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Crop Diversification Grown as Strip Intercropping Can Improve Farmers' Return in a Dryland with Sandy Soil

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Abstract: Maize and mungbean are two common crops grown in dryland areas with sandy soil structures. This study aimed to explore the potential of adding cayenne pepper to increase crop diversity using strip intercropping (SI) as a potential system to improve farmers' return. There were seven treatments tested: monoculture maize, monoculture mungbean, monoculture cayenne pepper, SI maize and mungbean, SI maize and cayenne pepper, SI mungbean and cayenne pepper, and SI maize, mungbean, and cayenne pepper. The size of the treatment plot was 700 cm × 500 cm, and all the treatments were arranged in a Randomized Block Design with three replications. The study showed no difference in the land equivalent ratio (LER) for all the SI treatments, with a value of around 1.0. This indicates no advantage of SI over monocropping in terms of land usage. However, when the market prices valued the yield of each component crop in SI at harvest, the highest economic value came from monocrop cayenne pepper treatment (IDR 246 million ha^{-1}). All the SI treatments involving cayenne pepper resulted in a higher return than the monoculture of maize or mungbean. The lowest economic value was shown by monoculture mungbean treatment (IDR 33.1 million ha^{-1}). These results indicate that diversifying crops can improve farmers' return, especially by incorporating cayenne pepper in dryland with sandy soil.

Keywords: Cayenne pepper; Diversification; Maize; Mungbean; Strip intercropping

Introduction

This study provides a potential solution to achieve some of the goals in Sustainable Development Goals (SDGs). Recently, Indonesian government is intensively carrying out intensification and extensification programs in agriculture, especially cereal crops. There are at least three (3) goals closely related to cereal crop production: Goal 1: to be free from poverty, Goal 2: freedom from hunger, and Goal 3: responsible production and consumption. This research will focus on goals 1 and 3 of the SDGs: to be free from poverty by responsibly producing foodstuffs on dryland. Responsible production means having high crop yields without damaging the environment so crop cultivation practices can be sustainable and adaptive to climate change. The forms of the program include the development of irrigation infrastructure (reservoirs, dams, irrigation networks, crop diversification) and the creation of food estate programs in several regions.

Maize (*Zea mays* L.) is one of the main cereal crops that is widely cultivated. Maize is grown intensively (monoculture) on dryland in the rainy and rice fields in the dry seasons. In carrying out the practice of cultivating maize, farmers use natural resources such as soil, water, air, and sunlight. The two natural resources, land and water, are increasingly limited due to very intensive plant cultivation activities. Very intensive agricultural activities reduce organic carbon in the soil (Acín-Carrera et al., 2013), thus impacting fertilization efficiency (Arif et al., 2017). As we know, the organic carbon in the soil has a significant role in maintaining the soil's physical, chemical, and biological properties (Bigelow et al., 2001). Many drylands in North Lombok Regency, West Nusa Tenggara have a sandy soil texture, so the soil cation exchange capacity (CEC) is expected to

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be low. With a low CEC value, fertilizer application must be made carefully to avoid nutrient loss due to leaching (Hoyle et al., 2011). The problem arising from nutrient leaching from maize planting because of the improper application is the reduction of soil biota, where the soil biota is beneficial in the process of recycling nutrients in the soil (Megyes et al., 2021).

Growing maize in a monoculture is also very vulnerable to the impacts of climate change, such as high rainfall variability. Monoculture practices are also reported to reduce organic matter in the soil (Gregorich et al., 2001). Organic matter plays a significant role in increasing soil fertility, retaining water, and providing energy for microbes. Unfortunately, the population of microbes in the soil is reduced with reduced rainfall (Ren et al., 2020, Cui et al., 2019). A long-term study in China showed that crop diversification improved soil health, such as the increase in soil organic carbon and the availability of some major elements in the soil (Wang et al., 2020).

