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Yield and Tolerance of Several Shallot Varieties in Sunlight Deficit

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Abstract: Shallot cultivation is usually carried out on land with a lack of sunlight, so that the selection of shade-adaptive shallot genotypes is very important. This study aimed to know yield potential and tolerance level of varieties of shallots in sunlight deficit. This study was arranged using a Completely Randomized-Split Plot Design with five replications. The genotypes used were Keta Monca, Lokananta, Bali Karet, Ampenan, Thailan Nganjuka and Super Philip. The sunlight deficit was carried out using a black paranet with 65% sunlight barrier. The experiment results showed that shallot varieties have different yields potential against sunlight deficit stress. Shallot crop under sunlight deficit stress caused a reduction in bulb wet weight, bulb dry weight, leaf wet weight, number of bulbs, root dry weight, and leaf dry weight. The Lokananta variety produced the heaviest wet weight of bulb per clump (33.7 g per clump) with a decrease in bulb wet weight only 4.8% under sunlight deficit conditions, and the sensitivity index value was moderate tolerant to sunlight deficit.

Keywords: Carotenoids; chlorophyll; photosynthesis; shade

Introduction

Shallots are nutritious vegetables that are economically important and are useful plants as spices for cooking and medicinal seasonings (Khorasgani and Pessarakli, 2019). Consumer demand for shallots continues to increase from time to time. The high demand for shallots has not been matched by shallot productivity which has decreased every year. The decrease in shallot productivity is due to the use of superior varieties that have not been implemented, the application of cultivation techniques that are still low and the influence of environmental stress (Saidah et al., 2020).

Onion farming is usually developed on marginal land with the condition of the land being shaded by tree stands. Land conditions like this cause shallot plants to experience shade stress, so that shallot plants experience a lack of sunlight. Solar radiation greatly affects the growth and productivity of plants through the process of photosynthesis. Plants use sunlight as their main energy source. Sunlight affects metabolic processes through photosynthesis and cellular respiration. The results of this process will then be used for plant growth and production. Shade conditions or low light intensity can affect the carbon balance in plants because the demand for carbohydrates (sugars) increases while their production decreases: the rate of physiological processes increases while the yield of photosynthesis decreases (Yang et al., 2018a).

Deficiency of sunlight due to shade causes changes in plant morpho-physiology, such as increasing specific leaf area, leaf length and width, but on the other hand decreases stem diameter and total plant dry matter (Perrin et al., 2013). The tuber yield of shallots has been reported to be directly related to the intensity of sunlight. The degree of tuber yield damage depends on the variety and phenology against shade stress (Ghodke et al., 2018). According to Sumarni and Rosliani (2010) that shade stress makes a difference in the weight yield of shallot bulbs and influences the growth process.

Efforts that may be made to overcome shade stress on shallots are the use of shade stress tolerant varieties. Shallot varieties that are tolerant to shade stress will

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produce optimally according to their genetic potential when macro and micro environmental conditions are under control for optimum shallot growth (Wardani, et al., 2021). Plants can adapt to shade stress by modifying their morphology and physiology, so that the available light energy can be used efficiently (Koike, 2013). Changes in plant morphology due to shade stress can be observed in increased plant height, decreased number of leaves and tillers (Buntoro et al., 2014), decreased leaf thickness (Fan et al., 2018) and increased leaf area (Umarie et al., 2018; Ritonga et al., 2019). Sunlight has a very large influence on physiological processes, such as photosynthesis, respiration, growth and development, closing and opening of stomata, various plant movements and germination (Taiz and Zeiger, 2002), therefore understanding the response of several shallot varieties to shade stress. be very important.

This research was conducted to screen several shallot varieties that have high yield and tolerance to sunlight deficit. The use of varieties that are tolerant to sunlight deficit stress is an alternative to increase shallot production. The use of tolerant varieties in shallot cultivation in sunlight deficit land is more efficient and practical compared to other cultivation techniques. Observation of yield and tolerance of several shallot varieties is a significant approach for identification of germplasm that is tolerant to shade stress. This shallot germplasm can then also be used as a gene source for plant breeding programs to obtain superior varieties. Based on this description, this study aims to determine the yield and tolerance of several shallot genotypes in sunlight deficit.

