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The editorial board and all involved managing group of JCNS are proud for presenting the Forthy issue of this journal to interested readers in scientific articles and texts on nutrition science and relevant subjects, in this six articles are presented.

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Editorial board is grateful for helps of dean of Islamic Azad University, the head of Ahvaz Branch, and all those who kindly helped us to continue the publishing this journal.

Dr. Shahram Lak
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- Regular articles in theoretical and applied researches on Nutrition Science
- Brief articles and short notes
- Critical reviews in the above mentioned areas

JCNS publishes original researches in the following fields

- Mineral metabolism of crops
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- Production and nutritional requirements of crops
- Organic and minerals with regard to their effect on the yield of crop
- Growth promoting bio-fertilizers and element nutrition as related to crop yield
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Yadav, S. K. 2009. Heavy metals toxicity in plants: An overview on the role of glutathione and phyto-chelatins in heavy metal stress tolerance of plants. South African J. Bot. 76: 167-179.

Articles not in English but with English Abstract

Modhej, A. 2009. Effect of terminal heat stress on source limitation and grain yield in bread wheat (*Triticum aestivum* L.) genotypes in Khuzestan conditions. Iranian J. Field Crop Sci. 39(1): 89-97. (Abstract in English)

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Chapters in Books

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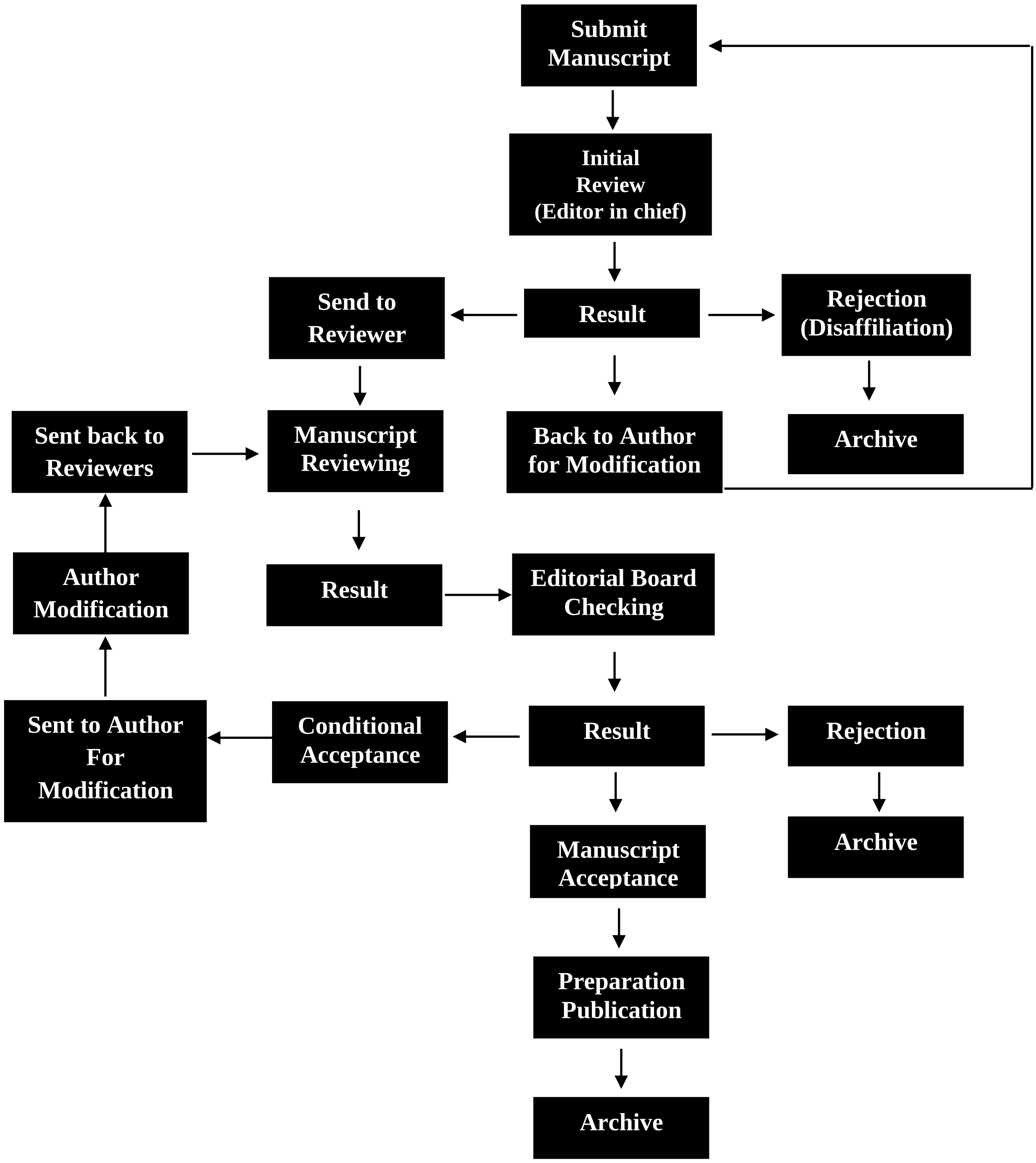

