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Nitrogen fertilization on topdressing and soil water replacement levels on carrot crop yield

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Abstract

Nitrogen is a fundamental nutrient required in large quantities for carrots, which raises concerns about the right time and doses to be used. Although irrigation is also an essential practice for crop success, the deficit or excess of water can provide unfavorable conditions for the development of carrots. This work was carried out aiming at evaluating the effect of nitrogen fertilization on topdressing and soil water replacement levels on carrot yield. The experiment was conducted at Federal Institute of Education, Science, and Technology of the Triângulo Mineiro (IFTM) – Uberaba Campus, MG, Brazil, in a 4 × 4 factorial and randomized blocks involving four nitrogen doses applied to the topdressing (0 kg ha^{-1}, 42 kg ha^{-1}, 84 kg ha^{-1}, and 126 kg ha^{-1}) and four water replacement levels (70 %, 100 %, 130 %, and 160 %) based on the estimated values of the ETc of the crop. The interaction was significant only for the root diameter variable. Among the results, we can see that the N dose for the 119.4 kg ha^{-1} topdressing was the one that provided the maximum number of commercial roots, while soil water replacement of 86.94 % induced maximum total productivity.

Keywords: *Daucus carota.* Irrigation management. Production.

Introduction

The carrot (*Daucus carota*) is a vegetable of the Apiaceae family, belonging to the tuberous roots group. It has much food importance due to its high nutritional value, being an important source of vitamin A. In addition, it has a large amount of vitamin C, vitamin E, vitamin B1, vitamin B2, fiber, and minerals such as potassium, phosphorus, calcium, magnesium, and iron (NICK; BORÉM, 2016).

In Brazil, the main producers are the states of Minas Gerais, São Paulo, Rio Grande do Sul, Paraná, Bahia, and Goiás, which, together, are responsible for 90 % of the national production, equivalent to approximately 760 thousand tons in an area of 24 thousand hectares and average productivity of 30 t ha^{-1}. These results show the great importance of culture to the Brazilian horticultural sector (IBGE, 2017).

Due to the interest in supplying the market and the consumer's demands, the cultural management of vegetables has been increasingly improving, a fact that also occurs in the carrot culture, highlighting the management of fertilization (LIGHT *et al*., 2009).

Nitrogen appears as a fundamental nutrient among those required by the culture, being used in large quantities, which worries producers as to the moment and the correct doses to apply to the crop. This nutrient has an essential character and is a constituent of many components of the plant cell; hence, its deficiency impacts directly on the inhibition of plant growth (TAIZ *et al.,* 2017).

Besides fertilization, irrigation is an essential practice for crop success since the development of carrots is strongly influenced by soil moisture, which can affect both the increase in productivity and the quality of the roots. However, the deficit or excess of water can provide unfavorable conditions for the development of carrots and cause a drop in productivity (LIMA JÚNIOR *et al.*, 2011).

In Brazil, particularly in the regions where this vegetable is grown in Minas Gerais, information on carrot production, especially the ideal time and amount of irrigation and fertilization, are still quite controversial.

That said, this work was carried out with the objective of evaluating the effect of nitrogen fertilization on the topdressing and soil water replacement levels on carrot yield.

Material and methods

This research was developed at the Fruticulture sector of the Federal Institute of Education, Science, and Technology of the Triângulo Mineiro, located in the municipality of Uberaba/MG, at 795 meters above sea level, latitude 19° 39' 19" S and longitude 47° 57' 27" W, average annual rainfall of 1,600 mm, average annual temperature of 23.2 °C, and average relative humidity of 68 % (VALLE JUNIOR *et al.*, 2010). The climate is classified according to Köppen as AW, hot tropical, with cold and dry winters.

The soil of the experimental area was classified as dystrophic red latosol (EMBRAPA, 2006), with a sandy loam texture, whose chemical characteristics are shown in Table 1.

The experiment was arranged in a 4 × 4 factorial in randomized blocks (RBD), with four replications, the treatments were the combination of four doses of nitrogen in topdressing (0 kg ha^{-1}, 42 kg ha^{-1}, 84 kg ha^{-1}, and 126 kg ha^{-1}) and four levels of water replacement in the soil (70 %, 100 %, 130 %, and 160 %) from the estimated values of the ETc of the crop), in a total of 64 plots. Each plot consisted of two beds of 1.1 meters × 3.0 meters each, containing two planting rows spaced 0.20 meters apart. The useful plot was constituted by the central meter of each bed of the plot, in a total of 2.2 m^2.

