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Abundance of arthropod pests and their natural enemies on cassava fields implementing different agroecosystem management

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Abstract. *Puspitarini RD, Purwantoro A, Pradifta VDA, Muhammad FN, Fernando I. 2024. Abundance of arthropod pests and their natural enemies on cassava fields implementing different agroecosystem management. Biodiversitas 25: 2901-2907.* Arthropod pests pose significant challenges to cassava (*Manihot esculenta* Crantz) cultivation, with detrimental effects on yield and crop quality. Agroecosystem management plays a crucial role in shaping the populations of pests and their natural enemies. Therefore, understanding and implementing appropriate management practices are essential for developing integrated pest management approaches that are effective and environmentally friendly. Our study examined herbivorous and predatory arthropod abundance across six cassava plantations with varying management practices. Field characteristics were examined to elucidate the factors contributing to differences in arthropod assemblages observed among the fields. We used Analysis of Variance (ANOVA) to assess the differences in arthropod abundance across the plantations. Additionally, arthropod assemblage was analyzed using analysis of similarity based on the Bray-Curtis Index, with differences visualized using non-metric multidimensional scaling (NMDS) plots. The high abundance of herbivorous arthropods in certain fields appeared linked to narrow plant spacing, which might facilitate pest dispersal. Furthermore, complete weed removal and the absence of organic fertilizer application, such as manure, could reduce predatory arthropod populations. Additionally, fields situated at lower altitudes demonstrated increased susceptibility to pest outbreaks. Therefore, strategic agroecosystem management is imperative, incorporating practices to mitigate pest population growth while conserving predatory arthropods. Comprehending the interplay between management practices and arthropod dynamics is crucial for developing sustainable pest management strategies in cassava cultivation.

Keywords: Integrated pest management, *Manihot esculenta*, organic fertilizer, plant spacing, weed removal

INTRODUCTION

Cassava *Manihot esculenta* Crantz (Euphorbiaceae) holds immense significance for the human population worldwide, especially in regions with challenging growing conditions. This versatile root vegetable is a vital source of sustenance, offering an energy-rich component to countless diets. Additionally, cassava leaves are part of many people's diets in various countries, including Indonesia (Latif and Müller 2015). Its drought-resistant nature makes it a resilient crop that can thrive in regions with erratic rainfall and poor soil quality (Li et al. 2017). Cassava's adaptability extends beyond sustenance; it serves as a foundation for various industries, including agriculture, pharmaceuticals, and even biofuel production (Sivamani et al. 2018; Kayiwa et al. 2022). Moreover, the processing of cassava into products like tapioca and cassava flour contributes to income generation and economic development in many societies (Chisenga et al. 2019). It has been reported that the land area of cassava plantations was increasing in Southeast Asia, mainly in Cambodia, Thailand, and Vietnam (Tokunaga et al. 2018). Similarly, in Indonesia, cassava production is a vital component of the country's agricultural landscape, with a significant portion of its rural population engaged in its cultivation. The tropical climate and abundant land resources in Indonesia create favorable conditions for cassava farming, making it one of the leading cassava-producing nations in the world (Suryaningrat et al. 2015; Ngongo et al. 2022).

Although cassava is well-known for its hardiness, various arthropod pests have been known to cause damage to its foliage, causing defoliation, stunting plant growth, and rendering the production of the tuber (Bellotti et al. 2012; Parsa et al. 2015; Ally et al. 2019). In Indonesia, the two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae) and the silverleaf whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) are regarded as important pests of cassava for decades (Nurkomar et al. 2021; Sholihin et al. 2022). Furthermore, in 2010, the destructive mealybug *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae) native to South America invaded Indonesia and caused significant damage to cassava plantations across the country to date (Fanani et al. 2019; Supartha et al. 2022). This invasion has led to increased costs for pest management and substantial yield losses, threatening the livelihoods of smallholder farmers who depend on cassava as a staple crop. Exacerbating the situation, another exotic pest from Neotropical Regions, the cassava lace bug *Vatiga illudens* (Drake) (Hemiptera: Tingidae), also entered Indonesia in late 2020. Currently, the cassava lace bug has widely spread across Java (Puspitarini et al. 2021), Bali (Sudiarta et al. 2024), and

Sumatra and is reported to cause serious injury on cassava plantations in Indonesia. The ongoing spread and impact of these pests underscore the need for comprehensive pest management strategies.

