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Titanium dioxide nano particles improving impact on sunflower seedling's emergence performance

Sibel DAY[1]*, Yasin ÖZGEN[2]
[1,2]*Ankara University, Agriculture Faculty, Department of Field Crops, Ankara, Türkiye*
**day@ankara.edu.tr, [2]senay.sengul@gop.edu.tr*

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Titanium dioksit nano partiküllerinin ayçiçeği fide çıkışı üzerine olumlu etkileri

Abstract: Seed germination and seedling emergence is the main step of cultivation and improving them could yield high performance in the field. Improved seedling emergence means less sensitivity to biotic and abiotic stress factors. It is possible to enhance seedling emergence via different technologies. Nanoparticles are one of the improving technology and their impact on crop cultivation are improving day by day. The seeds of hybrid-snack type cultivar Ahmetbey and for seed treatment agent TiO_2 nanoparticles were used in this experiment. This study was conducted to observe the impact of seed treatment with different titanium dioxide (TiO_2) nanoparticles (NPs) concentrations (6, 12, and 24 mg L^{-1}) with dimensions of 20-50 nm during 8 hours on the emergence and seedling growth performance of snack-type sunflower cultivar Ahmetbey. Four replicates of 50 seeds in each treatment were sown in plastic trays 4 cm deep and placed in a growth chamber at 20 ± 2 °C 45 µM photons m^{-2} s^{-1} light for 16 h. Mean emergence time (MET), emergence percentage, seedling vigor, root-to-shoot length ratio, shoot length, and root length seedling fresh and dry weight were measured. Emergence percentage, shoot length, root length, and fresh and dry weight of seedlings increased with TiO_2 NPs treatments. The results revealed that 8-hour priming with water has a low impact on seeds of cv. Ahmetbey compared to any treatment of TiO_2 NPs. In conclusion, it is proved that the improving effects of 8 hour priming of sunflower seeds with TiO_2 NPs solutions on sunflower seedling emergence.

Key words: TiO_2, seed priming, sunflower, hydropriming

Özet: Tohum çimlenmesi ve tarla çıkışı, ekimin ana adımıdır ve bunları geliştirmek tarla veriminde yüksek performans sağlayabilir. Geliştirilmiş fide tarla çıkışı, biyotik ve abiyotik stres faktörlerine daha az duyarlılık anlamına gelir. Farklı teknolojiler yoluyla fide çıkışını arttırmak mümkündür. Nanopartiküller gelişen teknolojilerden biridir ve bunların bitki yetiştiriciliği üzerindeki etkileri her geçen gün artmaktadır. Bu deneyde hibrid-çerezlik ayçiçeği çeşidi Ahmetbey ve tohuma ön uygulama materyali olarak titanyum dioksit (TiO_2) nanoparçacıkları kullanıldı. Bu çalışmada, ayçiçeği fide çıkışı ve fide büyüme performansını gözlemleyebilmek amacıyla, 8 saat boyunca 20-50 nm boyutlarında farklı titanyum dioksit (TiO_2) nanoparçacıkları (NPS) konsantrasyonlarında (6, 12 ve 24 mg L^{-1}) bekletilen tohumlar kullanılmıştır. Tohumlar her tekerrürde 50 tohum olacak şekilde (50 × 4 = 200) plastik çıkış kaplarına 4 cm derinliğinde ekilmiştir. Çıkış performansını ölçebilmek amacıyla 20 ± 2 ° C 45 µm foton M^{-1} ışıkta 16 saat boyunca bir büyüme odasına yerleştirildi. Ortalama çıkış süresi (MET), çıkış yüzdesi, fide canlılığı, kök-fide boyu uzunluğu oranı, fide uzunluğu ve kök uzunluğu fide yaş ve kuru ağırlıkları ölçüldü. TiO_2 NP'leri tohum uygulamaları ile çıkış yüzdesi, sürgün uzunluğu, kök uzunluğu ve yaş ve kuru ağırlıkta artış gözlenmiştir. Sonuçlar, tohumların 8 saat suda bekletilmesi uygulamasının TiO_2 NP'leri ile yapılan uygulamalara kıyasla Ahmetbey ayçiçeği çeşidi tohumları üzerinde düşük bir etkiye sahip olduğunu ortaya koymuştur. Sonuçlar ayçiçeği tohumlarının TiO_2 nanopartikülleri ile 8 saat ıslatılmalarının ayçiçeği fide çıkışı için olumlu etkileri olduğunu kanıtlamıştır.

