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Effect of Municipal Solid Wastes on the Growth of Rocket and Spinach Plants

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Abstract: Municipal solid waste (MSW) as a plant nutrient supply was evaluated. Some of the solid waste was collected from Hail city, Kingdom of Saudi Arabia. The solid waste was fermented partially after removing its contents of stones and metals. Eight kg of a sandy soil were packed in a plastic pot. Rocket and spinach seeds were sown in three greenhouse pot experiments for each plant. In the first, a portion of the complete MSW was mixed with the sandy soil at 1, 2 or 3% before seedling in the upper portion of soil pot. In the second, a portion of the MSW was mixed with distilled water at ratio of 1:2 for 15 days then extracted. The solid extracted MSW portion was mixed with the sandy soil at 1, 2, or 3%, then five weeks after rocket and spinach emergence, a foliar spray technique was used to spray the water extract. The third experiment was fertilized using the conventional rate of NPK fertilization (0.597, 0.224 and 0.426 g pot^{-1} of super phosphate, potassium sulfate and urea, respectively). The plants were harvested three times. Growth parameters such as shoot fresh weight, shoot dry weight and the water content percentages were determined. The moisture content of rocket plants was approximately 0.8 g g^{-1} of plant and was not affected by the rate of MSW (complete or extracted). However, the MSW rates gave slightly higher moisture content than the NPK treatment. Similar results were obtained for spinach. The 1% of MSW (extracted) gave the greatest shoot fresh and dry weights among all treatments for rocket plants. The NPK and 3% of complete MSW gave higher shoot fresh and dry weights than other MSW rates for spinach plants. The NPK treatments gave the greatest spinach shoot fresh and dry weights among all extracted MSW treatments. The results obtained with spinach encourage using the complete MSW as a source for plant nutrients. For future study, higher rates of the complete MSW should be performed for defining the maximum need for spinach growth.

Key words: Municipal solid waste, plant nutrients, water extractant, complete municipal solid waste, extracted municipal solid waste, spinach, rocket, growth parameters

INTRODUCTION

Municipal solid waste (MSW) contains large amounts of organic matter that can be beneficial to growing plants. The MSW is mixed waste from residential, commercial, institutional and industrial sources[1,2]. Its typical composition includes paper, glass, wood, plastics, soils, chemicals, food waste, plant debris, metals, textiles and rock, with the organic materials making up 30-60% of all MSW[3]. Agricultural lands are excellent sites for beneficially using MSW as an organic soil amendment[3]. The percentage of organic matter in the soils of Saudi Arabia is very low. In addition, most agricultural cropping systems result in a depletion of the organic matter percentage. Soil organic matter acts as a sink and a source of nutrients in the soil system because it has a high nutrient-holding capacity. It also acts as a large pool for the storage of nitrogen, phosphorus and sulfur and has the capacity to supply these and other nutrients for plant growth[4]. Therefore, the application of MSW to agricultural soil can be a mean to increase the organic matter in agricultural soil and in some cases reduce the cost of MSW disposal. The nutrients contained in a waste will be mineralized gradually and become available for plants. There is considerable variation in the nutrient content of municipal wastes. The values are as follow: 0.4-3.6% N, 0.3-3.5% P_2O_5 and 0.5-1.8% K_2O[5]. Soil organic matter interacts with trace metals, often reducing their toxicity to plants. Moreover, the application of MSW to a soil can increase cation exchange capacity[6] and soil microbial[7] and enzymatic activities[8] in the soil.

Field crop responses to MSW amendments vary widely, from N deficiency in pepper (*Capsicum annuum* L.)[9] to 22% yield increases for snap bean (*Phaseolus vulgaris* L.)[10] and 38% yield increases for tomato (*Lycopersicon esculentum* Mill.)[2]. Similarly, N mineralization rates of MSW-amended soils from incubation studies have differed considerably, ranging

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from negligible mineralization rates[11] to recovery of 22% of MSW N[12]. However, It has been observed that application of MSW may lead to the immobilization of soil mineral N[13,14] and can cause N deficiencies in plants and depress crop yield[9]. Supplemental fertilizer N, in excess of that necessary to satisfy crop demand, may be necessary to obtain a suitable C:N ratios favorable to crop growth[15].

