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EFFECT OF "KOMBA-KOMBA" PRUNING COMPOST AND PLANTING TIME OF MUNGBEAN IN INTERCROPPING WITH MAIZE ON YIELD AND SOIL FAUNA

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ABSTRACT

Soil fauna plays an important role in decomposition and nutrient mineralization. The objective of this research was to study the effect of "komba-komba" compost and planting time of mungbean intercropped with maize on yield and soil fauna. The research was conducted in research station of Agricultural Faculty, Haluoleo University. The experiment was laid out using split plot design with two factors ("komba-komba" compost and planting time of mungbean intercropped with maize). The result indicated that the highest net assimilation rate (NAR) of mungbean 5.78 g per cm^2 per week was obtained in the komba-komba compost 10 ton per ha with planting time of mungbean at 14 days after planting (DAP) maize whereas NAR of maize 5.50 g per cm^2 per week was obtained in the planting time of mungbean at 14 DAP maize. Coleoptera and Hymenoptera (Formicidae) were dominant and Shannon's diversity index ranged between 0.32 and 1.28. LER values tended to increase with the addition of "komba-komba" compost in soil and time variation of planting mungbean intercropped with maize. The relation between Shannon's diversity and LER values was variable.

Keywords: soil fauna, compost, intercropping, planting time, assimilation, LER

INTRODUCTION

Maize (*Zea mays*. L.) and mungbean (*Phaseolus radiatus* L.) serve as important sources of food other than rice for most people in Indonesia. Traditionally, farmers in their dry field or rice field in dry seasons planted maize and mungbean on sole crop or mixed culture system in southeast Sulawesi many years ago. In 2008, maize production was only about 78,266 ton from harvest area of 69,649 ha. The maize production decreased by around 18,770 ton (19.34%) if compared to the production in 2007. Likewise, the mungbean production (1.475 ton) in 2008 also decreased about 2.92% when compared to the mungbean production (1.831 ton) in 2007 (CBS, 2009). The production of maize and mungbean in this region have not been able to meet the food needs and industrial raw material. Low production of maize and mungbean was caused by poor nutrient and water soil content. This has implication on the intensive competition between individual crops for nutrients and water in the soil. On the other hand, the soil condition also negatively affected the abundance and activity of soil fauna in nutrient cycling regulation (Kilham 1996). According to Schadler and Brandl (2005); Huhta (2007) soil fauna plays an important role in decomposition and nutrient release in the soil solution. To date, the research aiming to understand the role of soil fauna in intercropping system of maize and mungbean has still been neglected.

In intercropping system, complementary and mutual interaction occurred between the two crops that have different growth properties, as in complementarity and interaction between legumes and non legumes (mungbean and maize). In agricultural practice, the mungbean (legume) and maize (non legume) in the intercropping system were combined. Mungbean root may be able to be associated with simbiotic rhizobium bacteria to fix N_2 from atmosphere (Hirota *et al*., 1995; Ahmed *et al*., 2000), whereas maize shaded mungbean from direct exposure of the sun during the growth periods. On the other hand, the negative effects of competitive interaction between individual crops or parts of crops in intercropping systems

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always occurs in the utilization of nutrients, water, light, and space to grow. Subsequently, individual yield of each crop planted could decrease.

One approach to solving the afore-mentioned problems is to use organic matter. The organic matter applied to agricultural lands functions as nutrient sources, substrate for microbes, and food resources for soil fauna and soil conditioner (Brady and Neil, 2008). The “Komba-komba” (*Chromolaena odorata*) is the most dominant in fallow vegetation and spreads widely in Southeast Sulawesi (Karimuna, 2000). In this region, the *C. odorata* was mostly known as “komba-komba” as termed by local people. Biomass of C. *odorata* is commonly used as organic matter to improve soil fertility (Chandrasjekar and Gajanna, 1996). Tian *et al*. (1999) also reported that organic matter of *C. odorata* biomass could increase nutrient availability in soil because there was low-activity clay. Suntoro *et al*. (2001) showed that decomposition product of *C. odorata* biomass could change P and K concentration level in soil solution. Sabaruddin *et al*. (2008) represented that biomass “komba-komba” compost plays an important role in the supply of nutrients for plant growth and food sources needed by the soil fauna. The releasing process of ensential nutrient including N and P which bound in organic matter occurs through eating activity and modifications of soil environment by soil fauna (Coleman, 2008).

