

Effect of CuO Nanoparticles and two lightning intensities on Growth parameters of Swiss Chard (*Beta vulgaris* ssp. *cicla* L.), Kale (*Brassica oleracea*) and Lettuce (*Lactuca sativa*)

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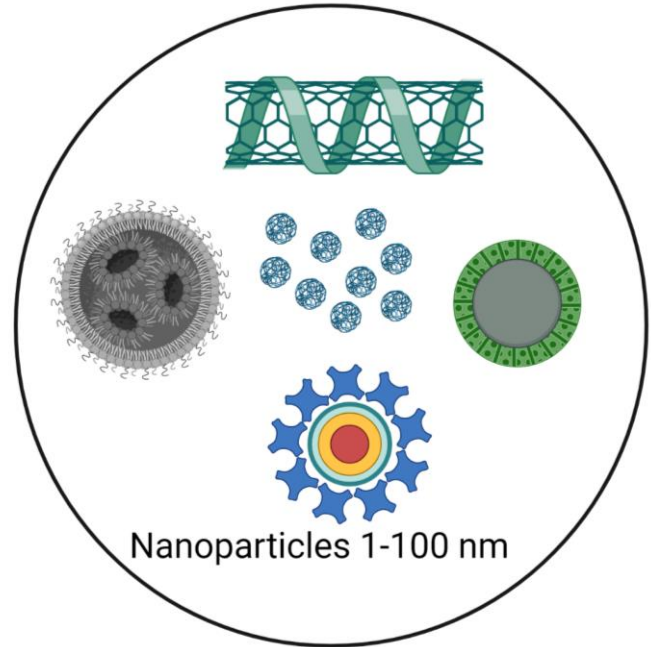
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Nanoparticles in agriculture



Reduce plant protection products

Minimize nutrient losses

Optimize nutrient management

Table 1. Properties of 10 and 40 nm CuO nanoparticles suspensions (30 ppm).

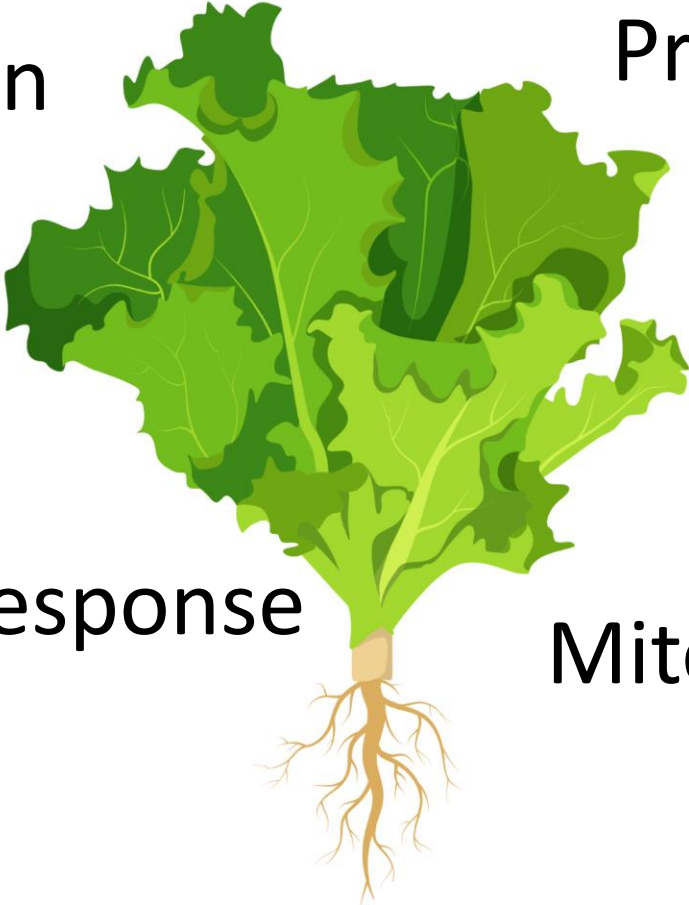
	CuO 10 nm	CuO 40 nm
Polydispersity index	0.310	0.313
Zeta Potential (mV)	-3.41	5.24
Particle size in solution up to 100 nm; %	60.7	78.3

