Journal of Plant Physiology and Breeding
University of Tabriz
Print ISSN: 2008-5168 Online ISSN: 2821-0174

2024, 14(2): 181-191

Effect of anti-transpirant and auxin on wheat (*Triticum aestivum* L.) grain yield, yield-related traits, and germination

Hassan Heidari

Department of Plant Production and Genetics Engineering, Faculty of Agricultural Science and Engineering, Razi University, Kermanshah, Iran.
Email: heidari1383@gmail.com

Article Info
Article type:
Research article

Article history:
Received August 12, 2024
Revised September 8, 2024
Accepted September 11, 2024
Published online December 31, 2024

Keywords:
Harvest index,
Maternal plant's environment,
Phytohormone,
Transpiration,
Water-saving

Abstract

Objective: The grain yield of wheat is always limited by drought in arid and semiarid areas. Field and laboratory experiments were conducted to investigate the effects of anti-transpirants and auxins on grain yield, yield-related traits, and germination of wheat.

Methods: The field experiment was carried out in the Chamchamal Plain of Kermanshah, Iran, using a split-plot design with three replications. Concentrations of auxin (0, 50, and 100 ppm) were arranged in main plots, and anti-transpirant (sunflower oil) concentrations (0, 5, and 10%) in subplots. 2,4-D + MCPA (2-methyl-4-chlorophenoxyacetic acid) were used as auxins. At the harvesting time (June 20, 2014), several agronomic characteristics, including grain yield and single-grain weight, were measured. In addition, a laboratory experiment was conducted by choosing random seeds from the mother plants in the field experiment to study the effect of anti-transpirant and auxin on germination characteristics, including germination percentage, caulicle length, and radicle length.

Results: Results showed that auxin application of 100 ppm had the lowest single-grain weight. Anti-transpirant and auxin application had no significant effect on grain yield. Auxin concentration of 100 ppm with an anti-transpirant application rate of 0%, and an auxin application rate of 100 ppm with an anti-transpirant concentration of 10% resulted in the lowest harvest index. Also, the auxin concentration of 100 ppm with an anti-transpirant application rate of 10% had the lowest seed germination. This is probably because hormonal and oil agents have mediated the increase in wheat seed germination inhibitors.

Conclusion: Using auxin and anti-transpirant in the reproductive stage didn't have a positive effect on grain yield, yield-related traits, and germination of seeds from mother plants in wheat. Also, auxin had a negative effect on the single-grain weight. Therefore, the studies about the effect of herbal anti-transpirants and auxin at the vegetative stage of wheat are recommended to gain further insight about the effectiveness of these compounds on agronomic traits in wheat.

Cite this article: Heidari H. 2024. Effect of anti-transpirant and auxin on wheat (*Triticum aestivum* L.) grain yield, yield-related traits and germination. J Plant Physiol Breed. 14(2): 181-191.

Publisher: University of Tabriz

Introduction

The grain yield of wheat is always limited by drought in arid and semiarid areas. In these areas, the amount of transpiration is higher than the amount of water absorbed by the plant. In this situation, although there is enough moisture around the roots of the plant during the day, the plant is forced to close its stomata. Different ways to reduce transpiration have been used by researchers, and each has different limitations and efficiencies (Bittelli *et al*. 2001; Haggag 2002; Maamoun and Hassan 2013; Freire *et al*. 2021). A spray of linseed oil as an anti-transpirant at concentrations of 7 and 10% on wheat and barley under drought showed that this substance maintained the plant moisture content compared to the control (Ouerghi *et al*. 2010). Abou Leila *et al*. (2007) studied three anti-transpirants of kaolin, calcium carbonate, and paraffin wax on sesame (*Sesamum indicum* L.) cultivars under salinity stress and found that kaolin increased grain yield components and paraffin wax decreased them compared to the control (non-anti-transpirant application). The use of foliar spraying of chitosan (750 ppm) as an anti-transpirant on faba bean (*Vicia faba* L.) plants led to improvement of plant height, number of branches per plant, number of pods per plant, number of seeds per pod, 100-seed weight, and grain yield (Fouda *et al*. 2022).

