Effect of antitranspirant and nitrogen on wheat seed yield and germination

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ABSTRACT

Drought is the most important limiting factor in dryland farming. One of the ways to reduce transpiration is antitranspirants application. To achieve the purpose, field and laboratory experiments were conducted to assess the effect of antitranspirant and nitrogen on yield, yield components, and germination traits in wheat. Treatments included different concentrations of antitranspirant, sunflower oil (0%, 5%, and 10%), and different rates of nitrogen (0, 75, and 150 kg ha^{-1}). Nitrogen and antitranspirant were applied at the time of spike emergence, May 15**.** In the laboratory experiment, the germination traits of seeds produced in the field experiment were assessed using a standard germination test. Results showed that the application of different rates of antitranspirant and nitrogen did not affect leaf and stem yield, seed number per spike, spike weight, seed yield, seed weight, biological yield, or germination traits of the produced wheat seeds. Antitranspirant rate application of 10% reduced harvest index compared to no or 5% application. Factors such as high soil nitrogen fertility, relatively proper soil moisture, and/or treatment application stage can be reasons for the lack of a significant effect of the mentioned treatments.

Keywords: Fertilizer, Harvest index, Radicle length, Water consumption.

Efeito do antitranspirante e do nitrogênio na produtividade e germinação de sementes de trigo

RESUMO

A seca é o fator limitante mais importante na agricultura de sequeiro. Uma das formas de reduzir a transpiração é a aplicação de antitranspirantes. Para atingir o objetivo, experimentos de campo e de laboratório foram conduzidos para avaliar o efeito do antitranspirante e do nitrogênio na produtividade, nos componentes da produção e nas características de germinação do trigo. Os tratamentos incluíram diferentes concentrações de antitranspirante, óleo de girassol (0, 5 e 10%) e diferentes doses de nitrogênio (0, 75 e 150 kg ha^{-1}). O nitrogênio e o antitranspirante foram aplicados no momento da emergência das espigas, em 15 de maio. No experimento de laboratório, o atributo germinação das sementes produzidas no experimento de campo foram avaliadas pelo teste de germinação. Os resultados mostraram que a aplicação de diferentes taxas de antitranspirante e nitrogênio não influenciou o número de folhas e de caules, o número de sementes por espiga, o peso da espiga, o rendimento das sementes, o peso das sementes, o rendimento biológico e a germinação das sementes de trigo produzidas. A aplicação de taxa de antitranspirante de 10% reduziu o índice de colheita em comparação com nenhuma ou 5% de aplicação. Fatores como alta fertilidade do nitrogênio do solo, umidade relativamente adequada do solo e/ou estágio de aplicação do tratamento podem ser alguns motivos para a falta de efeito significativo dos tratamentos mencionados.

Palavras-chave: Fertilizante, Índice de colheita, Comprimento da radícula, Consumo de água**.**

1. Introduction

Iran is located in the arid region of the world. Iran's annual rainfall is less than one-third of the global average annual rainfall. Various methods for addressing drought have been evaluated by numerous researchers. One of these ways is to use antitranspirants. Antitranspirants can reduce plant water consumption by 50% while also increasing water use efficiency (Anderson and Kreith, 1987). The use of atrazine as an antitranspirant increased the yield of sorghum (Fuehring, 1975). The use of atrazine as an antitranspirant increased the number of rows per ear, the number of grains per ear, the weight of 500 grains, the above-ground biomass (biological) yield, grain yield, and harvest index in maize (*Zea mays*) compared to the control, and atrazine produced better results than paraffin and wax (Kazempour and Tajbakhsh, 2002). The use of kaolin, nu-film, bio-film, folicote, and Polyacrylamide Anti-Stress 550 antiperspirants increased the height and yield of cucumber (Haggag, 2002). The use of linseed oil as an antitranspirant on wheat and barley maintained the leaf moisture content under drought stress conditions without affecting plant photosynthesis (Ouerghi et al., 2010).