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Response Corn Crop Production to Use Organic and Chemical Nitrogen Fertilizers Under Warm and Dry Climate Condition (Khuzestan Province)

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RESEARCH ARTICLE

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ABSTRACT

BACKGROUND: Long-term experiments in fixed plots of combined use of organic and chemical fertilizers showed the greatest increase in the amount of soil organic carbon compared to the use of each of the organic and chemical fertilizers alone.
OBJECTIVES: This Research was conducted to evaluate effect of different level of fertilizer and biofertlizer on seed yield and its components of Corn.
METHODS: Current study was done according randomized complete block design (RCBD) with three replications at Shahid Salemi field in south west of Iran-Ahvaz. The studied treatments included Urea application only, Nitroxin application only, Nitroxin + 25% Nitrogen from Urea source, Nitroxin + 50% Nitrogen from Urea source, Nitroxin + 75% Nitrogen from Urea source, Azotobacter application only, Azotobacter + 25% Nitrogen from Urea source, Azotobacter + 50% Nitrogen from Urea source, Azotobacter + 75% Nitrogen from Urea source.
RESULT: According result of analysis of variance effect of treatment on all measured traits was significant. As for Duncan classification made with respect to different level of treatment maximum and minimum amount of 1000-grain weight belonged to T5 (237 gr) and T6 (205 gr). Assessment mean comparison effect of treatments on all measured traits indicated maximum amount of seed yield (3670 $kg.ha^{-1}$), biological yield (9217 $kg.ha^{-1}$), harvest index (39.8%), 1000-grain weight (237 gr), number of row per ear (14) and number of grain per row (19) were noted for Nitroxin + 75% Nitrogen from the Urea (T_5) and lowest amount of mentioned traits belonged to Azotobacter application only treatment (T_6).
CONCLUSION: Generally, the simultaneous use of biological fertilizers and Urea can be an effective step towards reducing the consumption of chemical fertilizers and health quality of agricultural products, in addition to producing sufficient yields.

KEYWORDS: *Growth regulator, Harvest index, Macro elements, Seed yield, Urea, Zea mays* L.

***Corresponding Author:** Seyed Keyvan Marashi ✉ Marashi_47@yahoo.com

1. BACKGROUND

Chemical fertilizers have several negative impacts on environment and sustainable agriculture. Therefore, bio fertilizers are recommended in these conditions and growth prompting bacteria uses as a replacement of chemical fertilizers (Wu *et al*., 2005). Integrated nutrient management practice is recognized as a sustainable option for reinstating soil health, improving soil organic carbon, and sustaining the overall system productivity (Bhardwaj *et al*., 2022). Chemical fertilizers are important input to get higher crop productivity, but over reliance on chemical fertilizers is associated with decline in some soil properties and crop yields over time (Hepperly *et al*., 2009). Therefore, an integrated use of inorganic fertilizers with organic manures is a sustainable approach for efficient nutrient usage which enhances efficiency of the chemical fertilizers while reducing nutrient losses (Schoebitz and Vidal, 2016). Research has suggested that integrated nutrient management strategies involving chemical fertilizers and bio-fertilizers enhance the sustainability of crop production. Integrated plant nutrient management is the combined use of mineral fertilizers with organic resources such as cattle manures, crop residues, urban/rural wastes, composts, green manures and bio-fertilizers (Kemal and Abera, 2015). Increasing the yield requires the use of proper agricultural management in each region and the knowledge of physiological relationships of plant with the agricultural systems (Hassani *et al*., 2015). Cheraghi *et al*. (2016) studied the effect of organic manure and phosphorus fertilizer on yield and its components of bread wheat and reported that the combined application of organic manure or vermicompost with chemical fertilizer has a better effect on yield and yield components of common wheat rather than single application. On the other hand combined application of organic and chemical fertilizers had more efficiency due to some positive interaction between their microorganisms in the soil that led to a synergistic effect and therefore lead to an increase in seed yield. Cassman *et al*. (2017) pointed out the relationship between the use of basic chemical fertilizers and the increase in the amount of photosynthetic pigments in the plant and stated that this increase in the amount of pigments has an important effect in increasing the rate of materialization and accumulation of dry matter. In general, the simultaneous application of chemical and manure fertilizers, along with calcium and sulfur, has led to an increase in Nitrogen content in the plant. This increase has also resulted in higher levels of chlorophylls and carotenoids, which contribute to enhanced greenness, better sunlight absorption, increased production of photosynthetic substances, and ultimately improved growth and dry matter yield in asparagus. Many factors like soil fertility, imbalanced nutrition, disturbed soil properties, cultivars being grown weed infestation etc. limit its yield worldwide. Different management practices are adopted to increase and optimize the maize yields. For example, use of organic manures alongside inorganic fertilizers often lead to increased soil organic matter (SOM), soil structure, water holding capacity and improved nutrient cycling and helps to maintain soil nutrient status, cation exchange capacity (CEC) and soil's biological activity (Saha *et al.*, 2008).

