

Substrate Nutrient Retention and Growth of Container-grown Plants in Clinoptilolitic Zeolite-amended Substrates

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SUMMARY. Downy jasmines [*Jasminum multiflorum* (Burm. f.) Andr.] and areca palms [*Dyopsis lutescens* (H. Wendl.) Beentje & J. Dransf.] were grown in containers filled with a fine sand soil (SS) or with a pine bark-based potting substrate (PS). Each of these substrates was amended with 0%, 10%, or 20% clinoptilolitic zeolite (CZ) by volume. Plants were fertilized monthly with a water-nonsoluble 20N-4.3P-16.6K granular fertilizer. Downy jasmines were larger and had darker color in CZ-amended PS and were larger in CZ-amended SS than in nonamended SS or PS. Areca palms, which tend to be limited by K in SS had better color and larger size when the SS was amended with CZ. In PS, where K is seldom limiting, areca palms did not respond to CZ amendment of the PS. Both ammonium (NH₄)-N and potassium (K) were retained against leaching by CZ, but some of the NH₄-N adsorbed to CZ was subject to nitrification, either before or after its release into the soil solution. Some phosphate (PO₄)-P was also retained by CZ.

Clinoptilolitic zeolites (CZ) are naturally occurring volcanic aluminosilicate minerals known for their porous crystalline structure and high cation exchange capacities (CEC). These physical properties result in excellent retention of both water and nutrients and CZ have been used for these purposes in horticultural crops ranging from turfgrass (Nus and Brauen, 1991; Ferguson et al., 1986) to potted floral crops (Carlino et al., 1998; Williams and Nelson, 1997).

Although CZ are known primarily for their cation retention, Williams and Nelson (1997) demonstrated that the phosphate anion could also be retained for up to one month by this material. Ferguson and Pepper (1987) demonstrated that CZ-sorbed NH₄-N is protected from nitrifying bacteria due to the small diameter of the internal channels contained within CZ. Thus, CZ should reduce soil nitrogen losses due to nitrification and subsequent leaching.

Since CZ retains water-soluble nutrient ions in a form readily available to plants, these products could have great value in sandy field or landscape soils that have very low CEC. This material might increase nutrient retention in the root zone and reduce nutrient leaching into groundwater. CZ may also enhance the efficacy of cheaper, water-soluble fertilizers by serving as a controlled-release mechanism for solubilized nutrient ions. The purpose of this study was to determine if CZ would improve plant growth in a sand field soil and in a pine bark-based potting substrate when fertilized infrequently with a water-soluble granular fertilizer.

Materials and methods

Downy jasmines and areca palm liners were planted into #2 (6.2 L, 1.6 gal) plastic containers using a 5 pine bark: 4 sedge peat: 1 sand (by volume)

potting substrate (PS) or a sand field soil (Margate Fine Sand) from Davie, Fla. (SS). The PS was amended with dolomitic limestone at 7.1 kg·m⁻³ (12 lb/yard³) and Micromax (Scotts Co., Marysville, Ohio) at 890 g·m⁻³ (1.5 lb/yard³). Each soil type was amended with 0%, 10%, or 20% CZ (Hoodridge International, Parkland, Fla.) by volume. This low-sodium CZ was mined in Panjang, Indonesia and consisted predominantly of granules 0.5 to 1.5 mm (25.4 mm = 1.0 inch) in diameter. Some chemical and physical properties of the SS, PS, and CZ used in this study are shown in Table 1.

Ten replicate plants per treatment were arranged in a completely randomized design and grown in a full sun (max PPF = 2000 mE·m⁻²·s⁻¹) nursery in Fort Lauderdale, Fla. Pots received about 2 cm (0.8 inches) of water daily from overhead irrigation in addition to periodic rainfall. All plants were fertilized monthly with 8 g (0.28 oz) of a water-soluble 20N-4.3P-16.6K granular fertilizer (Peter's General Purpose, Scotts Co., Marysville, Ohio). The N in this product was 39% NH₄-N and 61% nitrate (NO₃)-N. Two d after the first and second applications, pour-through leachate samples were collected from all containers according to Yeager et al. (1983) and were analyzed for NO₃-N, NH₄-N, PO₄-P, and potassium (K). Nitrate-N and NH₄-N were determined by specific ion electrode, PO₄-P by the ascorbic acid method (Olsen and Sommers, 1982), and K by atomic absorption spectrophotometry. Pour-through leachates were similarly collected 14 d after the first and second fertilizer applications. Leachate nutrient concentration data from the two fertilization applications were combined for statistical analysis. After seven months, plants were subjectively rated for color (10 = darkest green, 5 = light green, 1 = completely yellow or orange) and were harvested for shoot dry weight deter-