Nitrogen is the most widely consumed and limiting nutrient in agricultural ecosystems (Du et al., 2021; Yao et al., 2021). Due to the motility and rapid deformation of nitrogen in the soil, there is usually a lack of nitrogen in the soil in the late stages of plant growth. High nitrogen consumption and high plant density increased the number of spikes per plot but decreased the number of grains per spike and the weight of 1000 grains of wheat. This effect was mainly due to the inhibition of sucrose transfer and the accumulation of starch in the secondary grain in the middle spikelets by reducing the ratio of abscisic acid to ethylene (Liu et al., 2021). Among different rates of nitrogen fertilizer (75, 150, 225, and 300 kg ha^{-1}), consumption of 225 kg N ha^{-1} was the most appropriate rate for wheat, and with increasing nitrogen consumption, the number of spikes, the number of seeds per spike, 1000-grain weight and grain yield increased (Saleem Kubar et al., 2021).

The maternal plant environment affects seed germination and seedling growth (Mojzes et al., 2015; Penfield, 2017; El-Keblawy et al., 2020; Aghdash et al., 2021). Consumption of 100 kg ha^{-1} of nitrogen at the time of planting in rapeseed increased the emergence percentage and decreased the average emergence time of the produced seeds (Oskouie, 2012). The supply of nitrogen in the mother plant environment at planting stage is involved in increasing the germination of offspring (Adeyemi et al., 2021). In the study of nitrogen management applied to the mother plant on lettuce seed quality, it was observed that seed quality began to decrease at nitrogen concentrations above 5 mM, while seed longevity improved below 5 mM nitrogen. The light requirements for seeds to germinate decreased with increasing nitrogen supply (Albornoz et al., 2019).

The interaction of nitrogen as an enhancer of source strength and consumption of antitranspirants to maintain plant photosynthesis under conditions of low moisture stress was a hypothesis evaluated in this study. Therefore, the objectives of the present study were: 1) To determine the best treatment combination of nitrogen fertilizer and antitranspirant that produced the highest grain yield. 2) To determine the germination characteristics of seeds obtained from the mother plant under the conditions of using nitrogen and antitranspirant.

2. Material and Methods

This research was conducted in the agricultural lands of the Chamchamal Plain, located 47 km from Kermanshah. Chamchamal Plain is one of the most fertile plains in western Iran, and the common crop rotation in this area is maize-wheat. Due to recent droughts, access to water for irrigation in this area has been limited. Some weather parameters during the wheat growth period are shown in Table 1. The average annual rainfall of the region is 442 mm (Iran’s Meteorological Organization, 2024). Soil properties of the field experiment are presented in Table 2. In November 2013, the land was plowed using a moldboard plow, and to increase soil fertility, urea and triple superphosphate fertilizers were applied at a rate of 250 kg ha^{-1}. Half of the urea fertilizer was applied to the plant at the beginning of the stem emergence. The wheat seed of the Pishtaz cultivar at 280 kg ha^{-1} was sown by hand on November 21, 2013. This experiment was conducted as a split-plot design with three replications. The main plot consisted of antitranspirant (concentrations of 0, 5, and 10%), and the subplot consisted of nitrogen fertilizer (0, 75, and 150 kg N ha^{-1}). The mentioned treatments were used at the spike emergence stage on May 15. Nitrogen was sourced from urea (46% nitrogen). Urea with the formula $CO(NH_2)_2$ was manufactured by Razi Petrochemical Company. Urea fertilizer was applied as top-dressing. Sunflower oil was used to prepare an antitranspirant. Famila brand sunflower oil was manufactured by Koresh Food Industry Company. The composition of sunflower oil included refined sunflower oil, citric acid (0.01%), an antioxidant (0.0075%), beta-carotene (0.0003%), vitamin A (240 mg), and vitamin D (45 mg). For this purpose, a few drops of dishwashing liquid were added to it to dissolve in water, and while spraying it on the plant, the back sprayer tank was shaken well.

Table 1. Average temperature, cumulative rainfall, and average relative humidity of the field experiment during wheat growth period (Iran's Meteorological Organization, 2024)

Months	Average temperature (°C)	Cumulated rainfall (mm)	Average relative humidity (%)
Nov	11.5	110.9	58.5
Dec	5.8	111.5	66.0
Jan	0.8	56.2	67.5
Feb	2.6	65.5	64.5
Mar	8.8	60.0	57.0
Apr	11.6	33.5	48.0
May	36.2	16.1	41.0
Jun	23	18.5	28.0

Table 2. Soil physical and chemical properties of the field experiment (depth of 0–30 cm).