Method

This research was conducted by following the stages in Figure 1.

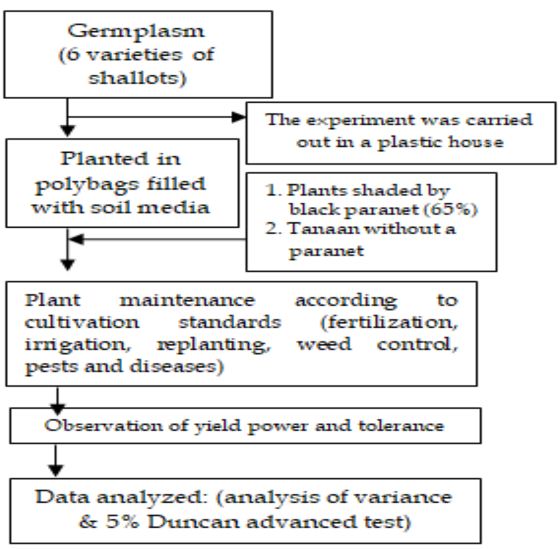

Figure 1. The flow of research implementation

Experimental design

This experiment used a completely randomized design and the treatments were arranged in Split Plot Design with two factors, namely the main plot of sunlight deficit (without shade and shade treatment) and the subplots, namely shallot varieties (Keta Monca, Lokananta, Bali Karet, Ampenan , Thai Nganjuk and Super Philip). Each treatment was repeated 3 times. Plant growing is carried out in a plastic house.

Experimental Implementation

The planting medium was carried out using polybags with a height of 20 and a diameter of 15 cm. The experimental soil was taken from the rice fields where peanuts were planted, and the soil was sifted and dried in the sun. The sifted soil is put into polybags in the amount of 6 kg per polybag. Soil media mixed with compost in the amount of 200 g per polybag.

The shallot seeds used come from farmers, are of medium size (2.6-4.1 g) or about 2-4 cm in diameter, have a good appearance and have a shelf life of more than 3 months. The selected shallot seeds are then cut about 1/3 of the end using a knife.

Planting was carried out on planting media and using seed tubers in the amount of 2 seeds per polybag with a depth of 2-3 cm. The planting hole is sprinkled with Sidafur 3 GR to prevent insect and nematode attacks. All polybags that have been planted with shallot seeds are stored on a bamboo bench 50 cm high.

Shading is carried out from the start of planting the seeds using a black paranet and the resulting shade is 65% or only 35% of the sunlight entering the plant. Other shallot varieties are treated with no shade or 100% sunlight shining on the shallot plants. Paranet installation is done using bamboo with a shade height of 2 m, a width of 1.5 m and a length of 3 m.

Maintenance is carried out by removing weeds that grow around the plant's growing environment with the aim of reducing nutrient competition during the plant's vegetative growth phase. Stitching is done by replanting tubers that do not grow in each polybag which is done seven days after planting.

Watering is done 2 times a week by irrigating the soil around the plants using a dipper and the water is taken from the drilled well. Each polybag is doused with 2 dippers of water.

Fertilization is done by providing NPK compound fertilizer (16-16-16) at a dose of 300 kg per hectare. Fertilizer application is carried out 3 times, namely basic fertilizer before planting, follow-up fertilizer at the age of 10-15 days and 30-35 days of age. Fertilizer application is done by spreading and stirring evenly on the surface of the soil.

Harvesting is done at 65 days after planting (DAP) or shallots after showing signs of 60% soft stem neck, drooping plants and yellowing leaves. Determination of the tolerance of several shallot varieties to sunlight deficit can be calculated by the S value based on the Fischer and Maurer formula (1978), namely:

$$S = (1 - Y/Yp)/(1 - X/Xp) \quad (1)$$

Description:
Y = The average value of certain variables (tuber dry weight and number of tubers) in one variety that experienced shade stress.
Yp = The average value of these variables in one optimum environmental variety.
X = The mean value of these variables for all varieties experiencing shade stress.
Xp = The average value of these variables in all varieties of optimum environment.
Score or Value:
T = Shade stress tolerant varieties if they have a value of: S < 0.5.
AT = Somewhat tolerant if 0.5 ≥ S ≤ 1.
P = Sensitive if S > 1.