Agroecosystem management wields profound impacts on the population dynamics of arthropod pests in agroecosystems, which can either intensify or mitigate pest outbreaks. Some cultivation practices often create ideal environments for phytophagous arthropods to flourish, while others can disrupt pest life cycles and reduce their overall numbers (Gurr et al. 2017). Similarly, cultivation practices can negatively or positively influence the abundance of beneficial arthropods (Puech et al. 2015; Zhao et al. 2015). Therefore, reasonable cultivation practices can promote integrated pest management and foster healthier and more resilient agroecosystems by balancing pests and their natural enemies. Strategic agroecosystem management that integrates ecological principles is essential for sustaining agricultural productivity and ecological health in the long term.

This research highlights the abundance of arthropod pests and their natural enemies in cassava fields under various agroecosystem management and cultivation practices in Batu and Malang City, East Java, Indonesia. The choice of these sites was driven by their varied agroecological conditions and the prevalence of cassava cultivation, offering a representative landscape for study. We aim to provide valuable insights into sustainable pest management strategies for cassava cultivation. Ultimately, the findings of this research have the potential to impact agricultural practices significantly, helping farmers implement more effective and environmentally friendly methods to maintain their crops while improving the ecological balance in the cassava ecosystem.

MATERIALS AND METHODS

Field locations and characteristics

Six cassava fields with different cultivation practices were determined as the research plots. All fields consisted of a single cassava variety (*Mentega*) planted using a monoculture system. Hence, it envisaged that the observed differences in the arthropod abundance among the fields were due to variation in cultivation practices, not host plant variation. All fields were in the vicinity of Malang City, East Java, Indonesia. Four fields were located in Ngasem (Kepanjen), Bakalankrajan (Sukun), Tegalgondo (Karangploso), and Sumbersekar (Dau), while two other fields were located in Donowarih (Karangploso). A standardized set of questions was asked to the farmers to obtain data on the cultivation practices applied in the fields. Moreover, temperature and relative humidity in the studied fields were also recorded weekly during the research (a total of eight times). The overall characteristics of each studied field are provided in Table 1.

Sampling design and collection of leaf samples

In each research field, three sub-plots were determined, each containing fifty cassava plants. Five cassava plants were selected diagonally as the sampling units in each sub-plot (Figure 1). Thus, fifteen cassava plants were selected in each field, functioning as an individual repetition. Leaves were taken from each plant's top, middle, and bottom parts. The leaves collected from each plant were then put into a zippered plastic bag, and the entire bag was then stored in a cooler to maintain the freshness of the leaves and arthropods. Sampling was conducted weekly up to eight times from June to August 2023.

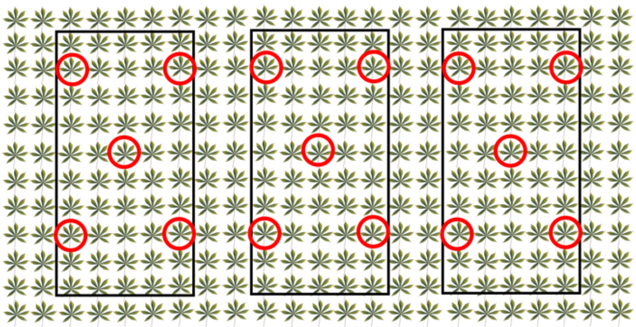

Figure 1. Arrangement of sampling units in each field. The plant image encircled by a red ring denotes the sampling unit

Table 1. Field characteristics during the survey and management practices implemented in the current growing season