The effect of auxin as a plant growth hormone on crop growth and development has been proven in many studies (Ma *et al*. 2013; Tavakkol Afshari *et al*. 2011; Wang *et al*. 2021; Yang *et al*. 2021). Ghodrat *et al*. (2012) observed that among the three concentrations of 0, 50, and 100 mg/L, consumption of 100 mg/L gibberellic acid and indole butyric acid in maize (*Zea mays* L.) had the highest crop growth rate. In a study, the effect of auxins on the improvement of grain yield of six varieties of wheat (*Triticum aestivum* L.) under heat stress was evaluated. The results showed that 4-Cl-IAA with a concentration of 1 µM increased the grain yield by only 8% in one of the cultivars, but the seed protein content was not affected (Abeysingha *et al*. 2021). Foliar application of indole-3-acetic acid maintained pollen grain viability, panicle fertility, and rice grain yield in drought conditions (Sharma *et al*. 2018). The use of naphthalene acetic acid in wheat genotypes was effective and promising on biomass, grain yield, and its yield components (Jahan et al. 2019). According to Khedr et al. (2022), foliar spray of naphthalene acetic acid increased plant height, spike number per square meter, 1000-kernel weight, and grain yield in wheat, but did not have a significant effect on kernel number per spike. The use of 40% methanol under conditions of extreme water deficit stress increased the biomass of the marigold plant due to the increased activity of antioxidant defense ability and maintaining many physiological activities (Khalilzadeh *et al*. 2020). In the study of the effect of drought and hormones on potato, it was observed that epibrassinolide improved plant height, dry matter of leaves, and tubers. Gibberellic acid had a better effect on transpiration rate and tuber number. These hormones mitigated the negative effects of drought in one study (Pourasadollahi *et al*. 2019). However, Blythe *et al*. (2004) reported that the application of auxin on *Aglaonema modestum*, *Gardenia augusta* (L.) Merrill, and *Ficus benjamina* L. did not improve the shoot growth.

The maternal plant environment can affect the germination traits of the produced seeds. In the iris (*Iris hexagona*), seeds of mother plants under salinity stress germinated more and earlier than seeds of mother plants under low salinity, which indicates the indirect effect of the mother plant environment (Van Zandt and Mopper 2004).

There is no research on the simultaneous effect of auxin and anti-transpirant on the germination characteristics of seeds obtained from the wheat mother plant. Therefore, this experiment was designed to determine germination traits of the produced seeds of wheat, and also the grain yield and yield-related traits under auxin and anti-transpirant application.

Materials and Methods

Field experiment

The field experiment was conducted in Chamchamal Plain located at 47 km from Kermanshah (Latitude 34° N, longitude 47° E, and altitude 1300 m above sea level), Iran. This plain is one of the fertile plains of Kermanshah. The research was carried out as a split-plot design with three replications. Different concentrations of auxin (0, 50, and 100 ppm) were arranged in main plots, and anti-transpirant concentrations (0, 5, and 10%) in subplots. Sunflower oil was used as an anti-transpirant (de Godoi and Kettlewell 2023). 2,4-D + MCPA (2-methyl-4-chlorophenoxyacetic acid)) was used as an auxin. After preparing the land using a moldboard plow in November 2013, the wheat seeds of the Pishtaz cultivar at 280 kg/ha were sown by hand. Urea and triple superphosphate fertilizers at the rate of 250 kg/ha were used to promote plant growth. Half of the urea fertilizer was applied to the plant at planting time, and the other half at the beginning of the stem emergence (Code 3 according to BBCH scale). Wheat rust and wheat sunn pest were observed in the field, which were controlled with pesticides. Weeds were controlled with herbicides. Experimental treatments were applied at the spike emergence stage (May 15, Code 5 according to BBCH scale). A back sprayer was used to spray the solutions. Throughout the growing season, the plants were irrigated three times.

At the harvesting (June 20, 2014, Code 8 according to BBCH scale), three plants per plot were selected to measure leaf and stem yield, grain number per spike, spike length, spike weight, and single-grain weight. Grain yield, biomass, and harvest index were measured from the whole plot.

