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RESEARCH ARTICLE

Effect of Starch Based Super-Absorbent Polymer (SAP) on Growth and Yield of Sugarcane (*Saccharum* Hybrid Spp.) Under Different Irrigation Intervals in Udawalawe, Sri Lanka

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ABSTRACT

Super absorbent polymer (SAP) can significantly improve soil moisture retention, which is an important factor in most agricultural production systems. Limited research exists on its specific application in sugarcane cultivation, particularly under the environmental conditions of the Dry Zone of Sri Lanka. Hence, the present study was conducted to evaluate the effect of starch-based SAPs, on sugarcane growth, yield, and nitrogen leaching under different irrigation intervals in Udawalawe, Sri Lanka. This study was conducted using a split-plot design with three replicates, where irrigation interval served as the main plot factor, and the levels of SAP application were treated as the subplot factor. Irrigation intervals of 10, 15, 20, and 25 d were evaluated with and without the application of SAP. The study was conducted over one crop cycle from June 2020 to June 2021 at the research farm of the Sugarcane Research Institute, Sri Lanka. The results of this study revealed that the application of SAP enhanced the sugarcane yield only under a 10-day irrigation interval. None of the other treatment combinations was significant at a probability level of 0.05. Hence, the application of SAP cannot be used as a management tool for increasing irrigation intervals aiming at reducing the irrigation water demand. While the SAP application can enhance sugarcane fresh yield in specific instances, it did not provide clear evidence of improvement in sugarcane quality under the environmental conditions in Udawalawe. However, the current study did not evident a decrease in fertilizer leaching rates in the deep-draining water or changes in soil pH due to the application of SAP. This study may not fully capture the potential benefits of the SAP application under diverse weather conditions, as the experimental location did not receive prolonged drought during the study period, which could mask the effectiveness of both SAP and irrigation treatments.

Keywords: *Irrigation, Leaching, Sugarcane, Super-absorbent polymers*

INTRODUCTION

In the Dry Zone of Sri Lanka, sugarcane frequently faces extended dry spells from June to October, characterized by an average monthly rainfall of less than 50 mm during this dry period (De Silva *et al.*, 2017). Soil moisture deficiency during the initial stages of sugarcane cultivation leads to a substantial reduction in plant density, subsequently suppressing stem elongation and resulting in a significant decline in final yield (De Silva, 2007). In *Yala* season-commenced crops, typically planted during March and April, this phenomenon is more pronounced (Wijayawardhana *et al.*, 2014). Previous studies have shown that the sugarcane yield and sugar yield of rain-fed crops were reduced by 37% and 51% respectively due to drought (De Silva and De Costa, 2004). However, it should be noted that practising supplementary irrigation for rain-fed sugarcane can prevent the above yield reduction to a certain extent (De Silva and De Costa, 2004; Wijayawardhana *et al.*, 2015). Nevertheless, because of the cost associated with irrigation and the limited availability of irrigation water in the area during periods of low precipitation, the adoption of supplementary irrigation remains constrained among rain-fed sugarcane cultivators in Sri Lanka (Kodituwakku, 2017).