Result and Discussion

Low sun intensity affects the growth and yield of shallots (Saidah et al., 2020). Sun deficit does not show a significant interaction with shallot varieties on plant height. shallot varieties provide different plant heights, especially at 42 and 56 dap. Differences in plant height due to differences in cell division and elongation of each variety (Figure 2).Shallot plants that experience shade stress produce taller plants than plants without a deficit of sunlight (Figure 3).

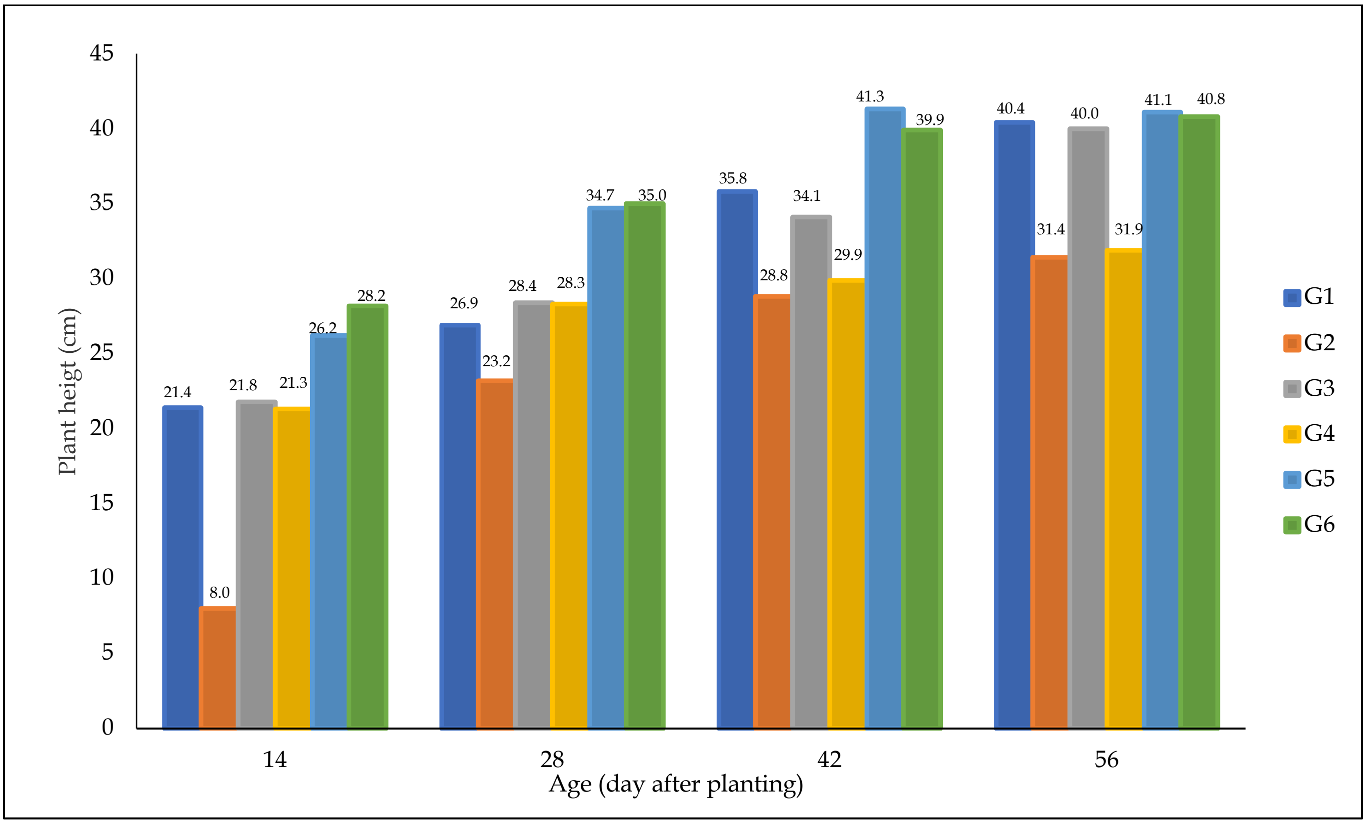

Figure 2. Plant height (cm) at 14, 28, 42, and 56 dap on several shallot varieties. G1 = Keta Monca; G2 = Ampenan; G3 = SuperPhilip; G4 = Thailand Nganjuk; G5 = Bali Rubber; G6 = Lokananta