Laboratory experiment

Randomly chosen seeds from the bulk of seeds harvested from each treatment in the field experiment were used to evaluate the effect of the mother plant environment (anti-transpirant and auxin) on seed germination characteristics at the laboratory. After superficial disinfection of wheat seeds with sodium hypochlorite, 15 seeds were placed within each disinfected Petri dish, and 6 mL of distilled water was added to each Petri dish. The Petri dishes were placed in plastic covers to prevent water evaporation. The research was conducted in a completely randomized design with three replications. After one week, seed germination characteristics, including germination percentage, caulicle length, and radicle length, were measured. Two-millimeter growth of the caulicle was used as the germination criterion.

Data analysis

SAS was used for variance analysis and mean comparison. SPSS was used for calculating the correlation between traits, and MINITAB was used to find outlier data and perform the normality test. Means were compared by the Duncan Multiple Range Test ($p \leq 0.05$).

Results and Discussion

Field experiment

Analysis of variance showed that different amounts of auxin and anti-transpirant had no significant effect on stem and leaf yield and the number of grains per spike (Table 1). Probably, the dry matter of the stem and leaves and the number of grains per spike at the stage of application of the treatments (emergence of spike) were almost determined and at this stage, only the weight of the reproductive part (grain) could change (Kocheki and Sarmadnia 2012).

Based on analysis of variance, auxin and anti-transpirant had no significant effect on wheat spike weight and spike length (Table 1). One of the reasons for the lack of effect of the different amounts of auxin and anti-transpirant on the weight of wheat spike may be due to the foliar application at the spike stage, because at this stage, the growth of vegetative parts of the plant is almost complete, and only the assimilate distribution between vegetative and reproductive parts may change. If auxin and anti-transpirant were applied before spike emergence, they probably had a greater effect on the studied traits. According to Mukhtar (2008), the use of indole acetic acid and gibberellic acid two weeks after planting changed many vegetative characteristics of *Hibiscus sabdariffa*.

Analysis of variance showed that the different amounts of auxin and anti-transpirant had no significant effect on grain yield and biomass, but auxin had a significant effect on single grain weight (Table 1). Mean comparisons showed that auxin application reduced single-grain weight (Figure 1). Excess auxin in these conditions may have upset the hormonal balance of the grains. After fertilization, the size of the seed increases, which is mainly due to an increase in the cell size. Auxin and gibberellin are major growth hormones. Seeds, like pollen grains, contain growth stimulants such as auxin, gibberellin, and cytokinin. Removal of seeds from strawberry fruit caused the fruit not to grow, and the use of auxin-containing paste on the fruit caused the fruit to grow (Kocheki and Sarmadnia 2012). The lack of effect of antiperspirant and auxin on wheat grain yield and biomass in this research may be related to the stage of application. If these treatments were used in vegetative growth stages, their effect on seed yield might have been significant. Our experiment was conducted in normal conditions, but if the experiment was performed in drought-stress conditions, the effect of the anti-transpirant would have been probably more pronounced. According to Paton *et al*. (1980), increasing the concentration of anti-transpirant increased stomatal resistance in mung beans. Bagheri *et al*. (2012) reported the negative effect of anti-transpirants on photosynthesis in safflower.

Based on analysis of variance, the auxin and its interaction with anti-transpirant had a significant effect on the harvest index (Table 1). Auxin application rates of 100 ppm with an anti-transpirant application rate of 0% and an auxin application rate of 100 ppm with an anti-transpirant application rate of 10% had the lowest harvest index (Table 2). These results showed that consumption of 100 ppm auxin changes the distribution of assimilates between the vegetative and reproductive parts. In other words, consuming large amounts of auxin causes a greater reduction in the reproductive part than the vegetative part. Excess and external auxin may interfere with the proper development of the grains by causing hormonal disturbances. Regarding single-grain weight, it was observed that the application of a high amount of auxin reduced single-grain weight. The positive and significant correlation of harvest index with grain yield, grain weight, and biomass confirms the negative effect of auxin on grain weight (Table 3). In our experiment, neither auxin nor anti-transpirant had a positive effect on harvest index, because the control treatment (without auxin and anti-transpirant) showed the highest harvest index. However, Bakhsh *et al*. (2011) have declared the positive effect of auxin on grain yield in rice.

Table 1. Analysis of variance of the effect of anti-transpirant and auxin rates on wheat traits in Chamchamal Plain, Kermanshah, Iran in 2013.