The literatures reviewed about the effect of MSW and its method of application on the growth of rocket and spinach plants are limited. Therefore, the objective of this work was to study the responses of rocket (*Eruca vesicaria* susp. *sativa*) and spinach (*Spinacia olercea*) to the MSW in comparison with conventional fertilization.

MATERIALS AND METHODS

Preparing the MSW: MSW was collected from Hail Province, Kingdom of Saudi Arabia. The stones and metals were removed then; the rest portion of the solid waste was fermented partially by spraying water to the raw solid waste (City Council of Hail, Personal communications). One portions of the MSW was mixed with distilled water at 1:2 ratios[16]. The mixtures were incubated at the room temperature under un-aerated conditions for 15 days then extracted. The analysis of the water extract is presented by Al-Redhaiman *et al.*[16].

Pot experiment: Pot experiments were conducted to evaluate the MSW as an organic fertilizer. A sandy soil used in this study was sampled from a surface layer (0.0-0.3 m depth) from the Agriculture and Veterinary College station, King Saud University, Al-Qassim. The soil was prepared by air-drying, crushing and sieving to pass through a 2 mm screen. The soil and solid waste were primarily characterized[17]. Three pot experiments were conducted during winter season (4/11/2002-28/2/2003) to study effect of the MSW fertilization methods on the growth of rocket (*Eruca vesicaria* susp. *sativa*) and spinach (*Spinacia olercea*). In the first experiment, the fermented municipal solid waste was mixed with 8 kg of the sandy soil at three rates 1.0, 2.0 and 3.0%, then packed in a plastic pot. Five seeds of either plants were sown in each pot. CMSW was used to refer to this experiment. In the second experiment, the solid extracted portion of MSW was mixed with 8 kg of the sandy soil at rates of 1.0, 2.0 and 3.0% then packed in a plastic pot. After 37 days of the experiment initiation, the extract of water was sprayed on the leaves of the plants in ratio 1:2:3. Another application of the extract was sprayed after 67 days. EMSW was used to refer to this experiment. For evaluation of the significant of the organic fertilization as a source of plant nutrients, a treatment of NPK was used at rates of 0.597, 0.224 and 0.426 g pot^{-1} of super phosphate, potassium sulfate and urea, respectively. A complete summary for description of the experiment is shown in Table 1. Irrigation water was added when the soil water matric potential reaches 10 KPa using tap water. The water matric potential was adjusted using a tensoimeter. Both plants were cut three times (25/12/2002, 21/1/2003 and 28/2/2003). Vegetative fresh weight, dry weight of the shoots and its dry matter percentages were recorded.

Table 1: A description for the treatments of fertilization used in the study

Treatments	Description
MSW1	Unextracted Solid MSW at 1%
MSW2	Unextracted Solid MSW at 2%
MSW3	Unextracted Solid MSW at 3%
EMSW1	Extracted MSW using water at 1%+ extract spraying
EMSW2	Extracted MSW using water at 2%+ extract spraying
EMSW3	Extracted MSW using water at 3%+ extract spraying
NPK	Mineral fertilization

Data analysis: The differences among the treatments were tested using the least significant differences (LSD) at 5% level according to Bisher and El-Robby[18].

RESULTS AND DISCUSSION

Effect of the MSW on the growth of rocket: Sandy soils have some problems on plant growth. They suffer from the lack of organic matter and plant nutrients. Incorporation of MSW as a source of organic matter and nutrients could alleviate some of these problems[19]. To minimize the effect of calcium carbonate of the soil on the availability of micronutrients, a foliar spray technique for the fertilizers application is recommended[20]. Therefore, incorporation of the MSW and spraying its extract were used in the present study. The results of CMSW and EMSW experiments are presented and discussed in the following section. Figure 1a shows the effect of CMSW rates on the moisture content of the fresh shoot of rocket in comparison with the NPK for three consecutive cuts. The moisture contents ranged from 0.78 to 0.85 g g^{-1} of shoot fresh weight for the rates of CMSW for the three cuts. These results do not show a consistent trend for neither the treatments nor the time of cutting. The CMSW treatments gave moisture content slightly higher than the NPK treatments. It can be concluded that the CMSW rates do not affect the soil water-holding capacity which affects the water plant uptake. In addition, the plants were not subject to water stress during the growing season. Similar results for the moisture contents of rockets were obtained when the EMSW treatments were applied (Fig. 1b).

