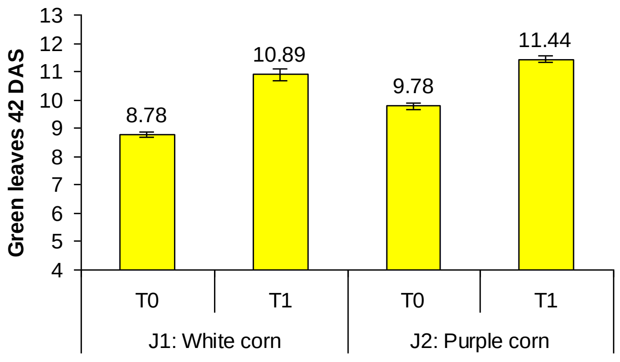

Figure 1. Green leaves of waxy corn (Mean ± SE) as affected by interaction effect of the treatment factors

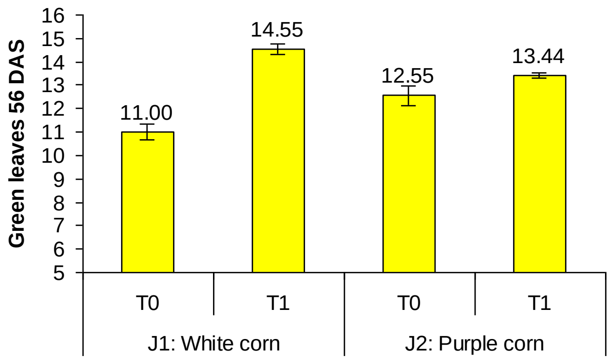

Figure 2. Green leaves of waxy corn (Mean ± SE) as affected by interaction effect of the treatment factors

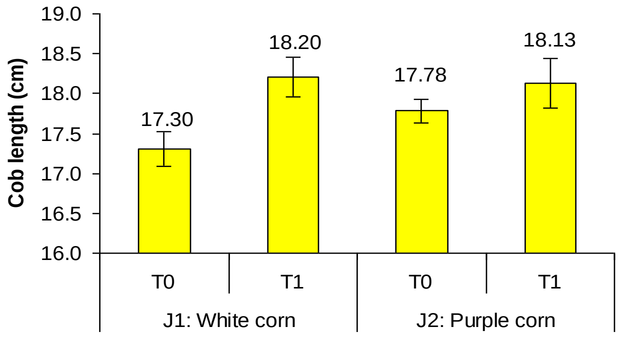

Figure 3. Cob lenght of waxy corn (Mean ± SE) as affected by interaction effect of the treatment factors

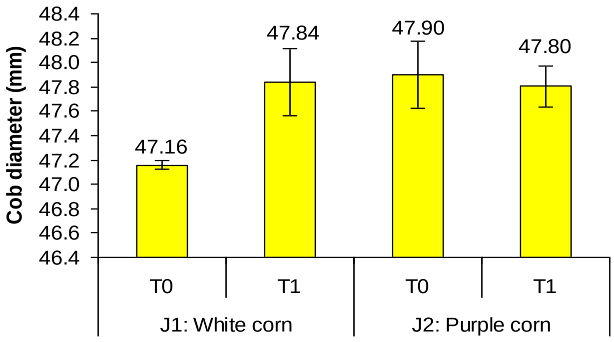

Figure 4. Cob diameter of waxy corn (Mean ± SE) as affected by interaction effect of the treatment factors

In relation to the protein contents of the waxy corn seeds, although there was no significant interaction of the treatment factors, it can be seen from Figure 8 that intercropping with mungbeans significantly increased seed protein contents both in the white and purple waxy corn. It can also be seen from Figure 8 that on average, the seed protein contents of the purple waxy corn were lower than those of the white waxy corn both under monocropping and intercropping systems.

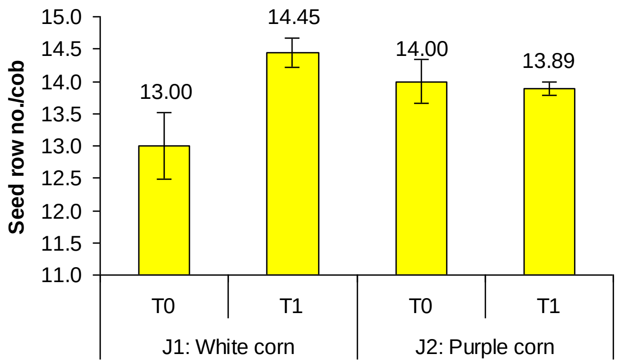

Figure 5. Seeds rows of waxy corn (Mean ± SE) as affected by interaction effect of the treatment factors