Anahtar Kelimeler: TiO_2, tohum uygulaması, ayçiçeği, hydropriming

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1. Introduction

Sunflower cultivated in Türkiye is mainly oil seed type (Kaya et al., 2013) grown on around 899.254 ha (TUIK, 2022). Snack type sunflower is used in making bread, chocolate production and are consumed as a snack (Day et al., 2008). Its production is increasing with present production of around 80.435 ha (TUIK, 2022). However snack type sunflower has less yield (2490 kg ha^{-1}) compared to oil seed types (2610 kg ha^{-1}). The low yield in snack type sunflower mostly depends on farmers' habit of cultivating the seeds they obtained the year before. The seeds, in this case, have low homogeneity and their hull percentage is increased which retard the germination and seedling could stand in the field.

Seed priming could be used to increase the efficiency of seed germination and seedling fidelity under optimal and unfavourable conditions (Devika et al., 2021; Day, 2022). New approaches are developing with the increasing nanoparticle industry (Acharya et al., 2017). Several nanoparticles (NPs) such as Al_2O_3 NPs (Aluminium oxide), Ag NPs (Silver), TiO_2 NPs (Titanium dioxide), CeO_2 NPs (Cerium oxide), FeO NPs (Iron oxide), ZnO NPs (Zinc oxide), silicon NPs, and carbon nanotubes are used in seed germination and growth of several plant species and varieties (Haghighi et al., 2014; Prasad et al., 2017). Nanoparticles have toxic or supporting effects on plant growth depending on species and the form and concentration of nanoparticles used.

Nanoparticles have unique physio-chemical properties, high stability, anticorrosion, and photocatalyst activity which suggests their application in many areas like cosmetics, cleaning products, transportation, energy, and agriculture (Haghighi and Teixeira da Silva, 2014). In agriculture, its usage in plant development is increasing. Particularly TiO_2 NPs usage is increasing due to its semiconductor properties, high visible spectrum transmittance, chemical stability, and high antimicrobial activity.

TiO_2 NPs can change the hormonal levels of plants during growth. Increased zeatin riboside and brassinolide in tobacco were observed after foliar application of TiO_2 nanoparticles (Hao et al., 2018). TiO_2 NPs supportive impact on plant growth, microorganism activity, and nutrient uptake was observed in barley (Marchiol et al., 2016), and wheat (Faraji and Sepehri, 2019; Zahra et al., 2019).

Seed germination stage is an important stage in sunflower cultivation. It sustain rapid germination and healthy seedlings' emergence by playing an important part in obtaining high yield for sunflower. Pre-sowing seed treatments hasten field emergence for many oil crops including canola (Day, 2022), sunflower (Bourioug et al., 2020) and soybean (Shrestha et al., 2019). TiO_2 biostimulation impacts has been reported successfully in many crops.

Although a limited number of studies have been carried out on the use of different nanoparticles on sunflower cultivars, to the best of our knowledge no study has been carried out to find the impact of TiO_2 NPs on snack-type sunflower seed germination parameters. Therefore the study aimed to compare seed germination and emergence behavior of snack-type sunflowers using hydro priming and different concentrations of TiO_2 NPs.

2. Materials and Method

The seeds of hybrid-snack type cultivar Ahmetbey were used in this experiment. TiO_2 nanoparticles, were purchased from a producer (NG Materials) of nanoparticles with the size of 28 nm. Distilled water and TiO_2 based treatments were used in priming by immersing in 200 mL water and different concentration of TiO_2 (6, 12 and 24 mg L^{-1}) for 8 hours. The immersed seeds were rinsed with distilled water after 8 h.