Soil moisture scarcity can be rectified to some extent by adjusting the timing of planting (Wijayawardhana *et al.*, 2017), changing cropping practices (De Silva *et al.*, 2012), and introducing new agricultural practices such as the application of soil amendments, compost, biochar and other soil moisture-absorbing materials (Wijayawardhana *et al.*, 2014; Duong *et al.*, 2017). Superabsorbent Polymers (SAPs), a popular soil moisture absorption material, is a unique granular product made from corn starch, known for its exceptional ability to retain moisture up to 400 times its dry weight (Chang *et al.*, 2010; Malik *et al.*, 2022; Patra *et al.*, 2022). SAPs have been shown to significantly enhance soil water retention capacity, particularly beneficial in water-scarce dry regions (Patra *et al.*, 2022; Radian *et al.*, 2022). Several studies conducted in Sri Lanka have shown the significant benefits of applying SAPs in agriculture (Fernando *et al.*, 2014; Rasanjali *et al.*, 2020; Rasanjali *et al*, 2023). It was revealed that the application of SAP at optimal doses improved soil properties, increased crop growth, and enhanced crop productivity (Shahrokhian *et al.,* 2013; Fallahi *et al.*, 2015). In addition to increasing water-holding capacity, SAP also mitigates nitrogen and mineral leaching from the soil (Islam *et al.*, 2014). Nevertheless, based on the literature evidence, it can be considered that soil moisture can be preserved for a longer duration, and the moisture content of the root zone soil can be augmented by SAP, thereby improving the overall efficiency of supplementary irrigation operations (Singh *et al.*, 2018). While super absorbent polymers (SAPs) offer significant benefits for enhancing soil water retention, several limitations have also been identified. For example, some research highlighted that the performance of SAPs is influenced by soil characteristics, as SAP mixed with larger soil particles sometimes leads to reduced water retention efficiency (Yu *et al.*, 2012). In addition, Malik *et al.* (2022) found that SAP particles tend to break down into smaller sizes after binding with soil particles, which reduced their anticipated water-holding capacity. Additionally, compacted soil can hinder the expansion of SAP particles, further diminishing their effectiveness in retaining moisture (John, 2011). As such, the effectiveness of SAP application may vary for different soil and crops under different environmental conditions (Shahrokhian *et al.*, 2013; Hasanvandi *et al.*, 2014; Fallahi *et al.*, 2015; Güneş *et al.*, 2016).

As demonstrated by Güneş *et al.* (2016), it showed that in fertile soils, SAP significantly improved sugarcane growth and yield while obtaining maximum benefits from irrigation water. This led to a reduction in irrigation costs for irrigation. Nevertheless, it may reduce the nitrogen (N) leaching from root zone soil. As such, the objectives of the study were to evaluate the effectiveness of super-absorbent polymers in extending irrigation intervals, thereby improving the growth and yield of sugarcane in Udawalawe, Sri Lanka and to evaluate their effect on the leaching fraction of nitrogen fertilizer.

MATERIALS AND METHODS

The experiment was conducted at the Sugarcane Research Institute (SRI) Udawalawe from June 2020 to July 2021. Two separate experiments were conducted; (i) an open field experiment and (ii) a pot experiment, in a protected house in order to determine the growth and yield performances of sugarcane, the effect on nitrogen leaching and soil pH variations due to SAP application, respectively. In both experiments, variety SL 96 128 was used.

Open-field experiment

The open-field experiment adopted a split-plot layout, with water regime (irrigation) and SAP treatments. The water regime was the main plot factor, while the application of SAP was the subplot factor. The main plot factor had four levels; 10-d, 15-d, 20-d, and 25-d irrigation interval. Each furrow was flooded for approximately 56 min for the application of 60 mm irrigation depth as per the properties of RBE soils in Udawalawe (Shanmuganathan, 1990; Wijayawardhana *et al.*, 2017). The subplot factor or SAP application had two levels; with SAP (SAP_1) and without SAP (SAP_0). SAP soil amendment was applied to each plot at a rate of 12.5 kg/ha as per the manufacturer's standards. Accordingly, the open-filed experiment was comprised of the following eight treatment combinations with three replicates.

Table 1: Treatment combinations applied for the experiment

Treatment combination	Description
T1	10-d irrigation interval with SAP
T2	15-d irrigation interval with SAP
T3	20-d irrigation interval with SAP
T4	25-d irrigation interval with SAP
T5	10-d irrigation interval without SAP
T6	15-d irrigation interval without SAP
T7	20-d irrigation interval without SAP
T8	25-d irrigation interval without SAP

SAP = Super absorbent polymer

The size of each plot was set at 120 m^2, 20 m in length with 5 rows. Sugarcane was planted with 3 budded 5 sets per meter (planting density = 15 buds per meter). Land preparation was carried out using the ridge and furrow system, with a 1% slope maintained along the furrow to facilitate proper drainage and optimize water distribution. Sugarcane cultivation was managed as per the recommendation of the Sugarcane Research Institute (SRI, 1991). The number of millable stalks, stalk diameter, stalk height and stalk weight were measured at harvesting time (365 d after planting, DAP) from 45 stalks in randomly selected 9 samples (5 × 9) in each plot. Soil moisture levels were measured at depths of 10 cm, 20 cm, and 40 cm across the root zone soil profile using an AquaPro AP-827 moisture logger. The aim was to assess the effect of SAP on soil moisture. Daily rainfall and pan evaporation data were obtained from the meteorological station located near the experimental site at the research farm of the Sugarcane Research Institute, Udawalawe.

