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Application Of Organic Fertilizer Raw Materials Of Chromolaena odorata And Mycorrhizal Fungi On Local Corn Plant In Sub-Optimal Land)

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ABSTRACT. Application of organic fertilizer raw materials *Chromolaena odorata* and mycorrhizal fungi is one solution to improve the physical, chemical and biological soil at sub-optimal land and reduce environmental pollution due to excessive use of inorganic fertilizers on the local corn plant. The aim of study was to evaluated the role of bokashi *C.odorata* and mycorrhizal fungi in improving the growth and production of local corn. The research design used was a factorial randomized block design (RBD), consisting of two factors. First factor was the dose of bokashi fertilizer (C), consisting of 4 treatment levels, namely: 0; 2; 4 and 6 t ha^{-1}. Second factor was mycorrhizal fungi (F) inoculation, consisting of 3 treatment levels, namely, 25; 50 and 75 g planting holes^{-1}. Bokasi fertilizer *C.odorata* and mycorrhizal fungi were significant on growth and production variables, such as: plant height (cm), leaf area index (cm^2), RGR (g.g^{-1}.day^{-1}), dry weight of corn cobs (g), and dry seed production (ton ha^{-1}). The Result of combination bokashi fertilizer *C.odorata* (6 tons ha^{-1}) and mycorrhizal fungi (50 g planting hole^{-1}) was the best treatment with obtained Konawe local dried corn production of 4.48 tons ha$^{-1.}$

Keywords : *C.odorata*; *Local corn*; *Mycorrhizal fungi*; *Sub optimal*

INTRODUCTION

The growth and development of corn (*Zea mays* L.) is not separated from the availability of nutrient that is utilized by plants to ensure optimal growth and production. Fertile planting media must contain macro and micro nutrients in adequate and balance amount according to plant needs. Currently, soil condition cannot support the development of corn plant since it contains excessive amount of chemical substances that are poisonous to plants, thus reducing the use of soil as planting media. Hence, the role of planting media with the addition of organic fertilizers and mycorrhizal fungi are important to be evaluate

The problem found in corn farming is sub-optimal land of Southeast Sulawesi with growth limiting factors include low soil fertility, acidic reaction, also Al and Fe solubility that may be toxic to plants (Moelyohadi et al., 2013). To solve this problem, it is required to conduct planting media engineering through the addition of Chromolaena odorata based bokashi fertilizer and mycorrhizal fungi that is widely found in dry land area of Southeast Sulawesi.

C.odorata (Siam weed) is one of weed species that grow widely in sub-optimal dry land area of Southeast Sulawesi and potentially utilized as the source of organic fertilizer for containing: 2.94% total N, 0.15% P; 0.97% K, 50.20% C-Organic, and 86.84% organic matter (Hasid dan Kandari, 2013). According to Hasid et al. (2018), arbuscular mycorrhiza can be found in the rhizosphere of reeds (Imperata cylindrica) and Siam weed (*C.odorata*). Mycorrhizal fungi has the ability to expand plant root absorption area thus utilizing nutrient that is available far below the soil surface.These two plants are considered as dominant weed in the dry land area of Southeast Sulawesi, Indonesia.

The combination of bokashi *C.odorata* fertilizer and mycorrhizal fungi is expected to support the improvement of physical, chemical, and biological property of soil since bokashi fertilizer has a function to improve soil structure. Soil crumb structure will support the growth of corn plant and provide space for plant root and other organisms in the soil. Therefore, good aeration is ensured and would be able to enhance the activity of mycorrhizal fungi related to planting media engineering to obtain fertile soil since nutrient is available for the growth of corn plant. Planting media engineering through the application of Siam weed based bokashi and arbuscular mycorrhizal fungi is one of solutions to perform sustainable and eco-friendly agriculture in sub-optimal land.