Table 2: The shoot fresh weight (g pot^{-1}) of rocket and spinach under different treatments with the LSD 95%

			CMSW (%)			EMSW (%)			
Plants	Cut	NPK	1	2	3	1	2	3	LSD 95%
Rocket	1	22.27	4.71	8.35	5.35	7.21	6.38	7.07	6.39
	2	15.29	16.56	19.72	10.43	24.51	11.30	14.39	12.41
	3	9.69	--	16.71	14.67	17.45	19.25	24.99	4.09
	Total	47.25	--	44.78	30.45	49.17	36.93	46.45	10.38
Spinach	1	8.38	10.01	10.49	17.53	9.16	11.04	5.87	2.39
	2	21.24	13.19	14.20	19.53	15.27	16.98	13.53	9.67
	3	44.41	26.83	22.20	31.47	29.22	35.92	33.81	10.46
	Total	74.03	50.03	46.89	68.53	53.65	63.94	53.21	17.29

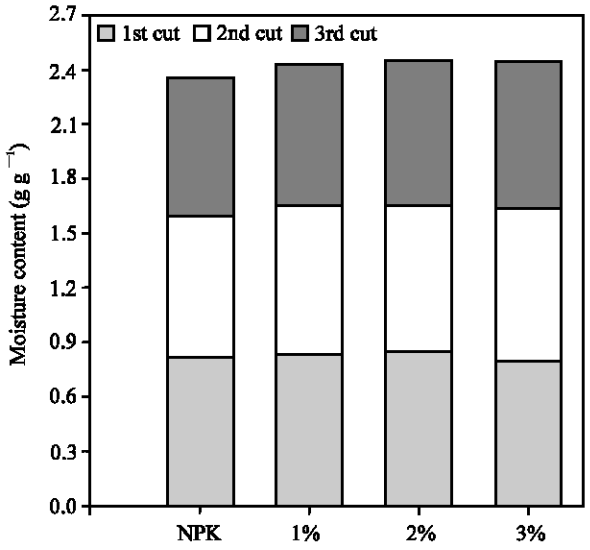

Fig. 1a: Effect of CMSW and mineral fertilization on the moisture contents of rocket for three cuts (average of three replicates)

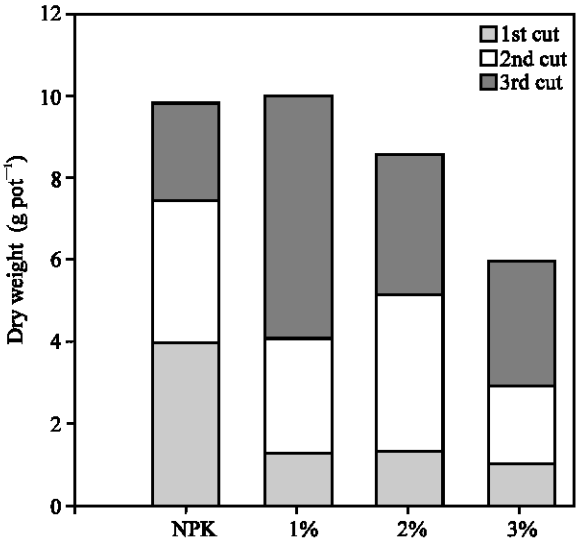

Fig. 2a: Effect of CMSW and mineral fertilization on the dry weight of rocket for three cuts (average of three replicates)

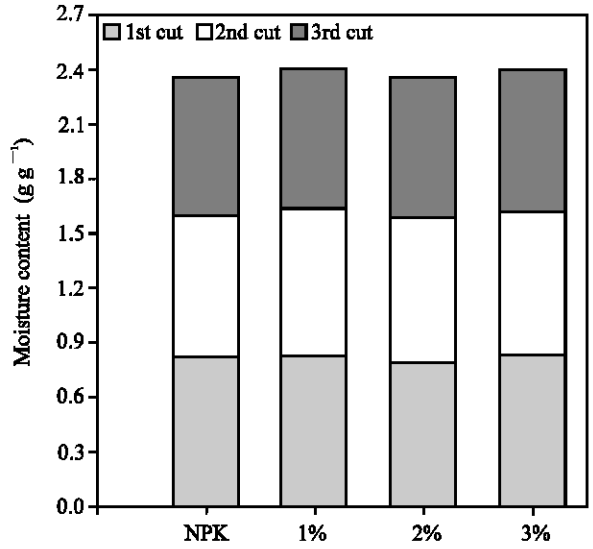

Fig. 1b: Effect of EMSW and mineral fertilization on the moisture contents of rocket for three cuts (average of three replicates)

