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Evaluation of germination, morphophysiological traits, and grain yield of wheat affected by foliar application and pretreatment of micronutrient fertilizers (Agrotin) in Miandoab

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Abstract

In recent years, special attention has been paid to using plant growth stimulants such as amino acids and humic acids along with micronutrients as one of the most effective ways to increase the quality and quantity of plants. Germination indices and performance characteristics in different varieties of rainfed wheat (Homa, Baran, and Sadra) were improved using micronutrient fertilizers (Agrotin) as pretreatment and foliar spraying to reduce the effects of environmental stress. This study was conducted in a factorial form of a randomized complete block design with three replications in 2021-2022 in Miandoab, Iran. The experimental factors included foliar application and pretreatment of micronutrient fertilizers (agrotin) in two levels (use and non-use, prime and non-prime, and rainfed wheat cultivars (Homa, Baran, and Sadra). The experiment results showed that the average comparison for different wheat cultivars indicated that the Homa cultivar had the highest average days to the ripening stage (178 days). The lowest number of days until the processing stage was related to the rain variety (168 days). In addition, the average treatment of cultivar x fertilizer interaction showed that the maximum leaf width of the Baran cultivar was obtained with the foliar treatment combination (14.12cm). The lowest leaf width (1.15cm) related to the Homa variety was obtained in the control condition. The correlation table of traits showed that increasing the number of days to maturity, plant height, stem fresh weight, leaf and stem dry weight, single plant dry weight, and spike length significantly positively affected flag leaf length.

Keywords: germination indicators, micronutrient fertilizers, crop growth rate, leaf area index, Miandoab
2020 MSC: Primary 62P12; Secondary 62K10, 62J10

1 Introduction

Wheat is one of Iran's essential agricultural products in production and area under cultivation. It is impossible to increase its production by increasing the area under cultivation due to limited arable land. Therefore, it is possible

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to increase the amount of production per unit area by following the correct agricultural principles, using high-yield varieties, and reducing the amount of damage caused by the attack of pests and diseases. The soil's limitation of usable plant nutrients is an essential factor limiting wheat growth and production due to the soil's low organic matter and non-fertility. Therefore, increasing wheat yield per unit area and responding to the growing society's basic needs in the food field requires appropriate mineral and organic fertilizers. Indiscriminate use of chemical fertilizers, especially with high solubility and especially in areas with an increased risk of salt leaching, seeped into underground and surface water and directly or indirectly exposed human life, livestock, and other organisms [26]. Foliar application of liquid fertilizers and foliar feeding is one of the effective methods of fertilizing all kinds of agricultural products, which can be provided directly to the branches, leaves, and fruits of the plant as soon as possible. Foliar fertilizers are appropriate to meet the plant's needs for secondary elements such as calcium and magnesium and micronutrients as a supplement to meet the needs of the wheat plant for the main elements such as nitrogen, potassium, and phosphorus in critical periods of growth or short-term growth periods. Micronutrient elements (iron, manganese, zinc) in the form of foliar spraying increase grain yield, thousand seed weight, and the number of seeds per spike, increase wheat protein, and increase the concentration of potassium, iron, and manganese and the ratio of potassium to sodium in the aerial parts of this plant [5, 6, 9]. Nowadays, the qualitative and quantitative increase of the yield in wheat fields has been made possible by increasing the quality of liquid fertilizers and correctly managing fertilization costs [28].

Today, paying attention to plant nutrition is one of the most effective ways to increase the quality and quantity of plants. The production of various fertilizers is a sign of efforts to achieve these goals. High-yielding varieties need many nutrients to complete their growth stages. The sensitivity of this category of plants is usually higher than native plants, and their effects of nutrient deficiency are more visible. Each plant needs special fertilizers for nutrition at each stage of growth, and using micronutrients improves growth and productivity and increases the performance of plants in stressful conditions. The correct timing of fertilizer consumption in wheat is critical to increase nutrient absorption and productivity and produce a healthy product. The most applied form of fertilizer by farmers, especially in the agriculture sector, is related to soil fertilizers, and they are not familiar with the application of nutrients in the form of foliar spraying [28].

The foliar application of liquid fertilizers and foliar feeding is one of the effective fertilization methods for all kinds of agricultural products. Quickly removing the deficiency, preventing element stabilization in the soil, making it easier to implement, reducing the toxicity caused by the accumulation of these elements in the soil, reducing the use of chemical fertilizers, and the environmental risks are essential features of the foliar application [10]. Foliar application with micronutrient elements is one of the methods of foliar feeding on the foliage of plants and can play an essential role in providing the materials needed for plant growth. The foliar application complements the soil method by using micro and macro elements, amino acids, fulvic acid, plant growth hormones, seaweed extract, and carbon hydrates, which is very useful due to the salinity of the soil in most regions of the country. The effectiveness of micronutrient fertilizers depends on the type of application method. The important point is that foliar feeding does not replace it with soil fertilization. On the other hand, the cost of fertilization operation is one of the most critical production costs, and it is cost-effective when the increase in yield is more significant than the total cost of fertilization. In other words, fertilizer use, like any additional investment, should have a reasonable return. Since the optimal economic efficiency of an agricultural unit requires correct planning and coordination of all agricultural activities, it is necessary to coordinate other production factors with fertilization. In general, the deficiency of one environmental factor neutralizes the beneficial effect of other factors. Nowadays, it is possible to increase the quality and quantity of the yield in wheat fields by using high-quality fertilizers due to the increase in the quality of liquid fertilizers [28].