The results showed that several shallot varieties experienced an increase in plant height at the age of 14 days after planting until 56 days after planting (Figure 1). Shallot varieties showed significant differences in plant height at 14, 28, 42, and 56 dap. The Bali Karet variety (G5) had the highest plant height of 41.27 cm at 42 dap. At the age of 56 hst the leaf height decreased, this was because at that age the plants entered the generative phase, namely the process of filling the shallot bulbs. In Figure 2 it can also be seen that plants that experience a lack of sunlight produce the highest plants, namely 26.43 cm, especially at the age of 56 DAP. Shade stress causes plants to experience etiolation (Sumarni and Rosliani, 2010). This etiolation is influenced by the formation of the hormone auxin and further auxin will stimulate the growth of taller stems (Yang et al., 2018b).

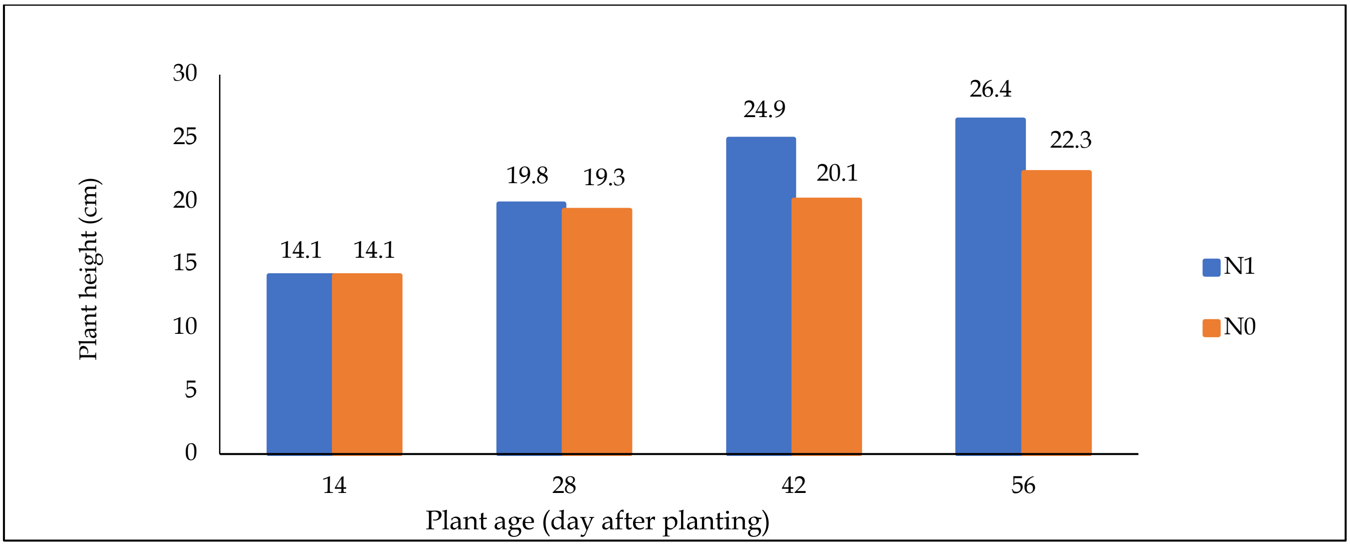

Figure 3. Plant height aged 14, 28, 42, and 56 days after planting (DAP) under shade stress (N1) and without shade (N0).

In general, the yield of shallots is affected by the intensity of sunlight (Dianawati, et al., 2021). Shallot varieties that are tolerant to sunlight deficit will be able to produce optimally according to their genetic potential when environmental conditions are under control for optimum growth. Sunlight deficit significantly interacted with varieties on tuber fresh weight, tuber dry weight, leaf fresh weight, and root dry weight. In Table 1 it can be seen that all shallot varieties in sunlight deficit tended to show a lighter tuber fresh weight than shallot varieties grown in conditions without sunlight deficit (control) (Figure 4).