Characteristics	Fields					
	Ngasem	Bakalankrajan	Tegalgondo	Sumbersekar	Donowarih I	Donowarih II
Coordinate	8°06'13"S; 112°33'45"E	8°00'50.9"S; 112°36'37.5"E	7°55'00"S; 112°35'48.7"E	7°55'15.46"S; 112°33'45.01"E	7°51'13.53"S; 112°34'43.88"E	7°50'44.93'S; 112°35'06.40"E
Altitude (masl)	343	422	561	708	861	950
Temperature (°C)	29.36	28.60	28.63	20.63	19.91	19.05
Relative humidity (%)	31.62	32.87	32.50	78.88	80.25	84.88
Plant spacing (m)	0.8 x 0.6	1 x 0.7	0.8 x 0.6	1 x 0.8	0.8 x 0.6	1 x 1.2
Weeding (manually)	Yes (4 times)	Yes (2 times)	Yes (2 times)	-	-	-
Synthetic insecticide application	-	-	-	-	-	-
Manure application (cow dung)	-	-	-	-	Yes (1 time)	Yes (1 time)
Synthetic fertilizer application (NPK)	Yes (2 times)	Yes (2 times)	Yes (1 time)	Yes (1 time)	Yes (1 time)	Yes (2 times)

Arthropod observation and identification

All collected leaves were cooled at 4°C for 2 hours to make the arthropods inactive, making it easier to observe and handle the arthropods. Each leaf was inspected carefully under a stereo microscope (Olympus SZX7). The obtained arthropods were counted and sorted based on their taxa and put in a vial filled with an Alcohol-Glycerin-Acetic Acid (AGA) solution (Schauff 2001). The arthropods were identified to the genus or species level using identification keys (Drake and Ruhoff 1965; Williams 2004; Krantz and Walter 2009; Seeman and Beard 2011; Belotti et al. 2012).

Data analysis

Based on the Shapiro-Wilk and Levene tests, most arthropod abundance data obtained in this study did not meet the assumption of normality and homogeneity. Hence, all data were initially transformed using the log(x+1) formula before being used for further analysis. The transformed data were then subjected to Analysis of Variance (ANOVA), and means were compared by applying Tukey's test at P<0.05. However, for visualization, means were shown as the back-transformed means. In addition, the species composition of each field was analyzed using Analysis of Similarity (ANOSIM) based on the Bray-Curtis Index. Differences in species composition were visualized with Non-Metric Multidimensional (NMDS) plots. All analyses were performed using R Statistics version 4.2.2.

RESULTS AND DISCUSSION

Arthropod abundance

The mean abundance of total, herbivorous, and predatory arthropods differed significantly among the studied cassava fields (Figure 2). The abundance of total arthropods was higher in Ngasem, Bakalankrajan, Tegalgondo, and Donowarih I, while it was lower in Sumbersekar and Donowarih II. Likewise, the highest abundance of herbivores was in Ngasem, Bakalankrajan, Tegalgondo, and Donowarih I, followed by the abundance in the Sumbersekar, while the lowest was in the Donowarih II. Lastly, the predatory arthropod abundance in Donowarih I and Donowarih II was higher than in the others.

In this study, four species of herbivorous arthropods were observed. Three species were hemipteran insect pests, i.e., silverleaf whitefly *B. tabaci*, mealybug *P. manihoti*, and cassava lacebug *V. illudens*. At the same time, the other was an acarine pest, i.e., two-spotted spider mite *T. urticae* (Table 2). The highest abundance of *B. tabaci* was found in Ngasem and Donowarih I; *P. manihoti* in Ngasem; *V. illudens* in Ngasem; and *T. urticae* in Bakalankrajan, Tegalgondo, and Donowarih I.

A total of five species of predatory arthropods were obtained from the studied cassava fields, three of which were insects and the other two were acarines, i.e., *Feltiella* sp. (Diptera: Cecidomyiidae), *Oligota* sp. (Coleoptera: Staphylinidae), *Stethorus* sp. (Coleoptera: Coccinellidae), *Anystis* sp. (Acari: Anystidae) and *Phytoseiulus* sp. (Acari: Phytoseiidae) (Table 2). The abundance of *Oligota* sp., *Stethorus* sp., and *Anystis* sp. did not differ among the cassava fields. In contrast, the abundance of *Feltiella* sp. was highest on Donowarih I and Donowarih II, and *Phytoseiulus* sp. was higher on Ngasem, Bakalankrajan, and Donowarih II.