Intercropping, one of the models of plant diversification, is said to be an adaptive practice to the impacts of climate change (Burgess et al., 2022). This practice can prevent plants from potential pest and disease attacks and protect plants from other harmful things that increase because of the impact of climate change (Huss et al., 2022; Lin, 2011). Diversifying crops through intercropping is to add one or two species of crops to a piece of land for various purposes. The goals of diversifying crops are improving the living standards of smallholder farmers (Makate et al., 2016), increasing diversity so that ecosystem services are maintained (Beillouin et al., 2021), avoiding nutrient leaching, and maintaining as well as improving soil health (Kumar et al., 2021), reducing the farmer income risks because the types of crops cultivated are diverse with different economic values (Mzyece & Ng'ombe, 2021) and increase farmers' incomes (van Zonneveld et al., 2020). Previously, it has also been reported that crop diversification has improved the living standards of smallholder farmers on dryland in the African region (Njeru, 2013). Crop diversification is a form of climate-smart agriculture (CSA) application. CSA is an effort to improve and sustain agricultural productivity (De Pinto et al., 2020) and income by building resilience to the impacts of climate change and reducing greenhouse gas emissions (Amin et al., 2015) in achieving food security (Paul Jr et al., 2023).

From the previous descriptions, it is evident that crop diversification activities on dryland in North Lombok Regency are needed. The plant diversification model required is not only able to increase people's income but also must be able to maintain soil health. Crops with higher economic value than maize are horticultural crops like cayenne pepper (*Capsicum frutescens* L.). Cayenne pepper or chili is a commodity with high economic and nutritional value (Olatunji & Afolayan, 2018). Demands for chili in Indonesia continue to increase along with the increase in population. Incorporating chili as one of the component crops in diversifying maize is expected to increase farmers' incomes.

Meanwhile, a crop that can nourish the soil and has a high nutritional value is mungbean (*Vigna radiata* (L.) R. Wilczek) (Pataczek et al., 2018). Mungbean is commonly cultivated on dryland as a monoculture or intercropping crop. The inclusion of mungbean as a component crop in the diversification of maize and cayenne pepper crops is expected to be one of the climate-smart agricultural strategies on dryland. This study explores the potential of adding cayenne pepper to increase crop diversity using strip intercropping (SI) as a potential system to improve farmers' resilience to climate change as well as to improve their return.

Method

A field experiment was conducted in Gumantar village, Kayangan sub-district, North Lombok, from May to September 2022. The research steps is presented in Figure 1.

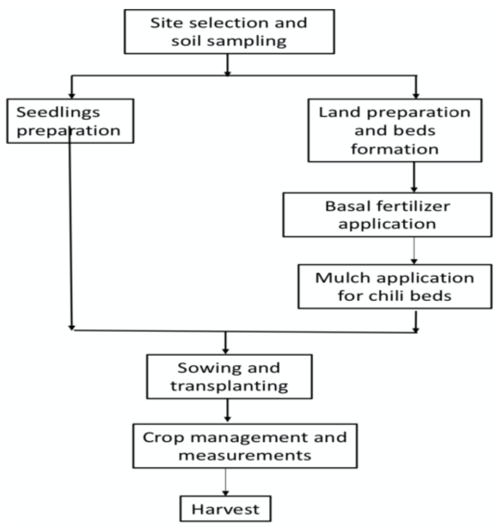

Figure 1. The steps of the field experiment.

The research objects were maize (Dekalb 771), mungbean (Vima-1), and cayenne pepper (Dewata 43 F1). Maize farmers in Gumantar have used inorganic fertilizers of urea at a rate of 500 kg ha^{-1} and NPK Phonska (15-15-15) at a rate of 360 kg ha^{-1} for maize, 1200 kg ha^{-1} NPK Phonska for cayenne pepper, and 150 kg ha^{-1} for mungbean. The very high rate of fertilizers used mainly due to the very poor soil conditions (Table 1). Those fertilizer doses were used as a reference in this research.

The treatments tested were as follows:

A. Maize monoculture (six double rows + one single row)
B. Mungbean monoculture (17 rows of mungbean)
C. Chili monoculture (five beds of chili)
D. Maize + mungbean (two single rows and two double rows of maize + eight rows of mungbean)
E. Maize + chili (two single rows and two double rows of maize + three beds of chili)
F. Mungbean + chili (eight rows of mungbean + three beds of chili)
G. Maize + mungbean + chili (two single rows and two double rows of maize + five rows of mungbean + one bed of chili).