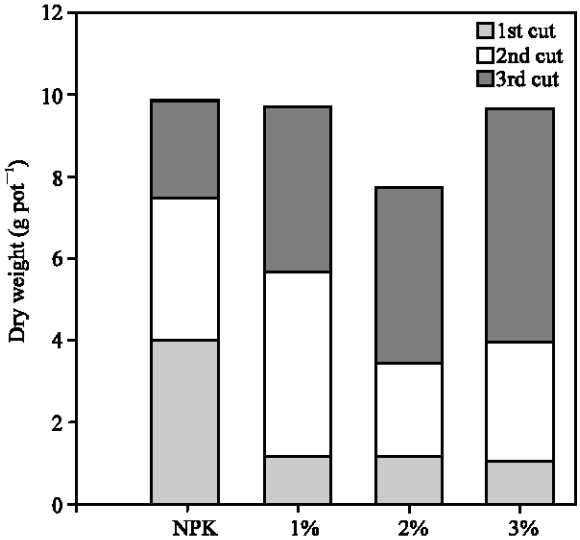

Fig. 2b: Effect of EMSW and mineral fertilization on the dry weight of rocket for three cuts (average of three replicates)

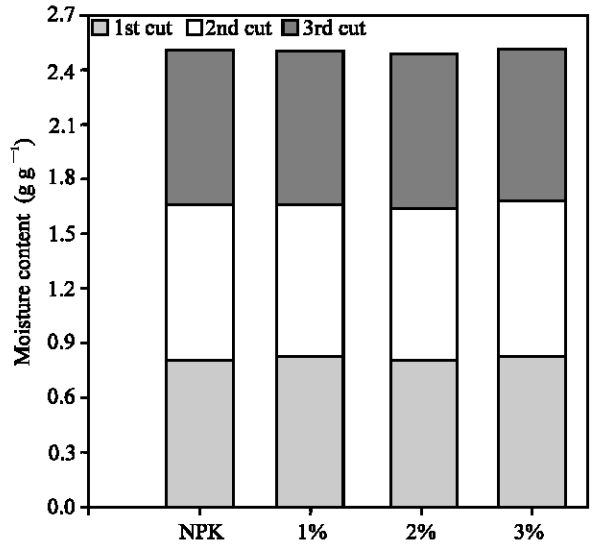

Fig. 3a: Effect of CMSW and mineral fertilization on the moisture contents of spanish for three cuts (average of three replicates)

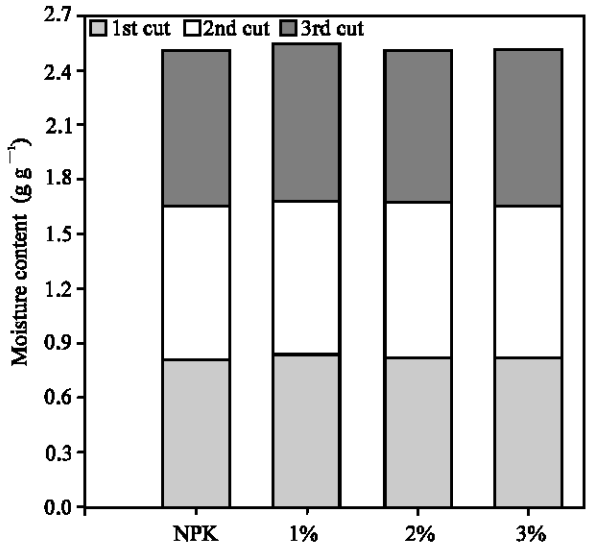

Fig. 3b: Effect of ESMW and mineral fertilization on the moisture contents of spanish for three cuts (average of three replicates)