The cultivar used was Natuna, a winter cultivar widely distributed in the producing regions of Minas Gerais. Its cycle lasts from 125 to 135 days, and has extremely smooth and cylindrical roots, an orange color, and excellent tip closure. Its good foliar architecture facilitates cultural treatments and mechanized harvesting (BEJO, 2019).

The sowing was on July 9, 2019, with a density of 80 seeds per meter. During the development of the culture, we thinned the bed to reduce the density to 20 plants per meter. Harvest took place on October 26, 2019, 110 days after sowing.

Table 1. Results of the chemical analysis of the soil used in the experiment.

pH in H_2O	Al^{3+}	Ca^{2+}	Mg^{2+}	H + AL	SB	t	T
	cmol$_c$.dm^{-3}						
6.5	0.0	2.7	0.8	1.4	3.9	3.9	5.3
K	**P**	**P_rem**	**V**	**m**	**M.O**	**Sand**	**Clay**
mg.dm^{-3}		mg.L^{-1}	(%)		dag.kg^{-1}	(%)	
145	49.9	29.8	73.4	0.0	1.7	73.0	17.0

*Analysis performed by the EPAMIG Soil Analysis Laboratory. SB is the sum of exchangeable bases; t is the effective CTC; T is the CTC at pH 7.0; V is base saturation; m is the aluminum saturation.

Source: Elaborated by the authors (2019).

The planting fertilization was carried out before sowing with 36 kg ha^{-1} of nitrogen, 64 kg ha^{-1} from K_2O is 240 kg ha^{-1} from P_2O_5. We fertilized the topdressings using doses of 42 kg ha^{-1}, 84 kg ha^{-1}, and 126 kg ha^{-1} of nitrogen (treatments) and 96 kg ha^{-1} from K_2O, both divided at 20 and 40 days after crop emergence.

We collected meteorological data with a digital thermohygrometer and a São Izidro model rain gauge installed at the experiment site. Irrigation was carried out by four micro-sprinklers installed in each plot, with an application intensity of 8.32 mm h^{-1}. The reference evapotranspiration was estimated using the Hargreaves model (Equation 1) and the evapotranspiration of the crop and raw water blade was obtained through equations 2 and 3.

$$ETo = 0.0023\ (Tmed + 17.8) \times (Tmax - Tmin)^{0.5} \times Ra \times 0.408 \quad (1)$$

$$ETc = ETo \times Kc \times Ks \quad (2)$$

$$LB = \frac{ETc}{Ea \times CUD} \quad (3)$$

at which:
ETo = reference evapotranspiration (mm day^{-1}); Tmin = minimum temperature (°C); Tmax = maximum temperature (°C); Tmed = mean temperature (°C) and Ra = radiation at the top of the atmosphere (MJ m^{-2}day-1); ETc = crop evapotranspiration (mm day^{-1}); Kc = crop coefficient; Ks = moisture coefficient; LB = gross irrigation depth (mm); Ea = system application efficiency (decimal) and CUD = system uniformity coefficient (decimal).

The radiation values at the top of the atmosphere were obtained following the recommendation of Doorenbos and Pruitt (1975). The adopted crop coefficient was proposed by Oliveira *et al.* (2002). During the entire experiment period, a value of 1 was assumed for the soil moisture coefficient; for the parameters of application efficiency and coefficient of uniformity of the system, values of 0.90 and 0.78 were adopted, respectively.

Table 2 shows the total values of the blade applied in each treatment. It is also possible to observe the daily values of reference evapotranspiration (ETo) and crop evapotranspiration (ETc) until the end of the experiment (FIGURE 1).