Texture	Silty-Clay-Loam
Bulk density (g cm^{-3})	1.1
Field capacity (%)	40.1
Wilting point (%)	23.1
Hydraulic conductivity (mm h^{-1})	16.1
pH	7.2
EC (ds m^{-1})	1.6
$CaCO_3$ (%)	32.0
K (mg kg^{-1})	335.0
Na (mg kg^{-1})	111.0
Nitrogen (%)	2.0
Organic matter (%)	2.51

The basis for the percentages mentioned for the antitranspirant was 400 liters of water in the sprayers behind the tractor. The dominant weeds in the field were wild mustard (*Sinapis arvensis*), myagrum (*Myagrum* sp.), and lady's bedstraw (*Galium verum*). The 2,4-D herbicide was used to control broadleaf weeds. Mild wheat rust disease was observed in the field. The plants were irrigated three times.

At the time of sampling (June 29), three plants were selected from each experimental plot with an area of two square meters, and their desired characteristics were measured. Stem and leaf yield, number of seeds per spike, spike length, spike weight, seed yield, seed weight, biological yield, and harvest index were calculated. The harvest index was obtained by dividing the seed yield by the biological yield.

Seeds obtained from the field experiment were evaluated in a laboratory experiment to determine the effect of the mother plant environment on the germination characteristics of seeds produced. Therefore, the seeds related to each field treatment were stored separately until the laboratory experiment.

The seeds were kept at 25 °C and 16% relative humidity, and a germination test was performed one month after harvest. The experiment was conducted in a completely randomized design with three replications at Razi University in 2014. In the laboratory experiment, wheat seeds were first disinfected using sodium hypochlorite. Sodium hypochlorite with 1% active chlorine was used for 10 minutes (Heidari, 2017).

The resulting seeds were then washed and placed on filter paper and inside sterilized Petri dishes. 20 seeds were placed in each Petri dish (Khaeim et al., 2022). Six milliliters of distilled water were added to each Petri dish, and the Petri dishes were placed in a plastic bag to prevent water from evaporating.

The Petri dishes were then placed in the germinator at 20 °C and after one week the seed germination characteristics including germination percentage and caulicle and radicle length were evaluated. Two millimeters of caulicle growth was considered as the germination criterion.

The percentage of seed germination was calculated by dividing the number of germinated seeds by the total number of seeds planted in the Petri dish (Saadatfar et al., 2023). To measure the length of the radicle and caulicle, three plants per Petri dish were randomly selected. The length of the largest radicle was measured as radicle length. The length of the caulicle and the length of the radicle were measured with the help of a ruler with millimeter accuracy (ISTA, 2025).

Data were analyzed using variance, and Duncan's multiple range test was employed to compare the means of the data. Correlation between traits was also calculated. The statistical software used was SAS, MINITAB, and SPSS.

3. Results and Discussion

The results showed that the application of different amounts of antitranspirant and nitrogen did not affect stem and leaf yield, number of seeds per spike, spike weight, seed yield, seed weight, and biological yield (Table 3). However, spike length (Table 3) and harvest index (Fig. 1) were affected by experimental treatments.

Table 3. Mean comparison for effect of antitranspirant and nitrogen rates on wheat seed yield and yield-related traits.

[a] Treatments	[b] Stem and leaf weight (g/plant)	Seed number per spike	Spike length (cm)	Spike weight (g/plant)	Seed yield (kg/ha)	100-seed weight (g)	Biological yield (kg/ha)
O1N1	1.21 a	49.17 a	9.8 ab	2.45 a	7000 a	3.5 a	14640 a
O2N1	1.23 a	39.78 a	9.3 ab	1.94 a	5400 a	3.4 a	12720 a
O3N1	1.66 a	56.67 a	11.7 a	2.61 a	6920 a	3.0 a	17080 a
O1N2	1.34 a	45.17 a	8.8 ab	2.14 a	5240 a	3.2 a	13960 a
O2N2	1.07 a	36.67 a	8.0 b	1.64 a	4560 a	3.1 a	10840 a
O3N2	1.63 a	53.17 a	10.8 ab	2.27 a	6000 a	2.7 a	15600 a
O1N3	1.37 a	53.78 a	10.4 ab	2.64 a	7680 a	3.5 a	16040 a
O2N3	1.30 a	49.58 a	9.9 ab	2.38 a	6880 a	3.4 a	14760 a
O3N3	1.41 a	55.34 a	10.5 ab	2.26 a	5920 a	2.6 a	14720 a

[a] O1, O2, and O3 are antitranspirant rates of 0, 5, and 10 %, respectively. N1, N2, and N3 are nitrogen rates of 0, 75, and 150 kg ha^{-1}, respectively. [b] Means with the same letter within each column are not significantly different as determined by Duncan's Test (P < 0.05).