The spacing for the double-row maize planting pattern was 70 x 35 x 20 cm, which means that the distance between two (2) double rows was 70 cm, the double row distance was 35 cm, and the planting distance within the double row was 20 cm with an east-west planting orientation. Mungbean seeds were planted at a spacing of 20 × 20 cm with one seed per hole. Meanwhile, the spacing for chili plants was 60 × 50 cm, and the width of each planting bed was 80 cm. The size of each treatment plot was 700 cm × 500 cm, and all treatments were laid out using a Randomized Block Design with three replications.

The land used for previous maize planting (rainy season 2021/2022) was cleaned and prepared using a tractor. Immediately after tillage, experimental plots were made according to the number of treatments. The distance between plots within blocks was 50 cm, and the distance between blocks was 100 cm. In the plots with cayenne pepper treatment, the number of planting beds was adjusted to the treatment. The planting beds for chili were then sprinkled with basal fertilizer as NPK Phonska (15-15-15) at a dose of 700 kg ha^{-1} and covered with plastic mulch. Other plots without chili treatment did not have planting beds made in them. Previously, chili seeds were sown in seedling trays using a seedling media mixture of soil, sand, and cow manure in a ratio of 1:1:1. Chili seedlings were transplanted when they had four leaves (28 days after sowing). Bamboo stakes were installed a week after planting in each chili planting hole to support the plants, so they did not easily break or collapse. The first supplementary fertilization was applied at the age of 35 days after planting (DAP) using NPK Phonska fertilizer at a dose of 250 kg ha^{-1}, and the second supplementary fertilization was applied at 56 DAP with the same type and dose of fertilizer.

Maize seeds were planted with a double-row planting pattern. At the same time, mungbean seeds were also planted according to the treatments. The first fertilization for maize as a basal fertilizer was applied at planting in the form of Urea and NPK Phonska (15-15-15) at a dose of 150 and 190 kg ha^{-1}, respectively. The first supplementary fertilizer was applied when the plants were at 35 DAP with doses of Urea and Phonska of 200 and 190 kg ha^{-1}, respectively. The third urea fertilizer was 150 kg ha^{-1} when the plants started to flower at 56 DAP. Mungbean was fertilized twice, first at planting and second at 28 DAP using NPK Phonska at the same rate of 75 kg ha^{-1}. Irrigation was applied in July, August, and September due to the lack of rain. Protection against pests and plant diseases was adjusted to the needs of the plants.

The observed variables were grouped into three parts. The first part was soil variables which included: soil texture, pH, C-organic, N, P, and K available in the soil, and cation exchange capacity (CEC) before the experiment. The second part was maize, mungbean, and chili yield and yield components. The third part was calculating the land equivalent ratio (LER) and the economic value of the crops' yield. The economic value was calculated based on the value or price of each commodity at harvest time. The prices of dry grains maize, mungbean seeds and chili at harvest were IDR 3,300, 20,000 and 40,000, respectively. Meanwhile, LER was calculated based on the equation:

$$LER = \Sigma(\frac{ypi}{ymi}) \quad (1)$$

where Yp and Ym were the yields of crops in intercropping and monoculture, respectively (Dariush et al., 2006).

Mungbean was harvested at 56 DAP three times a week apart. Meanwhile, the first chili harvest was at 70 DAP and was repeated every week up to the fifth harvest. However, the yield components of chili, the number of fruits, and fruit weight per plant were calculated from the first to the third harvest only. Meanwhile, the yield (fruit weight per plot) was observed until the fifth harvest. LER and economic value data were analysed using analysis of variance at a 95% confidence level, followed by Duncan's Multiple Range Test (DMRT) for those treatments with significant effects. Other observational data were analysed using descriptive statistics.

Result and Discussion

Soil laboratory analysis results showed that the soil fractions consisted of 92% sand, 8% silt, and 0% clay; hence, the soil texture was sandy soil. Based on the chemical properties of the soil data in Table 1, it can be said that the soil at the experimental site is deficient in nutrients except for available phosphor. The high rate of fertilizer applications, especially for maize and chili, was due to the very low soil organic carbon, very low total nitrogen, and very low exchangeable potassium, as well as a low soil cation exchange capacity (CEC).