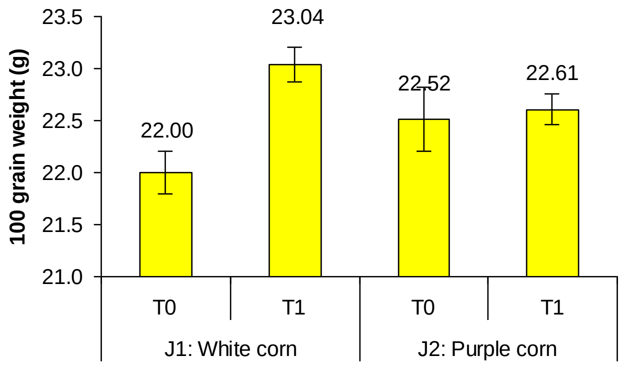

Figure 6. The 100 grain weight of waxy corn (Mean ± SE) as affected by interaction effect of the treatment factors

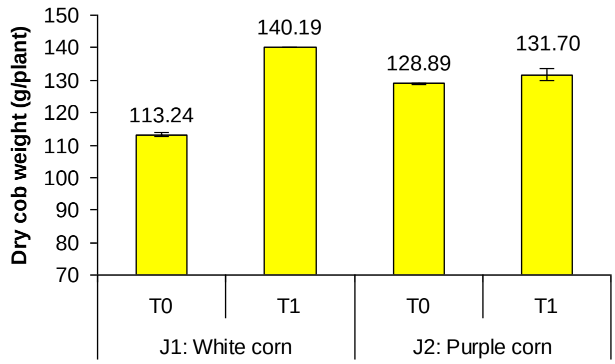

Figure 7. Dry cob weight of waxy corn (Mean ± SE) as affected by interaction effect of the treatment factors

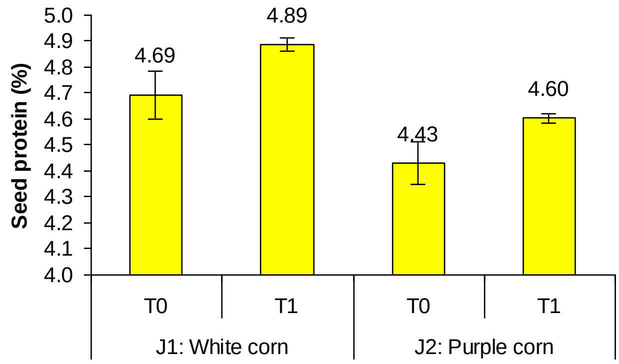

Figure 8. Seed protein content of each variety of waxy corn (Mean ± SE) as affected by intercropping with mungbean

The treatment of intercropping waxy corn with mungbean produced a greater number of green waxy corn leaves compared to the monocropping system. At 42 DAS, the highest number of leaves that were still green in color was on purple waxy corn at 11.44 leaves (Figure 1), while at 56 DAS, the highest number of green leaves was in white waxy corn at 14.55 leaves (Figure 2). Likewise with the length of the corn cob, the size of the waxy corn cob grown in intercropping was longer than without intercropping. White waxy corn had the longest cob size at 18.20 cm (Figure 3). For the cob diameter, it was seen that purple waxy corn without intercropping treatment had the highest diameter size at 47.90 mm (Figure 4). The results of observations on the number of seed rows per cob showed that white waxy corn with intercropping treatment had the largest number of seed rows at 14.45 rows (Figure 5). Similarly, in Figure 6, it can be seen that white waxy corn with intercropping treatment produced the highest weight of 100 seeds of 23.04 g, and the dry cob weight per plant was also higher under intercropping treatment as evidenced by the cob weight increasing compared to without intercropping treatment. The heaviest dry cob weight per plant was in the T1J1 treatment of 120.19 (Figure 7). Figure 8 also proves that with intercropping, corn seed protein becomes higher in which the T1J1 treatment showed the highest protein content of 4.89%.

IV. DISCUSSION

Based on the results of this study, it is known that with the intercropping treatment the number of leaves becomes more from 45 days after seed to 56 days after seeds, which shows that intercropping with mungbeans can provide sufficient nitrogen nutrients for the growth of waxy corn. As is known, mungbeans are legume plants that have root nodules that are symbiotic with the bacteria Rhizobium sp which can bind nitrogen from the atmosphere, then fix it so that it can be absorbed by corn plants. Nitrogen nutrients are the nutrients that have the most influence on leaf growth and development [21]. The number of leaves is an indicator of growth parameters that describe the photosynthetic ability of plants [22]. The results of photosynthesis can be used as a source of energy for the formation of new leaves and other plant organs, then the results of photosynthesis will be distributed to the upper part of the plant which will help the growth of the crown (leaf shoots and stems) so that the plants become taller and the number of leaves increases [23]. The increase in the number of leaves is also due to the increasing age of the plant [20]. The number of leaves has a close relationship with plant yields, and based on the results of the correlation analysis, the number of leaves at the age of 56 DAS is positively and very significantly correlated with the weight of dry cobs per plant, with $R^2 = 88.7\%$.