Arthropod assemblage

The composition of the arthropod communities recorded in the studied cassava fields differed significantly, indicating distinct groups (Figure 3). Based on the results of the NMDS analysis, it was revealed that the total composition of arthropods in Ngasem, Bakalankrajan, and Tegalgondo overlaps but did not overlap with Sumbersekar, Donowarih I, and Donowarih II. Likewise, the composition of herbivorous arthropods in Ngasem, Bakalankrajan, and Tegalgondo was quite similar but did not overlap with Donowarih I and Donowarih II. Finally, the composition of predatory arthropods in Sumbersekar overlaps with other fields.

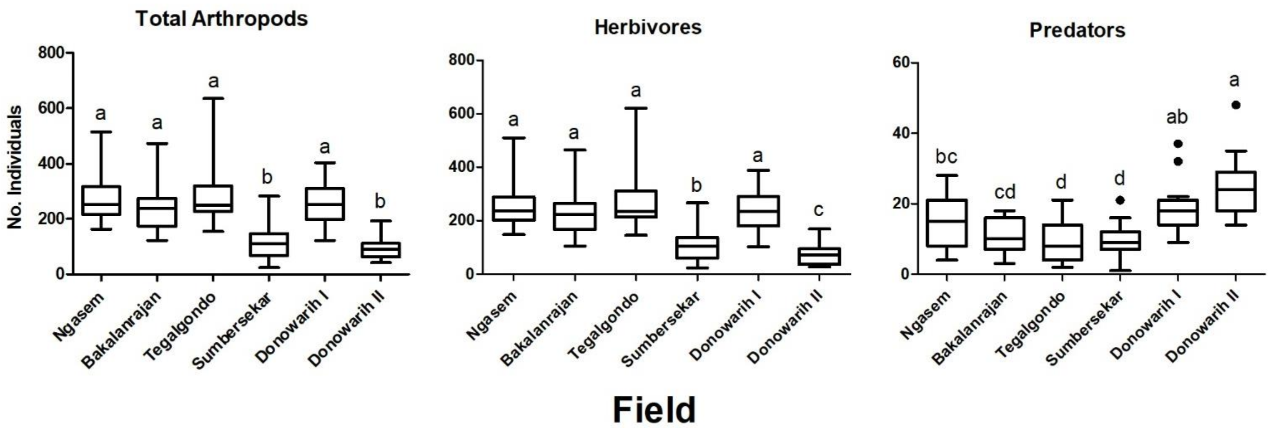

Figure 2. Effect of different agroecosystem management on the abundance of arthropods on cassava plantations: total arthropod ($F_{5,84}$=21.12; P<0.001); herbivorous arthropod ($F_{5,84}$=24.60; P<0.001); and predatory arthropod ($F_{5,84}$=10.47; P=0.166). According to Tukey's test, different letters denote significant differences at P<0.05. Detailed information on the field characteristics is provided in Table 1

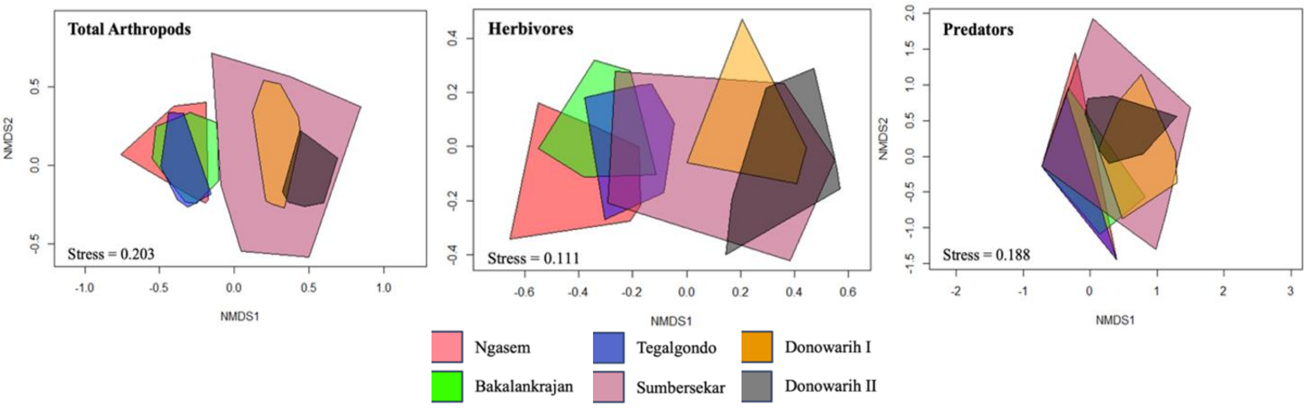

Figure 3. Non-metric multidimensional scaling ordinations (NMDS) of total arthropods (R-ANOSIM=0.203; P=0.001), herbivorous arthropods (R-ANOSIM=0.311; P=0.001), and predatory arthropods (R-ANOSIM=0.336; P=0.001). Detailed information on the field characteristics is provided in Table 1