Table 1. Soil chemical properties at the experimental site

Parameter	Unit	Method	Value	Criteria
pH (H_2O)		Electrode	7.0±0.03	neutral
C-organic Walkey & Black	%	Spectro	0.4±0.03	very low
N-total	%	Kjeldalh	0.08±0.02	very low
P- available	ppm	Spectro	36.22±1,29	very high
K-exchangeable	meq%	Ammonium acetate	0.37±0.06	very low
Cation Exchange Capacity	meq%	Ammonium acetate	9.21±1.12	low

The growing environment during the experiment was optimum for the growth of maize, mungbean, and cayenne pepper. The highest temperature recorded during the experiment was 39^{0}C (in September), with the lowest temperature of 21^{0}C in July. The average maximum temperature was 34.2^{0}C, and the average minimum temperature was 24.5^{0}C. These temperatures are within the ideal range for the growth of maize (Cicchino et al., 2010) and cayenne pepper (González-Zamora et al., 2013), although it is a bit too hot for mungbean (Malaviarachchi et al., 2016).

Rainfall was recorded to be relatively high for the dry season in drylands. The number of rainy days during the experiment was 14, with a total rainfall of 276 mm. This total rainfall was insufficient for maize or chili plants to grow, especially since the distribution was not very even, as shown in Figure 2. Maize plants require 684 to 864 mm of rainfall in one growing season (Rosenzweig et al., 2002), while 523 mm of rain was said to be insufficient for optimal mungbean production (Worku, 2014). The rest water requirements for the crops were met by irrigation, especially in July, August, and September, until the harvest of the maize and the fifth harvest of cayenne pepper.

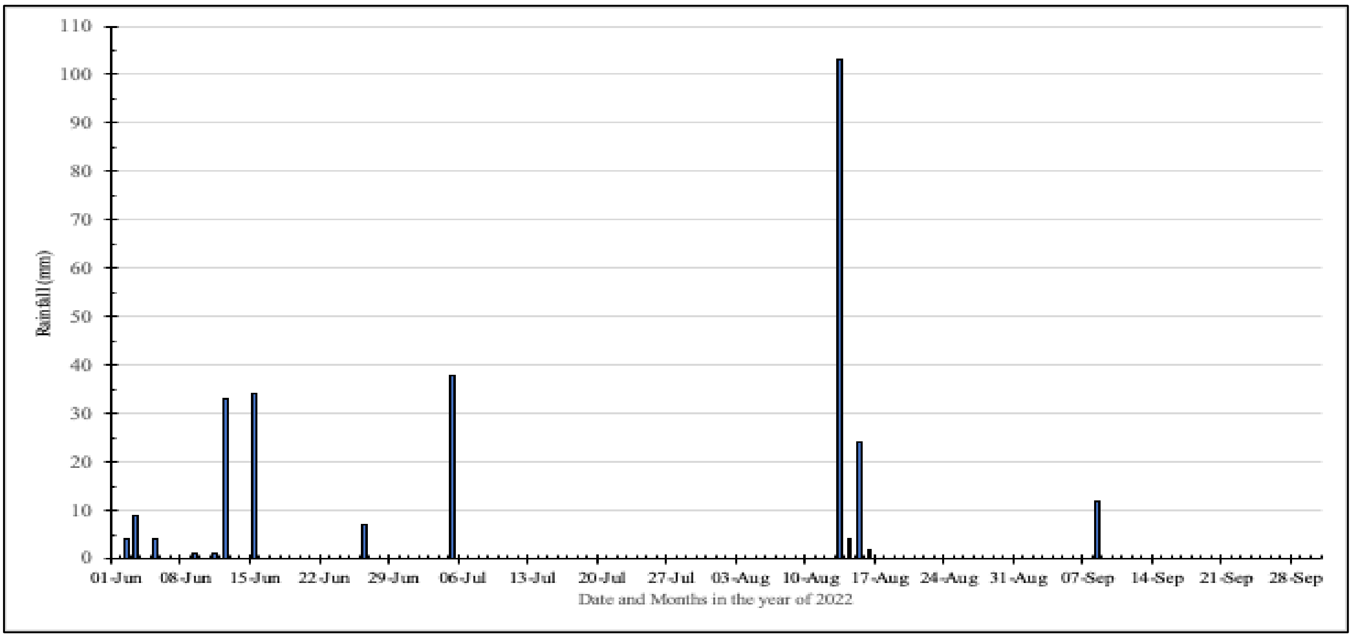

Figure 2. Rainfall pattern during the course of the experiment at Gumantar Village, North Lombok.