Pot experiment

A pot experiment was also conducted to identify the effect of SAP application on nitrogen leaching. The experiment consisted of soil-filled 24 plastic buckets (130 L), established with a single sugarcane plant and arranged as per the complete randomized design (CRD) under a protected house. A total of 12 pots were treated with SAP (0.5 g of SAP at the planting time and mixed with the surface soil) and the other 12 served as the control. Nitrogen leaching from each pot was measured by collecting water samples from the deep drainage water (leachate) at 2-wk intervals until 4 months after planting. It was assumed that SAP would undergo biodegradation within 4 months. Nitrogen concentration in the leachate sample was measured using a UV-VIS Spectro-photo meter (Gross *et al.,* 1999). The total nitrogen content of each leachate was calculated using the below equation:

$$N_t = D \times N_s$$

where, N_t =Total nitrogen amount in the leachate (mg), D= total volume of deep drained water, N_s = Nitrogen concentration in leachate (mg/L).

Statistical analysis

The effects of irrigation intervals, SAP levels, and their interactions on the growth and yield parameters of sugarcane were statistically tested using the analysis of variance (Two way ANOVA) procedure at a 0.05 probability level. The Friedman test (a non-parametric test) was employed to assess stalk density at harvest (count data). Possible outliers were removed using the box and whisker method. The Shapiro-Wilk normality test (Royston, 1982) was conducted before performing each test to verify the fulfilment of normality assumptions. The significance of differences among treatments was evaluated using the Tukey test at α=0.05. The treatment effect of the pot experiment was determined by the student's t-test.

RESULTS AND DISCUSSION

Climatic conditions and soil moisture content

Variations in daily rainfall and evaporation observed during the study period are shown in Figure 01. The total rainfall that was received from the planting date (15th June 2020) to the harvesting date (16th June 2021) was 1440.8 mm. Concurrently, the total pan evaporation recorded during the study period was 1152.0 mm.

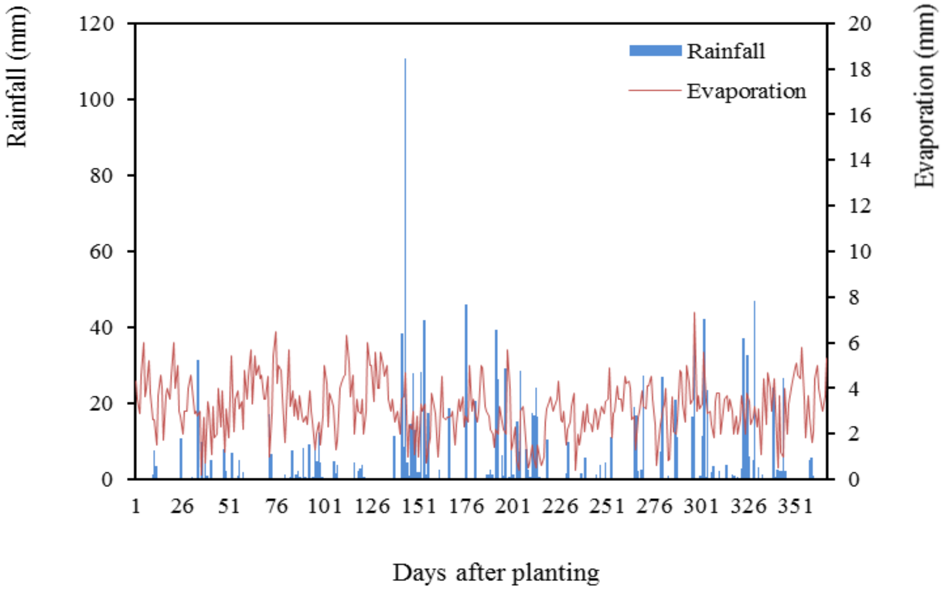


Figure 1: Daily rainfall and evaporation in the study area

It was observed that soil moisture levels were apparently high in SAP-applied plots, but statistically not significant at 0.05 probability due to the high variability of both data series (Figure 2).