Copper in plants

Cell wall formation

Photosynthesis

Oxidative stress response

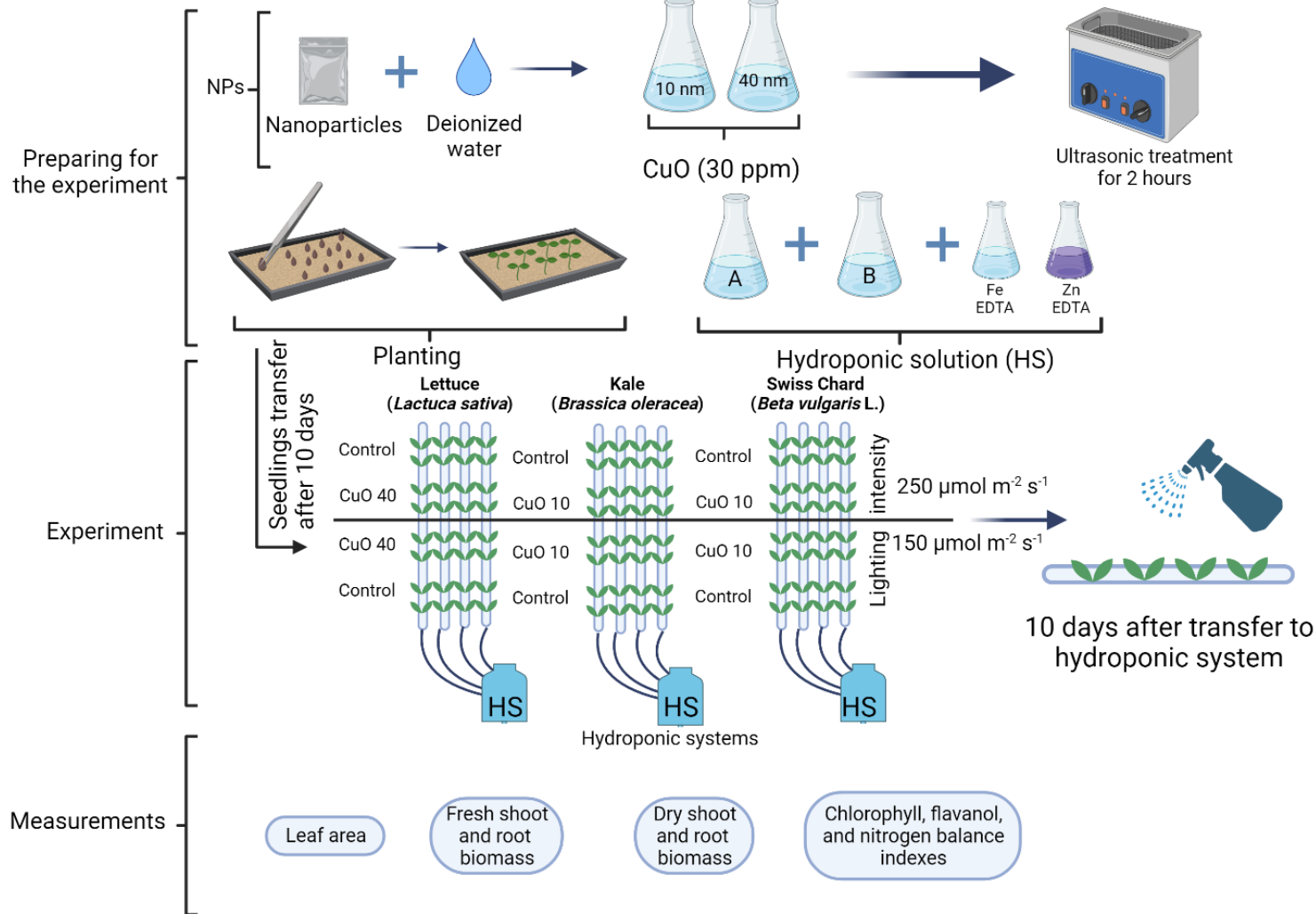


Protein metabolism

Enzyme activity

Mitochondrial respiration

Growing conditions and methods



This study aimed to evaluate the effect of copper oxide nanoparticles (CuO NPs) sprayed onto Swiss chard (*Beta vulgaris ssp. cicla L.*), kale (*Brassica oleracea*), and lettuce (*Lactuca sativa*) leaves grown in hydroponic Ebb systems in controlled environment chambers under the combination of white 65%, blue 5%, red 30% light emitting diodes (LEDs) with two intensities 150 and 250 $\mu\text{mol m}^{-2} \text{s}^{-1}$. The influence was determined on the fresh (FW) and dry (DW) shoot and root biomass, leaf area, chlorophyll and flavanol index, and nitrogen balance index. Swiss chard, kale, and lettuce were sprayed with suspensions of CuO NPs of 10 and 40 nm at a concentration of 30 ppm. Plants that were sprayed with distilled water were considered as control.

Table 2. Effect of 10 nm CuO NPs and lighting intensity on Swiss chard. Different letters indicate statistically significant differences between variants according to Tukey's test.

Lighting intensity	150 $\mu\text{mol m}^{-2} \text{s}^{-1}$		250 $\mu\text{mol m}^{-2} \text{s}^{-1}$	
CuO NPs concentration	0	30 ppm	0	30 ppm
Leaf area, cm^2	107.240 c	120.440 c	162.933 b	260.687 a
Fresh shoot biomass, g	8.261 c	9.232 c	14.136 b	24.627 a
Dry shoot biomass, g	0.422 c	0.437 c	0.802 b	1.326 a
Fresh root biomass, g	0.980 c	1.164 c	2.575 b	4.513 a
Dry root biomass, g	0.043 c	0.046 c	0.092 b	0.188 a
Chlorophyll index	27.058 b	31.533 a	28.375 ab	31.978 a
Flavanol index	0.410 a	0.444 a	0.495 a	0.507 a
Nitrogen balance index	67.590 ab	71.969 a	58.890 b	65.433 ab