2. OBJECTIVES

This research was conducted to evaluate effect of different level of fertilizer and biofertilizer on seed yield and its components of Corn.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This experiment was conducted in the crop year (2015-2016) at Shahid Salemi Farm in Ahvaz (Fig. 1), utilizing a randomized complete block design with three replications. The farm's geographical coordinates were 31 degrees and 20 minutes' north latitude, 48 degrees and 40 minutes' east longitude, and an elevation of 23 meters above sea level. Before the experiment, soil samples were collected at a depth of 0-30 centimeters for physical and chemical analysis (Table 1).

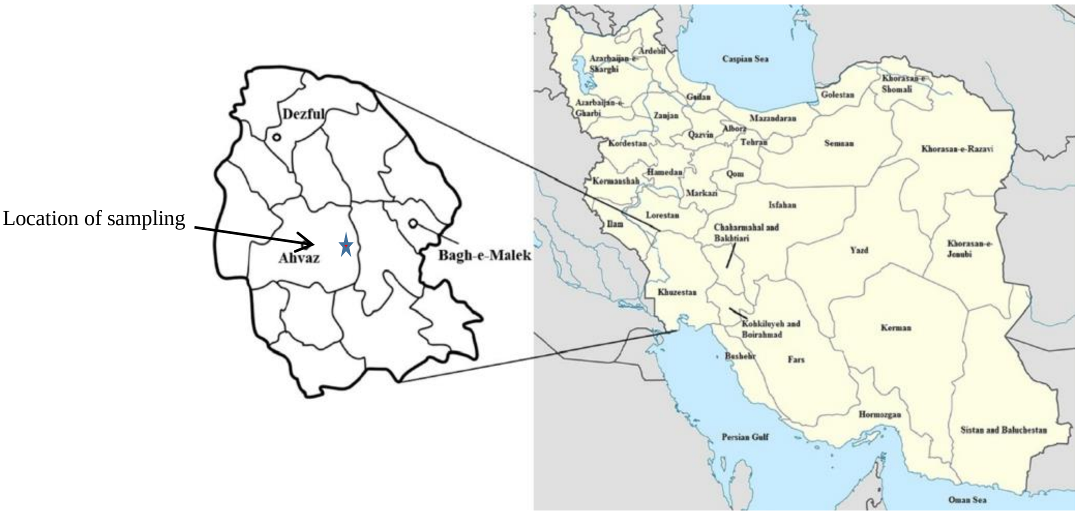

Fig. 1. Location of sampling

This experiment was conducted in the form of a randomized complete block design with three replications. The Nitrogen treatments included:

1. Urea application only (T_1)
2. Nitroxin application only (T_2)
3. Nitroxin + 25% Nitrogen from the Urea source (T_3)
4. Nitroxin + 50% Nitrogen from the Urea source (T_4)
5. Nitroxin + 75% Nitrogen from the Urea source (T_5)
6. Azotobacter application only (T_6)
7. Azotobacter + 25% Nitrogen from the Urea source (T_7)
8. Azotobacter + 50% Nitrogen from the Urea source (T_8)
9. Azotobacter + 75% Nitrogen from the Urea source (T_9)