Table 1. Fresh weight of bulbs (g) per clump of several shallot varieties in a deficit of sunlight

Variety	Control (no sunlight deficit)	Sunlight deficit	Percentage (%) reduction in fresh weight of tubers in light deficit
Keta Monca	37.8aB*)	28.1bAB*)	25.66
Ampenan	19.8aC	15.3aC	22.73
Super Philip	39.7aB	26.3bB	33.75
Thailand Nganjuk	29.3aB	22.6bB	22.87
Bali Rubber	48.6aA	38.0bA	21.81
Lokananta	35.4aB	33.7aA	4.80

*) Numbers followed by the same lowercase letters in the same row are not significantly different, and numbers followed by the same capital letters in the same column are not significantly different, on Duncan's 5% test.

Figure 4. Growth of shallot bulbs. (A) tuber growth without sunlight deficit and (B) tuber growth under sunlight deficit

In Table 1 it can be seen that all shallot varieties in sunlight deficit tended to show a lighter tuber fresh weight than shallot varieties grown under field capacity conditions (control). The decrease in tuber fresh weight occurred in all shallot varieties under shade stress and the largest decrease occurred in Super Philip variety (33.75%). The Lokananta variety produced the heaviest tuber fresh weight in a deficit of sunlight compared to other varieties. The reduction in tuber fresh weight in the Nganjuk Bauci variety was around 29%. According to Sumarni et al. (2012) that each variety has different yield potential and characteristics. This is because tuber formation is influenced by the plant's ability to distribute photosynthetic results to the leaves and tubers (Khalid, et al., 2019).

In Table 2 it can be explained that what is meant by dry weight of tubers is the weight of tubers after harvest which have been dried in the sun for 2 weeks. Reducing light intensity through the use of black paranet causes a lower tuber dry weight in all shallot varieties. Lokananta varieties (15.63%) and Keta Monca (12.27%) gave a lower percentage of dry tuber weight loss than other varieties in sunlight deficit. When the intensity of sunlight decreases, it will disrupt the carbon balance in plants. The need for carbohydrates (sugar) during plant growth increases while production decreases due to low light intensity (Yang et al., 2018a). In another study, it was shown that the carbohydrate content of several shallot varieties tended to increase under shade stress conditions (data not shown). This shows that under stress conditions plants are able to form carbohydrates to compensate for respiration (Devy et al., 2021).

Table 2. Bulb dry weight (g) per clump of several shallot varieties in sunlight deficit

Variety	Control (no sunlight deficit)	Sunlight deficit	Percentage (%) of tuber dry weight reduction in light deficit
Keta Monca	21.59B*)	18.94BB*)	12.27
Ampenan	11.74aC	8.32bC	29.13
Super Philip	25.57aB	20.60bB	19.44
Thailand Nganjuk	25.28aB	17.73bB	29.87
Bali Rubber	42.16aA	24.63bA	41.58
Lokananta	24.82aB	20.94bB	15.63

*) Numbers followed by the same lowercase letters in the same row are not significantly different, and numbers followed by the same capital letters in the same column are not significantly different, on Duncan's 5% test

Shallot varieties and shade stress conditions did not significantly interact on the number of tubers. The number of tubers was more influenced by shade stress conditions and conditions without shade stress (Table 3). Sunlight affects vegetative growth and tillering is a multiplication process from the growing point of the shoot apical meristem (Kamenetsky and Rabinowitch, 2010). The Bali Karet variety gave a greater reduction in the number of tubers under shade stress conditions.

Table 3. Number of bulbs per clump of several shallot varieties in a deficit of sunlight

Variety	Control (no sunlight deficit)	Sunlight deficit	Percentage (%) decrease in the number of bulbs at light deficit
Keta Monca	6.7	6.4	4.48
Ampenan	7.6	7.2	5.26
Super Philip	6.8	5.6	17.65
Thailand Nganjuk	9.4	9.1	3.19
Bali Rubber	8.4	5.5	34.52
Lokananta	5.1	4.4	13.73

Overall shade stress reduced leaf wet weight and leaf dry weight (Tables 4 and 5). Light intensity can affect plant biomass (Figure 5). At low light intensity it causes plant biomass to decrease because the rate of photosynthesis decreases. These results are in line with the research of Phonguodume, et al. (2012) and Hou (2009) who reported that the dry weight of plants decreased as the light intensity decreased. Decreasing light intensity significantly reduced plant dry weight in all treatments. Thus, light intensity is proven to have a major effect on plant biomass by producing carbohydrates as an energy source.

