International Journal on Agriculture Research and Environmental Sciences

Impacts of Nano-Ferric Oxide on Morpho-Physiological Traits of Durum Wheat

Research Article

Volume 3 Issue 1- 2022

Author Details

Furqan Ali[1], Ameer Khan[2], Ali Shahzad[3], Muhammad Shahzad[4], Quratul Ain[4], Hameed Gul[3] and Soufiane Mohamed[5]*

[1]*Department of Botany, The University of Lahore, Pakistan*
[2]*Department of Agronomy, Zhejiang University, China*
[3]*College of Agronomy and Biotechnology, Southwest University, China*
[4]*Department of Botany, University of Agriculture, Pakistan*
[5]*College of Resources and Environmental Sciences, Southwest University, China*

*Corresponding author

Furqan Ali, Department of Botany, The University of Lahore, Sargodha Campus, Pakistan

Article History

Received: June 17, 2022 Accepted: July 1, 2022 Published: July 5, 2022

Abstract

Nanotechnology has shown a promising potential to encourage sustainable agriculture in the recent years. Iron (Fe) is an essential element for plant growth and development which absence in the soil negatively effects the plant health. We proposed that the application of nano-ferric oxide at certain level would promote the overall performance of durum wheat. Thus, in the recent study, we evaluated the two durum wheat genotypes (Preco and Kronos) under three levels of nano-ferric oxide (0 ppm, 20 ppm and 50 ppm). The experiment was conducted in the Botany Laboratory of University of Lahore, Sargodha campus during 2017-2018 with a completely randomized block design. Nano-Ferric oxide particles were synthesized by the chemical reduction of ferric chloride hexahydrate (FeCl3.6H2O) using onion extract. The size of nanoparticles was determined by Zeta Particle Analyzer. The results of the observed traits revealed highly significant differences among treatments and genotypes. The results shown that observed traits improved under 20 ppm concentration of nano-ferric oxide but decreased under 50 ppm concentration. At 20 ppm treatment, variety Preco showed the highest plant height (109.56 cm), root length (19.42 cm), spike length (12.48 cm), awns length (19.83 cm), internode length (19.12 cm), number of leaves (14.55), number of spikelets (23.77), number of awns (55.88), thousand-grain weight (49.49 g), relative water contents (94.81), glaucousness (9.52) and pubescence (8.88). Overall, results suggested that ferric oxide nanoparticles improve the growth of durum wheat and can be used for crops improvement in future.

Keywords: Durum wheat; Nano-ferric oxide; Thousand-grain weight; Glaucousness; Pubescence

Introduction

Durum wheat (Triticum durum) is an important food crop globally with an estimated annual production of 37 million tons [1,2]. Its grain is rich with protein substance [3] and mostly utilized for the making pasta products and that's why generally referred as pasta wheat [4-6]. The quality of end-products is related to the quality of the durum grain, which, in turn, is mainly determined by the genotype, but also by the environment (weather and nutrition) and crop management.

Nowadays nanotechnology is a developing objective strategy with the possibility to bring fundamental modification in the community [7]. In agronomy and meal industry, the yield and dietary rate enhanced due to progress in nanotechnology, and it provides the exclusive way of atomic or molecular substance management in improving disorders and ultimately upgrade the capacity of plants to assimilate supplements [8]. Nanoparticles (NPs) size ranges from 1 to 1000 nm [9,10]. NPs have both beneficial and destructive consequences for agronomic characteristics, and yield of plants which ultimately incorporating with the changes in the nutritional value [11]. NPs quickly and totally consumed by the plants and improve nourishing requirements and insufficiencies [12]. Various NPs have been explored for their potential application in farming including copper (Cu), silica (SiO_2), aluminum (Al), silver (Ag), zinc oxide (ZnO), iron oxide and titanium dioxide (TiO_2) [13]. Some NPs like Ti (Titanium) and Cs (cesium) NPs aggregated in vital parts and edible segments of various crops such as rice, cucumber and wheat [14-16].

Iron (Fe) as the part of several vital enzymes activate biological responses and therefore performs a significant role in plant development [17]. Poor Fe availability in land caused harmful affect to wheat granules indirectly decreasing human food chain [3]. Fe NPs have a positive role in betterment of dehydrated weights of leaf and crop of soybean [18,19] and promotes the germination rate of seeds of forage and medicinal plants [20]. Ferric oxide is standout amongst the most well-known attractive nanoparticles in drug and biomechanics [21]. Thus, in this perspective we proposed that the current study to evaluate the effect of nano-ferric oxide on durum wheat growth.