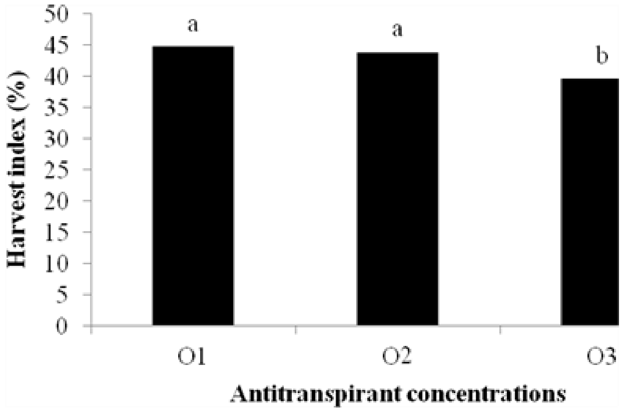

Figure 1. Effect of antitranspirant concentrations on wheat harvest index. O1, O2, and O3 are antitranspirant concentrations of 0, 5, and 10 %, respectively. Means with the same letter are not significantly different as determined by Duncan's Test ($p < 0.05$).

The effect of nitrogen and antitranspirant on the length of the spike was also minor and there was only a difference between the treatment of non-nitrogen consumption with 10% antiperspirant and the treatment of 75 kg nitrogen with 5% antiperspirant (Table 3). Seed yield had a positive and significant correlation with all studied traits (Table 4). The lack of effect of antitranspirant and nitrogen on the yield and yield components of wheat seed has probably several reasons. The time of treatment can be involved in its effectiveness. Many crops absorb most of their required nutrients by the end of the vegetative growth period. Therefore, the consumption of nitrogen at the beginning of the emergence of the spike probably changes the seed quality more than its quantity.

Ooro et al. (2010) reported that the timing of nitrogen application in wheat has a greater effect on grain quality than on yield and yield components. In this study, nitrogen consumption at the time of spike emergence had two purposes. It was used both to determine the effect of nitrogen at this stage on seed yield and yield components and to investigate the effect of nitrogen on seed germination characteristics. The effect of nitrogen on seed germination at this stage was likely to be greater than its effect on the growth of the mother plant. Herbal antitranspirant was used to control and narrow plant stomata. It is clear that the plant has undergone major vegetative growth and dry matter accumulation until the emergence of the spike, and from this stage onwards, the current photosynthesis of the leaves and other green organs, such as the stem, declines to its peak.

Perhaps at this stage, the only antitranspirant can change the distribution of assimilate between vegetative and reproductive parts, which has also happened in the study, i.e. the use of 10% antitranspirant reduced the harvest index compared to its non-consumption or 5% consumption (Fig. 1).

However, the non-significant differences in treatments for harvest index became significant. That is, minor differences had a significant effect when combined. These results indicate that high consumption of the antitranspirant has led to the accumulation of dry matter in the stems and reduced their movement towards the seeds. Of course, these values were low because the differences in biological yield components, i.e., stem and leaf yield, and grain yield, were not significant.

Table 4. Pearson's correlation coefficients among wheat seed yield and yield-related traits under antitranspirant and nitrogen.

	Spike length	Spike weight	Stem leaf weight	Seed no per spike	Seed yield	Seed weight	Biological yield	Harvest index
Spike length	1	735**	813**	868**	644**	-102	795**	105
Spike weight	735**	1	821**	906**	983**	472*	979**	590**
Stem leaf weight	813**	821**	1	851**	729**	113	920**	070
Seed no per spike	868**	906**	851**	1	840**	074	926**	337
Seed yield	644**	983**	729**	840**	1	593**	935**	715**
Seed weight	-102	472*	113	074	593**	1	364	806**
Biological yield	795**	979**	920**	926**	935**	364	1	430*
Harvest index	105	590**	070	337	715**	806**	430*	1

*,**. Significance at the levels of 0.05 and 0.01, respectively.