Source of variation	df	Mean squares							
		Stem and leaf yield	Grain number per spike	Spike length	Spike weight	Grain yield	Single-grain weight	Biomass	Harvest index
Block	2	0.06^{ns}	35.8^{ns}	0.7^{ns}	0.08^{ns}	0.05^{ns}	0.000003^{ns}	0.28^{ns}	7.1^{ns}
Auxin (A)	2	0.10^{ns}	116.3^{ns}	6.25^{ns}	0.86^{ns}	0.71^{ns}	0.000271**	1.27^{ns}	172.9**
Error (a)	4	0.01	52.5	0.91	0.20	0.07	0.000004	0.29	12.8
Anti-transpirant (T)	2	0.06^{ns}	49.8^{ns}	0.43^{ns}	0.14^{ns}	0.16^{ns}	0.000019^{ns}	0.34^{ns}	33.7^{ns}
A × T	4	0.08^{ns}	91.4^{ns}	3.10^{ns}	0.25^{ns}	0.14^{ns}	0.000014^{ns}	0.54^{ns}	38.7*
Error (b)	12	0.12	111.3	1.60	0.44	0.24	0.000015	0.97	10.3

*,**: Significant at 5% and 1% probability level, respectively; ns: Not significant.

Table 2. Effect of the combination of auxin and anti-transpirant rates on wheat traits in Chamchamal Plain, Kermanshah, Iran, in 2013.

Treatment[a]	Harvest index (%)[b]	Germination percent	Caulicle length (cm)
A1O1	47.78a	93.3a	3.8ab
A2O1	45.45a	82.2a	3.4abc
A3O1	33.64b	42.9bc	2.1bc
A1O2	47.44a	64.7ab	3.1abc
A2O2	44.75a	68.8ab	3.6abc
A3O2	45.47a	94.1a	3.8ab
A1O3	47.05a	36.5bc	1.9c
A2O3	44.03a	58.8ab	3.0abc
A3O3	37.46b	20.0c	4.0a

[a]A1, A2, and A3 are auxin rates of 0, 50, and 100 ppm, respectively; O1, O2, and O3 are anti-transpirant rates of 0, 5, and 10 %.
[b]Means with similar letters in each column are not significantly different at $p \leq 0.05$ as determined by Duncan's multiple range test.

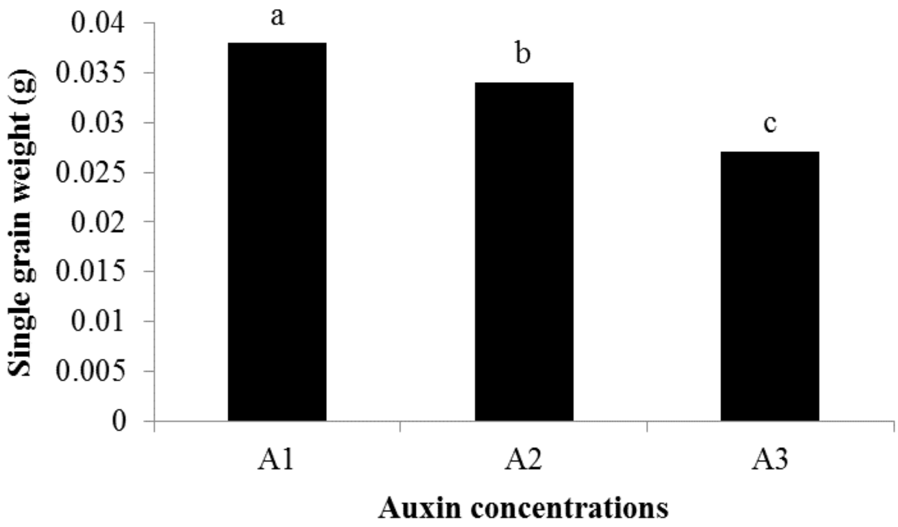

Figure 1. Mean comparisons of the effect of auxin application rates on wheat single-grain weight in Chamchamal plain, Kermanshah, Iran, in 2013. A1, A2, and A3 are auxin rates of 0, 50, and 100 ppm, respectively. Means with different letters are not significantly different at $p \leq 0.05$ as determined by Duncan's multiple range test.