MATERIALS AND METHODS

Location and Time of Research.: This study was conducted in the Laboratory of Agronomy, Faculty of Agriculture, University of Halu Oleo from July to December 2021. The research consisted of two factors of treatment, namely (1) the dose of bokashi *C.odorata* and (2) mycorrhizal fungi originated from the rhizosphere of reeds (*Imperata cylindrica*).

Tools and Materials : Tools used included tractor, hoe, watering pot, measuring tape, analytical balance, and oven. Moreover, materials used consisted of sub-optimal dry land, grain of local corn, *C.odorata* based bokashi fertilizer, and inoculum of mycorrhizal fungi obtained from the rhizosphere of cogon grass.

Experimental design: The design applied was Randomized Block Design (RBD) with factorial treatment, those were: (1). Bokashi *C.odorata*, consisted of 4 levels, namely: without bokashi *C.odorata* (C0), Bokashi *C. odorata* 2 t ha^{-1} (C1), Bokashi *C.odorata* 4 t ha^{-1} (C2), and bokashi *C.odorata* 6 t ha^{-1} (C3); and (2). Inoculum of mycorrhizal fungi, consisted of 3 levels, namely: 25 g planting $hole^{-1}$ (F1), 50 g planting $hole^{-1}$ (F2), and 75 g planting $hole^{-1}$ (F3). There were 12 combinations of treatment. Each treatment was repeated 3 times resulted in 36 units of treatment.

Preparation of bokashi *C.odorata* and inoculum of mycorrhizal fungi: the bokashi fertilizer used was previously fermented for 2 weeks. Later, bokashi was wind dried until they were no longer stuck together and able to be sieved. Inoculum of mycorrhizal fungi was collected from the root area of reeds (*I.cylindrica*), that was in the form of soil and root by digging the soil using crowbar at depth of ± 30 cm. Soil was broken up using *parang* machete and soil chunks were further squeezed to a small size. Soil and root containing inoculum of mycorrhizal fungi were wind dried and sieved using *waring net* (Hasid *et al*. 2018).

Application of bokashi *C.odorata* and inoculum of mycorrhizal fungi in planting media. Application of bokashi and mycorrhizal fungi was done by putting both materials together into the planting hole of corn plant.

Parameters: Evaluation of local corn growth and yield:

(1) Plant height (cm) at age of 2 and 4 week after planting (WAP),

(2) Leaf Area Index (LAI) using the formula:

$$ILD = A/P$$

Description:
A = Leaf area
P = Spacing area

(3) Relative Growth Rate (RGR), using the formula:

$$RGR = \frac{\ln w_2 - \ln w_1}{t_2 - t_1}$$

Deskription:
$\ln w_1$ = Logarithm of the initial weight
$\ln w_2$ = Logarithm of final weight

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t_1 and t_2 = Time interval

(4) Dry weight of corn cobs (g), was measured by weighing the cobs after being in the oven at 60^0C for 3x24 hours.

(5) Poduction (t ha^{-1}).

Statistical analysis: The analysis applied was ANOVA. Any significant results were further analyzed using Tukey's HSD test of 95%.

RESULTS AND DISCUSSION

The recapitulation of research results on the application of bokashi fertilizer and mycorrhizal fungi to local corn plants on sub-optimal land is showed in Table 1.

Table 1. Recapitulation of the application of bokashi fertilizers *C. odorata* and mycorrhizal fungi on corn plants in sub-optimal land

Observed Variable	Treatment		
	C. odorata (C)	Mycorrhizal Fungi	Interaction (CxF)
Plant height (cm) at 2 WAP	*	*	*
Plant height (cm) at 4 WAP	*	*	*
Leaf area index (cm^2) at 4 WAP	*	*	*
RGR (g.g^{-1}. day^{-1})	*	*	*
Cob weight (g plant^{-1})	*	**	**
Production (ton ha^{-1})	*	**	**

Description: ** : very significant effect (P≤0.01)
* : significant effect (P≤0.05)

Table 1 showed that the interaction of bokashi *C. odorata* fertilizer and mycorrhizal fungi treatment had a significant effect on the average plant height aged 2 and 4 WAP, leaf area index aged 4 WAP, relative growth rate 4 WAP age and very significant effect on the average cob weight and production.