A very high yield components indicated the optimum growth of maize plants (Table 2) compared to the results of previous studies in the exact location. Previously Jaya et al. (Jaya et al., 2021) reported that the highest maize ear weight produced was 210 g, with 169.9 g of seed weight per ear. In this study, the highest ear weight resulted from the intercropping treatment of maize with chili, 251.7 g (Table 2). However, it was not significantly different from the results of maize plants in other treatments. Meanwhile, the highest seed weight per ear in this study was 200.5 g resulting from the intercropping treatment of maize with mungbean, although it was not significantly different from the other treatments (Table 2). The maize seed weight per ear in this study was also much higher than the same parameter in a strip intercropping study between maize and mungbean in the same area a few years earlier. The highest maize seed weight per ear produced at that time was only 141.8 g. The difference in ear weight per plant and seed weight per ear from the previous results may be due to the different varieties tested.

Table 2. Yield components of maize, mungbean and chili in all treatments

Treatments	Maize		Mungbean		Chili	
	Ear weight per plant (g)	Seeds weight per plant (g)	Pod number per plant	Seed weight per plant (g)	Fruit number per plant	Fruits weight per plant (g)
Maize monoculture	245.4±15.03[1)]	198.1±10.46	-	-	-	-
Mungbean monoculture	-	-	26.7±2.60	20.0±0.93	-	-
Chili monoculture	-	-	-	-	95.7±5.92	195.0±13.61
Maize+Mungbean	247.3±20.0	200.5±14.74	20.3±2.33	19.0±0.17	-	
Maize+Chili	251.7±10.51	198.0±7.49	-	-	97.0±3.61	196.3±7.12
Maize+Mungbean+Chili	234.3±11.08	190.1±7.07	16.7±0.67	16.0±0.57	89.7±3.71	180.3±6.56
Mungbean+Chili	-	-	20.7±1,20	18.3±0.62	94.7±4.63	190.3±8.95

Notes: [1)] Standard error

The yield components of mungbean, such as the number of pods per plant and the weight of seeds per plant, were highest in the monoculture treatment and lowest in the intercropping treatment of maize + mungbean + chili (Table 2). The shading effect of maize and chili plants in the maize + mungbean + chili treatment (the position of the row of mungbean crops was between the rows of maize and chili plants), was likely to be the low productivity of mungbean crops in the strip intercropping treatment. It was previously reported that some varieties of mungbean crops are relatively sensitive to shade, so it can reduce crop yields (Hossain et al., 2017). The selection of mungbean varieties that are relatively tolerant to shade is important in diversifying crops through intercropping. However, in general, the yield components of mungbean from monoculture treatments were reasonably similar to those of several mungbean varieties grown in the same area several years earlier (Jaya et al., 2018).

The cropping system did not influence the yield components of chili, such as the number of fruits and fruit weight per plant (Table 2). The value of yield components of chili plants in monoculture was not significantly different from the value of yield components in intercropping. This indicates that cayenne pepper plants, especially the Dewata 43 variety, are suitable varieties to be planted in an intercropping system because the shading of maize plants did not affect the yield components of the chili. It was previously reported that a 25% shade level on cayenne pepper plants coupled with the addition of microbial consortium into the soil could increase the growth of chili plants (Hariyono et al., 2021).

Data in Table 3 shows that all intercropping systems produced land equivalent ratio (LER) of around 1.0 and not significantly different in all treatments. These values indicate that there was no advantage or disadvantage of intercropping systems compared to monoculture in terms of land use to produce the exact yield (Mead & Willey, 1980). LER value slightly less than one was shown by the intercropping treatment of maize + mungbean + chili. This was reasonable because the inferior appearance of mungbean crops in the strip intercropping system, especially its yield component (Table 2), as compared to the one in monoculture treatment. Similar results were reported in intercropping maize with soybean in dryland China, that the LER value of less than 1.0 may be due to competition between component crops in intercropping (Wang et al., 2022). From these results, it can be said that diversifying crops through strip intercropping and each component crop can produce relatively the same yields as those grown in monoculture.