Conceptual basis used in this study is that "komba-komba" compost is a source of energy to increase the abundance and activity of soil fauna in the transformation of nutrients while delayed planting time is to keep the period of active growth of the two crops that are intercropped not occur simultaneously. So the combination of two treatments was able to increase the production of all two crops planted in intercropping system. The objective of this research was to study the effect “komba komba” compost and planting time of mungbean intercropped with maize on yield and yield components and the characteristics of soil fauna community.

MATERIALS AND METHODS

The research was conducted in research station of Agricultural Faculty, Haluoleo University, Kampus Hijau Anduonohu Kendari in five months from August to December, 2008. The location of the research was at an altitude of 25 m above sea level with geographic coordinate 4˚ 00’ 46” SL; 122˚ 31’ 06” EM.

The experiment was arranged with split-plot design which consisted of two factors: “komba-komba” pruning compost and delayed planting time of mungbean intercropped with maize. The dose of “Komba-komba” pruning compost was treated as a main plot consistsing of two levels, i.e. 6.25 kg per plot equal 5 ton per ha and 12.5 kg per plot equal 10 ton per ha. The delayed planting time of mungbean intercropped with maize was treated as sub-plot consisting of three levels, i.e. mungbean and maize planted together relatively at the same time with planting time of mungbean at 7 and 14 DAP maize.

Land Preparation, Treatment Application and Field Maintenance

Before planting, the land was cleared from grass, remaining plant roots and all other materials.Tillage was done by using a hoe which included cleansing, destruction of soil masses, scarifying and land leveling. The tillage was aimed to control weeds, improve soil porosity, nutrient absorption and the air in the soil so that the root system could develop more freely. The further step was making the experimental plots, each of which was made in 5 m x 2.5 m with the space of 30 cm between plots. All Komba-Komba compost obtained from the vicinity of the experiment

All “komba-komba” compost obtained from the vicinity of the experiment. The komba-komba materials were cut into pieces in 2 – 3 cm in length by using parang knife. Pieces of “komba-komba” pruning were loaded into a sack, and then composted for one month. Compost treatment of “komba-komba” pruning was approximated with values C/N ratio < 20 in dried air condition applied with dispersed way on the plot experiment surface. After two weeks, compost treatment application was treated as sub plot. Maize and mungbean were planted with the space of 75 cm x 40 cm 37.5 cm x 30 cm both in intercropping and sole crop.

Urea fertilizer (125 g per plot) equal to 100 kg per ha, 188 g per plot of SP-36 equal to 150 kg per ha, and 94 g per plot of KCl equal to 75 kg per ha were applied. Application of anorganic fertilizer was given by distributing it evenly over the surfaces of the plots. As much as 50 kg per ha urea was applied twice during the experiment, where it was given at beginning of maize planting and the remaining 50 kg per ha was given after the three weeks old of maize. Other anorganic fertilizer dosage consisting SP-36 and KCl was applied together with urea at beginning of maize planting. The application of anorganic fertilizers at beginning of maize planting involved strip method.

The maintenance includes weeding sprinkling. Weeding is done manually by using a hoe, intended that the plant does not compete with weeds for water and nutrient utilization. The supply of water by sprinkling was done on each plot equal to 6 mm, unless it rained. The sprinkling is done after ten days of crops grow in order for the crops get better performance.

Data Collection and Analysis

Plant Growth

Values of shoot-root ratio, net assi-milation rate, relative growth rate, 100 grain weight of maize and 1,000 grain weight of mungbean with 14% water content, yield of maize and mungbean (t per ha), land equivalent ratio (LER) and diversity index of soil fauna communities were measured. All parts of crop material were dried at temperature 80ºC for 72 hours in oven. Maize and mungbean plant dry weight was determined after harvest. Shoot root ratio and net assimilation rate were determined at 42 and 52 days for maize and at 28 and 42 for mungbean. The calculation of shoot root ratio (SRR) from crop species and time sampling was based on the formula by Sitompul and Guritno (1995):

$$SRR = \frac{\text{shoot dry weight(g)}}{\text{root dry weight(g)}}$$

Net assimilation rate (NAR) was calculated from all crop species and time sampling is based on the formula by Gardner *et al*. (1991):

$$NAR_{(1-2)} = \frac{W_2 - W_1}{t_2 - t_1} x \frac{\ln A_2 - \ln A_1}{A_2 - A_1} \text{ (g per cm}^2 \text{ per week)}$$

where :

