Molybdenum Trioxide Nanoparticles Enhance Drought Tolerance in Pea Plants

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INTRODUCTION

Legumes family plants, high in protein and essential minerals for humans and animals, play a vital role in the food industry. However, they are susceptible to a warming climate and especially droughts. The pea plant is a legume that carries out nitrogen fixation from the air to the soil with the help of symbiotic bacteria on the root nodules. A sufficient amount of molybdenum in the soil is significant for nitrogen fixation. The aim of this research was to investigate the effects of an aqueous suspension of molybdenum trioxide nanoparticles (MoO_3 NPs) on the antioxidant system, mineral composition, and yield of drought-affected peas (*Pisum sativum* L. cultivar 'Respect').

METHODS

The experiments were conducted using potted plants in a greenhouse with natural daylight. Pea plants were treated with different concentrations (0, 12.5, 25, and 50 ppm) of MoO_3 NPs by watering and spraying and were subjected to ten days of drought. Drought was initiated by maintaining substrate moisture at 30% while standard conditions were 80%. The researchers evaluated the impact of MoO_3 NPs and drought on the growth of the plants, the activity of enzymes (CAT, SOD, APX, GR, GPX), and the level of non-enzymatic antioxidants (FRAP, DPPH, ABTS, TPC) and stress biomarkers (H_2O_2, MDA amount). Elemental analysis was performed using the leaves, stems, and roots.

1 Picture: Vegetation pots in greenhouse.

2019	Temperature, C^0		Humidity, %	
	Day	Night	Day	Night
Before drought	24.2	14.4	54.1	75.3
During drought	26.2	17	50.1	73.2
After drought	26.7	16.6	52.8	73.5

Table 1. Temperature and humidity in greenhouse during experiment.

CONCLUSION

MoO_3 nanoparticles increased the resistance of pea plants to drought stress by boosting the antioxidant activity, which may have led to higher growth parameters and yield of pea plants.

RESULTS

About 68% of nanoparticles up to 100 nm remained in the aqueous suspension (Figure 2), although their size in powder form was 35-45 nm. Zeta potential (-24.92±0.314) and polydispersity index (0.218) indicate that the aqueous suspension of MoO_3 NPs was stable. The pH of the suspension was 7.8, close to the pH of deionized water. Cumulation percentage shows the percentage of particles in the suspension that have combined.

The findings indicated that 50 ppm MoO_3 NPs significantly increased the yield, height, leaf area, and nodule number of drought-stressed pea plants.

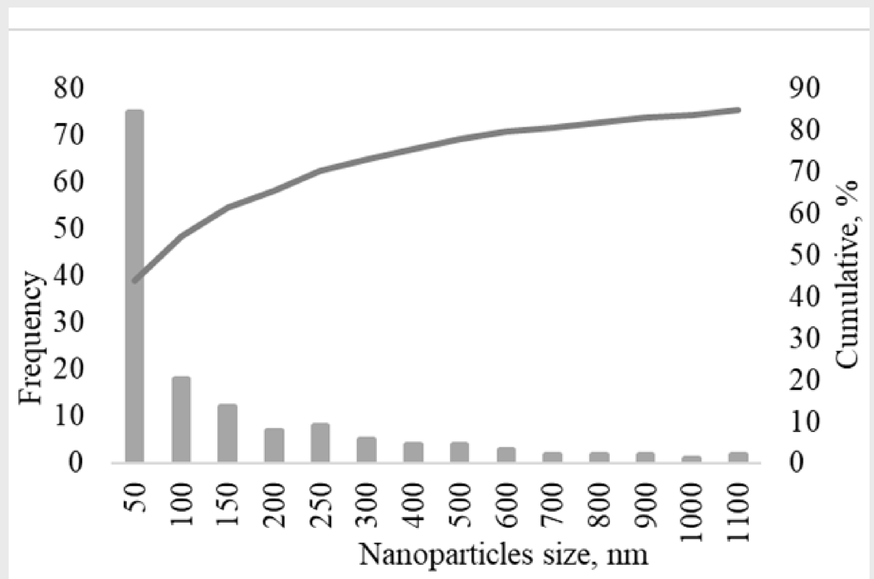

Figure 1. Size distribution of MoO_3 nanoparticles in DI water.