Materials and Methods

Experimental Site, Plant Material and Experimental Design

The current experiment to detect the impact of ferric oxide nanoparticles on durum wheat was conducted in the Botany Laboratory of University of Lahore, Sargodha Campus, Pakistan (2017-2018). The experiment was conducted by using completely randomized block design. Two genotypes of durum wheat (Preco and Kernos) were used as experimental material (Table 1).

Synthesis of Ferric Oxide Nanoparticles

Ferric oxide nanoparticles were synthesized by chemical reduction of ferric chloride hexa-hydrate (FeCl3.6H2O) and onion extract using as source. A mixture of FeCl3.6H2O was prepared by dissolving 968.37 mg of ferric chloride to one-liter distilled water. The solution was boiled for 4 min 10 sec. It was reduced stepwise by the addition of 30 mL of onion extract. The solution was boiled continuously until the color of solution changed to reddish brown. So, the resultant solution was the stock solution of Fe NPs having concentration 200 ppm. Dilutions of the required concentrations were made from stock solution for further use. Size of Iron nanoparticles was determined by Zeta Particle Analyzer. Size of the nanoparticles was determined in solution form. The size as tested by Zeta Particle Analyzer range from 8 nm to 14 nm.

Table 1: Information about the two durum wheat genotypes used in this study.

Genotype	Registration		Pedigree
	Year	Country	
Preco	1995	Italy	EDMORE WPB881 UNKNOWN
Kronos	1996	Southwest US	APB MSFRS POP Sel (D03-21)

Soil Analysis

The physicochemical properties of experimental soil were analyzed by using the method described Homer and Pratt [22]. The soil was clay loamy having pH 7.42, EC 3.05 dSm-1, available potassium 120 ppm and available phosphorus 6.5 ppm.

Experimental Procedure

The soil that used to conduct the experiment was air dried and sieved with a 1 cm mesh screen. Each pot was filled with 6 kg of soil with the prescribed dosages of potassium, phosphorus and nitrogen by utilizing Potassium chloride, Urea and DAP (0.5g/pot, 0.73g/pot and 0.65g/pot) separately. All pots were watered with tap water (100 ml) just before sowing. Eight seeds were sown in each pot for each variety under three replications. Ferric oxide NPs prepared in laboratory exposed to soil of each pot with 0 ppm (T0), 20 ppm (T1) and 50 ppm (T2) concentration. Weeds were physically and periodically discarded. Time domain reflectometer was used to analyze moisture level and water was applied according to the situation.

Data Observation

At the maturity stage, three plants from each pot were randomly chosen to measure the traits such as plant height, root length, spike length, awn length, internode length, number of leaves, number of spikelets, number of awns per spike, thousand grain weight, leaf rolling, relative water content, glaucousness and pubescence for each replication. For measuring leaf rolling, glaucousness and pubescence, we used 1-10 scale.

Relative water contents were calculated by used following equation,

RWC = FW-DW/TW-DW * 100

Where, FW = Fresh weight; DW= Dry weight; TW= Turgidity weight

Statistical Analysis

The data of observed traits were subjected to analysis of variance (ANOVA) corresponding with two factorial randomized complete block design (RCBD) using the procedure of Steel et al. [23]. Statistical software Statistix 8.1 (Analytical, Tallahassee, FL, USA) was used to perform the analysis, and the treatment means were compared by using the Tukey's HSD test ($p \leq 0.05$).

Results and Discussion

Plant Height and Root Length

Results indicated that Fe NPs played a significant role in promoting plant height. Analysis of variance (ANOVA) for plant height and root length showed that highly significant ($p \leq 0.001$) difference exists between the treatments and genotypes (Table 2). Preco variety showed maximum plant height (109.56 cm) at 20 ppm treatment (T1), while the lowest value of plant height (91.59 cm) was observed of Kronos variety under 50 ppm treatment (T2). Kronos variety has the significantly lower plant height (94.983 cm) under the control conditions (T0) and the similar trend were observed under all treatments. The research results showed plant height increased up to 20 ppm concentration and decreased under 50 ppm treatment (Figure 1a). Our results are similar to Yuan et al. [24] who found that Fe nanoparticles significantly promotes the plant height of Capsicum annuum under limited concentrations.

Plant root system helps in water absorbing deep beneath the surface. Preco variety showed maximum root length (19.42 cm) at 20 ppm treatment (T1), while the lowest value of root length (14.51 cm) was observed of Kronos variety under 50 ppm treatment (T2). Kronos variety has the significantly lower root length (15.58 cm) under the control conditions (T0) and the similar trend were observed under all treatments. Interestingly the percentage increment in the root length (15.362 %) in Kronos variety was higher than Preco as compared to the control conditions (Table 3). The research results showed root length increased up to 20 ppm concentration and decreased under 50 ppm treatment (Figure 1b). These results are in accordance with Yuan et al. [24] who proved that root length increased with a limited concentration of iron oxide nanoparticles in both Capsicum annuum (chillies) and Arachis hypogaea (peanut) [25]. Ferric oxide NPs were found to improve the length of wheat shoots and roots [26]. It has been discovered that NPs have a lot of promise for supplying nutrients to plants [27]. Another argument for higher plant growth with NPs could be because nutrients like Fe drive chlorophyll production and the redox process in plants, both of which may benefit plant development [28].