A B

Figure 5. Growth of shallot plant leaves. (A). leaf growth without sunlight deficit, (B) leaf growth under sunlight deficit

Table 4. Leaf wet weight (g) per clump of several shallot varieties in sunlight deficit

Variety	Control (no sunlight deficit)	Sunlight deficit
Keta Monca	11.7aA*)	3.5bB*)
Ampenan	6.7aB	2.8bB
Super Philip	14.1aA	3.3bB
Thailand Nganjuk	6.5aB	2.9bB
Bali Rubber	7.6aB	2.7bB
Lokananta	11.4aA	5.1bA

*)Numbers followed by the same lowercase letters in the same row are not significantly different, and numbers followed by the same capital letters in the same column are not significantly different, on Duncan's 5% test

Table 5. Leaf dry weight (g) per clump of several shallot varieties in sunlight deficit

Variety	Control (no sunlight deficit)	Sunlight deficit
Keta Monca	3.28aA*)	1.45bB*)
Ampenan	3.78aA	1.40bB
Super Philip	3.43aA	1.13bB
Thailand Nganjuk	4.86aA	0.87bB
Bali Rubber	4.81aA	0.83bB
Lokananta	4.60aA	1.67bB

*)Numbers followed by the same lowercase letters in the same row are not significantly different, and numbers followed by

the same capital letters in the same column are not significantly different, on Duncan's 5% test

In Table 6 it can be seen that several shallot varieties have a lighter root dry weight in a deficit of sunlight and lighter in optimum conditions. Dry weight and root length are indicators of a plant's ability to survive in a deficit of sunlight. The number of roots that are many and long will be able to help absorb water for the process of plant growth. Shade stress will reduce root growth, so that ultimately the process of water absorption and photosynthesis is disrupted. The large number and long roots will be able to help absorb water for the plant growth process (Wahyuni et al., 2020).

Table 6. Root dry weight (g) per clump of several shallot varieties in sunlight deficit

Variety	Control (no sunlight deficit)	Sunlight deficit
Keta Monca	1.44aA*)	0.37bB*)
Ampenan	1.37aA	0.15bB
Super Philip	1.37aA	0.25bB
Thailand Nganjuk	1.29aA	0.16bB
Bali Rubber	1.24aA	0.19bB
Lokananta	1.54aA	0.26bB

*)Numbers followed by the same lowercase letters in the same row are not significantly different, and numbers followed by the same capital letters in the same column are not significantly different, on Duncan's 5% test

Based on the value of the sensitivity index (S) to shade stress, it turned out that the 6 varieties tested showed different tolerances to sunlight deficit. The calculation of the S value is based on the dry weight of tubers and the number of tubers produced by each variety. The S value of each variety can be seen in Table 7. The shallot varieties tested have the ability to withstand sunlight deficit stress through morphological, anatomical or physiological adaptations. This sensitivity index value indicates that the decrease in yield weight and number of tubers can avoid the negative effects of shade stress. Plants that face shade stress will express genes to resist the stress.

Table 7. Sensitivity index values of six shallot varieties in sunlight deficit stress

Variety	Sensitivity Value (S)		Ave-rage	Pheno-type
	Root dry weight	Number of tubers		
Keta Monca	0.21	0.29	0.25	T
Ampenan	1.35	0.48	0.92	AT
Super Philip	0.15	3.31	1.73	P
Thailand Nganjuk	1.40	0.60	1.00	AT
Bali Rubber	2.33	0.34	1.34	P
Lokananta	0.61	1.04	0.83	AT

Description: T = Tolerant (≤ 0.5); AT = Somewhat Tolerant (> 0.5 S ≤ 1); P = Sensitive (S > 1);

Conclusion

Shallot varieties have different yields against sunlight deficit stress. The red onion plants that experienced sunlight deficit stress caused a reduction in tuber wet weight, tuber dry weight, leaf wet weight, tuber number, root dry weight, and leaf dry weight. The Lokananta variety produced the heaviest tuber wet weight per clump (33.7 g per hill) with a decrease in tuber wet weight of only 4.8% in conditions of deficit sunlight, and its sensitivity index value was somewhat tolerant of deficit sunlight.

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