Plant Height (cm)

The results of statistical analysis of the interaction effect of bokashi *C. odorata* fertilizer and mycorrhizal fungi treatment on the average height of plants aged 2 and 4 WAP (Table 2a & 2b) were as followed.

Table 2a. Interaction of bokashi *C. odorata* fertilizer and mycorrhizal fungi on plant height (cm) of local corn aged 2 WAP

C.odorata (t ha^{-1})	Mycorrhizal Fungi (g planting hole^{-1})						HSDα=0.05
	F1(25 g)		F2 (50 g)		F3 (75 g)		
C0 (0 t ha^{-1})	6.34 p	b	6.33 p	a	6.80 p	b	1.23
C1 (2 t ha^{-1})	8.17 p	a	6.87 q	a	8.02 pq	ab	
C2 (4 t ha^{-1})	6.81 q	b	7.47 pq	a	8.06 p	a	
C3 (6 t ha^{-1})	7.38 p	ab	7.19 p	a	8.03 p	a	

Description: Numbers followed by different letters at the same column (p,q) and row (a,b,c) are significantly different according to Tukey's HSD test at significance level of 95%.

Table 2b. Interaction of bokashi *C.odorata* fertilizer and mycorrhizal fungi on plant height (cm) of local corn aged 4 WAP

C.odorata	Mycorrhizal Fungi (g planting hole^{-1})						
(t ha^{-1})	F1(25 g)		F2 (50 g)		F3 (75 g)		HSDα=0.05
C0 (0 t ha^{-1})	15.24 p	b	17.15 p	c	17.21 p	c	2.50
C1 (2 t ha^{-1})	21.00 q	a	23.53 p	a	21.50 pq	b	
C2 (4 t ha^{-1})	22.68 p	b	21.52 p	b	23.26 p	b	
C3 (6 t ha^{-1})	22.41 q	a	25.31 p	a	25.90 p	a	

Description: Numbers followed by different letters at the same column (p,q) and row (a,b,c) are significantly different according to Tukey's HSD test at significance level of 95%

Based on the test results BNJα = 0.05 (Table 2a and 2b) showed that the combination of bokashi *C. odorata* fertilizer 6 tons ha^{-1} and mycorrhizal fungi 75 g per planting hole (C3F3) was the best treatment for the height plant of local corn aged 2 and 4 WAP. This is thought to be because bokashi has a positive effect on the activity of mycorrhizal fungi. The higher the dose of bokashi given, the more mycorrhizal activity increases. Husna *et al*., (2019) reported that AMF significantly increased plant height, leaf length and width. While the addition of organic matter increased plant height, stem diameter, length, width and number of leaves of *P. mooniana* 5 months after transplanting. The increase was due to organic matter contributing to the improvement of soil structure, facilitating root penetration and availability of nutrients for microbial growth and activity. As reported by Vaidya *et al*. (2007); Hammer *et al*. (2011) organic materials have a positive effect on the growth of the external mycelium of AM fungi. Therefore, it can change soil conditions for the better and be beneficial for mycorrhizal fungi and plants (Rillig and Steinberg, 2002).

Soil chemical components involved in the decomposition process of organic matter and secondary metabolites produced by microorganisms affect the growth of AM fungal mycelia (Gryndler *et al*., 2009). Thus affecting the availability of N, P and K nutrients (Kumar *et al*., 2017). Prasad *et al.* (2017) stated that an increase in root biomass led to higher absorption of nutrients and had the potential to increase crop yields and productivity. Furthermore, Samanhudi *et al*. (2017) stated that mycorrhizal inoculation and manure had a significant effect on the dry weight of soybean plants.