Further, agriculture in Iran faces many production gaps (any factor that causes a farmer's lack of access to success in production is called a production gap). Many of these production gaps can be solved scientifically so that farmers can achieve significant success by following these scientific tips [32].

The speed of germination and seedling establishment in stressful conditions are essential for increasing plant growth. Seed priming is one of the simple techniques used to increase the speed and uniformity of germination and the emergence of resistant plants [12]. Seed priming improves the risk of inappropriate seedling establishment in various environmental conditions [18]. The priming of seed damage enhances germination, seedling growth, and seed structure indicators and increases the percentage and uniformity of seed germination by reducing the stopping stage between the stages of watering, germination, changes in germination events, and regeneration [19]. Seed priming in the field can increase drought resistance and yield. Primed seeds use better nutrients and can be more resistant to pests and diseases [21].

Previous efforts in agricultural production were primarily focused on increasing the yield of crops. Nevertheless, the accompanying decrease in the concentration of low-use elements in seeds is a new threatening problem for increasing crop yield and food security. The ultimate goal of modern agriculture is to produce sufficient and sustainable, nutritious food [34].

Malnutrition in developing countries is caused by nutritional elements in humans caused by deficiencies in fundamental foods, especially wheat and rice in Asia and corn and sorghum in Africa. The leading cause of micronutrient deficiencies in humans, especially in developing countries, is the low quality of agricultural products [4]. In these areas (in developing countries), the increase of micronutrient elements in the nutrition of agricultural plants can significantly increase their absorption from the diet. The deficiency of micronutrient elements such as zinc and iron is an essential factor affecting human health [13].

Using low-use essential elements is one of the ways to increase quantitative and qualitative yield in different plants [14]. Micronutrients are necessary for plant growth but are required in much smaller amounts than primary nutrients such as nitrogen, phosphorus, sulfur, and potassium [15]. The micronutrients zinc and copper are essential for plants, humans, and animals that feed on plants. Increasing the concentration of micronutrients in major crops has greatly improved human nutrition on a global scale [16]. In an experiment with zinc fertilizer application, seed zinc concentration and corn performance increased by 67 and 29%, respectively [23, 29]. A study showed that foliar and soil application of zinc did not significantly affect biomass parameters and grain yield of corn and wheat [24].

A study indicated that applying foliar boron in the early stages of corn growth (4 to 6 leaves) was more beneficial for high yields [20].

In addition, another study showed that the treatment of the combined application of boron and zinc in common millet plants produced the highest dry weight of shoots, with a 16.5% increase compared to the control [31]. In a study, soil application of boron at the rate of 10 kg per hectare increased dry shoot weight and spike length in common millet, while grain yield and 1000 seed weight decreased by 20.2% and 13.8%, respectively. Yield reduction due to high boron concentrations has been reported in various plants [31]. Experimental findings showed that the application of copper up to 250 mg/kg was ineffective in corn growth, the amount of copper greater than 250 mg/kg in the soil caused an increase in copper concentration and decreased corn growth [17]. Soil application of copper showed a significant effect on grain yield and 1000-grain weight of wheat and improved these traits, and it did not show a significant impact on the number of grains in the spike of wheat plants [7]. Another study showed that foliar application of zinc, iron, manganese, and copper elements significantly affected panicle length, number of seeds in panicle, grain yield, and biological performance of cluster sorghum, but it had a significant effect on thousand seed weight and harvest index.

It is possible to improve the condition of plant growth in stressful conditions by applying micronutrients by spraying method. The positive effect of micronutrients on dry matter performance may be due to increasing auxin biosynthesis, chlorophyll concentration, phosphoenol pyruvate carboxylase and ribulose biphosphate carboxylase activity, nitrogen and phosphorus absorption efficiency in the presence of zinc element, and decreasing sodium accumulation in plant tissues. Boron plays a role in cell division, and iron plays a role in chlorophyll formation [25, 27]. Using micronutrients in the peppermint medicinal plant increased the number of essential oil-secreting glands and consequently increased the essential oil's performance [30].

The foliar application of micronutrient elements on peppermint increases the yield of dry matter and essential oil [11]. Foliar application of zinc, iron sulfate, zinc sulfate, and the combination of zinc and zinc in safflower also increases the grain yield [35]. The agronomic characteristics of wheat have been reported [33].

In the conditions of deficiency of micronutrients, the activity of antioxidant enzymes decreases, and the sensitivity of plants to environmental stress increases [4]. Wheat is one of the plants sensitive to zinc and manganese deficiency and less sensitive to iron and copper. Lack of low-consumption elements in food has been observed in most parts of the world [3]. Of the lands under wheat cultivation in Iran, 37% have a severe iron deficiency, 40% have a severe zinc deficiency, 25% have a manganese deficiency, and 24% have a copper deficiency [3].

The widespread lack of zinc and iron in Iranian soils has caused a decrease in the concentration of these elements in crops and the lack of these elements in livestock and humans [28]. Wheat grown in such soils will produce little grain yield, consequently decreasing their zinc and iron content [1]. Micronutrient fertilizers in soil or foliar spraying to increase their concentrations in seeds is known as the agricultural biological enrichment method, which is flexible and can be used for all types and cultivars of agricultural plants.