NAR $_{(1-2)}$: net assimilation rate between first and second observation; W_1 and W_2 represent dry weight crop (g) in the first and second observation, respectively;

A_1 and A_2 : leaf area (cm^2) in the first and second observation, respectively; t_1 and t_2 represent the crop age (week) in the first and second observation, respectively

Land Equivalent Ratio (LER) was calculated based on the following formula by Hirota *et al*. (1995); and Baldy and Stigter (1997); Ciftci *et al*. (2006):

$$LER = \sum \frac{Y_{j,i}}{Y_{j,s}}$$

Where:

$Y_{j,i}$ = the crop yield in intercropping;

$Y_{j,s}$ = represents the crop yield in sole cropping

Soil Fauna Community Characteristic

Soil sampling was sampled from center of each plot using metal frame in 15 cm x 10 cm x 20 cm in the final experiment period. Soil fauna was removed from soil core with *Barlese Tullgren Funnel*. The extraction of soil fauna was done in 7-day period with the assistance of 40-watt lamp. The soil fauna was sized in the bottle containing 70% alcohol connected to funnel under terminal then it was collected by using hand sorting method. Identification of soil fauna was conducted under the microscope in 40x magnification to count the number of individuals of each taxon.

Shannon's diversity index of soil fauna communities was calculated using equation by Camargo (2008):

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \text{ and } p_i = \frac{n_i}{N}$$

Where:

H' = *Shannon's diversity index;*

n_i = individual number *i*th taxon:

N = total individual number of all taxon; and S is total taxon number.

Statistical Analysis

Effect of treatment on all variables of crop performance was statistically analysed with ANOVA, and the Least Significant Difference (LSD) method ($p<0.05$) was used to evaluate differences between cropping system means. Descriptive analysis was used to describe variation in abundance and diversity of soil fauna among treatments.

RESULTS AND DISCUSSION

Shoot Root Ratio

The shoot root ratio can be used to explain photosynthate flow in plant tissues during their development. It was found that interaction effect between "komba-komba" compost and planting time of mungbean intercropped with maize produced shoot root ratio of all crop. Planting time of mungbean effect on shoot root ratio of maize crop at 56 days after planting (DAP) was significant (Table 1).

The highest shoot root ratio of maize was 8.63, was obtained in mungbean and maize planted at the same time, while the lowest value 7.30 was obtained in the planting of mungbean 14 DAP maize. It indicates that the active growth of maize and mungbean not occur at the same time. Chance of intense competition to water and nutrient resources between mungbean and maize can occur if the active growth of the two crops occurs at simultaneously. Maize can benefit from mungbean to increase the growth rate in shoot during the vegetative phase. In this phase, maize can obtain nitrogen transformation process bound in the soil biomass including dead roots and nodules of mungbean. Planting time of mungbean at 14 DAP maize eliminated intense competition over water and nutrient absorption. Such an intense competition between two crops during their active growth occurred at the same time as those crops needed lots of water and nutrient to supply their growth (Clement *et al*., 1992; Ahmed *et al*., 2000).

The effect of planting time of mungbean intercropped with maize showed no significant effect on shoot root ratio of mungbean. Such a phenomenon was caused by silt fraction dominance and low fertility level in the soil of the experiment station. Consequently root system of mungbean could not develop, and therefore root ability to obtain water and nutrient for their shoot growth became limited. Marschner (1997) said that composition of soil fraction particle directly influenced soil water holding capacity (SWHC), cation exchange capacity (CEC), porosities, infiltration, aeration, and indirectly root development, water and nutrient uptake activity from soil for the production of photosynthate in the shoot part of crop. Generally, soil containing most silt fraction particle had nutrient retention capacity and water holding capacity lower than soil containing most clay fraction particle. Likewise, in soil, the mungbean is supposed to keep energy in root part to take water and nutrient directly to deeper soil layers. In other words, low rainfall and high evapotranspiration are factors which reduce soil water content level triggering compaction. Thus, mungbean root could not penetrate the soil under this experiment condition.