Leaf Area Index (cm^2)

The results of the statistical analysis of the interaction effect of bokashi *C. odorata* fertilizer treatment and mycorrhizal fungi had a significant effect on the leaf area index aged 4 WAP as shown in Table 3.

Table 3 Interactions of bokashi *C. odorata* fertilizer and mycorrhizal fungi on Leaf Area Index of corn plants aged at 4 WAP

C.odorata	Mycorrhizal Fungi (g planting hole^{-1})						
(t ha^{-1})	F1 (25g)		F2 (50g)		F3 (75g)		HSDα=0.05
C0 (0 t ha^{-1})	0.154 q	b	0.278 pq	c	0.349 p	b	0.150
C1 (2 t ha^{-1})	0.275 q	b	0.489 p	ab	0.543 p	a	
C2 (4 t ha^{-1})	0.504 p	a	0.412 p	bc	0.474 p	ab	
C3 (6 t ha^{-1})	0.476 p	a	0.601 p	a	0.612 p	a	

Description: Numbers followed by different letters at the same column (p,q) and row (a,b,c) are significantly different according to Tukey's HSD test at significance level of 95%

Based on the results of the BNJα=0.05 test (Table 3), it shows that the best treatment for the interaction of bokashi *C. odorata* fertilizer and mycorrhizal fungi was obtained in the combination treatment of 6 tons ha^{-1} of bokashi *C. odorata* fertilizer and 75 g of mycorrhizal fungi per planting hole (C3F3). This shows that soil chemical components during the decomposition process of organic matter and secondary metabolites produced by microorganisms influence the growth of AM fungal mycelia (Gryndler *et al*. 2009), thereby significantly influencing the availability of N, P and K nutrients. Samanhudi *et al*. (2017) reported that mycorrhizal inoculation and manure significantly affected soybean plant dry weight.

Hasid *et al.* (2018) reported that in the rhizosphere of the dominant weed (*bladygrass*) on dry land there are various arbuscular mycorrhizal genes, the dominant species of the genus Glomus. The presence of AM in nature is quite high, ie, 792-901 spores per 100 g in dry land with the percentage of root infection in host plants reaching 70-90%. Husna *et al*. (2016) reported that under heavy metal stress conditions, arbuscular mycorrhizal fungi can increase root nodulation. Furthermore, growth in height and root nodules was followed by an increase in shoots and total dry weight of *P. mooniana* aged 5 months after planting.

According to Sahur and Junaid, (2022), mycorrhiza increases P nutrient uptake in plant height, stem diameter and flower formation time and increases P nutrient uptake in leaf tissue of upland rice plants by an average of 0.26%. Ferdi *et al*. (2023) reported that arbuscular mycorrhizal fungi had an effect on increasing the total N and P available in Ultisol soil at a dose of 20 g $polybag^{-1}$ so that eggplant plant growth was better.

Arbuscular mycorrhizal fungi (AMF) are root symbionts that provide plant nutrition and other benefits (Denison and Kiers, 2011) such as increasing P uptake by soybeans (Abdel-Fattah *et al*, 2014), increasing the activity of enzymes such as phosphatase (Mar Vazquez *et al*. , 2000); increasing the salinity tolerance of soybean plants (Younesi *et al.*, 2013); increasing soil aggregation (Bethlenfalvay and Schuepp, 1994; Borie *et al*, 2008; Leifheit *et al*, 2014); protect roots from pathogens (Sikes, 2010); and drought tolerant (Auge, 2004; Finlay, 2004).

Relative Growth Rate (RGR) ($g.g^{-1}. day^{-1}$)

The results of statistical analysis of the effect of the interaction of bokashi *C. odorata* fertilizer treatment and mycorrhizal fungi significantly affected the relative growth rate (g.g-1.day-1) of local corn plants as shown in Table 4. Based on the results of the BNJα=0.05 test (Table 4), it shows that the best interaction treatment of bokashi *C. odorata* fertilizer and mycorrhizal fungi was obtained in the combination treatment of 4 tons ha^{-1} of bokashi fertilizer and 75 g of mycorrhizal fungi per planting hole (C2F3). This fact is in line with the results of research by Hasid *et al*. (2021) that inoculation of arbuscular mycorrhizae and the addition of organic material to corn plants is able to infect plant roots in the field, resulting in increased plant growth and yield. This illustrates that the symbiosis between arbuscular mycorrhiza and organic matter in corn plants in the field is going well.