Table 1. Water extractable basic cations, pH, and cation exchange capacity (CEC) of the potting substrate (PS), sand soil (SS), and clinoptilolitic zeolite (CZ) used in this study, n=3.

Substrate	pH	CEC (meq/100 g)	Mg (mg·mL ⁻¹) ^z	Ca (mg·mL ⁻¹)	K (mg·mL ⁻¹)	Na (mg·mL ⁻¹)
PS	6.00	34.4	78.3	131.4	39.1	12.3
SS	7.39	1.8	0.9	12.6	1.9	7.4
CZ	6.80	30.3	1.2	0.6	39.9	7.8

^z1.0 mg·mL⁻¹ = 1.0 ppm.

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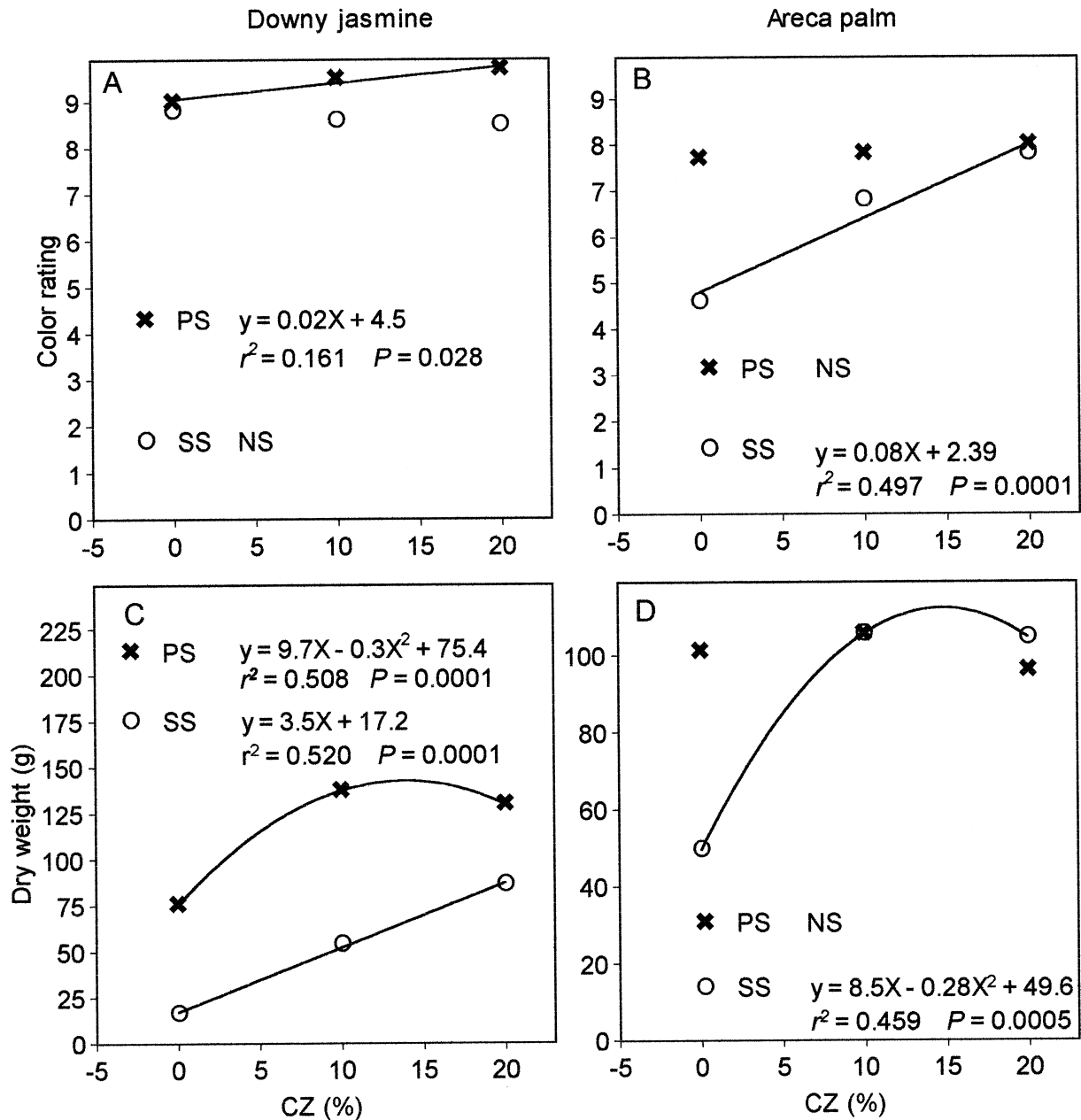