3.2. Farm Management

The specified Nitrogen fertilizer from the Urea source was considered at a rate of 200 kilograms of pure Nitrogen per hectare. The experiment had three replications, and each replication included nine experimental plots. Each experimental plot consisted of six rows of crops, each 5 meters in length, with 75-centimeter spacing between rows and 15-centimeter spacing between seeds in the rows. A 1.5-meter distance was maintained between each experimental replication, and no line was drawn between each plot. Land preparation involved plowing with a moldboard plow and disc harrowing, followed by leveling with a harrow. The base fertilizer used in the field included 200 $Kg.ha^{-1}$ of triple superphosphate and 150 $Kg.ha^{-1}$ of Potassium Sulfate. Biological fertilizer was applied through seed inoculation, while chemical Nitrogen fertilizer was applied in two stages (50% at planting and 50% at the six-leaf stage). For seed inoculation with Azotobacter, seeds were first moistened and then spread on a plastic surface. According to the manufacturer's recommendation, 100 grams of Azotobacter per hectare was applied, mixed with the amount of seeds needed for the hectare. For seed inoculation with Nitroxin, the liquid fertilizer was sprayed completely over the seeds according to the manufacturer's recommendation, with a rate of 1 liter per 35 kilograms of seeds. The sowing operation took place in late December by hand. The first irrigation was applied after seed sowing, and subsequent irrigations were performed at the required plant intervals. Manual weeding was conducted for weed control. For grain yield measurement, after removing 0.5 meters from both ends of the central lines in each plot, all ears present in the 3-meter-long central rows were manually harvested.

Table 1. Physiochemical characteristics of field soil

Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	O.C (%)	N (%)	P (ppm)	K (ppm)	pH	EC ($ds.m^{-1}$)
0-30	41.5	37.5	21	0.6	0.085	9.1	143	7.7	4.62

3.3. Measured Traits

The studied traits included seed yield, 1000 seed weight, number of seed per ear, number of seed per row, number of rows per ear, ear length, ear diameter, length of ear without a seed, percent of ear without seed, inoculation percentage and plant height. In order to determine the number of seed rows per ear, number of seed per row and number of seed per ear samples including 10 plants were selected randomly from each experimental unit and the mean values for each trait were recorded. After drying the samples (48 hours in oven at 75 °C) and weighing, the biological yield was obtained. After separating seed from the selected plants and weighing them, seed yield was calculated based on 14% moisture. In order to 1000 seed weigh, 5 samples of seed containing 100 seed were separated and the means were calculated. The final harvest area of each plot was 1.5 m^2.

Harvest index (HI) was calculated according to formula of Gardner *et al*. (1985) as follows: **Equ.2.** HI= (Grain yield/Biological yield) ×100.

3.4. Statistical Analysis

Analysis of variance and mean comparisons were done via SAS (Ver.8) software and Duncan multiple range test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. *Grain Yield*

Yield is a complex feature which depends on the function of physiological combined processes in particular, the limiting components that change with the cultivar (Azarpour *et al*., 2014). The analysis of variance results indicates a significant effect of Nitrogen treatments on grain yield (Table 2). In this experiment, the treatment Nitroxin + 75% Nitrogen from the Urea source (T5) exhibited the highest grain yield, followed by the Azotobacter + 75% Nitrogen from the Urea source (T9) treatment, which showed the second-highest grain yield. The lowest grain yield was observed in the treatment using Azotobacter alone (T6) (Table 3). Plant inoculation with growth-promoting bacteria not only led to a 30% to 35% reduction in Nitrogen fertilizer consumption but also increased plant performance through enhancements in leaf area index, total dry matter, and net assimilation rate. Seyed Sharifi *et al*. (2012) reported that the combination of biological and chemical fertilizers contributes to increased maize productivity, aligning with the findings of this study. Naseri Rad *et al*. (2011) stated that the biological fertilizer Nitroxin, containing Nitrogen-fixing bacteria, enhances biological Nitrogen fixation ability, root surface area, optimal water and nutrient absorption, and the production of certain vitamins, resulting in improved quantitative and qualitative plant growth and increased yield. Singh *et al*. (2004) highlighted the Nitrogen-fixing bacteria's ability to produce anti-fungal compounds against various plant diseases, promoting seed germination and plant architecture, consequently enhancing basal plant growth. In another study, Oliverira *et al*. (2006) suggested that the lack of a sole positive impact of biological fertilizer application on maize yield could be attributed to the timing and the presence of bacteria in the soil, emphasizing the need for an optimal timeframe for the manifestation of positive effects on plant growth and yield, aligning with the results of this research.