Table 2. The average number of individuals ± SD of each arthropod species found in the six cassava plantations implementing different agroecosystem management

Species	Fields						Statistics	
	Ngasem	Bakalankrajan	Tegalgondo	Sumbersekar	Donowarih I	Donowarih II	$F_{5,84}$	P
Herbivores								
Bemisia tabaci	14.60±8.15 ab	7.13±3.71 cd	11.06±6.40 bc	7.53±2.77 cd	19.33±11.59 a	6.53±2.79 d	7.183	<0.001
Phenacoccus manihoti	88.66±103.12 a	38.00±40.47 b	30.73±24.45 b	9.20±10.26 cd	8.80±8.15 c	6.66±9.25 d	17.06	<0.001
Tetranychus urticae	130.60±50.06 b	173.46±81.18 ab	228.66±117.73 a	91.86±64.33 c	208.46±75.95 a	60.60±42.83 c	15.05	<0.001
Vatiga illudens	23.73±13.21 a	15.80±10.19 b	13.93±8.85 b	1.73±3.19 c	0.33±1.04 d	0.00±0.00 d	116.5	<0.001
Predators								
Anystis sp.	0.133±0.35 a	0.20±0.56 a	0.20±0.41 a	0.20±0.56 a	0.13±0.35 a	0.20±0.41 a	0.079	0.995
Feltiella sp.	0.00±0.00 c	0.00±0.00 c	0.00±0.00 c	2.60±2.02 b	9.33±4.95 a	11.33±5.47 a	107.6	<0.001
Oligota sp.	0.13±0.35 a	0.13±0.35 a	0.00±0.00 a	0.40±0.63 a	0.40±0.63 a	0.13±0.35 a	2.011	0.085
Phytoseiulus sp.	14.93±7.33 a	10.26±4.60 ab	9.33±5.78 bc	6.20±3.74 c	8.73±4.47 bc	13.06±7.14 ab	4.168	0.001
Stethorus sp.	0.33±0.72 a	0.13±0.35 a	0.13±0.35 a	0.26±0.59 a	0.26±0.59 a	0.00±0.00 a	0.85	0.518

Note: Means followed by the same letters within each row are not significantly different at P<0.05, according to Tukey's test. Detailed information on the field characteristics is provided in Table 1

Discussion

In this study, we observed that the arthropod abundance differed significantly across the studied cassava fields, indicating that field characteristics profoundly affected the dynamics of arthropods in agroecosystems. The obtained arthropods belonged only to two functional roles, i.e., herbivores and predators. The most dominant herbivores were *T. urticae*, followed by *P. manihoti*. In China, the two-spotted spider mite *T. urticae* infestations caused yield losses of up to 70% on cassava plantations, with instances reported where its attacks have resulted in no harvest (Lu et al. 2017). Similarly, the mealybug *P. manihoti* is recognized as a devastating pest that inflicts severe damage on cassava by feeding on the plant's sap, leading to stunted growth, leaf deformation, wilting, and potentially plant death. This pest can drastically reduce cassava yields and quality, resulting in substantial economic losses for farmers (Schulthess et al. 1991; Takano et al. 2023). Among the five identified predators, only one species is a generalist predator, while the rest are specialist predators. *Anystis* is known to prey on various small insect and mite pests (Cuthbertson et al. 2014; Chen et al. 2019). On the contrary, *Feltiella*, *Oligota*, *Stethorus*, and *Phytoseiulus* are obligate predators of tetranychid mites (Liu et al. 2017; Fedotova and Kozlova 2019; Jafari et al. 2022; Lin et al. 2023).