Spike Length, Awn Length and Internode Length

Analysis of variance results for spike length, awn length and internode length indicated the highly significant differences ($p<0.001$)

Citation: Furqan A, Ameer K, Shahzad A, et al. Impacts of Nano-Ferric Oxide on Morpho-Physiological Traits of Durum Wheat.*Int J Agri Res Env Sci*. 2022;3(1):1–7. DOI: 10.51626/ijares.2022.03.00019

for treatments and genotypes but the interaction between them was non-significant except the spike length which showed higher significant (p<0.01) interaction among treatments and genotypes (Table 2). Under 20 ppm treatment (T1) both varieties Preco and Kronos showed the highest spike length values 12.48 cm and 11.84 cm respectively. The lowest spike length (8.22 cm) was recorded for Kronos under T2 treatment (Figure 2a). The spike length was increased in the Preco variety under the T1 and T3 treatment as compared to control treatment (22.306 %, 2.809 %) respectively (Table 3). These results are similar to Yasmeen et al. [29] who stated that analysis of iron NPs at 25 ppm concentration increased the spike length of wheat. Rizwan et al. [30] confirmed that the iron oxide NPs improves the spike length of wheat.

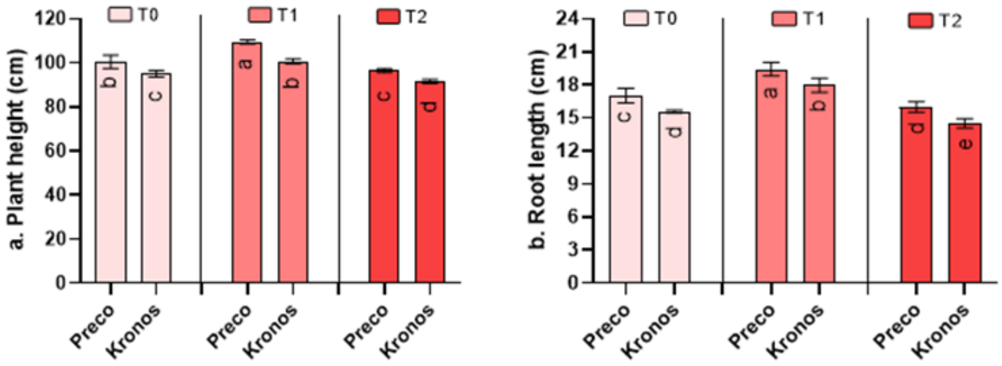

Figure 1. a: Plant height b. Root length. Comparison of durum wheat characteristics under different levels of nano-ferric oxide application. Means with different letters are significantly different (Tuckey's HSD, p ≤ 0.05).

Table 2: Analysis of variance results of observed traits of durum wheat under different levels of nano-ferric oxide.

Traits	Treatment (T)	Variety (V)	T × V
Plant height	63.78***	61.00***	2.19NS
Root length	74.86***	38.27***	0.00NS
Spike length	83.54***	37.29***	9.27**
Awn length	93.67***	220.56***	1.53NS
Internode length	111.28***	20.74***	2.75NS
Number of leaves	119.82***	8.22*	1.08NS
Number of spikelets	71.38***	18.33**	2.76NS
Number of awns per spike	79.47***	0.00NS	4.45*
Thousand-grain weight	43.87***	25.99***	0.74NS
Leaf rolling	240.01***	0.70NS	14.19**
Relative water content	44.81***	55.43***	7.08**
Glaucousness	23.57***	21.48***	1.47NS
Pubescence	35.93***	20.92***	1.65NS

NS = Non-significant; * = Significant at p≤0.05; ** = Significant at p≤0.01; *** = Significant at p≤0.001

Preco variety showed maximum awn length (19.83 cm) under T1 treatment, and the lowest value (13.29 cm) was observed in Kronos variety under T2 treatment. Kronos variety has the significantly lower awn length (14.42 cm) under the control conditions (T0) as compared to Preco variety and the similar trend were observed under all treatments. Interestingly the percentage increment in awn length (16.663 %) in Kronos variety was higher than Preco as compared to the control conditions (Table 3). The research results showed that awn length increased up to 20 ppm concentration and decreased under 50 ppm concentration (Figure 2b). Maximum internode length (19.12 cm) was observed under T1 treatment in Preco variety, while the lowest value (13.14 cm) was observed of Kronos variety under T2 treatment. The increment rate of internode length under T1 treatment was higher in Preco variety as compared to Kronos such as 20.201 %, 16.678 % respectively (Table 3). Kronos variety has the significantly lower internode length (14.71 cm) under the control conditions (T0) and the similar trend were observed under all treatments. The research results showed internode length increased up to 20 ppm concentration and decreased under 50 ppm treatment (Figure 2c).