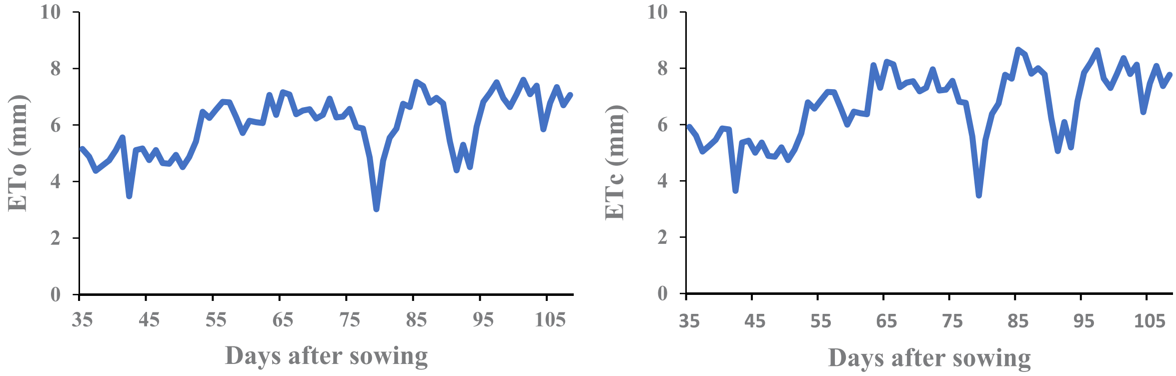
In a study carried out by Santos *et al.* (2009) in the Pernambuco agreste, a total blade value of 811.84 mm was found for a 98-day cycle.

Table 2. Values of the total blade applied in each treatment

Levels of water replacement (%)	Blade Applied (mm)
70	486.18
100	694.54
130	902.90
160	1111.3

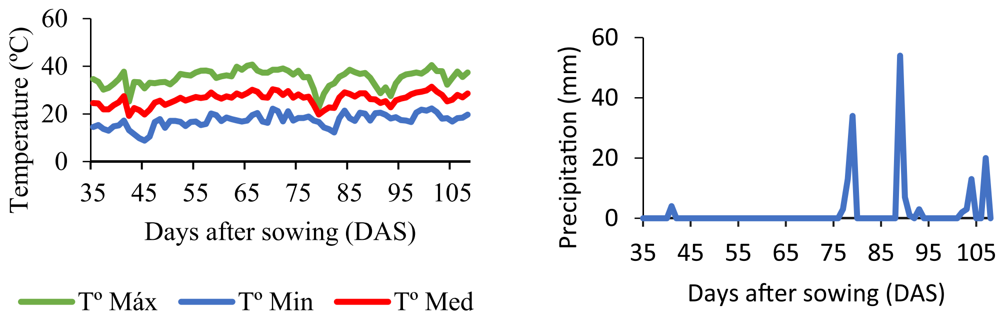
Source: Elaborated by the authors (2019).

Figure 1. Daily values of ETo and ETc



Source: Elaborated by the authors (2019).

Figure 2. Maximum, minimum, and average temperature values and precipitation



Source: Elaborated by the authors (2019).

During the application of the treatments, there was accumulated precipitation of 157 mm. At 89 days after the sowing, there was a precipitation of 54 mm, and the precipitations were more frequent at the end of the crop cycle. On rainy days, the precipitation was discounted from irrigation management values. In the period evaluated, the temperature ranged from 8.8 °C to 40.7 °C, with an average of 26.25 °C. Vieira and Pessoa (2008) recommend temperatures between 10 °C and 15 °C to help root elongation. Temperatures above 21 °C stimulate the formation of short roots. Also according to the authors, temperatures above 30 °C reduce the vegetative cycle of the crop, a fact that occurred in the experiment, showing a reduction from 125 to 135 days to 108 days (FIGURE 2).

The characteristics evaluated were: diameter and length of the roots; the total number of roots; the number of commercial roots; total productivity; commercial productivity; commercial classification of roots; pH and shoot dry mass.

We measured the diameter and the length, and identified the commercial classification of the roots using 20 randomly selected roots per plot. The diameter was measured with the aid of a digital caliper with millimeter precision, the length was measured with the aid of a ruler, and the commercial classification of the roots was performed according to Table 3 as per CEAGESP (2019).

For the total number of roots, we considered all roots harvested from the useful area of each plot. For the number of commercial roots, we considered all the roots of the useful area of each plot that was longer than 10 cm and free from cracks, bifurcations, mechanical damage, rot, and green shoulder.

Total productivity was expressed in t ha^{-1} and was constituted by the mass of all the roots harvested from each plot. Commercial productivity was also expressed in t ha^{-1} and consisted of all the commercial roots of each plot.