Husna *et al*. (2019) reported that the addition of organic matter and the presence of AMF limited metal levels in the roots and shoots of *P. moniana* plants and was very important for improving plant quality. Hasid *et al*. (2014) found that the populations of arbuscular mycorrhizae in the rhizosphere of reeds (*Imperata cylindrical*) and krinyuh (*C. odorata*) which grow on sub-optimal dry land in Kendari City. As reported by Husna *et al*. (2019) that the inoculum of arbuscular mycorrhizal fungi isolated from the rhizosphere of *P.*

mooniana increased the growth of seedlings in post-coal mining media. Hasid *et al.* (2018) reported that in the rhizosphere of the dominant weed (*bladygrass*) in dry land there are various arbuscular mycorrhizal genes, the dominant type from the genus Glomus. The presence of AM in nature is quite high, ie, 792-901 spores per 100 g in dry land with the percentage of root infection in host plants reaching 70-90%.

Table 4. Interaction of bokashi *C. odorata* fertilizer and mycorrhizal fungi on RGR variables (g.g-1.day-1) of local corn plants

C.odorata ($t\ ha^{-1}$)	Mycorrhizal Fungi (g planting hole^{-1}) F1 (25g)		F2 (50g)	F3 (75g)	BNJα=0.05
C0 (0 $t\ ha^{-1}$)	0.180 q	c	0.293 p	0.237 pq	0.1050
C1 (2 $t\ ha^{-1}$)	0.350 P	ab	0.287 p	0.307 p	
C2 (4 $t\ ha^{-1}$)	0.283 P	bc	0.267 p	0.323 p	
C3 (6 $t\ ha^{-1}$)	0.403 P	a	0.273 q	0.270 q	

Description: Numbers followed by different letters at the same column (p,q) and row (a,b,c) are significantly different according to Tukey's HSD test at significance level of 95%

Cob weight (g plant^{-1})

The results of the statistical analysis of the interaction effect of bokashi cromolaena odorata and mycorrhizal fungi had a very significant effect on the cob weight variable of local corn plants as shown in Table 5.

Tabel 5. Interaction of bokashi *C. odorata* fertilizer and mycorrhizal fungi on cob weight (g plant-1) of local corn plant

C. odorata ($t\ ha^{-1}$)	Mycorrhizal Fungi (g planting hole^{-1}) F1 (25g)		F2 (50g)		F3 (75g)		BNJα=0.05
C0 (0 $t\ ha^{-1}$)	2.20 q	c	5.40 p	ab	4.63 p	a	1.72
C1 (2 $t\ ha^{-1}$)	6.13 p	a	4.04 q	b	4.98 pq	a	
C2 (4 $t\ ha^{-1}$)	3.67 p	bc	4.59 p	b	4.38 p	a	
C3 (6 $t\ ha^{-1}$)	5.27 pq	ab	6.87 p	a	4.16 q	a	

Description: Numbers followed by different letters at the same column (p,q) and row (a,b,c) are significantly different according to Tukey's HSD test at significance level of 95%

Based on the results of the BNJα=0.05 test (Table 5), it shows that the best interaction treatment of bokashi *C. odorata* fertilizer and mycorrhizal fungi was obtained in the combination treatment of 6 tons ha^{-1} of bokashi fertilizer and 50 g of mycorrhizal fungi per planting hole (C3F2). This is thought to be because the addition of organic material can improve the condition of degraded soil because organic fertilizer can bind nutrients that are easily lost and help provide soil nutrients so that fertilization is more efficient. Providing bokashi fertilizer and mycorrhizal fungi can help provide nutrients, especially P, which plays a role in the cob formation process.