Table 1. Mean of shoot root ratio of maize after 56 days according to planting time of mungbean in intercropping system with maize

Komba-komba compost dosage	Mungbean and maize planted at same time	Planting mungbean 7 DAP maize	Planting mungbean 14 DAP maize
5 ton per ha	9.57	8.78	7.68
10 ton per ha	7.69	7.89	6.93
LSD $_{0.05}$ = 1.04	8.63^{b}	8.33^{ab}	7.30^{a}

Remarks = number followed by same letter are not significantly different at 95% test level.

Net Assimilation Rate

Net assimilation rate was used as one of all indicators of plant growth to explain leaf ability in producing total dry weight for a unit leaf area in units of time. This result found that the effect of planting time of mungbean intercropped with maize on net assimilation rate of maize was significant (Table 2).

The highest NAR value of maize 5.5 g per cm^2 per week occur in delay planting mungbean 14 DAP maize and it was significantly different compared to mungbean and maize planted at the same time ($p<0.05$). Highest NAR values in this treatment were triggered by strongly related plant condition to the plants' net assimilation rate. The leaves of a crop unshaded by their neighbouring plant canopy were exposed to sunlight which increased their NAR. Bilman (2001) stated that NAR was related to the strength of light intensity which was received on each unit of a leaf area index of the crop.

The interaction effect between "komba-komba" compost and planting time of mungbean intercropped with maize on NAR of mungbean crop was significant. Interaction effect on NAR of mungbean is presented in Table 3.

Maize crop ranging from 42 to 56 periods after growing stayed in generative phase development, where, in this period, mungbean was in its active growth stage. This stage of mungbean was indicated from its maximum leaf area index. It was expected that the maize obtained most nitrogen from soil solution derived from nitrogen mineralization process contributed from dead root and nodules rich with nitrogen. Nitrogen released into soil solution became available to be taken by maize roots for increasing their biomass in dry weight form.

Similar to other organic matter in the soil, biomass of "komba-komba" compost has the ability to play a role as a former of physical, chemical and biological environmental which are suitable for the growth of mungbean roots. Decomposition and mineralization of nutrient product of "komba-komba" compost in soil solution can supply macro essential nutrient including N, P, and K for metabolism process needed by plant cells.

Table 2. Mean of net assimilation rate (g per cm^2 per week) of maize after 42 - 56 days according to planting time of mungbean in intercropping system with maize

Komba-komba compost dosage	Mungbean and maize planted at same time	Planting mungbean 7 DAP maize	Planting mungbean 14 DAP maize
5 ton per ha	4.10	5.10	6.60
10 ton per ha	3.90	3.90	4.50
$LSD_{0.05}$ = 0.12	4.00^a	4.50^{ab}	5.50^b

Remarks = Number followed by same letter are not significantly different at 95% test level

Table 3. Interaction effect between the amount of "komba-komba" compost and planting time of mungbean in intercropping system with maize on net assimilation rate (g per cm^2 per week) of mungbean after 28 - 42 days.

Komba-komba compost dosage	Planting mungbean and maize at the same time	Planting mungbean 7 DAP maize	Planting mungbean 14 DAP maize	
5 t ha^{-1}	2.72^a_p	3.98^b_p	4.23^b_p	$LSD_{(0.05)}$ = 0.66
10 t ha^{-1}	2.90^a_p	3.63^a_p	5.78^b_q	
	$LSD_{(0.05)}$ =1.23			

Remarks = Number followed by same letter in same column (p,q) and row (a,b) are not significantly different at 95% test level

This research revealed that the NAR of mungbean was about 5.78 g per cm^2 per week produced from interaction between "komba-komba" compost at 10 ton per ha with planting time of mungbean 14 DAP maize, and NAR values of mungbean were higher than those in combination of "komba-komba" compost at 5 ton per ha with planting time of mungbean 14 DAP maize ($p<0.05$). This result indicated that planting time of mungbean was only to 14 DAP maize so that the overlapping in maximum growth of those crops can be eliminated. In this periode, the mungbean initiated its active growth phase. Subsequently, most photosynthate as a product of metabolism process was accumulated in plant tissue of mungbean. NAR values which are relatively high in this conditions also showed that mungbean crop during the early phase receive direct of solar radiation without shaded by a canopy of maize so that affect the rate of CO_2 assimilation for mungbean crop growth, then this circumstances impacted CO_2 assimilation rate for young mungbean crop continued to increase. Consequently, NAR values were higher.