- MoO_3 NPs suspension positively affected plant morphological parameters determined by the effective reduction of oxidative biomarkers, increased total phenolics, and non-enzymatic antioxidant activity under drought conditions.
- MoO_3 NPs had an effect in enhancing the activity of CAT, APX, SOD, and GPX but reducing the activity of GR under both drought and normal conditions.
- The highest accumulation of Mo was found in pea plants when they were watered with 50 ppm MoO3 NPs suspension.
- Comparing the application methods, MoO_3 NPs through the roots have a more substantial effect on peas.

Table 3 The impact of MoO_3 *NPs (12,5; 25; 50 ppm) on P. sativum L. grown in the substrate with sufficient (SM 80%) and insufficient (SM 30%) moisture is expressed as a percentage change (%) compared to the control (for SM 80% control means plants grown under SM 80% and NPs untreated; SM 30% control means drought affected but NPs untreated plants) in the heat map. Statistically, significant differences are marked in bold*

Treatment MoO_3 NPs, ppm	SM 80%						SM 30%					
	Watered			Sprayed			Watered			Sprayed		
	12.5	25	50	12.5	25	50	12.5	25	50	12.5	25	50
Plants height	**6**	**21**	**25**	**7**	**5**	**17**	**10**	**18**	**40**	**4**	**10**	**24**
Leaf area	-3	15	**25**	**-9**	2	**15**	-7	-8	**30**	**12**	**10**	**10**
Number of noodles	40	**320**	**560**	40	20	**140**	-50	**117**	**533**	-17	**117**	**183**
Yield	**6**	**5**	**6**	1	-12	**7**	**11**	**26**	**80**	**3**	**15**	**64**
ABTS	**-11**	-5	2	-3	**-8**	4	**60**	**67**	**105**	**43**	**65**	**70**
DPPH	5	**27**	**36**	6	-7	13	**59**	**53**	**145**	**36**	**76**	**81**
TPC	**-20**	4	4	**-23**	**-15**	1	**20**	**28**	**37**	-1	**22**	**15**
FRAP	**117**	**141**	**202**	**111**	**146**	**190**	**231**	**241**	**242**	**55**	**100**	**142**
H_2O_2	**109**	**101**	**122**	**68**	**120**	**65**	**-8**	**-12**	**-20**	**-9**	**-12**	**-30**
MDA	**18**	-2	**13**	**19**	**24**	**5**	**9**	**11**	**25**	**13**	-1	**-17**
GR	**-70**	**-59**	**-56**	-33	**-52**	**-62**	**-56**	**-57**	**-31**	**-88**	**-79**	**-71**
GPX	**161**	**76**	**28**	**110**	**142**	**168**	-11	**43**	**55**	**17**	-2	**56**
APX	**692**	**899**	**607**	**423**	**481**	**748**	**198**	**490**	**622**	**216**	**276**	**422**
SOD	**25**	**65**	**19**	5	**24**	**35**	-2	**-15**	**17**	-10	0	**20**
CAT	-16	-19	-4	**41**	-10	-2	**234**	**215**	**224**	**161**	**191**	**183**
Mo (leaves)	**14**	**27**	**43**	**14**	**26**	**47**	**160**	**234**	**310**	**27**	**421**	**454**
Mo (stem)	**10**	**34**	**34**	**29**	**44**	**46**	**201**	**205**	**215**	**114**	**122**	**136**
Mo (roots)	**200**	**213**	**360**	**130**	**177**	**184**	**21**	**28**	**69**	**38**	**56**	**73**

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