Number of Leaves, Number of Spikelets, Number of Awns Per Spike and Thousand-Grain Weight

Analysis of variance results for number of leaves, number of spikelets and thousand-grain weight indicated the highly significant variations (p<0.001) among treatments and genotypes but the interaction between them was non-significant (Table 2). While for number of awns per spike, the analysis of variance results revealed the highly significant variations among the treatments but non-significant for varieties (Table 2). Leaves are the most important parts of plant because of photosynthesis. These have stomata and therefore role in stomatal conduction. Under T1 treatment both varieties Preco and Kronos showed the highest number of leaves 14.55 and 13.66 respectively. The lowest number of leaves (8.77) were recorded for Kronos under T2 treatment (Figure 3a). The results revealed that number of spikelets

Citation: Furqan A, Ameer K, Shahzad A, et al. Impacts of Nano-Ferric Oxide on Morpho-Physiological Traits of Durum Wheat.*Int J Agri Res Env Sci*. 2022;3(1):1–7. DOI: 10.51626/ijares.2022.03.00019

was significantly increased in T1 treatment while it decreased in T2 treatment. Maximum number of spikelets was observed under T1 treatment in Preco variety (23.77), while Kronos variety also showed increase in number of spikelets (21.99) under T1 treatment and this increase was higher than the Preco variety as compared to control (17.86 %, 14.42 % respectively; (Figure 3b) (Table 3).

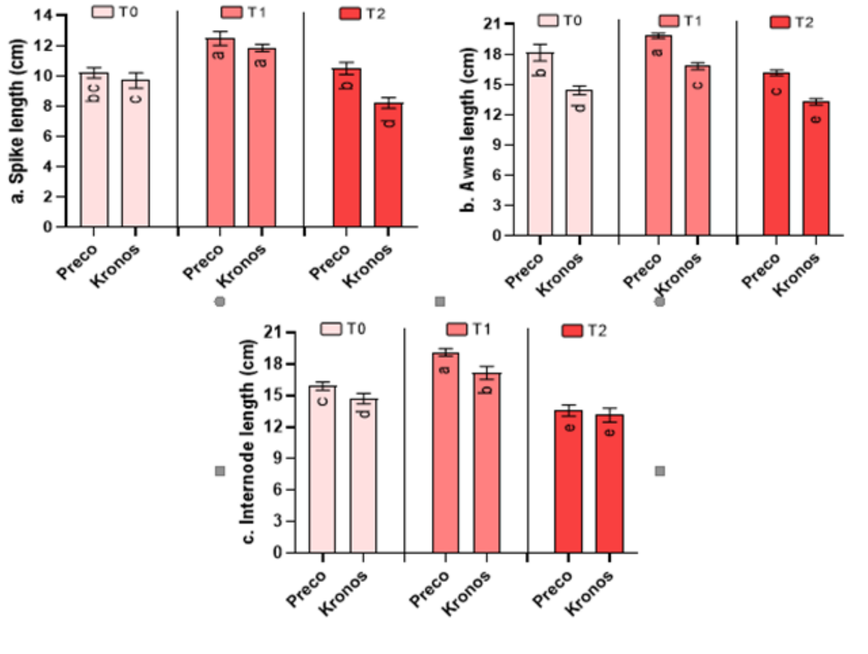

Figure 2. a: Spike length b. Awn length c. Internode length. Comparison of durum wheat characteristics under different levels of nano-ferric oxide application. Means with different letters are significantly different (Tuckey's HSD, $p \leq 0.05$).