Plant Dry Weight

In this research, the planting time of mungbean in intercropping with maize significantly affect the dry weight of maize and mungbean. The effect of dose of "komba-komba" compost and planting time of mungbean in intercropping with maize significant independently on the dry weight of both crops (Table 4).

The results showed that dry weight of maize was about 1.55 kg in delayed planting time of mungbean at 14 DAP maize (Table 4). The maize dry weight with planting time of mungbean at 7 DAP maize was not different. It would be different when mungbean and maize were planted at the same time relatively. A similar effect also occured in mungbean, where the delayed planting time of mungbean in intercropping with maize may have affected the dry weight of mungbean. The mungbean dry weight (0.13 kg) was obtained in the delayed planting time of mungbean at 14 DAP maize, and it was significantly different from the planting times of mungbean. Moreover, mungbean at 7 DAP maize produced dry weight of mungbean, and it was not different compare to mungbean and maize planted at the same time relatively.

Table 4. Mean of maize and mungbean dry weight (kg) according to planting time of mungbean intercropped with maize

Komba-komba compost dosage	Planting mungbean and maize at the same time	Planting mungbean 7 DAP maize	Planting mungbean 14 DAP maize
	Maize dry weight		
5 ton per ha	1.09	1.33	1.64
10 ton per ha	1.40	1.45	1.46
$LSD_{0.05}$ = 0.20	1.24^{a}	1.39^{ab}	1.55^{b}
	Mungbean dry weight		
5 ton per ha	0.11	0.11	0.13
10 ton per ha	0.11	0.11	0.12
$LSD_{0.05}$ = 0.20	0.11^{a}	0.11^{a}	0.13^{b}

Remarks = Number followed by same letter in same row are not significantly different at 95% test level

Table 4 reveals that maize or mungbean dry weight increased with along delayed planting time of mungbean 14 DAP maize in intercropping system. It was indicated that a negative effect of competition between mungbean and maize on water, nutrient, and light could be minimized by delaying planting time of mungbean intercropped with maize. Similar statement was stated by Suntoro *et al.* (2001) where plant dry weight was an indicator of plant growth because the dry weight produced from photosynthate was accumulated in the plant tissue during its life cycle. According to Marschner (1997), plant dry weight can function as nutrient status indicator in soil because changes in nutrient availability level are strongly related to an increase in plant dry weight. However, nutrient in soil solution is available as uptake in plant root but the intense competition among individual plant becomes one of many biotic factors which can reduce the accumulation of photosynthate into parts of tissue and plant storage organs.

Land Equivalent Ratio

Land equivalent ratio values of various combinations of "Komba-Komba" compost and delayed planting time of mungbean intercropped with maize was greater than 1.0 (Table 5). This means that combination of "komba-komba" compost and planting time of second plant into row space of other plants grown during some days in intercropping system could be used to increase land efficiency, especially in the agro-ecosystem like environmental condition of the research site including climate, soil type and cultivation management.

Table 5 represents that LER values ranged from 1.55 – 1.58. The highest LER value (1.58) was obtained in the combination between "komba-komba" compost of 10 ton per ha and planting time of mungbean at 7 DAP maize. This value gives an indication that the yield (8.65 ton per ha) in intercropping system was higher than 43.24% compared to the average yield in sole crop, which means that land use via intercropping system was more efficient than that of sole crop system. LER value more than 1.0 explains that there was complementary and mutual interaction between mungbean and maize through intercropping system in this research. It is mean that competition between plant individuals (intraspecific and interspecific) to light and nutrients could be minimized by combining a legume and cereal crops in intercropping system (Seran and Brintha, 2010; Worku and Demisie, 2012).

Diversity Shannon's index in combination of the "komba-komba" compost was 10 ton per ha and mungbean dan maize planted together in same time was the highest (about 1.28), whereas the combination of the "komba-komba" compost 5 ton per ha and planting time of mungbean 14 DAP maize was the lowest (about 0.32), meaning that organic matter availability was significant in soil tropical management.