Table 3. Pearson's correlation coefficients among studied traits in wheat under auxin and anti-transpirant rates in Chamchamal plain, Kermanshah, Iran, in 2013.

Trait	Spike length (SL)	Spike weight (SW)	Stem and leaf yield (SLY)	Grain Number per spike (SNS)	Grain yield (GY)	Single-grain Weight (SW)	Biomass (Bio)	Harvest index (HI)
SL	1	0.60^{**}	0.74^{**}	0.79^{**}	0.49^{**}	-0.09	0.67^{**}	-0.13
SW		1	0.82^{**}	0.909^{**}	0.98^{**}	0.68^{**}	0.98^{**}	0.52^{**}
SLY			1	0.88^{**}	0.77^{**}	0.34	0.91^{**}	0.11
SNS				1	0.87^{**}	0.37	0.93^{**}	0.36
GY					1	0.77^{**}	0.95^{**}	0.66^{**}
SW						1	0.60^{**}	0.83^{**}
Bio							1	0.40^{*}
HI								1

*,**: Significant at 5% and 1% probability level, respectively.

Laboratory experiment

Analysis of variance showed that the interaction of auxin and anti-transpirant had a significant effect on germination percentage and caulicle length. Auxin and anti-transpirant had no significant effect on radicle length (Table 4). When the anti-transpirant application rate was 0%, the auxin application rate of 100 ppm reduced the germination percentage of seeds obtained from the mother plant.

However, the anti-transpirant application of 5% on the mother plants eliminated the negative effect of high auxin content on the germination percentage of the resulting seeds (Table 2). Consumption of 10% anti-transpirant also reduced germination percentage when auxin was not used. The results of the field experiment showed that mother plants had smaller seeds under conditions of high auxin consumption, except for the use of 5% anti-transpirant. These seeds probably had thicker coatings and were dormant due to hormonal changes within the seed. The oily anti-transpirant may have been absorbed by the embryo and endosperm or prevented from absorbing moisture during seed germination as a hydrophobic layer in the seed coat (Sorana *et al*. 2020). A study of auxin-synthesizing mutants showed that these mutants induce seed dormancy with the auxin signal. The action of auxin in seed dormancy requires the signal of abscisic acid, and these two hormones are related to seed dormancy (Liu *et al*. 2013).

In the treatment of 100 ppm auxin with 10% anti-transpirant, which had the lowest wheat germination percentage, both hormonal and oil factors were probably involved in increasing the inhibition of seed germination. Under the no auxin application, an anti-transpirant application of 10% significantly reduced caulicle length (Table 2). The oil in the anti-transpirant may be absorbed by the seed, slowing down the absorption of oxygen and moisture by the seed, thus reducing the seedling length. According to Barua *et al*. (2011), the reduction in seed germination of four plant species was due to the prevention of water and oxygen from reaching the seeds by crude oil during germination.

Table 4. Analysis of variance of the effect of anti-transpirant and auxin rates on wheat seed germination traits in Chamchamal Plain, Kermanshah, Iran, in 2013.

Source of variation	df	Mean squares		
		Germination percent	Radicle length	Caulicle length
Auxin (A)	2	740.5^{ns}	1.2^{ns}	0.30^{ns}
Anti-transpirant (T)	2	2951.8**	2.5^{ns}	0.77^{ns}
A × T	4	1398.7*	4.5^{ns}	2.55*
Error	18	370.2	2.0	0.72

*,**: Significant at 5% and 1% probability level, respectively; ns: Not significant.

Conclusion

Application of auxin and anti-transpirant at the start of the reproductive stage, not only didn’t have a significant and/or positive effect on grain yield, yield-related traits, and germination of seeds from mother plants in wheat, but also, the application of auxin had a detrimental effect on the single-grain weight. Therefore, application of herbal anti-transpirants and auxin at the vegetative stage of wheat is recommended to gain further insight about the effects of these compounds on the agronomic characteristics of wheat.

Funding

This research received no external funding.

Conflict of Interest

The author declares no conflict of interest concerning this article.