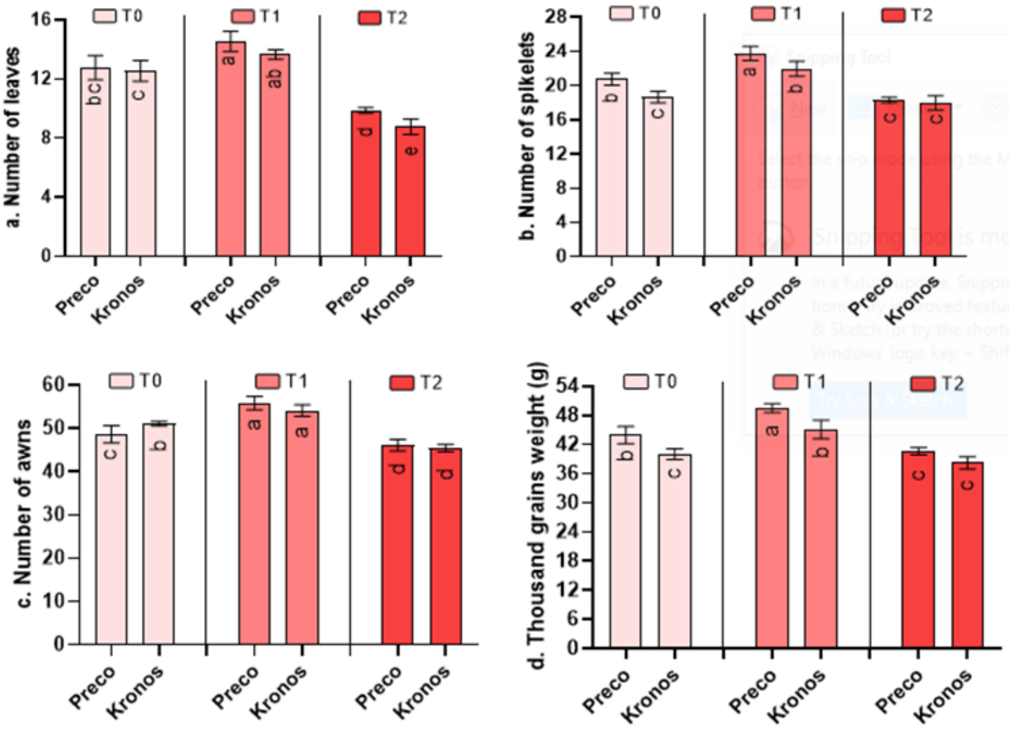

Figure 3. a: Number of leaves b. Number of spikelets c. Number of awns d. Thousand grain weight. Comparison of durum wheat characteristics under different levels of nano-ferric oxide application. Means with different letters are significantly different (Tuckey's HSD, $p \leq 0.05$).

Maximum increase in number of awns was observed under T1 treatment (20 ppm). Preco variety showed highest number of awns at 20 ppm treatment with 55.88 mean value. Kronos showed number of awns value of 55.11 in 20 ppm treatment. Under the T2 treatment the number of awns were significantly decreased in both varieties (Figure 3c) (Table 3). It is one of the vital yields contributing components considered as a significant part in deciding yield capability of an assortment. Maximum thousand-grain weight (49.49 g) was observed under T1 treatment in Preco variety, while the lowest value (38.21 g) was observed of Kronos variety under T2 treatment. The increment rate of internode length under T1 treatment was little bit higher in Kronos variety as compared to Preco; 12.40 %, 12.66 % respectively (Table 3). The research results showed thousand-grain weight increased up to 20 ppm concentration and decreased under 50 ppm treatment

(Figure 3d). Nanoparticles application resulted in yield enhancement at 20 ppm of nanoparticles progressively. Fe is one of the most critical rare elements that plants, and animals require. It is an important component of cell metabolism and is involved in photosynthesis, respiration, enzyme activity, and other processes [31].

Table 3: Percentage (%) variation of observed traits of durum wheat varieties as compared to control under different application levels of nano-ferric oxide.

Traits	Treatments	Varieties	
		Preco	Kronos
Plant Height	T1	8.989	6.085
	T2	-4.042	-3.569
Root Length	T1	14.081	15.362
	T2	-6.012	-6.868
Spike Length	T1	22.306	22.096
	T2	2.809	-15.292
Awn Length	T1	9.234	16.663
	T2	-10.997	-7.881
Internode Length	T1	20.201	16.678
	T2	-14.627	-10.696
Number of Leaves	T1	13.935	8.842
	T2	-22.599	-30.111
Number of Spikelets	T1	14.423	17.86
	T2	-11.776	-3.572
Number of Awns Per Spike	T1	14.837	5.87
	T2	-5.254	-11.088
Thousand-Grain Weight	T1	12.655	12.696
	T2	-7.564	-4.515
Leaf Rolling	T1	-48.541	-24.026
	T2	16.216	38.961
Relative Water Content	T1	4.355	11.844
	T2	-3.181	-7.238
Glaucousness	T1	7.17	5.809
	T2	-11.599	-6.846
Pubescence	T1	17.668	26.278
	T2	-6.184	-16.202

(Note: Positive (+) values indicated the increment while negative (-) values presented reduction of specific trait as compared to control)

Leaf Rolling and Relative Water Content

Leaf rolling reduced the ability to absorb sunlight. The results of leaf rolling trait indicated that this was significantly different at ($p<0.001$) among treatments and interaction between treatments and genotypes was also significant at $p<0.01$ (Table 2). The results revealed that leaf rolling was significantly decreased in T1 treatment while it increased in T2 treatment. The highest decrease was observed in Preco variety (1.59, 48.54 %) as compared to control (Figure 4a) (Table 3). The highest increase in leaf rolling value was observed in Kronos variety under T2 treatment (3.57, 38.96 %). Our results are in accordance with Bogale et al. [32] who proposed that grain yield altered by leaf position and rolling. In current study the decrease in leaf rolling suggests its role in higher yield.