The dry mass of the aerial part was obtained by 20 plants randomly selected from the useful plot at the time of harvest. We got the pH variable by taking the same 20 roots we used to obtain root diameter and length in the laboratory.

All parameters were submitted to analysis of variance through the statistical program Sisvar version 5.6 (FERREIRA, 2014). Treatment effects, when significant at 5 % probability, were studied by regression analysis.

Table 3. Commercial classification of carrots in terms of length

Class	Length (cm)
10	10 to 14
14	14 to 18
18	18 to 22
22	22 to 26

Source: Adapted from CEAGESP (2019).

Results and discussion

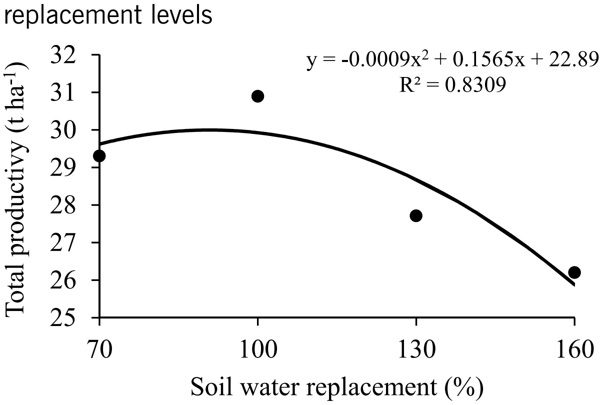
For the variables: total productivity, commercial productivity, root length, root diameter, and numbers of commercial roots, there was a statistical difference (p < 5 %). There was an interaction between the levels of soil water replacement and the nitrogen doses only for the root diameter variable. The total number of roots, shoot dry mass, and pH did not show any significant difference between the treatments studied.

Total productivity was influenced by soil water replacement levels and nitrogen doses when studied separately. The water replacement level of 86.94 % provided the highest total productivity, 29.69 t ha^{-1} (FIGURE 3).

In work conducted by Silva *et al.* (2011) with irrigation levels of 30 %, 60 %, 90 %, 120 %, 150 %, and 180 %, we found that the level of 180 % provided the best productivity result (67.4 t ha^{-1}). Silva (2016), adopting irrigation levels of 60 %, 80 %, 100 %, and 120 %, found that the replacement level that provided the highest total productivity value was 120 %, obtaining an average increase of 48 % to more in productivity.

For topdressing nitrogen doses, a linear increase in total productivity was observed as a function of the increase in the doses (FIGURE 4).

Figure 3. Total productivity as a function of soil water replacement levels



Source: Elaborated by the authors (2019).

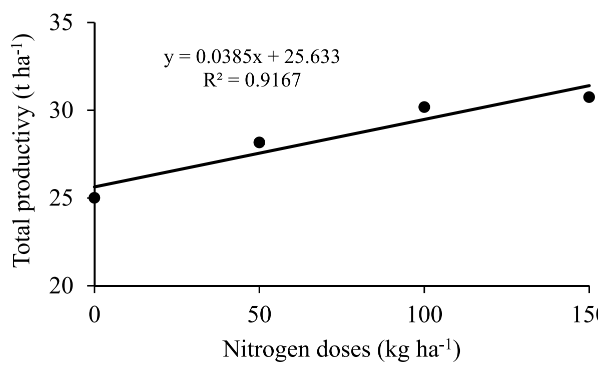
For each kilogram of nitrogen applied, there was an increase of 38.5 kg ha^{-1} in the total yield of carrots.

When evaluating the effect of nitrogen dose in the topdressing in summer carrots, Ávila *et al.* (2016) found that 73 kg ha^{-1} reached maximum productivity of 36.7 t ha^{-1}. According to the authors, a higher dose had a deleterious effect.

Colombari *et al.* (2018), when evaluating different doses and forms of splitting, found that 102 kg ha^{-1} and 138 kg ha^{-1} doses caused the highest yields of 107.7 t ha^{-1} and 117.66 t ha^{-1}, respectively.