In this study, it can be seen that there are differences in the results of the two types of waxy corn. White waxy corn tends to have optimal results with an intercropping system compared to without intercropping. The longer cob size due to this intercropping treatment indicates that the nitrogen absorbed by the plant is able to meet the nutrients needed in both the vegetative and generative phases. The availability of nitrogen at the beginning of growth greatly affects the next development phase such as pollination, seed filling, and increasing cob weight [24]. Nitrogen is a component in protein synthesis. The protein produced will then be used by plants to form important organs such as cobs and seeds [25]. It is reiterated that nitrogen plays a role in stimulating cob formation [26]. Figure 4 shows that the diameter of the white waxy corn cob is higher than without intercropping. The diameter of the cob is also influenced by the number of rows of seeds, the more rows there are, the wider the cob diameter will be, conversely, if the number of rows of seeds in the cob is small, the diameter of the cob will also be small. It can be seen from the results of this study, the number of rows of white waxy corn seeds with intercropping treatment has a greater number of rows of seeds than without intercropping. This is thought to be due to the presence of nitrogen nutrients that help optimize the photosynthesis process so that it produces photosynthate which is then distributed to parts of the corn plant, thus metabolism will take place actively, resulting in the process of cell division and elongation in corn plant organs such as cobs and seeds [27, 28].

In Figure 6, it can be seen that white waxy corn with intercropping has the highest 100-grain weight value. This indicates that the results of photosynthesis are allocated maximally to parts of the corn plant. The increase in dry seed weight is related to the amount of photosynthate transferred into the seed [29]. The translocation of photosynthate which is quite large to the reproductive organs causes the formation of cobs and seed filling to take place well and the seeds formed are full with a larger size. Likewise, the results of the study on the weight of white waxy corn cobs showed that the treatment with intercropping produced heavier cobs. The results of this study are in line with previous research conducted by Wangiyana et al [33] that intercropping sweet corn with peanuts can increase the number of green leaves, fresh cob weight, and dry stover weight. Intercropping corn with peanuts also produces a higher dry corn weight, namely 4,727.95 kg/ha compared to without intercropping, which is only 2,852.46 kg/ha [34]. It has also been reported that corn planted in intercropping with peanuts produces a higher dry weight of corn compared to the monocropping systems [35].

Intercropping with mungbeans also increases seed protein content of the waxy corn (Figure 8). This is thought to be due to the availability of nitrogen nutrients that support the growth process and productivity of corn plants. In line with what was conveyed by Zainal [30] that nitrogen is a component of amino acids and protein formation. It can be seen from the observation parameters in this study that have shown that intercropping of mungbeans can increase the number of leaves and yield of waxy corn, this is correlated with the protein content of corn. The protein content of corn is influenced by the characteristics and biomass of plants [36]. There have been many studies that prove that intercropping can increase corn seeds. The results of this study are in line with the study conducted by Sowinski [36] that intercropping of corn with faba beans can increase protein from 42% to 39%. Likewise, the results of research from Javanmard et al [37] reported that intercropping of corn with the legume Visia villosa can increase corn protein by 180% compared to monoculture. Stoltz et al [38] also showed research results that intercropping corn with faba beans can increase protein content by 7-39%.

The increase in yield seen in this study and supported by previous studies was due to the positive response between the two types of plants. Corn is a C4 plant that requires large amounts of nitrogen nutrients for its growth and productivity, while legumes (mungbeans) are plants that can biologically fix nitrogen and contribute it to corn plants. The difference in results in this study is thought to be due to differences in the response of purple waxy corn plants to mungbeans. Not all intercropping can increase corn yields. Several research results also show that intercropping does not contribute to higher yield pf corn plants. The results of research by Worku [31] also showed that mungbean intercropping did not affect the yield of corn plants, which is in line with the results of Trelogames' research [32] that intercropping corn with mungbeans did not contribute to corn yields. Likewise, the research results from Sophoanrith [33] showed that intercropping corn with mungbeans did not provide optimal results.

However, all the results of this study indicated that on average, intercropping waxy corn plants with mungbeans can provide a significant impact in increasing the growth and yield of the waxy corn plants compared to growing the waxy corn under monocropping systems. Based on the patterns of the significant interaction effects, it can be concluded that the white waxy corn was more responsive to intercropping with mungbean than the purple waxy corn. To make sure why these happened, further studies are recommended. In relation to the effects of intercropping with legume crops, upland red rice plants in which the grains contain high levels of anthocyanin, intercropping red rice with soybean was found to increase anthocyanin contents of the red rice grains [39].

V. CONCLUSION

Although intercropping with mungbean in general increased growth and yield components of the waxy corn varieties tested, there was a significant interaction effect of treatment factors on the number of green leaves at 42 and 56 HST, cob length, cob diameter, number of seed rows, weight of 100 seeds and weight of dry cob per plant, in which the effects of intercropping with mungbean were more significant on the white waxy corn than on the purple waxy corn. So it can be concluded that white waxy corn is more responsive than the purple waxy corn to intercropping with mungbeans.

VI. DISCLOSURE

We do not have any conflicts of interest in this work.

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