Relative water contents are proportionally associated with water quantity in soil [33]. Results of relative water contents revealed the highly significantly variations ($p<0.001$) among treatments, varieties and their interaction (Table 2). The highest value of relative water contents (94.81) was observed in Preco variety under T1 treatment (Figure 4b), while the lowest value of relative water contents (76.64) was observed in Kronos variety under T2 treatment.

Glaucousness and Pubescence

According to Richards [34] spot estimation of leaf photosynthesis may fluctuate with leaf development and leaf surface. Glaucousness, the waxy bloom on the surface of leaves and other plant components, is related to wheat grain output [35]. Leaf pubescence (hairiness) has a wide phenotypic range and plays an important biological role in pest resistance and adaptability to the environment [36]. Pubescence has been shown to be significant for water retention in spring common wheat and is generally connected with a more efficient use of water [37,38].

The result of current investigation shows that the glaucousness and pubescence values were significantly different at ($p\leq0.001$) for treatments and genotypes but their interaction was non-significant (Table 2). The highest glaucousness value (9.52) were observed under T1 treatment in Preco variety. While the lowest glaucousness value (7.48) were observed under T2 treatment in Kronos variety (Figure 5a). Similarly, the maximum increase (7.71 %) in glaucousness were observed in Preco variety under T1 treatment. In Kronos variety the glaucousness value (5.81 %) also significantly improved in T1 treatment as compared to control (Table 3). Maximum increase in value of pubescence was observed under T1 treatment (20 ppm). Preco variety showed highest pubescence at 20 ppm treatment with 8.88 mean value. Kronos showed pubescence value of 8.31 in 20 ppm treatment and this increase was higher than the Preco variety pubescence as compared to control (26.28 %, 17.67 % respectively). Under the T2 treatment the pubescence values were significantly decreased in both varieties (Figure 5b) (Table 3). Our results suggest that the increase in the glaucousness and pubescence value under the application of optimistic level of ferric oxide NPs can also promotes the wheat resistance for biotic and abiotic stresses.

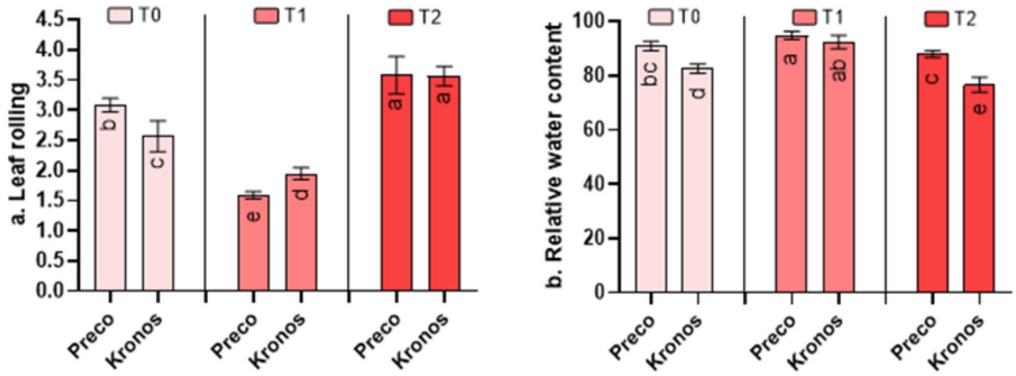

Figure 4. a: Leaf rolling b. Relative water content. Comparison of durum wheat characteristics under different levels of nano-ferric oxide application. Means with different letters are significantly different (Tuckey's HSD, $p \leq 0.05$).