The total shoot fresh weights of rocket were 44.78 and 30.45 g pot^{-1} for 2 and 3% of the CMSW (Table 2). The NPK treatment ranked the first among the treatments studied. Moreover, the NPK treatments gave the greatest shoot fresh weight for the first cut in comparison to the CMSW treatments. This later results was due to the high solubility of NPK in the mineral fertilization. The contribution of the NPK treatments for plant nutrients decreased as time increased. For example, the shoot fresh weights were 22.3, 15.3 and 9.7 g pot^{-1} for the first, second and third cut, respectively. Usually, the organic fertilizer, i.e. CMSW, requires time to be decomposed and release the plant nutrients. The contribution of CMSW as a source for plant nutrients increased as time increased. For example, the shoot fresh weights under 3% CMSW were 5.4, 10.4, 14.7 g, for the first, second and third cut, respectively. Therefore, it can be concluded that using CMSW as an organic fertilizers enhanced the rocket growth in the sandy soil. The results presented here are supported by the finding of Tisdall[4] who reported that the organic matter acts as a large pool for the storage of nitrogen, phosphorus and sulfur and has the capacity to supply these and other nutrients for plant growth. The LSD values revealed that the difference in the shoot fresh weight between the NPK and 3% of CMSW was significant for the present study. Table 2 also shows the effect of the extracted MSW (EMSW) on the shoot fresh weight. Results show that 1 and 3% rates enhanced the growth and gave greater fresh weight than both the NPK and 2% rates. The NPK gave the greatest shoot fresh weight for the first cut as the CMSW treatments. The shoot fresh weight using the EMSW treatments increased as the time of cutting increased. These results are in agreement with the effect of CMSW treatments. The average of the shoot fresh weight for the CMSW and EMSW were 37.6 and 44.2 g pot^{-1}, respectively. Both averages are less than the shoot fresh weight of NPK treatment. The increase in the growth of rocket plants might be partially attributed to the increase in the amounts of available nutrients in the soil due to the EMSW application rates. Ahmed *et al.*[21] reported similar results for wheat plants when water-hyacinth was mixed with a calcareous soil. In addition, it is obvious that extraction of the MSW then spraying the extract enhanced the nutrient availability for the rocket plants. Al-Redhaiman *et al.*[16] found that the water extract of the municipal garbage gave the highest value for shoot fresh for lettuce plants in comparison with conventional mineral fertilization.

The shoot dry weight behaved similarly to shoot fresh weights. The dry weight decreased as the percentage of CMSW increased (Fig. 2a). In the case of CMSW, the 1% rate gave the greatest shoot dry weight among the NPK and other rates. The dry weight of rocket plants for the three cuts behaved similar to the fresh weight for the EMSW treatments (Fig. 2b).

Effect of the MSW on the growth of spinach: It was obvious that the moisture contents for the three rates of CMSW were similar (Fig. 3a). Further, the results of moisture contents using CMSW rates were less than using mineral fertilization of NPK. It can be concluded that

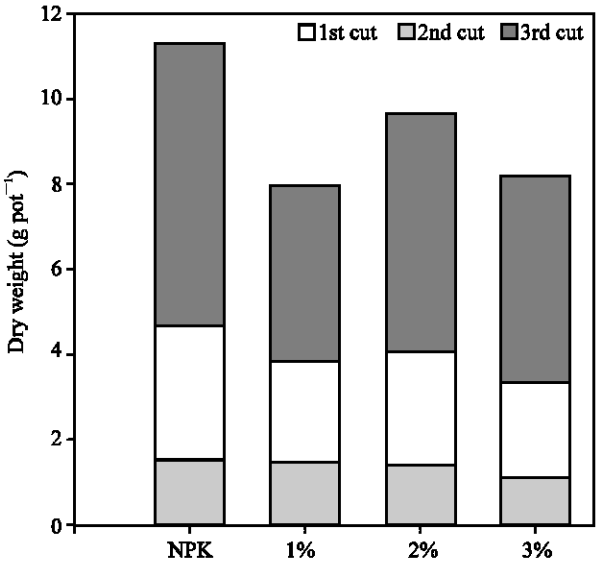

Fig. 4a: Effect of CMSW and mineral fertilization on dry weight of spanish for three cuts (average of three replicates)