2.1 Emergence tests

Four replicates of 50 seeds in each treatment were sown in plastic trays, 4 cm deep and placed in a growth chamber (Sanyo versatile Growth chamber, Japan) at 20 ± 2 °C, 45 µM photons m^{-2} s^{-1} light for 16 h. The compost in trays had a pH 6.5 and electrical conductivity of 40 mS m^{-1}. The irrigation was done regularly two times a week using 200 ml water to adjust the water lost during evapotranspiration. The plastic trays were checked daily to count the number of emerging seedlings. The seedling emergence criteria occurred as unfolding cotyledons above the surface. The experiment ended 25 d after sowing.

The mean emergence time (MET, days) was calculated with the formula below (ISTA, 2017)

$$\text{MET} = \frac{\sum n \times t}{\sum n}$$

n= number of cotyledons on the compost surface at time t

t= days from planting

Σn= final cotyledon number on the compost surface

Shoot length, root length, seedling fresh weight, and dry weight were measured for all seedlings from each replicate on the 25th day. Fresh weights of seedlings were determined soon after harvest to obtain accurate results (Day, 2016). The dry weights of the seedlings were ascertained after drying the samples in an oven at 70 °C for 48 h (Day et al., 2017). Vigor index calculation was done according to the equation given below (Raskar and Laware, 2013)

$$Vigor\ index = Germination\ percentage\ (\%) \times Seedling\ dry\ weight\ (g)$$

Root to shoot length ratio was calculated by formula described below (Khatun et al., 2013)

$$Root\ length\ (cm) \div Shoot\ length (cm)$$

2.2 Statistical analysis

The experimental design was randomized block design with four replicates. Germination percentage data were transformed into arcsine before analysis of variance. MSTAT-C statistical software was used for the analysis of variance and the comparisons of differences between the means were computed by Duncan's multiple range test (DMRT).

3. Results

MET depending on the different priming treatment did not show any differences (F=2.0714, df=12, p=0.1479). It ranged 8.25 to 9.28 days (Table 1).

Emergence percentages ranged 90.00 to 97.50 % with significant differences (F=5.2689, df=12, p=0.0110). The maximum and the minimum emergence percentage was observed using 24 mg L^{-1} TiO_2 and distilled water-treated seeds respectively. However, no statistical differences were indicated among 6, 12 and 24 mg L^{-1} TiO_2 treatments and they were placed in the same group (Table 1).

The seedling vigor index (Table 2) in each treatment was significantly different (F= 7.6766, df=12, p=0.0026). The minimum and the maximum vigor index was observed in control treatment (47.78) and 24 mg L^{-1} TiO_2 treatment (95.25). Root-to-shoot length ratio varied between 0.75 and 0.95 (F=1.4364, df=12, p=0.2814).

Impact of seed treatment on the shoot length showed statistically significant differences (F=11.5159, df=12, p=0.0004). The result proved that 6, 12 and 24 mg L^{-1} TiO_2 impact on the shoot and root length was similar. Control

Table 1. TiO_2 priming impacts on mean emergence time and emergence percentage

Priming treatment	MET (day)	Emergence percentage (%)
Control	9.28 ± 0.249	90.50 ± 1.84 b*
Hydro	8.60 ± 0.300	90.00 ± 3.00 b
6 mg L^{-1} TiO_2	8.65 ± 0.059	97.00 ± 2.279 a
12 mg L^{-1} TiO_2	8.25 ± 0.341	97.00 ± 2.219 a
24 mg L^{-1} TiO_2	8.50 ± 0.067	97.50 ± 1.821a

All values shown with different letters in single columns are statistically different using DMRT *: p<0.05; ±: Standard Error and hydro-primed seeds had shorter shoot length compared to TiO_2 treated seeds (Table 3).

Seedling fresh weight ranged from 1.73 to 2.91 g plant-1 (Table 4). Hydropriming and TiO_2 NPs treatments increased the fresh weight compared to the control treatment. (*F*=5.3161, *df*=12, *p*=0.0107). There were no statistical differences determined among priming treatments and took the same group statistically. Seedling dry weight showed statistical importance (*F*=6.9517, *df*=12, *p*=0.0039). The dry weight values were observed between 0.53 and 0.98 mg plant-1.