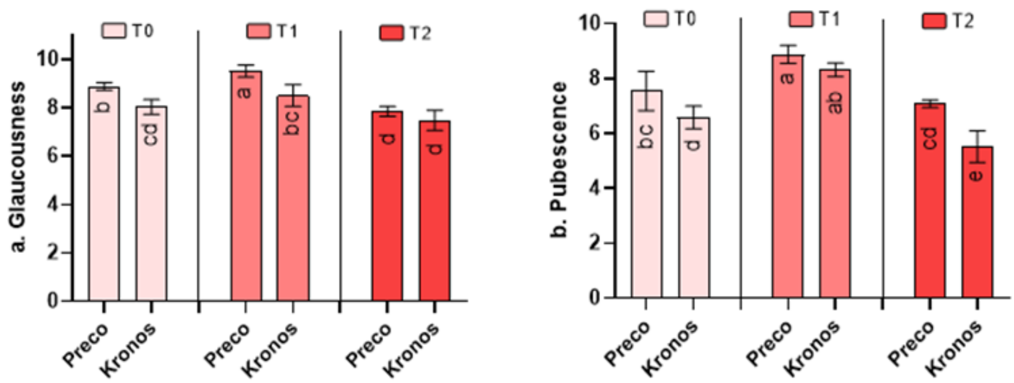

Figure 5. a: glaucousness b. Pubescence. Comparison of durum wheat characteristics under different levels of nano-ferric oxide application. Means with different letters are significantly different (Tuckey's HSD, $p \leq 0.05$).

Conclusion

In recent study the durum wheat genotypes were evaluated under different nano-ferric oxide. Results shows that nano-ferric oxide could improve the plant growth and development at the critical point. But we found that higher dose of nano-ferric oxide harmful for plant health. Nano-ferric oxide application at the level of 20 ppm significantly enhanced durum wheat observed traits in both genotypes. Preco genotype showed the highest plant height (109.56 cm), root length (19.42 cm), spike length (12.48 cm), awns length (19.83 cm), internode length (19.12 cm), number of leaves (14.55), number of spikelets (23.77), number of awns (55.88), thousand-grain weight (49.49 g), relative water contents (94.81), glaucousness (9.52) and pubescence (8.88). Nano-ferric oxide application at the level of 50 ppm significantly decreased as compared to control which indicated that higher application of nano-ferric oxide from optimal point harmful for plant growth.

References

1. Ranieri R (2015) Geography of the durum wheat crop. Pastaria Int 6: 24-36.
2. Taylor RD, Koo WW (2015) Outlook of the U.S. and world wheat industries, 2015-2024. Agribus Appl Econ 738: 1-23.
3. Razmjoo J, Ghafari H (2015) Response of durum wheat to foliar application of varied sources and rates of iron fertilizers. J Agric Sci Techno 17(2):321-331.
4. Bonjean AP, Angus WJ (2001) The World Wheat Book: A history of wheat breeding. Lavoisier Publishing; France.
5. Sissons M (2008) Role of durum wheat composition on the quality of pasta and bread. Food 2(2): 75-90.
6. William AN, Alain BO, Maarten VG (2011) World Wheat Book 2, vol 2: A History of Wheat Breeding. Lavoisier.
7. Fernandez MP, Hullmann A (2007) A boost for safer nanotechnology. Nano Today 2(1): 56.
8. Tarafdar JC, Sharma S, Raliya R (2013) Nanotechnology: Interdisciplinary science of applications. Afr J Biotechnol 12(3): 219-226.
9. Batista CAS, Larson RG, Kotov NA (2015) Nonadditivity of nanoparticle interactions. Science 350(6257): 1242477.
10. Auffan M, Rose J, Bottero JY, Lowry GV, Jolivet JP, et al. (2009) Towards a definition of inorganic nanoparticles from an environmental, health and safety perspective. Nat Nanotechnol 4(10): 634-641.
11. Gardea-Torresdey JL, Rico CM, White JC (2014)Trophic transfer, transformation, and impact of engineered nanomaterials in terrestrial environments. Environ Sci Technol 48(5): 2526-2540.

12. Guendouz A, Hafsi M, Khebbat Z, Moumeni L, Achiri A (2014) Evaluation of grain yield, 1000 kernels weight and chlorophyll content as indicators for drought tolerance in durum wheat (Triticum durum Desf.). Adv Agric Biol 1(2): 89-92.

13. Gogos A, Knauer K, Bucheli TD (2012) Nanomaterials in plant protection and fertilization: current state, foreseen applications, and research priorities. J. Agric Food Chem 60(39): 9781-9792.

14. Agi A, Junin R, Jaafar MZ, Mohsin R, Arsad A, et al. (2020)Synthesis and application of rice husk silica nanoparticles for chemical enhanced oil recovery. J Mater Res Technol 9(6): 13054-13066.

15. Zhao L, Sun Y, Hernandez-Viezcas JA, Servin AD, Hong J, et al. (2013) Influence of CeO2 and ZnO nanoparticles on cucumber physiological markers and bioaccumulation of Ce and Zn: a life cycle study. J Agric Food Chem 61(49): 11945-11951.