References

Abeysingha DN, Ozga JA, Strydhorst S, Doyle P, Iqbal M, Yang RC, Reinecke DM. 2021. The effect of auxins on amelioration of heat stress-induced wheat (*Triticum aestivum* L.) grain loss. J Agron Crop Sci. 207(6): 970-983. https://doi.org/10.1111/jac.12555

Abou Leila B, Gaballah MS, El-Zeiny HA, Khali S. 2007. The effect of antitranspirant application on yield and fatty acid of sesame cultivars grown under saline conditions. J Appl Sci Res. 3(9): 879-885.

Bagheri H, Andalibi B, Azimi Moghad'dam MR, Zangani E, Jamshid S. 2012. Safflower (*Carthamus tinctorius* cv. Sina) oil and seed yield improvement in rainfed condition by atrazine foliar application. Ann Biol Res. 3(2): 1202-1209.

Bakhsh I, Awan I, Sadiq M, Niamatullah M, Zaman KU, Aftab M. 2011. Effect of plant growth regulator application at different growth stages on the economical yield potential of coarse rice (*Oryza sativa* L.). J Anim Plant Sci. 21(3): 612-616.

Barua D, Buragohain J, Sarma SK. 2011. Impact of Assam petroleum crude oil on the germination of four crude oil resistant species. Asian J Plant Sci Res. 1(3): 68-76.

Bittelli M, Flury M, Campbell GS, Nichols EJ. 2001. Reduction of transpiration through foliar application of chitosan. Agric For Meteorol. 107(3): 167-175. https://doi.org/10.1016/S0168-1923(00)00242-2

Blythe EK, Sibley JL, Ruter JM, Tilt KM. 2004. Cutting propagation of foliage crops using a foliar application of auxin. Sci Hortic. 103(1): 31-37. https://doi.org/10.1016/j.scienta.2004.04.011

de Godoi RGP, Kettlewell PS. 2023. Applying sunflower oil to rapeseed plants reduces water loss. J Sci Food Agric. 103(15): 7941-7943. https://doi.org/10.1002/jsfa.12872

Fouda SEE, El-Saadony FMA, Saad AM, Sayed SM, El-Sharnouby M, El-Tahan AM, El-Saadony MT. 2022. Improving growth and productivity of faba bean (*Vicia faba* L.) using chitosan, tryptophan, and potassium silicate anti-transpirants under different irrigation regimes. Saudi J Biol Sci. 29(2): 955-962. https://doi.org/10.1016/j.sjbs.2021.10.007

Freire FBS, Bastos RLG, Bret RSC, Cândido-Sobrinho SA, Medeiros DB, Antunes WC, Fernie AR, Daloso DM. 2021. Mild reductions in guard cell sucrose synthase 2 expression leads to slower stomatal opening and decreased whole plant transpiration in *Nicotiana tabacum* L. Environ Exp Bot. 184: 104370. https://doi.org/10.1016/j.envexpbot.2020.104370

Ghodrat V, Rousta MJ, Tadaion MS, Karampour A. 2012. Yield and yield components of corn (*Zea mays* L.) in response to foliar application with indole butyric acid and gibberellic acid. American-Eurasian J Agric Environ Sci. 12(9): 1246-1251. https://doi.org/10.5829/idosi.aejaes.2012.12.09.1880

Haggag W. 2002. Application of epidermal coating antitranspirants for controlling cucumber downy mildew in greenhouse. Plant Pathol Bull. 11: 69-78.

Jahan MAHS, Hossain A, Da Silva JAT, El Sabagh A, Rashid MH, Barutçular C. 2019. Effect of naphthaleneacetic acid on root and plant growth and yield of ten irrigated wheat genotypes. Pak J Bot. 51(2): 451-459.

Khalilzadeh R, Seid Sharifi R, Pirzad A. 2020. Mitigation of drought stress in pot marigold (*Calendula officinalis*) plant by foliar application of methanol. J Plant Physiol Breed. 10(1): 71-84. https://doi.org/10.22034/jppb.2020.12507

Khedr RA, Sorour SGR, Aboukhadrah SH, El Shafey NM, Abd Elsalam HE, El-Sharnouby ME, El-Tahan AM. 2022. Alleviation of salinity stress effects on agro-physiological traits of wheat by auxin, glycine betaine, and soil additives. Saudi J Biol Sci. 29(1): 534-540. https://doi.org/10.1016/j.sjbs.2021.09.027

Kocheki E, Sarmadnia GH. 2012. Physiology of crop plants. Mashhad, Iran: Jahade Daneshgahi of Mashhad Press, 400 p. (In Persian).