Subardja *et al*. (2017) reported that the combination of 1 ton ha^{-1} compost + 125% recommended dose of N produced the highest cob weight with husks of 8.27 kg plot^{-1}. The research results of Hasid *et al*. (2021) showed that in the rhizosphere there are various genera of arbuscular mycorrhizae which are effective in increasing local corn yields on marginal dry land when combined with cow dung and increasing plant P uptake and available P in the rhizosphere of one month old plants.

Production (ton ha^{-1})

The results of statistical analysis of the interaction effect of bokashi *C. odorata* fertilizer treatment and mycorrhizal fungi have a very significant effect on local corn production as shown in Table 6.

Table 6. Interaction of bokashi *C. odorata* fertilizer and mycorrhizal fungi on corn production (ton ha-1)

C.odorata (t ha^{-1})	Mycorrhizal Fungi (g planting hole^{-1}) F1 (25g)		F2 (50g)		F3 (75g)		BNJ α= 0.05
C0 (0 t ha^{-1})	1.59	b	2.04	c	2.21	b	0.829
	p		p		P		
C1 (2 t ha^{-1})	3.12	a	3.24	b	3.02	ab	
	p		p		P		
C2 (4 t ha^{-1})	2.70	a	3.14	b	3.47	a	
	p		p		P		
C3 (6 t ha^{-1})	3.12	a	4.15	a	3.48	a	
	q		p		pq		

Description: Numbers followed by different letters at the same column (p,q) and row (a,b,c) are significantly different according to Tukey's HSD test at significance level of 95%

Based on the test results BNJα = 0.05 (Table 6) showed that the best interaction between bokashi *C. odorata* and mycorrhizal fungi was obtained in the combination of 6 tons ha^{-1} doses of bokashi fertilizer and 50 g of mycorrhizal fungi per planting hole (C3F2). This fact illustrates that the application of 6 tons ha^{-1} of bokashi fertilizer and 50 g of mycorrhizal fungi per planting hole is sufficient for the growth and production needs of local corn plants. This is thought to be because bokashi fertilizer can provide sufficient nutrients according to the needs of corn plants. As reported by Larney and Angers (2012) that plant growth in media enriched with organic matter is related to the provision of nutrients for plants. N levels and accumulation of C, N, P, K and Mg in organic matter treatment increased plant biomass production and soil amelioration.

The research results of Tufaila *et al.* (2014a) and Tufaila et al. 2014b) shows that the use of compost can improve the fertility of acidic soil and can increase the yield of rice and cucumber plants. Juwarkar and Jambhulkar (2008) reported that the addition of amendments and biological fertilizers can support plant growth. Furthermore, Hasid *et al*. (2021) reported that the use of indigenous arbuscular mycorrhizal inoculum combined with 80 g of cow dung per planting hole on local corn plants produced 3.85 t ha^{-1} of dry seed, whereas plants without arbuscular mycorrhizal inoculation and without cow manure did not produce seed.

Roychowdhury *et al*. (2017) reported that the application of biofertilizer and vermicompost increased cob weight and corn yield. This is in line with the research results of Nurmas *et al*. (2017) that the combination of manure treatment with *Azotobacter* sp biofertilizer resulted in the waxy local corn of Konawe dry seed production of 4.48 tons $ha^{-1.}$

CONCLUSION

1. Application of bokashi *C. odorata* fertilizer and mycorrhizal fungi had a significant effect on the plant height (cm), leaf area index (LAI) (cm^2), RGR ($g.g^{-1}.day^{-1}$), and dry seed production (ton ha^{-1}).
2. Combination treatment of bokashi *C.odorata* 6 tons ha^{-1} and mycorrhizal fungi 50 g planting $hole^{-1}$was the best treatment with production of waxy local corn reached 4.15 tons ha^{-1}.

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