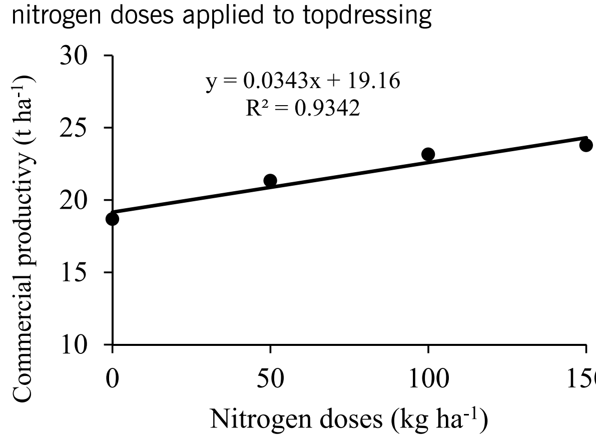
Commercial productivity was influenced only by the topdressing nitrogen doses, showing a linear increase as a function of the nitrogen addition (FIGURE 5). For each kilogram of

Figure 4. Total productivity as a function of topdressing nitrogen doses



Source: Elaborated by the authors (2019).

Figure 5. Commercial productivy as a function of nitrogen doses applied to topdressing



Source: Elaborated by the authors (2019).

nitrogen applied, there was an increase of 34.3 kg ha^{-1} in commercial productivity.

When testing doses of NPK 20-0-20 fertilizer on topdressing, Light *et al.* (2009) observed that 229.1 kg ha^{-1} showed maximum productivity of 27.5 t ha^{-1}, which is higher than the result found in this work, in which the maximum commercial productivity found was 23.78 t ha^{-1}.

The root length variable was influenced only by the soil water replacement levels, observing a linear decrease as a function of the increase in replacement levels (FIGURE 6). For each unit increase in the soil water replacement level, there was a 0.1 % reduction in root length.

Palharin *et al.* (2012), in Cascavel/PR, observed an increase in commercial root length in response to increasing water replacement. This result differed from that found by Cunha *et al.* (2016), for whom replacement levels of 50 %, 75 %, 100 %, and 125 % did not significantly influence root length.

Regarding the commercial classification of the roots, we verified that the plants irrigated with the water replacement levels studied produced class 14 roots (14 cm to 18 cm), with lower levels producing greater length values and greater levels producing smaller length values.

According to Lana and Vieira (2000), the Brazilian market prefers roots from 15 cm to 22 cm in length; therefore, the average length of 17.16 cm obtained in this work is within the standards of carrot marketing in Brazil.

For the variable root diameter, there was an interaction between the levels of water replacement in the soil and the doses of nitrogen on topdressing. This result was significant for replacement levels when evaluated at 0 kg ha^{-1} dose and for topdressing nitrogen doses when studied at the replacement level of 160 %.

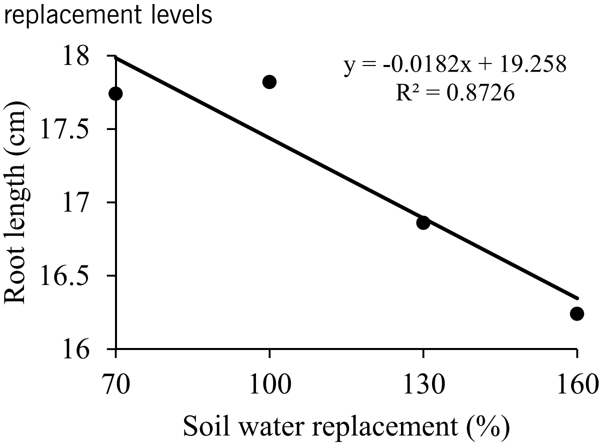
At a dose of 0 kg ha^{-1}, the replacement level of 108.33 % provided a maximum root diameter of 34.83 mm (FIGURE 7).

At the water replacement level of 160 %, we can observe a linear increase in the diameter of the roots as a function of the increase in the nitrogen doses in topdressing (FIGURE 8).

When studying nitrogen doses and soil water tensions in the sweet pepper crop, Santos (2019) observed that the fruit diameter variable showed a significant difference only for soil water tensions.