Fig. 1. Shoot growth and quality of downy jasmines and areca palms grown in a native sand substrate (SS) and a pine bark-based potting substrate (PS) amended with clinoptilolitic zeolite (CZ), $n = 10$. The color rating scale used was: 10 = darkest green, 5 = light green, and 1 = completely yellow or orange. NS indicates not statistically significant.

mination. Plant shoots were dried at 63 °C (145 °F) until constant weight was achieved. All data were analyzed using regression analysis (SAS System, Cary, N.C.).

Results and discussion

Both plant color rating and shoot dry weight were significantly greater for jasmines grown in PS amended with 10% or 20% CZ than in PS without CZ (Fig. 1A and C). However, there were no differences in color or shoot dry weight for areca palms grown

in PS with or without CZ (Fig. 1B and D). Jasmines grown in SS showed no treatment-related differences in color, but shoot dry weight increased with increasing CZ in the SS (Fig. 1A and C). For areca palms in SS, both CZ treatments had significantly higher plant color ratings and dry weight than palms grown without CZ, although there were no differences in dry weight between 10% and 20% CZ treatments (Fig. 1B and D).

Color differences in the jasmines appeared to be primarily due to vary-

ing degrees of N deficiency which results in uniform light green coloration of the foliage (Dickey, 1977). Pine bark potting substrates are known to bind $\text{NH}_4\text{-N}$ (Ogden et al., 1987), and jasmines are highly sensitive to soil N concentrations (T.K. Broschat, unpublished data). It appears that $\text{NH}_4\text{-N}$ retention by CZ in PS may have reduced the incidence of N deficiency in this species.

Color differences in areca palms were mostly due to varying degrees of K deficiency, which in its early stages, appears as an orange to bronze discoloration of the older leaves (Broschat, 1990). Potassium deficiency is known to be the primary limiting element for this species on sandy soils, whereas N