Table 3. Effect of 40 nm CuO NPs and lighting intensity on Lettuce. Different letters indicate statistically significant differences between variants according to Tukey's test.

Lighting intensity	150 $\mu\text{mol m}^{-2} \text{s}^{-1}$		250 $\mu\text{mol m}^{-2} \text{s}^{-1}$	
CuO NPs concentration	0	30 ppm	0	30 ppm
Leaf area, cm^2	260.603 c	249.293 c	295.083 b	373.160 a
Fresh shoot biomass, g	12.329 b	11.313 b	16.485 a	18.772 a
Dry shoot biomass, g	0.638 b	0.620 b	0.946 a	1.088 a
Fresh root biomass, g	1.175 b	1.265 b	2.353 a	2.375 a
Dry root biomass, g	0.047 a	0.046 a	0.072 a	0.077 a
Chlorophyll index	19.182 a	22.145 a	20.559 a	23.922 a
Flavanol index	0.285 b	0.347 ab	0.313 ab	0.394 a
Nitrogen balance index	72.644 a	72.309 a	71.108 a	64.247 a



Table 4. Effect of 10 nm CuO NPs and lighting intensity on Kale. Different letters indicate statistically significant differences between variants according to Tukey's test.

Lighting intensity	150 $\mu\text{mol m}^{-2} \text{s}^{-1}$		250 $\mu\text{mol m}^{-2} \text{s}^{-1}$	
CuO NPs concentration	0	30 ppm	0	30 ppm
Leaf area, cm^2	113.643 c	114.953 c	128.343 b	147.100 a
Fresh shoot biomass, g	5.609 b	5.393 b	6.052 ab	6.880 a
Dry shoot biomass, g	0.519 b	0.558 b	0.583 b	0.728 a
Fresh root biomass, g	0.950 b	1.044 b	0.968 b	1.543 a
Dry root biomass, g	0.050 b	0.056 b	0.048 b	0.075 a
Chlorophyll index	37.913 b	43.729 a	41.554 ab	41.791 ab
Flavanol index	0.540 a	0.564 a	0.580 a	0.636 a
Nitrogen balance index	72.297 a	82.478 a	72.275 a	69.403 a



CONCLUSION

In conclusion, these results revealed that CuO NPs could be used in plant production to improve growth parameters. Meanwhile, lower $150 \mu\text{mol m}^{-2} \text{s}^{-1}$ intensity resulted in smaller plants and a lower effect of CuO NPs on their growth rates compared to plants grown under higher intensity conditions.

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