Table 5. Land equivalent ratio values on varied "komba-komba" compost dosage and planting time of mungbean intercropped with maize

Treatments	Yield of maize (ton per ha)		Partial LER of maize	Yield of mungbean (ton per ha)		Partial LER of mungbean	LER values
	Inter cropping	Sole crop		Inter cropping	Sole crop		
B_1W_0	7.94	8.74	0.91	0.41	0.64	0.64	1.55
B_1W_1	7.90	8.74	0.90	0.45	0.67	0.67	1.57
B_1W_2	8.52	8.74	0.97	0.44	0.79	0.56	1.53
B_2W_0	7.82	8.85	0.88	0.66	0.98	0.67	1.55
B_2W_1	8.00	8.85	0.90	0.65	0.96	0.68	1.58
B_2W_2	8.02	8.85	0.91	0.61	0.93	0.66	1.57

Remarks = B_1, "komba-komba "compost amount 5 ton per ha; B_2, "komba-komba" compost amount 10 ton per ha; W_0, mungbean and maize planted in same time; W_1, delayed planting of mungbean 7 DAP maize; W_2, delayed planting time of mungbean 14 DAP maize.

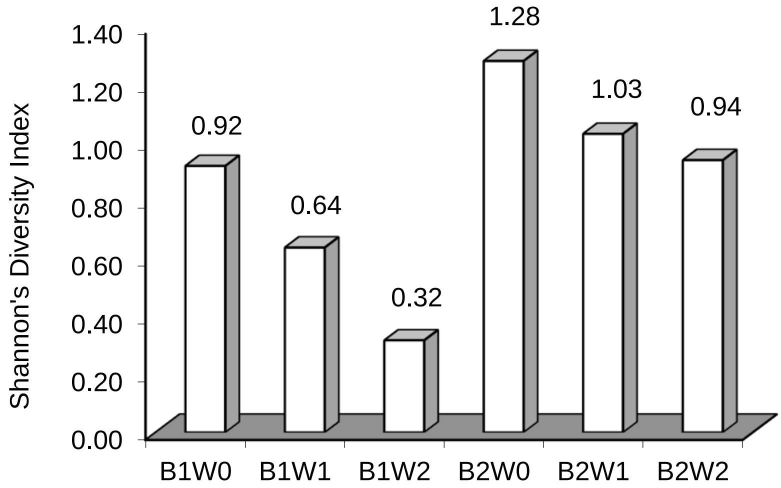

Figure1. Soil fauna Shannon's diversity index according to combination between komba-komba compost level and planting time of mungbean intercropped with maize. Symbol details: B_1 is "komba-komba" compost 5 ton per ha; B_2 is "komba-komba" compost 10 ton per ha; W_0 is mungbean and maize planted in same time; W_1 is planting time of mungbean 7 DAP maize; W_2 is planting time of mungbean 7 DAP maize

Soil fauna is able to have indirect influence on productivity of plant through its role in decomposition and nutrient released into soil solution. Ouedraogo *et al*. (2006) reported that soil macrofauna (such as Coleoptera, Orthroptera, Isoptera, and Formicidae) was able to increase water and nutrient efficiency of crop in tropical agro-ecosystem. It was compared in Shonnon's index and LER values to know how the relation between soil fauna diversity and land efficiency was. It was found that the relation between soil fauna diversity and LER values were variable.

CONCLUSIONS

Interaction effect between "komba-komba" compost 10 ton per ha and delayed planting time of mungbean 14 DAP maize in intercropping system with maize affected NAR of mungbean 5.78 g per cm^2 per week. Net assimilation rate of maize 5.50 g per cm^2 per week obtained at planting time of mungbean 14 DAP maize. LER values was increased trend according to addition of "komba-komba" compost amount on soil in varied delayed planting time of mungbean after few days of maize grown. Abundance and diversity of soil fauna were also increased according to addition of the compost amount in this intercropping system. The relation between soil fauna diversity and LER values was variable. In conclusion, the application of "komba-komba" compost of 10 ton per ha and delayed planting time of mungbean 14 DAP maize in intercropping with maize is suitable for the region where the experiment was conducted.

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