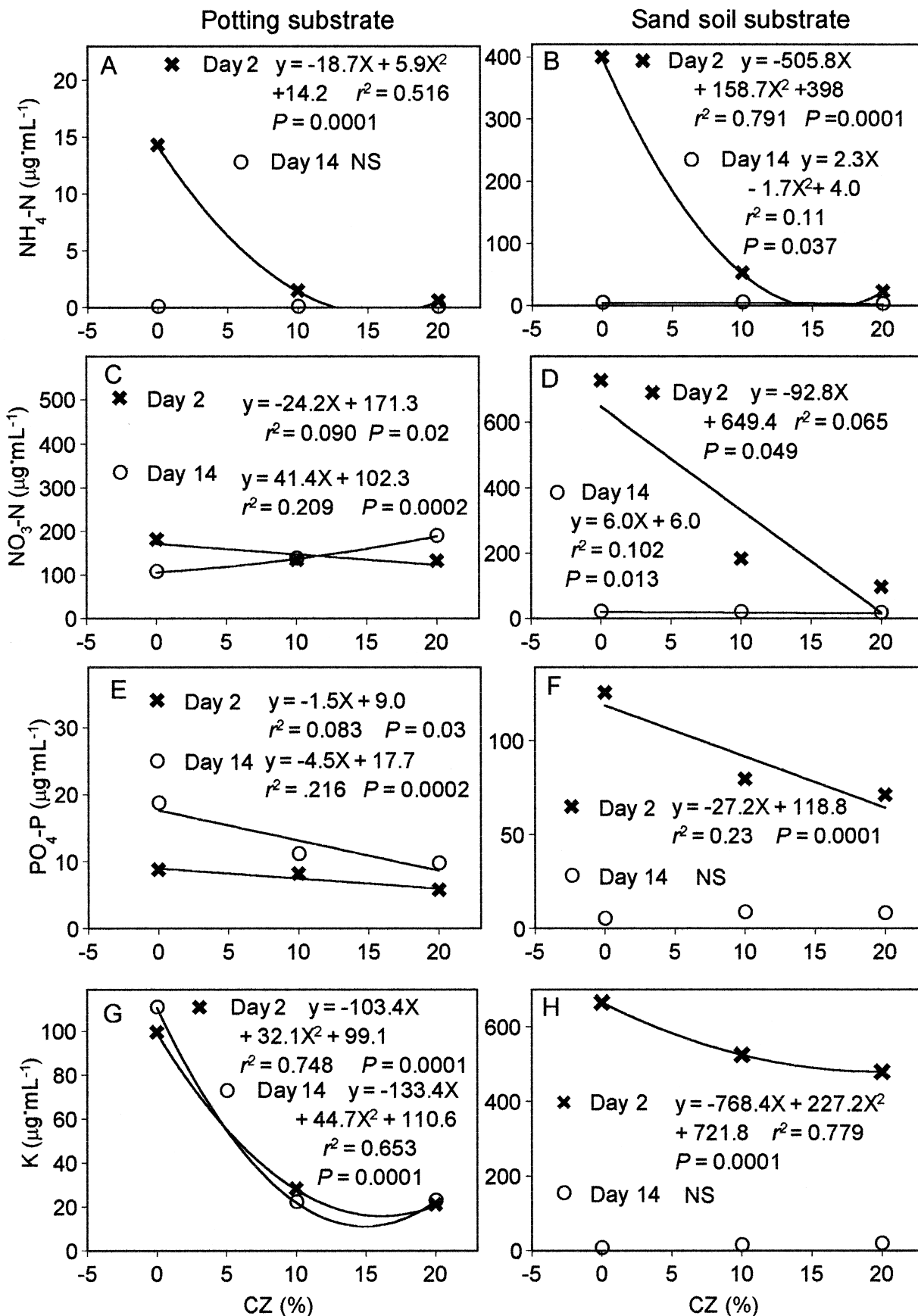


Fig. 2. Ammonium (NH_4)-N, nitrate (NO_3)-N, phosphate (PO_4)-P, and potassium (K) concentrations in $\text{mg}\cdot\text{mL}^{-1}$ (ppm) in pour-through leachates from a native sand substrate (SS) and a pine bark-based potting substrate (PS) amended with clinoptilolitic zeolite (CZ). Data are means from 10 replicate pots fertilized monthly with 8 g of a water soluble NH_4 -N (39%) and NO_3 -N (61%) source (20N-4.3P-16.6K). Data from the two fertilization events were combined for analysis and presentation. NS indicates not statistically significant. 28.4 g = 1.0 oz.

is usually the primary limiting element in potting substrates (Broschat, 1990, 1999). Since K is generally not a limiting factor in PS, it is not surprising that no differences in color or dry mass were observed in PS. In SS, however, it appeared that increased K retention by CZ resulted in better growth and less severe K deficiency symptoms than in unamended SS.

In PS, both $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ concentrations in pour-through extracts were significantly lower in PS amended with 10% or 20% CZ than in unamended PS 2 d after fertilization, suggesting that CZ retained some of the applied $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ (Fig. 2A and C). However, 14 d after fertilization, pour-through $\text{NO}_3\text{-N}$ was significantly higher for CZ-amended PS than for unamended PS. Ammonium-N concentrations in the 14-d pour-through extracts were extremely low for all treatments. This suggests that $\text{NH}_4\text{-N}$ adsorbed to unprotected surface sites on the CZ was subject to nitrification and subsequent leaching. The small diameter of internal channels within CZ traps cations such as NH_4^+ and K^+ and prevents the entrance of nitrifying bacteria (Ferguson and Pepper, 1987). Although $\text{NO}_3\text{-N}$ appeared to increase during the first 14 d in the PS amended with 20% CZ, $\text{NO}_3\text{-N}$ concentrations decreased in PS without CZ. Since very little $\text{NH}_4\text{-N}$ was extracted after 2 d or 14 d from CZ-amended PS, this would suggest that some of the $\text{NH}_4\text{-N}$ retained by CZ may be susceptible to nitrification while adsorbed to the surface of CZ particles.