4.2. *Biological yield*

According result of analysis of variance effect of treatment on biological yield was significant at 1% probability level (Table 2). Assessment mean comparison result indicated maximum biological yield (9217 $kg.ha^{-1}$) was noted for T5 and minimum of that (7350 $kg.ha^{-1}$) belonged to T6 treatment (Table 3). Javid *et al*. (2010) that the dry weight of corn aerial parts increased by 68% due to the application of biofertilizers and growth-promoting bacteria simultaneously with the use of chemical Nitrogen fertilizer. Also Hamidi *et al*. (2009) reported that the use of biofertilizers containing amino acids along with Nitrogen fertilizers increased growth and produced more dry matter in Corn crop. Zahir *et al*. (2004) stated that use of biofertilizers in corn increases the biological yield because, in addition to their ability to fix Nitrogen, these fertilizers help produce growth stimulants such as indole acetic acid and gibberellin which increase the absorption of nutrients and, as a result, increase crop growth.

Table 2. The results of analysis of variance of measured traits

S.O.V	df	Grain yield	Biological yield	Harvest index	1000-grain weight	No. row per ear	No. grain per row
Replication	2	537711^{ns}	755432^{ns}	19.28^{ns}	117.64^{ns}	21.23^{ns}	16.75^{ns}
Treatments	8	4998329*	22789366**	203.71*	925.41**	102.23**	133.09**
Error	16	372448	632919	52.43	88.3	16.8	27.4
C.V (%)	-	13.41	12.94	9.17	12.65	9.71	11.36

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

Mirza *et al*. (2000) reported use of bio-fertilizers, in addition to Nitrogen fixation, also causes the production of auxin, which increases the number of shoot fibers, thereby increasing the absorption of nutrients and Nitrogen consumption, and ultimately improving the crop dry matter. Nouraki *et al*. (2016) reported bacteria have positive role in the production of bio-fertilizers and hormones which play a significant role in regulating plant growth while mixing them with chemical fertilizers as a supplement the level and depth of the roots. This combination also increases the rate of water and nutrient absorbance which raise the rate of growth and photosynthesis. These combinations also increase the grain yield, yield components, and biological function, it has been found that bio-fertilizers can be combined with chemical fertilizers in a complementary way to reduce the excessive amount of chemical fertilizers used to grow corn. It was shown that the mixing of biological fertilizers with chemical fertilizers could reduce the needs of chemical fertilizers up to 25% and these results are comparable to the application of 100% chemical fertilizers. Therefore, the best hybrid maze is the single cross 704 that has good yield potential when the chemical fertilizer is used at either 25% or 50% of the current application when mixed with the bio-fertilizer.

4.3. *Harvest index*

Harvest index shows the way of dividing the nutritional materials between the growing structures of grain and plant. As one of the components for calculating the HI is grain yield, the changes in HI depend very much on the changes of grain yield. Based on the formula of HI, every factor can change the harvest index when the grain yield is influenced more than total dry weight (Sinclair *et al*., 1990). Result of analysis of variance revealed effect of treatment on harvest index was significant at 5% probability level (Table 2). Assessment mean comparison result indicated maximum harvest index (39.8%) was noted for T_5 and minimum of that (36.2%) belonged to

T_6 treatment (Table 3). Biari *et al*. (2008) stated that the application of Pseudomonas bacteria led to increase Corn harvest index by 2.57%.

4.4. *1000-grain weight*

According result of analysis of variance effect of treatment on 1000-grain weight was significant at 1% probability level (Table 2). The results of mean comparisons showed that in different treatments, the weight of grains weight increased due to the application of biological fertilizers along with Urea due to greater and longer-term access to Nitrogen. As for Duncan classification made with respect to different level of treatment maximum and minimum amount of 1000-grain weight belonged to T5 (237 gr) and T6 (205 gr) (Table 3).