The abundance of herbivorous arthropods is generally higher in lowland cassava fields (Ngasem, Bakalankrajan, and Tegalgondo). These regions are characterized by higher temperatures, which typically contribute to the increased population of pests. Higher temperatures can accelerate the metabolic rates and reproductive cycles of many herbivorous arthropods, leading to more frequent and numerous generations within a growing season (Skendžić et al. 2021). In addition, increasing temperatures can increase the survival rate of immature pests and extend the period of pest activity, all of which contribute to higher pest densities in lowland areas. Conversely, pest populations actually decrease on fields with higher altitudes and lower temperatures. For example, in the cassava lace bug population *V. illudens*, the pest eventually disappeared completely on the highest land (Donowarih II). Cooler climates in the highlands would likely slow herbivorous arthropods' metabolic and reproductive rates, reducing their abundance and impact on cassava plants.

Interestingly, even though located at a high altitude, the herbivore abundance on Donawarih I was comparable to that of the lower altitude fields. This may be due to the narrower plant spacing implemented in Donowarih I. The dispersal limitations of cassava pests like *T. urticae* and *P. manihoti*, which lack wings, are significant in understanding their population dynamics. These pests primarily disperse through ambulation (crawling), which restricts their movement to nearby plants, or passively by winds, which is less reliable for widespread dispersal (Azandémè-Hounmalon et al. 2014; Aguilar-Fenollosa et al. 2016; Mani and Shivaraju 2016). Therefore, narrow plant spacing in cassava fields can facilitate and accelerate the spread of these pests, thereby causing higher population densities. In addition, although pests such as *B. tabaci* and *V. illudens* have wings, their natural mobility is relatively low. For that reason, narrow plant spacing also aids their movement between plants, thereby increasing their ability to infest multiple plants in the same field. Several studies have also proven that narrow plant spacing causes higher pest populations (Asghar et al. 2021; January et al. 2021; Asiry et al. 2022). This illustrates that planting density is an important factor in pest management. It influences the ease of winged and non-winged pests colonizing cassava plants. Therefore, the high herbivore abundance in Ngasem, Bakalankrajan, and Tegalgondo could also be due to the farmers' implementation of narrow plant spacing.

The higher abundance of predatory arthropods in Donowarih I and Donowarih II is caused by the absence of weeding on these fields. The total eradication of weeds carried out by farmers could negatively impact predatory arthropod populations because weeds are an important natural habitat where these predators can take refuge. Weeds provide protection not only from environmental stress but also from disturbances caused by cultivation practices. Additionally, weeds offer alternative prey, maintaining predator populations even when primary pests are scarce. They also provide additional food sources, such as pollen and nectar, which are important for many predatory arthropods' nutrition and reproductive success. In concordance, Mailloux et al. (2010) showed that naturally occurring plant species can serve as reservoirs for phytoseiid mites, supporting abundant and diverse populations throughout the year. Many other studies have demonstrated that weeds help preserve predatory arthropod populations (Norris and Kogan 2005; Atakan and Pehlivan 2020; Madden et al. 2021). Therefore, maintaining some level of weed presence in agroecosystems supports a diverse and stable population of natural predators, which contributes to effective and sustainable pest control.

Organic fertilizers, such as manure applied in Donowarih I and Donowarih II, can also contribute to the higher population of predatory arthropods. Manure enhances soil fertility and organic matter content, supporting diverse soil fauna. This enriched soil environment fosters higher populations of prey species, providing a stable food source for predatory arthropods. Moreover, the improved soil structure and increased microbial activity associated with manure application create a more hospitable environment for these predators (Aguilera et al. 2021; Rowen and Tooker 2021; Chapman et al. 2023). As a result, fields treated with organic fertilizers often experience an increase in predatory arthropod populations.

The variation in arthropod assemblages observed across the studied cassava fields underscores the significant influence of agroecosystem management practices. Cassava plantations on lower altitudes showed higher vulnerability to pest outbreaks, highlighting the importance of strategic planning to mitigate pest populations. Effective measures include maintaining proper plant spacing to prevent the buildup of pest populations, maintaining the presence of weeds at a certain level as a natural habitat for predatory arthropods, and applying organic fertilizers such as manure to support the conservation of predatory arthropods further. By implementing these ecologically relevant practices, farmers can promote sustainable pest management while improving the health and resilience of their agroecosystems.

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