This study aims to reduce the effects of environmental stresses, improve germination indices and functional characteristics in different varieties of rainfed wheat (Homa, Baran, and Sadra) by using micronutrient fertilizers (Agrotin) in the form of pretreatment and foliar application.

2 Materials and methods

This experiment was conducted in 2021-22 in Miandoab, Iran, with $2694Km^2$ (longitude of 46° and 6' east of the Greenwich Meridian and within 36° and 58' north of the equator) in the middle of the plains leading to Lake Urmia with a height of 1314 meters above sea level. The region's climate is variable, with relatively hot summers and short cold winters. The average rainfall in the region is 289mm. Miandoab has been named with this name due to its location between two Zarinerood and Siminerood rivers. The sample should have a certain minimum weight according to its size to conduct the soil granulation test and create valid and usable results. The materials to be tested for soil gradation should be sampled according to AASHTO T88-70 and reduced based on AASHTO T247- guidelines. Soils are divided into the following categories in terms of size by a general review.

Table 1: Classification of soil in terms of size

Soil type	**Grain diameter in mm**
Sand	More than 4.75
Coarse-grained sand	From 2 to 4.75
Medium grain sand	From 0.425 to 2
Fine-grained sand	0.075 to 0.425
clay or silt	Smaller than 0.075

The soil granulation test determines which group most of the soil grains belong to. For example, if most of the tested particles are smaller than 0.075mm, the tested soil is probably clay-type (Table 2). Such a process is called soil granulation.

2.1 Soil grading calculations

Equation (2.1) can be used to assess the accuracy of the mechanical sieving process. In other words, it is acceptable to weigh the material left on the sieve and also to wash the material on the 200 sieve if Equation (2.1) is valid.

$$\left|\frac{M_1 - M_2}{M_1}\right| \times 100 < 2\% \tag{2.1}$$

M_1 shows the initial weight of the sample poured on the sieves, and M_2 donates the cumulative weight remaining on the sieves.

The initial weight of the weighed materials equals 1000g, and the weight remaining on the sieves is weighed (Table 2.1).

Table 2: Calculation of the percentage of the sieved

Sieve No.	**Remained**	**Cumulative remained material**	**Cumulative sieved material**	**Sieved weight percentage p.p%**
3/4.in	0	0	991-0=991	$(991/991) \times 100 = 100$
3/8.in	40	0+40=40	991-40=951	$(951/991) \times 100 = 96$
NO4	42	40+42=82	991-82=909	$(909/991) \times 100 = 92$
NO8	62	82+62=144	991-144=847	$(847/991) \times 100 = 85$
NO12	192	144+192=336	991-336=655	$(655/991) \times 100 = 66$
NO25	160	336+160=496	991-496=495	$(495/991) \times 100 = 50$
NO40	200	496+200=696	991-696=295	$(295/991) \times 100 = 30$
NO50	145	696+145=841	991-841=150	$(150/991) \times 100 = 15$
NO100	65	841+65=906	991-906=85	$(85/991) \times 100 = 9$
NO200	35	906+35=941	991-941=50	$(50/991) \times 100 = 5$
Pan under Sieve	50	941+50=991	991-991=0	$(0/991) \times 100 = 0$

$£ = 991$

$$\left|\frac{1000 - 991}{1000}\right| \times 100 = 0.9\% < 2\%$$

The data of Table 2.1 can be plotted on a semi-logarithmic table. The size of the particles is the same as the number of sieves on the horizontal component of the graph, which is plotted on the vertical component with a logarithmic scale and percentage of sieved material.

Note: C_U and C_C parameters which are determined as follows can be used after drawing the diagram to check the soil type.

$$C_U = \frac{D_{60}}{D_{10}}, \qquad C_C = \frac{D_{30} \times D_{30}}{D_{60} \times D_{10}} \tag{2.2}$$

D_{60}, D_{10}, and D_{30} mean the diameter of the sieve corresponds to the passing percentage of 60, 10, and 30%. D_{60} means the size that 60% of the weight of the soil is smaller. D_{30} means the size that 30% of the weight of the soil is smaller. D_{10} means the size that 10% of the weight of the soil is smaller.

The term C_U is greater than 4 in fine-grained sand and greater than 6 in fine-grained sand.

The word C_C for well-grained sand is larger equal to 1 and smaller equal to 3, and for uniform soils, the size of these two parameters is equal to 1.

2.2 Fuller's granular soil

Fuller's grading is another way to know the soil, which can be drawn using the sieves used in the experiment. If the drawn diagram is above the Fuller diagram, it means that the soil is fine-grained, and below the Fuller diagram, means that the soil has all the necessary grains to create a dense soil. This digram can be used to plan the mixing of the existing soil with the soil complementing grains and plan the mixing of the existing soil with the soil complementing grains. The seieved percentage can be determined by the following method to draw Fuller's diagram.

$$PP\% = \sqrt{\frac{d_i}{d_{\max}}} \times 100 \tag{2.3}$$

d_i is the size of the sieves used in mm, and $d_{\max}$ shows the size of the largest sieve used.