Variation of cane yield

The results showed that different irrigation intervals had a significant effect on sugarcane yield (p=0.007), while the application of super absorbent polymer (SAP) had no significant effect on sugarcane yield (p=0.424; Table 2). However, the interaction between irrigation interval and SAP application showed a marginal effect on sugarcane yield (p=0.05).

The highest sugarcane yields were recorded (Table 3) for 10 days × SAP_1 combination (199.9 t/ha) which was statistically similar to the yield recorded by all other combinations except for 20 d × SAP_1.

The application of SAP did not lead to a significant improvement in yields at any irrigation interval level (Table 3). This shows that the application of SAP does not provide an opportunity to effectively modify the existing irrigation schedule. The 10-d irrigation interval is currently recommended for sugarcane plantations in Udawalawe (Shanmuganathan, 1990).

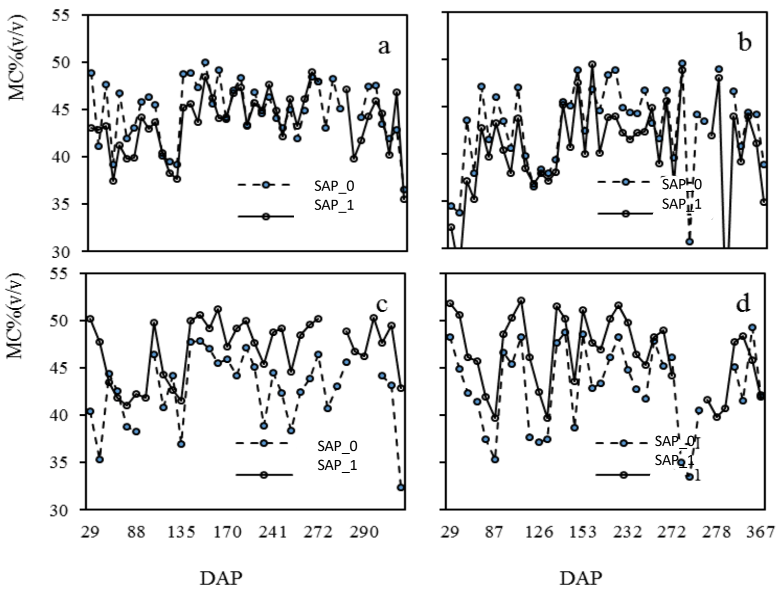


Figure 2: Average soil moisture levels of the soil during the study period (a, b, c and d indicate irrigation intervals with 10, 15, 20 and 25-d respectively, SAP_1= with SAP, SAP_0 = without SAP, MC% = Soil moisture in volume basis)

Table 2: Probability values (>F) for different parameters

Source of variation	Sugarcane yield	Stalk length	Stalk diameter	Stalk density
Irrigation	0.007	0.001	0.714	0.338
Super absorbent polymer (SAP)	0.424	0.106	0.511	0.627
Irrigation × SAP interaction	0.050	0.000	0.733	0.187

These findings are consistent with those of Santos and Mendonça (2013), who demonstrated that the application of SAP did not have a statistically significant effect on the growth and yield of sugarcane, particularly in conditions where monthly rainfall exceeded 50 mm. During the study period, the average rainfall at the experimental site was 120 mm (Figure 1).

Table 3: Variation of sugarcane yield, stalk length and stalk diameter due to the application of SAP under different irrigation intervals

Treatment combination	Sugarcane yield (t/ha)	Stalk length (m)	Stalk diameter (mm)
10 d × SAP_1	$199.9^{a}\pm10.6$	$3.57^{a}\pm0.12$	$26.6^{a}\pm0.14$
10 d × SAP_0	$176.7^{ab}\pm7.4$	$3.24^{bc}\pm0.06$	$26.1^{a}\pm0.64$
15 d × SAP_1	$181.0^{ab}\pm2.7$	$3.26^{bc}\pm0.05$	$26.3^{a}\pm0.53$
15 d × SAP_0	$199.0^{a}\pm12.4$	$3.45^{ab}\pm0.08$	$26.4^{a}\pm0.35$
20 d × SAP_1	$152.0^{b}\pm10.4$	$3.28^{bc}\pm0.05$	$26.6^{a}\pm0.28$
20 d × SAP_0	$172.2^{ab}\pm3.0$	$3.39^{ab}\pm0.05$	$26.8^{a}\pm0.26$
25 d × SAP_1	$165.1^{ab}\pm2.1$	$3.25^{bc}\pm0.05$	$26.6^{a}\pm0.12$
25 d × SAP_0	$166.8^{ab}\pm3.7$	$3.07^{c}\pm0.20$	$26.3^{a}\pm0.35$