Liu X, Zhang H, Zhao Y, Feng Z, Li Q, Yang H-Q, Luan S, Li J, He Z-H. 2013. Auxin controls seed dormancy through stimulation of abscisic acid signaling by inducing ARF-mediated ABI3 activation in Arabidopsis. Proc Natl Acad Sci USA. 110(38): 15485-15490. https://doi.org/10.1073/pnas.1304651110

Maamoun HA, Hassan MA. 2013. Effect of irrigation water levels and anti-transpirants on productivity of sesame (*Sesamum indicum* L.) plant at New Valley, Egypt. Egypt J Agron. 35(1): 21-35. https://doi.org/10.21608/agro.2013.91

Ma Q, Ding Y, Chang J, Sun X, Zhang L, Wei Q, Cheng Y, Chen L, Xu J, Deng X. 2013. Comprehensive insights on how 2,4-dichlorophenoxyacetic acid retards senescence in post-harvest citrus fruits using transcriptomic and proteomic approaches. J Exp Bot. 65(1) 61-74. https://doi.org/10.1093/jxb/ert344

Mukhtar, FB. 2008. Effect of some plant growth regulators on the growth and nutritional value of *Hibiscus sabdariffa* L. (Red sorrel). Int J Pure Appl Sci. 2(3): 70-75.

Ouerghi F, Bouzaien G, Albouchi A, Ben-Hammouda M, Cheikh M'hamed H, Aloui-Rezgui S, Nasraoui B. 2010. Effects of linseed oil spray on some physiological traits of durum wheat and barley under glasshouse water deficit stress. Tunis J Plant Prot. 5: 1-8.

Paton DM, Dhawan AK, Willing RR. 1980. Effect of eucalyptus growth regulators on the water loss from plant leaves. Plant Physiol. 66(2): 254-256. https://doi.org/10.1104/pp.66.2.254

Pourasadollahi A, Siosemardeh A, Hosseinpanahi F, Sohrabi Y. 2019. Physiological and agro-morphological response of potato to drought stress and hormone application. J Plant Physiol Breed. 9(1): 47-61. https://doi.org/10.22034/jppb.2019.10337

Sharma L, Dalal M, Verma RK, Kumar SVV, Yadav SK, Pushkar S, Kushwaha SR, Bhowmik A, Chinnusamy V. 2018. Auxin protects spikelet fertility and grain yield under drought and heat stresses in rice. Environ Exp Bot. 150: 9-24. https://doi.org/10.1016/j.envexpbot.2018.02.013

Sorana IȚ, Mihăilescu S, Strat D, Florentina GI. 2020. Effects of oil pollution on seed germination and seedling emergence toxicity. Rom Biotechnol Lett. 25(1): 1194-1201. https://doi.org/10.25083/rbl/25.1/1194.1201

Tavakkol Afshari R, Angoshtari R, Kalantari S. 2011. Effects of light and different plant growth regulators on induction of callus growth in rapeseed (*Brassica napus* L.) genotypes. Plant Omics J. 4 (2): 60-67.

Van Zandt PA, Mopper S. 2004. The effects of maternal salinity and seed environment on germination and growth in *Iris hexagona*. Evol Ecol Res. 6: 813-832.

Xiong Y, Wu B, Du F, Guo X, Tian C, Hu J, Lü S, Long M, Zhang L, Wang Y, *et al*. 2021. A rosstalk between auxin and brassinosteroid regulates leaf shape by modulating growth anisotropy. Mol Plant. 14(6): 949-962. https://doi.org/10.1016/j.molp.2021.03.011

Yan X, Xu Q, Li D, Wang J, Han R. 2021. Carbon dots inhibit root growth by disrupting auxin biosynthesis and transport in Arabidopsis. Ecotoxicol Environ Saf. 216: 112168. https://doi.org/10.1016/j.ecoenv.2021.112168