Table 2. TiO_2 priming impacts on seedling growth parameters

Priming treatment	Seedling vigor index	Root-to-shoot lenght ratio)
Control	47.78 ± 3.563 b**	0.75 ± 0.618
Hydro	63.78 ± 3.518 b	0.95 ± 0.816
6 mg L^{-1} TiO_2	70.28 ± 4.762 ab	0.85 ± 0.713
12 mg L^{-1} TiO_2	69.60 ± 5.184 ab	0.88 ± 0.743
24 mg L^{-1} TiO_2	95.25 ± 8.796 a	0.82 ± 0.683

All values shown with different letters in single columns are statistically different using DMRT **: p<0.01; ±: Standard Error

Table 3. TiO_2 priming impacts on seedling growth parameters

Priming treatment	Shoot lenght (cm)	Root lenght (cm)
Control	11.65 ± 0.193 b**	8.75 ± 0.485 b**
Hydro	12.05 ± 1.099 b	11.40 ± 1.175 ab
6 mg L^{-1} TiO_2	15.70 ± 0.311 a	13.30 ± 0.675 a
12 mg L^{-1} TiO_2	15.15 ± 0.104 a	13.30 ± 0.613 a
24 mg L^{-1} TiO_2	15.55 ± 0.551 a	12.68 ± 0.634 a

All values shown with different letters in single columns are statistically different using DMRT **: p<0.01; ±: Standard Error

Table 4. TiO_2 priming impacts on seedling growth parameters

Priming treatment	Fresh weight g $plant^{-1}$	Dry weight g plant-1
Control	1.73 ± 0.137 b*	0.53 ± 0.035 b**
Hydro	2.47 ± 0.328 a	0.71 ± 0.059 ab
6 mg L^{-1} TiO_2	2.46 ± 0.148 a	0.72 ± 0.061 ab
12 mg L^{-1} TiO_2	2.61 ± 0.147 a	0.72 ± 0.032 ab
24 mg L^{-1} TiO_2	2.91 ± 0.111 a	0.98 ± 0.097 a

All values shown with different letters in single columns are statistically different using DMRT *: *p*<0.05; **: *p*<0.01; ±: Standard Error

4. Discussions

Seed germination and early seedling growth are the critical stages for crop establishment. These stages are vulnerable to biotic and abiotic stress factors. The priming treatment could support these stages when the plantlets are under the stress from inside or outside.

TiO_2 priming is more effective on germination percentages, shoot length, root length, seedling fresh weight and seedling dry weight compared to hydro priming and control treatments. Germination percentage was the minimum in hydro priming treatment and it did not show diversity from control treatment statistically.

Quality of seed generally has effect on the seedling establishment and its vigor (Kandasamy et al., 2020). Seedling emergence is directly influenced by vigor because this shows ability of seeds' to emerge under optimal or adverse field conditions. Emergence delay could lead to many unwanted results like delayed harvest.

TiO_2 showed improving results in seedling vigor, especially in 24 mg L^{-1} TiO_2. TiO_2 NPs, related to dose, particle size, and exposure time (Gohari et al., 2020), could be toxic to plant growth. But for this study beneficial impacts on seedling growth parameters were observed in line with the increased shoot length and root length seedling fresh and dry weight increased due to priming treatments. Fresh weight and shoot length increase in hemp and root length increase in flax depending on the NP's concentration were observed (Akgur and Aasim, 2022; Clément et al., 2013). Similar findings were observed for increased dry weight due to TiO_2 treatment in Moldavian balm (Gohari et al., 2020) and maize (Shah et al., 2021).

Considering these results 8 hour priming with water has low impact for snack type sunflower cv. Ahmetbey seeds compared to TiO_2 NPs. However nanoparticles have different dimension and their production process are different, this dimension range used in this research is found suitable for sunflower seed multiplication. Further studies are needed to attain standardization and achieve homogeneity, which is the main issue in using these kind of nano products in agricultural production.

Conflict of Interest

Authors have declared no conflict of interest.

Authors' Contributions

The authors contributed equally.

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