Note: Mean values followed by the same letter are not significantly different at the 5% significance level, SAP_1 = with super absorbent polymer, SAP_0 = without super absorbent polymer

Variation of stalks length at the harvesting

Similar to the sugarcane yield, stalk length also exhibited a significant improvement in the 10 d × SAP_1 treatment compared to the other treatment combinations (Table 3). Notably, a significant increase of 10% in sugarcane stalk length (deference between SAP_1 and SAP_0) was observed in plots treated with a 10-d irrigation interval. The treatments 10 d × SAP_0 (3.24 m), 15 d × SAP_1 (3.26 m) and 15 d × SAP_0 (3.45 m) are statistically similar to each other but lower than the 10 d x SAP_1 treatment. It was noted that the lowest value of stalk length (3.07 m) was given in the treatment combination of 25 d irrigation interval without application of SAP, and could be considered as the most unfavourable treatment combination among the tested treatment combinations. As such, it can be concluded that the significant positive effect due to the application of SAP can only be observed from stalk length at 10-d irrigation intervals under the environmental conditions in Udawalawe.

Variation of stalk diameter at the harvesting

Stalk diameter was relatively consistent across all treatment combinations (Table 3). On average, stalk diameter was 26.4 mm.

Variation of stalk density at the harvesting

The analysis clearly showed that there were no significant effects on sugarcane stalk density due to the application of SAP or different irrigation intervals or their interactions at the harvesting time (Tables 2 and 4). On average, the stalk density was 106,616±4375 stalks/ha. Post hock test was not conducted.

Table 4: Stalks density variation due to application of SAP under different irrigation intervals, 10, 15, 20 and 25 d

Treatment	**Irrigation interval (d)**			
	10	**15**	**20**	**25**
SAP_0	103329±4499	118236±5871	104440±2121	103051±6461
SAP_1	112958±4174	109070±5821	96015±4931	105829±3255

SAP_0 = Without super absorbent polymer, SAP_1 = With super absorbent polymer

Sugarcane quality at the harvesting

The results depicted in Table 5 demonstrate that none of the sugarcane quality attributes exhibited significant changes at the 0.05 probability level. Even though the application of SAP significantly increased the fresh yield and stalk length of sugarcane with a 10-d irrigation interval, it did not have a positive impact on sugar production point of view. However the sugar yield was significant at 90% confidence (p=0.097) due to the application of SAP.

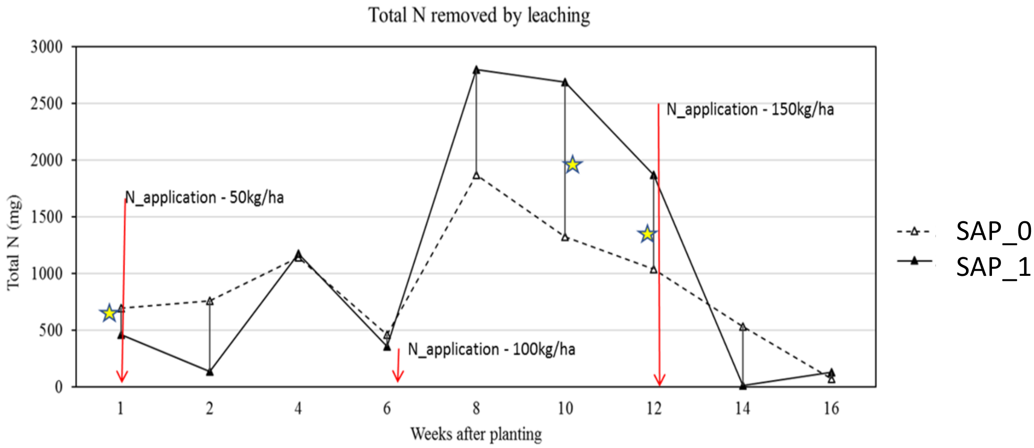
Table 5: Probability values (>F) for different parameters