Table 3. Yield of the component crops, land equivalent ratio (LER) and economic value of the treatments

Treatments	Maize yield/plot ($kg/35m^2$)	Mungbean yield/plot ($kg/35m^2$)	Chilli yield/plot ($kg/35m^2$)	LER	Economic value/ha (Rp)
Maize monoculture	37,0±1.15[1)]	-	-	-	33,883,978a[2)]
Mungbean monoculture	-	5.8±0.72		-	33,141,200a
Chili monoculture	-	-	21.5±0.36	-	246,006,747f
Maize+Mungbean	18.8±0.72	2.9±0.35	-	1,01a	34,460,944b
Maize+Chili	18.7±0.44	-	11.2±0.16	1,03a	145,928,894e
Maize+Mungbean+Chili	14.9±0.06	1.8±0.24	5.6±0.6	0.98a	88,462,243c
Mungbean+Chili	-	3.1±0.22	10.7±0.43	1.04a	140,697,727d

Notes: [1)] Standard error
[2)]Values followed by different letter are significantly different at 5% level according to DMRT

In terms of the selling value, growing chili in monoculture was much higher than the selling value of maize or mungbean grew in monoculture. The selling value of chili per hectare was about 626% higher than the selling value of maize or mungbean monoculture (Table 3). Likewise, comparing the selling value of monoculture chili yields with the selling value of the yields of other component crops in strip intercropping (Table 3). As other strip intercropping, such as maize and legum (Abdul Rahman et al., 2021), strip intercropping maize with chili can provide high income to farmers, but both crop species are highly vulnerable to rainfall variability or water shortages. Planting monocultures in drylands in the rainy season under climate change has a very high risk of total yield loss (Jaya et al., 2020). In addition, no research shows the contribution of chili cultivation to improving the fertility of maize cropping land. Meanwhile, previous mungbean crops and mungbean crop waste have increased maize yields on sandy dryland soils (Jaya & Sudika, 2021). Therefore, adding mungbean to maize crops through strip intercropping and rotating the crop position in the field in the following season is believed to improve soil fertility in the long term (Uzoh et al., 2019).

Data in Table 3 also shows that the selling value of maize and mungbean in the strip intercropping was only 1.70% higher than that of maize monoculture. This result is not attractive enough for maize farmers to diversify their crops, even though, in theory, their land will increase in fertility over a long time (Yadav et al., 2017). The most rational crop diversification option to increase the selling value of maize growing areas on dryland and maintain soil fertility is to include chili (cayenne pepper). By having chili along with maize and mungbean in crop diversification, the selling value of crops will increase by 330% compared to only growing maize or mungbean monoculture (Table 3). This crop diversification model is enough to increase farmers' income in sandy dryland soils so that they can be more resilient to the impacts of climate change (Adzawla et al., 2020; Tui et al., 2021). Cayenne pepper can grow well on sandy drylands in the rainy season because the potential for inundation, which can make plants rot, is minimal. The presence of three component crops in a strip intercropping can certainly increase crop diversity in drylands, which in turn can increase farmers' income.

Conclusion

All the strip intercropping models tested in this study had land equivalent ratio (LER) values around 1.0, showing no intercropping advantage in producing yields over monoculture. Adding chili (cayenne pepper) to enrich crop diversification increased the economic importance of component crops grown as strip intercropping in dryland with sandy soil. The increase was up to 330% compared to growing maize or mungbean as the sole crop or monocropping. The strip intercropping of maize + mungbean + chili is a promising model of crop diversification in dryland to improve farmers' income and increase their resilience to climate change. More studies are needed to assess the benefit of the intercropping model to soil health for sustainable production, as well as calculate the economic benefits of the model in the long run.

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Author Contributions
Idea and methodology of the study, I Komang Damar Jaya; field establishment and coordinating for data collection, Herman Suheri and Akhmad Zubaidi; data analysis and interpretation Wayan Wangiyana. Preparation of the draft, I Komang Damar Jaya; writing-review, Herman Suheri and Akhmad Zubaidi; editing, Wayan Wangiyana.

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Conflicts of Interest
The authors declare no conflict of interest.

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