Table 3: Calculation of the percentage

Sieve No.	Hole size mm	Fuller's Weight percentage of sieved material $\sqrt{\frac{d_i}{d_{\max}}} \times 100$	Weight percentage of sieved in the test
3/4.in	19	100	100
3/8.in	9.5	71	96
NO4	4.75	50	92
NO8	2.36	35	85
NO12	1.7	30	66
NO25	0.71	19	50
NO40	0.425	15	30
NO50	0.3	13	15
NO100	0.15	9	9
NO200	0.075	6	5

The comparison of the pass percentage numbers of the test and Fuller shows that the graph of the test results is higher than the Fuller graph and is finer-grained. Here is an example of a semi-logarithmic chart along with relevant data that is commonly reported in laboratories (the numbers in the presented table are different from the above example).

Cultivation was done on November 24, 2022. Each block has 12 plots with three iterations at a distance of 1.5m, and each plot has a length of 3.5 meters and a width of 1.2 meters at a distance of 100cm. The seeds were sown in the plots in 6 rows with a row spacing of 17.5 cm and a row spacing of $4 \times 5.1cm$. The total number of experimental unit plots was 36, and the plant density per unit area in this experiment was 160 kg of seeds per hectare (336 plants per square meter). Before planting, the consumed seeds were disinfected with the fungicide tebuconazole two at a ratio of two per thousand to prevent fungal diseases. According to soil analysis, 5.8kg of urea fertilizer, 5.8 kg of superphosphate, and 8.5kg of potash fertilizer were used during land preparation.

First, the seeds were hydroprimed in pure water at 20°C for 12 hours. The oxygen necessary for seed respiration was supplied through the aquarium pump during the dewatering process. After the mentioned time, the seeds were removed from the water and placed on metal nets at room temperature. The moisture level was brought to the initial moisture of the seed, and after the drying process was completed, the seeds were transferred to the field on the mentioned sowing date.

The osmopriming method was used to priming the seeds by the osmopriming method of 4% mannitol solution. About 100cc of the solution was poured into a container in each use, and the seeds were soaked in this solution for 12 hours at 25℃ with gentle aeration. Then, the seeds were removed from the solution under sterile conditions and washed three times with distilled water. The excess water was removed by filter paper and then they were dried at the temperature of the laboratory until their moisture content reached the initial level. Distilled water was used for hydropriming. The seeds were soaked in 100 cc of sterile distilled water for 12 hours at 25℃. After this period, they were removed from the water and dried in the laboratory temperature until reaching the initial moisture level, just like the osmopriming method. In the standard germination test, hydroprimed seeds were surface disinfected with sodium hypochlorite solution of 1% chlorine (activated for 2 minutes) and then washed with distilled water. A total of 50 seeds from each treatment were transferred to standard glass Petri dishes in 3 replicates for seven days at 20°C. Root emergence of 2 mm was considered as the germination criterion. Further, 1.5 liters of agrotin seed organic fertilizer was mixed with 1L of water to soak 100 kg of seeds. Then the required fertilizer was sprayed on the used seeds, and the seeds were turned upside down until all the seeds were covered with the fertilizer, and finally, the seeds were transferred to the field for cultivation.

Agrotin fertilizer was obtained from Adina Fam Khorram Company in Khorramabad, Iran. The germination percentage trait was obtained by dividing the number of sprouted seedlings in each plot by the number of seeds planted in the same plot. The field was weeded daily, and the number of sprouted seedlings was recorded to calculate the seed germination rate. This information calculated the germination rate, average germination time, rate coefficient, and seedling weight index. In this regard, GC is the germination speed coefficient, and MGT is the average germination time.

Sampling was done for each experimental treatment to measure the seedling characteristics of the samples by removing the marginal effects and harvesting the seedlings with a length of 30cm from the four middle cultivation lines each time. A total of 10 seedlings from the seedlings in each treatment were selected during the sampling stage to measure the leaf area index. The amount of leaf surface index was evaluated based on square centimeters for ten seedlings after transferring to the laboratory after separating the leaves and placing the leaves on the glass chamber of the LAI measuring device. Ten identical leaves were selected from each plot during the flowering stage in each treatment. The SPAD device calculated the greenness index by placing the middle part of the leaf blade between the clamp of the device and pressing the clamp. Then, ten seedlings were selected from the seedlings in each treatment during the sampling stage. The number of claws for each plantlet was counted separately after transfer to the laboratory. It was used to measure seedling growth rate (SGR)

$$SGR(gr/m^2/day) = \frac{W_2 - W_1}{T_2 - T_1} \tag{2.4}$$

in which, W is the dry weight of seedlings in the first sampling, W_2 shows the dry weight in the second sampling, and T presents the second and first sampling times in days, respectively. A number of 10 seedlings were selected from the seedlings in each treatment during two sampling stages, and the growth rate of the seedlings was determined using the above formulas after determining their dry weight. Then, ten seedlings from the seedlings in each treatment were selected during the sampling stage to measure the number of spikes in each plant, and then the number of fertile spikes in each plant was counted, and their average was analyzed as the number of fertile spikes. First, 1000 seeds in each treatment combination were determined by a seed counting machine, and finally, the weight of 100 seeds was determined by a digital scale with an accuracy of 100g. A sample of 10 spikes was placed separately for each spike in a thick bag to calculate the number of seeds per spike in each plot. The number of seeds in the spike was determined after pressing by hand and separating the seeds from the spike. The same plants were transferred to the laboratory to determine the biological yield to calculate the seed yield. At first, their seeds were weighed separately and considered as grain yield. Finally, the seed protein percentage was generalized to hectares with the device. NIR725 was measured.

2.3 Statistical analysis

Data variance analysis was performed by MSTAT-C software, and the mean comparison was made at 0.05 level by Duncan's method. Finally, graphs were plotted using Excel software.