Source of variation	**Sugar yield**	**Purity**	**POCS**
Irrigation	0.459	0.898	0.729
Super absorbent polymer (SAP)	0.097	0.736	0.601
Irrigation × SAP interaction	0.378	0.928	0.504

POCS = Pure obtainable cane sugar

Nitrogen leaching behaviour through soil profile (deep drainage water) with application of SAP

During the 10th and 12th wk after planting (4 wk after application of urea; 1st top dressing), SAP-applied pots showed significantly high nitrogen content in the leachate (Figure 3). However, it is difficult to form a strong conclusion about the nitrogen leaching behaviour after the application of SAP, as those pots showed a significant reduction of nitrogen content in the leachate during the first week



(Figure 3). A similar circumstance was observed by others. For example, Li *et al.* (2012) reported that the SAP had strong water absorption but did not significantly absorb nitrogen.

Figure 3: Variation of nitrogen (N) content in the drained water (leachate) during the early 4 months from the sugarcane planting; stars indicate the significant changes at 0.95 probability (α=0.05)

Variation of potential of hydrogen in deep drainage water due to application of SAP

Changes of pH levels in leachate water samples have not shown significant change between the samples with SAP applied and not applied (Figure 4). Similar results have been reported by others as well. For instance, the application of SAPs in leachate treatment has not resulted in notable changes in pH levels between treated and untreated samples (Pereira *et al.*, 2020). Another study (Makhtar *et al.*, 2023) mentioned that while SAPs effectively reduce other parameters such as turbidity and chemical oxygen demand (COD), the pH remains relatively stable, often slightly acidic, under various conditions. As such, the present study concluded that the soil pH level was not changed due to the application of SAP under sugarcane growing reddish brown earth soil in Udalawawe.

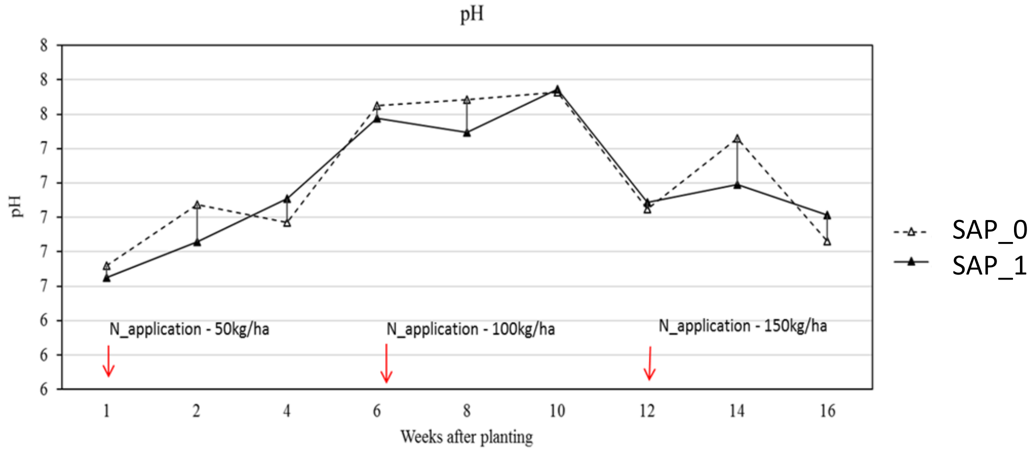


Figure 4: Variation of potential hydrogen (pH) in the drained water (leachate) during the early 4 months of the sugarcane planting

CONCLUSIONS

Current analysis revealed that the application of SAP cannot be used as a management tool for increasing irrigation intervals aiming at irrigation water saving. Nevertheless, the sugarcane quality (sugar yield) did not show a significant change with the application of SAP (sugarcane verity SL 96 128) in this experiment. However, different sugarcane varieties may perform in different ways on SAP applications. Furthermore, a clear effect on nitrogen leaching (deep drainage water) has not been demonstrated by the application of SAP. The pH of the deep-draining water remained unchanged following the application of SAP.

This study may not fully reflect the potential benefits of the SAP application under diverse weather conditions, as the lack of prolonged drought events experienced during the study period, and could create an unclear situation on the effectiveness of the SAP application. This highlights the need for further research across different years and planting seasons of *Yala* and *Maha* to provide strong recommendations.

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