16. Hussain A, Ali S, Rizwan M, Rehman MZ, Qayyum MF, et al. (2019) Responses of wheat (Triticum aestivum) plants grown in a Cd contaminated soil to the application of iron oxide nanoparticles. Ecotoxicol Environ 173: 156-164.

17. Briat JF, Curie C, Gaymard F (2007) Iron utilization and metabolism in plants. Curr Opin Plant Biol 10(3): 276-282.

18. Yang X, Alidoust D, Wang C (2020) Effects of iron oxide nanoparticles on the mineral composition and growth of soybean (Glycine max L.) plants. Acta Physiol Plant 42: 128.

19. Sheykhbaglou R, Sedghi M, Shishevan MT, Sharifi RS (2010) Effects of nano-iron oxide particles on agronomic traits of soybean. Not Sci Biol 2(2): 112-113.

20. Abbasi Khalaki M, Moameri M, Asgari Lajayer B, Astatkie T (2021) Influence of nano-priming on seed germination and plant growth of forage and medicinal plants. Plant Growth Regul 93: 13-28.

21. Babadi VY, Najafi L, Najafi A, Gholami H, Zarji MEB, et al. (2012) Evaluation of iron oxide nanoparticles effects on tissue and enzymes of liver in rats. J Pharm Biomed Sci 23(23): 1-4.

22. Homer DC, Pratt PF (1961) Methods of Analysis for Soils, Plants and Waters. Davis: University of California, Davis.

23. Steel RGD, Torrie JH, Dickey DA (1997) Principles and Procedures of Statistics: A biometrical Approach, 3rd edition, McGraw-Hill, New York.

24. Yuan J, Chen Y, Li H, Lu J, Zhao H, et al. (2018) New insights into the cellular responses to iron nanoparticles in Capsicum annuum. Sci Rep 8(1): 1-9.

25. Rui M, Ma C, Hao Y, Guo J, Rui Y, et al. (2016) Iron oxide nanoparticles as a potential iron fertilizer for peanut (Arachis hypogaea). Front Plant Sci 7: 815.

26. Konate A, He X, Zhang Z, Ma Y, Zhang P, et al. (2017) Magnetic (Fe3O4) nanoparticles reduce heavy metals uptake and mitigate their toxicity in wheat seedling. Sustainability 9(5): 790.

27. Liu R, Lal R (2015) Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. Sci Total Environ 514: 131-139.

28. Briat JF, Curie C, Gaymard F (2007) Iron utilization and metabolism in plants. Curr Opin Plant Biol 10(3): 276-282.

29. Yasmeen F, Razzaq A, Iqbal MN, Jhanzab HM (2015) Effect of silver, copper and iron nanoparticles on wheat germination. Int J Biosci 6(4): 112-117.

30. Rizwan M, Ali S, Ali B, Adrees M, Arshad M, et al. (2019) Zinc and iron oxide nanoparticles improved the plant growth and reduced the oxidative stress and cadmium concentration in wheat. Chemosphere 214: 269-277.

31. Bakhtiari M, Moaveni P, Sani B (2015) The effect of iron nanoparticles spraying time and concentration on wheat. Biological Forum 7(1): 679.

32. Bogale A, Tesfaye K, Geleto T (2011) Morphological and physiological attributes associated to drought tolerance of Ethiopian durum wheat genotypes under water deficit condition. J Biodivers Environ Sci 1(2): 22-36.

33. Qadir M, Wang X, Baloch AH, Baloch IA, Azeem M (2018) The impact of drought on phenotypic characters of five advance bread wheat genotypes. Pure Appl Bio 7(2): 635-642.

34. Richards RA (2000) Selectable traits to increase crop photosynthesis and yield of grain crops. J Exp Bot 51(suppl_1): 447-458.

35. Clarke JM, McCaig TN, Depauw RM (1994) Inheritance of glaucousness and epicuticular wax in durum wheat. Crop Sci 34(2): 327-330.

36. Genaev MA, Doroshkov AV, Pshenichnikova TA, Kolchanov NA, Afonnikov DA (2012) Extraction of quantitative characteristics describing wheat leaf pubescence with a novel image-processing technique. Planta 236(6): 1943-1954.

37. Johnson HB (1975) Plant pubescence: an ecological perspective. Bot Rev 41(3): 233-258.

38. Hameed M, Mansoor U, Ashraf M, Rao AUR (2002) Variation in leaf anatomy in wheat germplasm from varying drought-hit habitats. Int J Agr Biol 4: 12-16.

Citation: Furqan A, Ameer K, Shahzad A, et al. Impacts of Nano-Ferric Oxide on Morpho-Physiological Traits of Durum Wheat.*Int J Agri Res Env Sci*. 2022;3(1):1–7. DOI: 10.51626/ijares.2022.03.00019