MSTAT-C software analyze all sub-branches of agriculture and researchers in this field. MSTAT-C software has a wide range and many commands to analyze various experimental designs, calculate linear and multiple regression, calculate correlation coefficients, calculate statistical parameters, and stability analysis. Working with MSTAT-C is easier and faster than other software.

3 Results and discussion

According to the analysis of variance, a significant difference at the level of 1% was observed between the wheat cultivars studied in terms of the number of days to maturity. The effects of different levels of agrotin fertilizer treatment and the interaction effect of variety and fertilizer treatment were insignificant for the mentioned trait. The results of the average comparison for different wheat cultivars investigated indicated that the Homa cultivar had the highest average days to maturity (178 days). The lowest number of days until the processing stage was related to the rain variety (168 days) (Figure 1). The results of the correlation table also indicated that the dry weight of leaves and stems, spike length, number of claws, number of seeds per plant, seed yield per plant, and seed yield per hectare also increased significantly by increasing the average number of days until the processing stage.

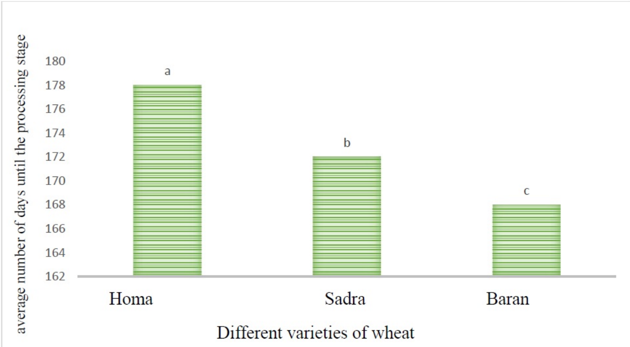

Figure 1: Comparison of the average effect of different wheat cultivars on the number of days to maturity

3.1 Leaf length trait of a single plant

Variance analysis showed that cultivar treatment significantly affected leaf length traits at a 1% probability level. The effects of different levels of agrotin fertilizer treatment and the cultivar × fertilizer treatment interaction were insignificant.

The average comparison for different wheat cultivars studied showed that a single plant's highest and lowest average leaf length was related to Sadra (24.33cm) and Baran (13.36cm) cultivars, respectively.

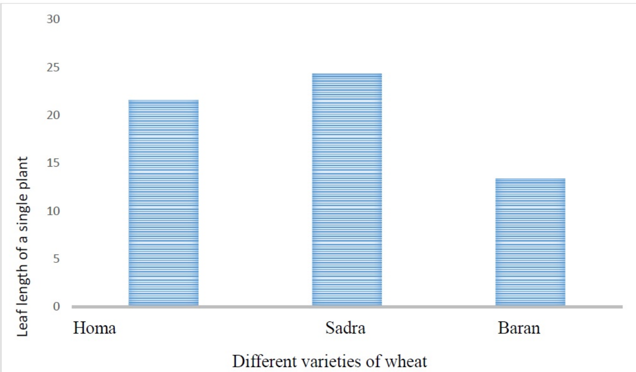

Figure 2: Comparison of the average effect of different wheat cultivars studied on the length of a single leaf

3.2 Width and leaf area of a single plant

Variance analysis showed that the effect of cultivar and agrotin fertilizer treatments on a single plant's width and leaf area traits was significant at the 1% probability level. The effect of cultivar × fertilizer interaction treatment on the two traits was significant at the 5% probability level.

The comparison of the average treatment of cultivar×fertilizer interaction showed that the maximum leaf width was obtained in the Baran cultivar along with foliar spraying treatment combination (4.12cm), and the lowest leaf width (1.15cm) was obtained in the Homa cultivar and the control condition.

Seed treatment combined with foliar application in the Sadra variety increased the leaf area of the said variety. The highest leaf area of a single plant (47.28cm) was related to this treatment combination. The lowest leaf area of a single plant (20.27cm) was associated with the Baran variety in control conditions. Ghassemi-Golezani et al. [8] stated that seed germination in chickpea plants accelerates the characteristics of the width and leaf area of a single plant.

3.3 Flag leaf length trait

A significant difference was observed between wheat cultivars and agrotin fertilizer treatment regarding flag leaf length at the 1% probability level. However, the interaction effect of variety in fertilizer treatment did not affect the length of the flag leaf.

Comparisons of the average of different wheat varieties showed that the highest average length of flag leaf (24.07cm) was related to the Baran variety, and the lowest was related to the other two studied varieties. Homa and Sadra cultivars were placed in the same group regarding average flag leaf length.

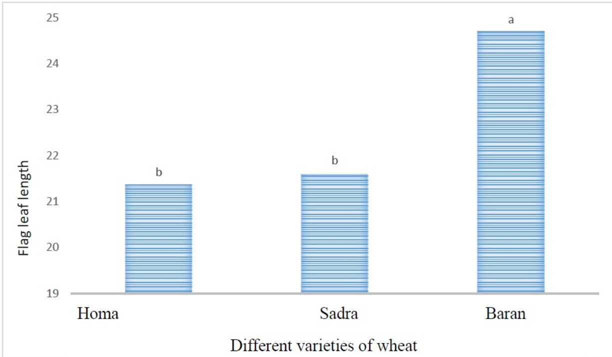

Figure 3: Comparison of the average effect of different cultivars on flag leaf length trait

Average comparisons in agrotin fertilizer treatment indicated that among different levels of agrotin fertilizer treatment, the highest (24.68cm) and the lowest (20.37cm) flag leaf lengths were observed in the foliar and control levels, respectively.