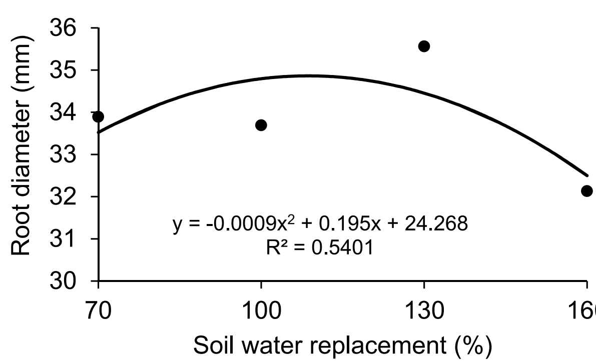
The number of commercial roots was also influenced only by topdressing nitrogen doses, and the rate of 119.4 kg ha^{-1} provided a maximum number of commercial roots of 54.8

Figure 6. Root length as a function of soil water replacement levels



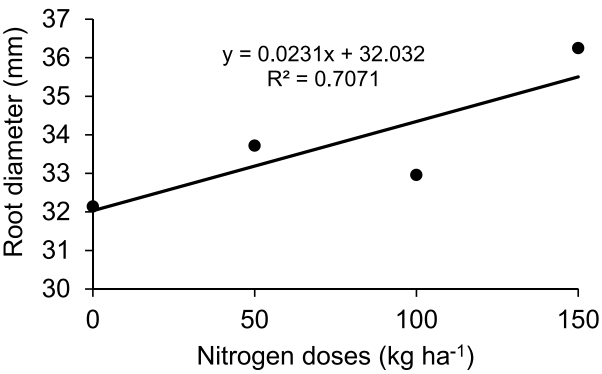
Source: Elaborated by the authors (2019).

Figure 7. Root diameter as a function of soil water replacement levels at a dose of 0 kg N ha^{-1}



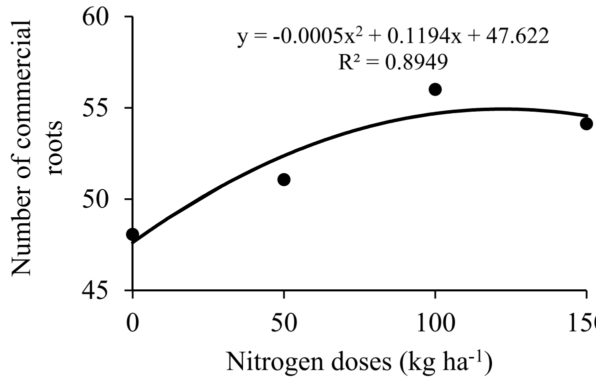
Source: Elaborated by the authors (2019).

Figure 8. Root diameter as a function of topdressing nitrogen doses at 160 % soil water replacement level



Source: Elaborated by the authors (2019).

Figure 9. Number of commercial roots as a function of topdressing nitrogen doses



Source: Elaborated by the authors (2019).

(FIGURE 9). From this dose onwards, there was a decrease in the number of commercial roots.

Light *et al.* (2009), testing doses of NPK 20-0-20 fertilizer in topdressing, reported a linear growth in the number of marketable roots as a function of increasing doses of fertilizer.

Just like the one found by Luz *et al.* (2009), who tested doses of NPK 20-0-20 fertilizer in topdressing, in the present work, there was no effect of topdressing fertilization on the total number of carrot roots.

The variable dry mass of the aerial part was not significantly influenced by the treatments studied, with an average of 7.50 g plant^{-1}. Colombari *et al.* (2018), evaluating splitting and topdressing nitrogen doses, found similar results, obtaining maximum values of 6.77 g and 9.42 g per plant at the highest rates of the splitting used. Different results were obtained by Silva *et al.* (2011) who, studying soil water replacement levels of 30 %, 60 %, 90 %, 120 %, 150 %, and 180 %, found an increase in shoot dry matter with increasing water replacement levels.

The pH also did not change depending on the treatments studied, with an average of 6.14. Colombari *et al.* (2018), when evaluating the splitting and doses of nitrogen in topdressing, in the splitting 1/3 + 1/3 +1/3, also did not find a significant difference in pH as a function of the doses, with an average of 6.22.

Conclusion

Commercial productivity showed a linear increase as a function of the increase in nitrogen doses, and 119.4 kg ha^{-1} was the dose that provided the maximum number of commercial roots.

The replacement level of 86.94 % provided maximum total productivity, and the length of the roots increased linearly with the addition of water replacement levels.

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