Excessive use of antitranspirants may have reduced the current photosynthesis of the leaf by closing or narrowing some of the stomata, and to some extent, reduced the excess material needed by the stem and leaf to fill the seeds. However, the limitation was such that, as mentioned, it did not make a significant difference in seed yield. The negative effect of high doses of antiperspirant on plant seed yield has been reported by some researchers (Bagheri et al., 2012).

Another possible reason for the lack of effect of nitrogen on the yield and yield components of wheat seed in this study is the suitability of the soil nitrogen. Perhaps another reason for the lack of effect of the antitranspirant on the studied properties is the relatively good soil moisture. If this study examined different moisture conditions, the effect of the antitranspirant would probably be more pronounced in low soil moisture conditions.

It seems that the use of plant antitranspirant (sunflower oil) after the start of the reproductive stage of the plant in conditions of relatively good soil moisture is not very practical. In this study, wheat was irrigated three times to determine the potential for wheat yield in this area, indicating that twice the amount of irrigation is needed. With this number of irrigations, the plant will suffer from drought stress in some growing seasons, especially in the late growing season and at noon due to the high intensity of transpiration, but the antitranspirant used could not increase the yield.

Many researchers have reported the positive effect of the antitranspirant on maintaining plant yield under severe to moderate water deficit stress (Kazempour and Tajbakhsh, 2002). Ouerghi et al. (2010) reported that the antitranspirant of linseed oil maintained leaf moisture without reducing the photosynthesis of durum wheat and barley.

The use of different amounts of nitrogen and antiperspirant on the mother plant did not affect the germination characteristics of the produced seeds (Table 5). There was a significant positive correlation between germination percentage, caulicle length, and radicle length (Table 6). Given that the amount of nitrogen in soil and wheat seed has not been measured, it cannot be said with certainty that the accumulation of nitrogen in the seeds produced was different.

Some researchers have reported increased germination in rapeseed due to nitrogen (Oskouie, 2012), while others have reported decreased germination of *Sinapis arvensis* seeds with increased nitrogen consumption by the mother plant (Luzuriaga et al., 2006).

Table 5. Mean comparison for effect of antitranspirant and nitrogen rates on wheat seed germination traits.

[a] Treatments	[b] Germination percent	Radicle length (cm)	Caulicle length (cm)
O1N1	71.9 a	5.7 a	3.9 a
O2N1	73.3 a	5.8 a	3.1 a
O3N1	88.9 a	5.4 a	3.7 a
O1N2	84.4 a	5.0 a	3.0 a
O2N2	70.0 a	5.1 a	2.9 a
O3N2	66.6 a	4.6 a	3.4 a
O1N3	83.2 a	5.7 a	3.1 a
O2N3	72.9 a	5.0 a	3.3 a
O3N3	80.7 a	3.8 a	2.7 a

[a] O1, O2 and O3 are antitranspirant rates of 0, 5 and 10 %. N1, N2, and N3 are nitrogen rates of 0, 75, and 150 kg ha^{-1}, respectively. [b] Means with the same letter within each column are not significantly different as determined by Duncan's Test ($p < 0.05$).

Table 6. Pearson's correlation coefficients among seed germination traits in wheat under antitranspirant and nitrogen rates.

	Germination percent	Root length	Shoot length
Germination percent	1	.399*	.391*
Root length	.399*	1	.745**
Shoot length	.391*	.745**	1

*,**. Significance at the levels of 0.05 and 0.01, respectively.

Nitrogen-rich soil may be the reason for the non-significant effect of nitrogen on the germination characteristics of wheat seeds. Although seed treatment with certain substances, such as thiourea and hormones like gibberellin, is involved in increasing seed germination in some plants, it does not appear that oily substances, like the antiperspirant used in this study, affect the germination of seeds obtained from the mother plant. If the sprayed materials on the mother plant were absorbed by the seeds and did not decompose, it was likely to affect the germination and dormancy of the seeds produced. Hormones such as coumarin, abscisic acid, and even essential oils have been reported to cause seed dormancy (Koocheki and Sarmadnia, 2012; Liu et al., 2013).

4. Conclusions

In general, the application of different amounts of nitrogen and antitranspirant did not affect the yield, yield components, and germination characteristics of wheat seeds. Factors such as the richness of field soil in terms of nitrogen, relatively good soil moisture conditions, or the stage of treatment application can be reasons for the ineffectiveness of these treatments. The use of herbal antiperspirants from different oils at the vegetative stage of wheat is recommended for further studies.

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