The trait correlation table showed that increasing the number of days to the ripening stage, plant height, stem fresh weight, leaf and stem dry weight, single plant dry weight, and spike length significantly positively affected flag leaf length.

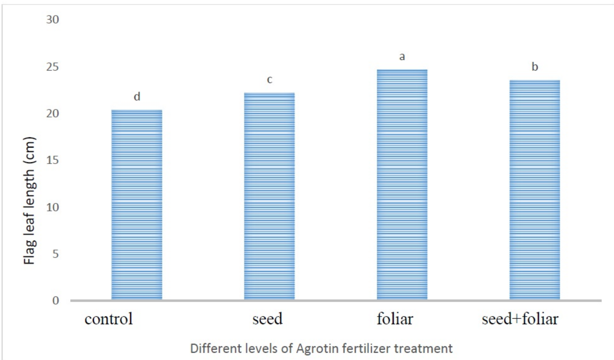

Figure 4: Comparison of the average effect of different levels of agrotin fertilizer treatment on flag leaf length trait

Table 4: Variance analysis of morphological traits of different wheat cultivars under the influence of different levels of agrotin fertilizer

		Mean square (MS)																
Sources of changes	**Degree of freedom**	**Number of days until processing**	**Number of leaves**	**Leaf length**	**Leaf width**	**Leaf area**	**Bush height**	**Internode length**	**The length of the internode leading to the spike**	**Number of nods**	**Stem fresh weight**	**Stem dry weight**	**Leaf fresh weight**	**Leaf dry weight**	**Weight of leaves**	**The fresh weight of the spike**	**Bush fresh weight**	**The length of the flag leaf**
Repetition	3	0.39^{ns}	0.175^{ns}	3.53^{ns}	27.89^{ns}	8.02^{ns}	5.68^{ns}	0.053^{ns}	0.152^{ns}	0.176^{ns}	0.35^{ns}	0.006^{ns}	0.0002^{ns}	0.0001^{ns}	0.017^{ns}	0.15^{ns}	0.41^{ns}	4.21^{ns}

Plant variety	2	296.8**	0.827**	1759.9**	4352.2**	1366.1**	217.5**	7.621**	223.43**	0.827**	11.07**	5.39**	0.19**	0.17**	0.15**	1.31**	9.19**	57.06**
Agrotin fertilizer treatment	3	0.26^{ns}	0.193^{ns}	3.87^{ns}	94.97**	76.23**	522.3**	10.113**	62.013^{ns}	0.194^{ns}	8.08**	2.63**	0.09**	0.05**	0.07**	4.59**	29.13**	26.11**
Cultivar × Agrotin fertilizer treatment	6	0.17^{ns}	0.753**	2.23^{ns}	87.98**	29.76*	59.44**	8.771^{ns}	13.613**	0.753**	1.98**	1.34**	0.16**	0.017**	0.008^{ns}	0.75**	0.93^{ns}	2.71^{ns}
error	36	0.17	0.089	2.06	21.95	14.07	0.17	1.237	2.394	0.088	0.67	0.063	0.003	0.004	0.006	0.09	1.07	2.31
Coefficient of variation		13.07	6.29	9.17	16.86	11.93	13.19	5.673	4.538	6.28	10.84	11.34	9.73	20.06	9.89	5.72	8.54	6.83

Table 5: Variance analysis of functional traits of different wheat cultivars under the influence of different levels of agrotin fertilizer

		Mean square (MS)														
Sources of changes	**Degree of freedom**	**Dry weight of a spike**	**Dry weight of a single plant**	**Spike length**	**Number of claws**	**Number of spikes**	**Number of seeds per spike**	**Number of seeds per plant**	**Grain length**	**Single seed weight**	**1000-seed weight**	**The weight of the seeds of a spike**	**Single plant seed yield**	**Grain yield per unit area**	**Grain yield per hectare**	**harvest index**
Repetition	3	0.14^{ns}	0.17^{ns}	0.47^{ns}	0.73^{ns}	2.41^{ns}	2.02^{ns}	4483.7^{ns}	0.001^{ns}	0.00005^{ns}	11.47^{ns}	0.02^{ns}	30.67^{ns}	7253.7^{ns}	238249.8^{ns}	2528098.8^{ns}
Plant variety	2	0.57*	11.69**	11.89**	5.21**	0.54^{ns}	612.5**	33079.3**	0.01^{ns}	0.00007**	98.19**	0.93**	70.55**	47831.8**	4540087.3**	337431.4**
Agrotin fertilizer treatment	3	2.86**	12.02**	12.83**	10.69**	1.73^{ns}	547.3**	45837.7**	0.02^{ns}	0.00006**	78.05**	2.17**	123.11**	78667.8**	7707328.8**	1703.81^{ns}
Cultivar × Agrotin fertilizer treatment	6	0.29*	2.01**	1.73^{ns}	1.78^{ns}	3.56^{ns}	22.94^{ns}	21.08^{ns}	0.17*	0.00004**	23.38**	0.63^{ns}	9.17^{ns}	11132.8^{ns}	1700764.9**	880.62^{ns}
error	36	0.17	0.19	1.57	0.91	1.51	56.08	2113.2	0.01	0.00001	7.09	0.08	5.04	7349.1	664208.7	1211.73
Coefficient of variation		12.13	8.16	9.87	13.18	21.23	15.16	17.06	12.18	6.98	6.51	11.33	17.01	16.09	15.73	26.18