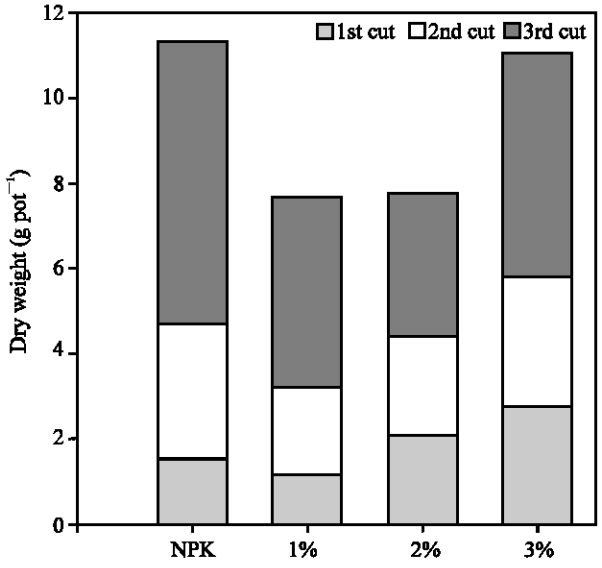

Fig. 4a: Effect of EMSW and mineral fertilization on dry weight of spanish for three cuts (average of three replicates)

the CMSW rates do not affect the soil water-holding capacity which affects the water plant uptake. In addition, the plants were not subject to water stress during the growing season. The water contents for the three cuts ranged between 0.80 to 0.84 g g^{-1} of fresh weight of spinach. The results of water contents for the spinach are similar to that reported for the rocket plant. The moisture contents ranged between 0.83 to 0.85 g g^{-1} for the three cuts using the rates of EMSW (Fig. 3b). The water content using the NPK fertilizers was slightly greater than both CMSW and EMSW fertilizers.

The shoot fresh weights (Table 2) revealed an increase as the time increased for all treatments. For example, the weights were 10.01, 13.19 and 26.63 g pot^{-1} for the three consecutive cuts under 1% of the CMSW. The effect of NPK on the fresh weight of spinach was positive while its effect on the rocket was negative. These results could be attributed to the growth of roots of each plant where the root growth of spinach was slower than the rocket roots. The NPK treatments gave the greatest total shoot weight among all treatments and the 2% of CMSW gave the lowest. It is obvious that the rates of MSW do not contain enough nutrient to enhance the spinach growth. So, it is recommended using more than 3% of the CMSW for greater growth of spinach plant. The average shoot fresh weight of CMSW and EMSW were 55.2 and 56.9 g pot^{-1}, respectively. This result is in agreement with the result of rocket. The differences in the total fresh weights between the NPK and 1% (CMSW and EMSW) were significant at 95% level.

The NPK and 3% of the CMSW gave similar dry shoot weights. The data showed also an increasing in the dry weight as the percentage of CMSW increased (Fig. 4a). The later results occurred for the three cuts. The positive effect of either the NPK or 3% of the CMSW was due to the high concentration of macronutrients such N, P and K. Harris *et al.*[5] found a considerable variation in the nutrient content of municipal wastes. Their reported values are as follow: 0.4-3.6% N, 0.3-3.5% P_2O_5 and 0.5-1.8% K_2O. The effect of EMSW rates not showed a clear trend for the dry weights of shoot (Fig. 4b). The NPK treatments gave the greatest dry weight among the EMSW rates. The later results were obvious in the third cuts.

MSW of Hail City, Kingdom of Saudi Arabia, was used as an organic fertilizer. The MSW was mixed with sandy soil in one experiment. In another experiment, the MSW was water extracted then solid portion was mixed with sandy soil and the extract was sprayed on the plant leaves of rocket and spinach. The NPK was used for a comparison. A high rocket yield was obtained when the water extract of MSW was sprayed on the leaves and the solid extracted portion of MSW was mixed with the sandy soil. The previous condition of using the extracted MSW gave slightly higher shoot fresh weight than the mineral fertilization for the rocket plants. Therefore, it is recommended using the later technique of organic fertilization for the rocket. The spinach shoot fresh weight increased as the rate of MSW (without extraction) increased. The NPK fertilization gave greater shoot fresh

weights than any MSW rates. More research work is needed to define the optimum rate of the MSW for spinach crop.

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