Ammonium-N concentrations were much lower in CZ-amended SS than in unamended SS 2 d after fertilization, indicating strong $\text{NH}_4\text{-N}$ adsorption by CZ (Fig. 2B). Ammonium-N concentrations 14 d after fertilization were very low for all treatments, but were significantly higher for the CZ-amended than nonamended SS. This suggests that at least some $\text{NH}_4\text{-N}$ retained by CZ was being released into the soil solution.

In SS, $\text{NO}_3\text{-N}$ concentrations were lower when amended with 10% or 20% CZ than in unamended SS (Fig. 2D). Fourteen d after fertilization, $\text{NO}_3\text{-N}$ concentrations were higher in CZ-amended SS than in unamended SS. As with PS, this increase in $\text{NO}_3\text{-N}$ associated with CZ could be due to the release of previously retained $\text{NO}_3\text{-N}$ or nitrification of $\text{NH}_4\text{-N}$ adsorbed by CZ.

Phosphate-P concentrations in the

pour-through extracts decreased slightly with increasing CZ percentage both at 2 d and 14 d following fertilization in PS (Fig. 2E). However, $\text{PO}_4\text{-P}$ concentrations in the pour-through extracts were higher across all treatments at 14 d than 2 d following fertilization. The reason for this is not clear. Phosphate-P concentrations were also lower in CZ-amended SS 2 d after fertilization than in unamended SS, but there were no differences among treatments 14 d after fertilization (Fig. 2F). The much lower $\text{PO}_4\text{-P}$ levels in SS 14 d after fertilization suggests that $\text{PO}_4\text{-P}$ was either rapidly leached or rendered insoluble by this slightly alkaline soil. It appears that the PO_4 ion was retained to a limited extent in both substrates by the CZ, although there is no evidence in this data that this $\text{PO}_4\text{-P}$ was subsequently released into the soil solution as reported by Williams and Nelson (1997).

In PS, K concentrations in the pour-through extracts had patterns similar to those of $\text{NH}_4\text{-N}$, with unamended PS having much higher K concentrations than PS amended with 10% or 20% CZ (Fig. 2G). Potassium concentrations in SS extracts were somewhat lower in CZ-amended SS than in unamended SS, but there were no differences among treatments 14 d following fertilizer application.

Clinoptilolitic zeolite is known to have a very porous structure in addition to having a high CEC. Williams and Nelson (1997), as well as this study, have shown that PO_4 can be retained by CZ and gradually released over a period of 1 month. The PO_4 anions may simply be trapped in the interstitial water within the CZ particle or CZ may have weak anion exchange properties in addition to CEC. Since anion exchange tends to increase with decreasing soil pH and our CZ had a pH of 6.8, PO_4 adsorption by anion exchange appears unlikely. In the case of N, it appears that some $\text{NH}_4\text{-N}$ is released into the soil solution by CZ where it is subsequently nitrified. Alternatively, $\text{NH}_4\text{-N}$ adsorbed to surficial sites on CZ particles may not be protected from nitrifying bacteria, thus limited nitrification could occur while the $\text{NH}_4\text{-N}$ is still adsorbed.

Conclusions

Downy jasmines, a species that responds strongly to N, were larger and had darker color in PS when this substrate was amended with 10 or 20% CZ. Plant size was also larger for jasmines

growing in CZ-amended SS. Areca palms, which respond primarily to K, showed no response to CZ amendment in PS where K deficiency is normally not a problem, but did have better color and size in SS amended with 10% or 20% CZ. Retention of $\text{NH}_4\text{-N}$ and K by the CEC of CZ may be responsible for some of the increased growth in CZ-amended soils, but $\text{PO}_4\text{-P}$ was also retained to some degree by CZ. This study demonstrated that CZ amendment of PS or sandy landscape soils can improve the efficacy of water-soluble fertilizers.

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