Table 6: Comparison of the average interaction effect of variety × different levels of agrotin fertilizer on the morphological traits of different wheat cultivars

Treatment		**Number of leaves**	**Number of nodes**	**Leaf area (cm)**	**Leaf width (cm)**	**Plant height (cm)**	**Internode length (cm)**	**The length of the internode leading to the spike (cm)**	**Spike fresh weight (gr)**	**Leaf fresh weight (gr)**	**Leaf dry weight (gr)**	**Stem fresh weight (gr)**	**Stem dry weight (gr)**
Wheat cultivars	Agrotin fertilizer												
Homa	Control	4.2i	4.2i	35.17d	1.15e	68.75i	21.93bc	25.23i	4.92h	0.39h	0.13i	5.32g	1.51g
	seed	4.65ef	4.65ef	28.88f	1.41e	84.29de	19.73e	34.15f	5.03g	0.46g	0.35fg	6.89de	1.92ef
	Foliar	4.46gh	4.46gh	38.56c	1.54e	81.12f	19.48e	29.73h	6.12d	0.73bc	0.33gh	9.32a	1.91ef
	Seed+foliar	4.86e	4.86e	32.29e	1.49e	81.73ef	21.77bc	31.67g	6.07de	0.51f	0.25h	8.33c	1.72f
Sadra	Control	4.33hi	4.33hi	44.97b	1.62e	73.09h	17.17h	31.87g	4.27i	0.54ef	0.34fg	5.67f	1.75f
	seed	4.7ef	4.7ef	43.83b	1.83e	85.29cd	20.91d	34.19f	5.61f	0.71bcd	0.36ef	6.59e	1.93ef
	Foliar	5.1d	5.1d	44.17b	2.07e	91.69b	23.74a	36.66d	6.49c	0.88a	0.46c	7.17d	4.32a
	Seed+foliar	5.8a	5.8a	47.28a	2.16e	97.42a	20.38de	40.83a	5.83ef	0.76b	0.49b	6.73e	2.87d
Baran	Control	5.5b	5.5b	20.27h	3.17c	77.09g	19.26f	35.86e	4.36i	0.61e	0.39e	8.21c	2.09e
	seed	5.38c	5.38c	21.93gh	2.58d	87.11c	19.51ef	39.73a	6.26d	0.68cd	0.50ab	8.27c	4.07b
	Foliar	4.9e	4.9e	25.23g	4.12a	93.72c	21.62c	38.92b	7.52a	0.66c	0.52a	8.93b	3.54c
	Seed+foliar	4.57gh	4.57gh	23.78g	3.53b	85.67cd	18.66g	37.52c	7.17b	0.75b	0.42d	9.01b	4.09b

Table 7: Table of correlation coefficients between morphological and functional traits of different wheat cultivars under the influence of varying levels of agrotin fertilizer

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1- The number of days until the processing stage	1																	
2- Bush's height	-0.37^{ns}	1																
3- Number of leaves	0.46**	0.49**	1															
4- The length of the flag leaf	0.59**	0.53**	0.23**	1														
5- The length of the internode	0.36^{ns}	0.52**	0.25^{ns}	-0.08^{ns}	1													
6- Stem fresh weight	-0.31^{ns}	0.38**	-0.005^{ns}	0.58**	-0.08^{ns}	1												
7- Bush fresh weight	-0.23^{ns}	0.51**	0.11^{ns}	0.59**	0.25^{ns}	0.83**	1											

8- Leaf dry weight	0.70**	0.71**	0.49**	0.67**	0.15^{ns}	0.25^{ns}	0.36**	1										
9- Stem dry weight	0.63**	0.59**	0.27^{ns}	0.62**	0.11^{ns}	0.43**	0.52**	0.77**	1									
10- Single bush dry weight	0.55**	0.70**	0.34^{ns}	0.67**	0.28^{ns}	0.43**	0.57**	0.81**	0.97**	1								
11- Spike length	0.49**	0.53**	0.17^{ns}	0.67**	0.15^{ns}	0.33^{ns}	0.33^{ns}	0.38**	0.68**	0.65**	1							
12- Number of claws	0.39*	0.19^{ns}	-0.16^{ns}	0.28^{ns}	0.46**	0.28^{ns}	0.44**	0.05^{ns}	0.26^{ns}	0.34^{ns}	0.26^{ns}	1						
13- Number of spikes	0.12^{ns}	0.35^{ns}	-0.17^{ns}	0.08^{ns}	0.49**	0.007^{ns}	0.14^{ns}	0.17^{ns}	0.5^{ns}	0.28^{ns}	0.22^{ns}	0.43**	1					
14- The number of seeds per plant	0.48**	0.34**	-0.12^{ns}	0.19^{ns}	0.49**	0.39**	0.54**	-0.05^{ns}	0.13^{ns}	0.25^{ns}	-0.006^{ns}	0.83**	0.39*	1				
15- 1000-seed weight	-0.17^{ns}	0.71**	0.27^{ns}	0.26^{ns}	0.48**	0.17^{ns}	0.41**	0.62**	0.65**	0.76**	0.43**	0.34^{ns}	0.27^{ns}	0.36^{ns}	1			
16- The weight of the seeds of a spike	0.35**	0.42**	0.16^{ns}	-0.01^{ns}	0.53**	0.29^{ns}	0.46**	0.13^{ns}	0.33^{ns}	0.42**	0.19^{ns}	0.49**	0.27^{ns}	0.67**	0.68**	1		
17- Seed yield of a single plant	0.45**	0.37**	-0.09^{ns}	0.11^{ns}	0.56**	0.17^{ns}	0.49**	-0.06^{ns}	0.19^{ns}	0.31^{ns}	0.08^{ns}	0.77**	0.47**	0.93**	0.47**	0.85**	1	
18- Seed yield per hectare	0.41**	0.28^{ns}	0.07^{ns}	-0.09^{ns}	0.47**	0.35^{ns}	0.49**	-0.19^{ns}	0.16^{ns}	0.25^{ns}	-0.11^{ns}	0.49**	0.28^{ns}	0.73**	0.48**	0.89**	0.91**	1

3.4 Single seed weight trait

Variance analysis of the data showed that the single seed weight trait was affected by the main effects of cultivar and agrotin fertilizer treatment and the double interaction effect of cultivar × agrotin fertilizer treatment and was significant at the 1% probability level. The highest single seed weight (0.059g) was obtained according to the average comparisons of the Sadra variety at the level of agrotin fertilizer application, and the lowest single seed weight (0.034g) of the Homa variety was obtained at the agrotin fertilizer seeding level.

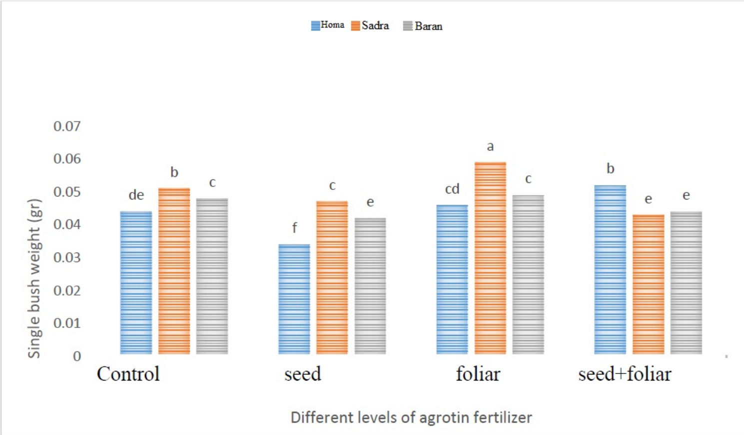

Figure 5: Comparison of the average interaction effect of cultivar treatment and different levels of agrotin fertilizer

3.5 1000-seed weight

Variance analysis indicated that the main effects of the variety and the treatment of different levels of agrotin fertilizer and the interaction between the two treatments on the 1000-seed weight trait significantly impact the 1% probability level (Table 3.3). Comparisons of the mean weight of a thousand seeds showed that the Homa cultivar had the highest average 1000-seed weight (54.2g) in the foliar application of Agrotin fertilizer. The same cultivar had the lowest average 1000-seed weight (37.8g) in the control condition.

The trait 1000-seed weight had a positive and significant correlation with plant height, internode length, plant fresh weight, leaf dry weight, stem dry weight, single plant dry weight, spike length, single spike seed weight, length of the spike, the weight of seeds of a spike, seed yield of a single plant and seed yield per hectare. 1000-seed weight increased significantly with the increase of each of these traits. Bamari et al. [2] and Kobraei et al. [22] also reported an increase in the weight of 1000 seeds with the foliar application of micronutrient elements.

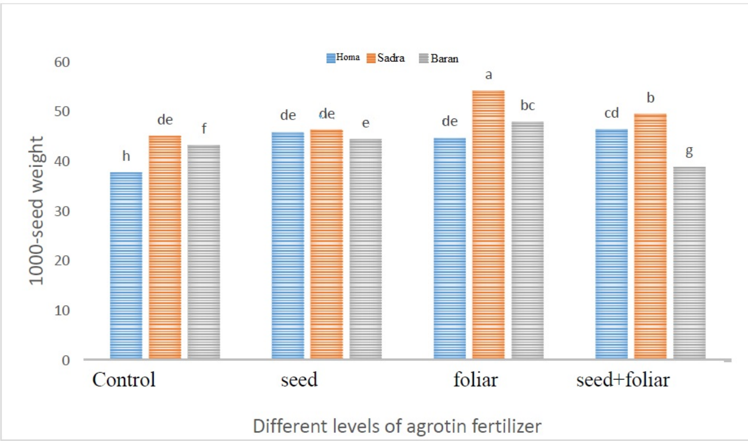

Figure 6: Comparison of the average interaction effect of variety on different levels of agrotin fertilizer on 1000 seed weight trait

4 Conclusion

Based on the results, foliar application and pretreatment of micronutrient fertilizers (agrotin) significantly affected all tested traits. The highest seed yield (2404 kg/ha) was obtained using agrotin, and the lowest yield (1755 kg/ha) was obtained in the condition of not using them. The Ohadi cultivar had more grain yield than the other two cultivars. Therefore, agrotin organic fertilizer and foliar application is a suitable solution for the availability of more nutrients and, as a result, the increasing trend in improving wheat growth.

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