Table 3. Mean comparison different level of fertilizer combination on studied traits

Treatments	Grain yield ($kg.ha^{-1}$)	Biological yield ($kg.ha^{-1}$)	Harvest index (%)	1000-grain weight (gr)	No. row per ear	No. grain per row
T1	3450b	8800ab	39.7a	227.4b	13b	18b
T2	2830d	7530c	37.5ab	211.32c	11d	14cd
T3	3050cd	8200bc	37ab	213.5c	11.5cd	15c
T4	3411b	8650b	39a	225.6b	13.2b	17bc
T5	3670a	9217a	39.8a	237.06a	14a	19a
T6	2600e	7350cd	36.2b	205.05d	10.5e	13.5d
T7	3111ce	8195bc	37.5ab	215.2c	12bc	15c
T8	3323bc	8510b	39a	222b	12.5b	16bc
T9	3550a	9210ab	38.1ab	230.03b	13b	18b

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).
T1: Urea application only, T2: Nitroxin application only, T3: Nitroxin + 25% nitrogen from the urea source, T4: Nitroxin + 50% nitrogen from the urea source, T5: Nitroxin + 75% nitrogen from the urea source, T6: Azotobacter application only, T7: Azotobacter + 25% nitrogen from the urea source, T8: Azotobacter + 50% nitrogen from the urea source, T9: Azotobacter + 75% nitrogen from the urea source.

The number of grains per ear and the grain weight are the most important traits to decrease Corn yield. It seems that with increasing soil Nitrogen content, a greater amount of this element was absorbed by the plant and the excess was used for vegetative growth and grain formation. So at higher Nitrogen levels, the grain weight increases simultaneously with the use of biofertilizers. In this regard, similar results were reported by Alpaji (2022), who reported that with increasing Nitrogen content from zero to 90 kg of pure Nitrogen per hectare, the grain weight increased along with the increase in grain yield per unit area. Nemati and Seyed Sharifi (2014) reported that Nitrogen deficiency reduces Corn grain yield by reducing grain number and weight. These researchers attributed this to the increased absorption of nutrients required by the plant due to the use of organic and chemical Nitrogen fertilizers and, consequently, to an increase in the photosynthesis process. These researchers attributed this to the increased absorption of nutrients required by the plant due to the use of organic and chemical Nitrogen fertilizers and, consequently, to an increase in the photosynthesis process. They believed carbohydrates and Nitrogen stored during the flowering period determine the amount of grain in the corn ear, and Nitrogen deficiency reduces grain weight through a decrease in photo assimilates. Ebrahimvand (2014) reported that the use of Nitrogen biofertilizers, by increasing protein compounds and also increasing the vegetative growth of Corn and stimulating photosynthesis, causes the transfer of more nutrients to the grain and improve grain weight.

4.5. *Number of row per ear*

Result of analysis of variance revealed effect of treatment on number of row per ear was significant at 1% probability level (Table 2). According result of mean comparison maximum of number of row per ear (14) was obtained for T_5 treatment and minimum of that (10.5 and 11) was for T_6 and T_2 treatment (Table 3). The significant reduction in the number of rows per ear in the 100% biological fertilizer treatment (T_6) resulted from Nitrogen deficiency stress, which led to a decrease in leaf area development, photosynthesis rate, number of ear florets (potential seeds), and increased leaf senescence and seed abortion. Mentioned results showed that the use of Nitrogen chemical fertilizers along with biological fertilizers is essential. The reason for this has been attributed to the ability of biofertilizers to fix Nitrogen and produce growth-stimulating hormones (Moser *et al*., 2006). Majidian *et al*. (2006) reported that combining biofertilizers with chemical fertilizers significantly increased the number of rows per ear compared to the use of chemical fertilizers alone. Sharifi *et al*. (2011) stated that Nitroxin, due to growth-promoting bacteria, and Azotobacter, due to Nitrogen fixation and production of growth-regulating hormones, through expansion of root surface and depth and increasing the plant's ability to absorb Nitrogen in combined treatments, increase the number of rows per ear. Hamzeh and Sarmadi (2010) stated that biofertilizers in combination with Nitrogen indirectly increased grain yield by improving yield components, including the number of rows per ear and the number of grains per row, which was consistent with the findings of this study.

4.6. *Number of grain per row*

According result of analysis of variance effect of treatment on number of grain per row weight was significant at 1% probability level (Table 2). Mean comparison result of different level of treatment indicated that maximum number of grain per row (19) was noted for T_5 and minimum of that (13.5) belonged to T_6 treatment (Table 3). It seems that combined use of Nitroxin and Azotobacter with Urea fertilizer provided nutrients to the ear through sustained photosynthesis and increased the number of grains per row due to reduced grain competition. Biari *et al*. (2008) by evaluated the effect of Azospirillium and Azotobacter on Corn, they stated that inoculating corn seeds with growth-promoting bacteria significantly increased the number of grains per row. They attributed this to the increased absorption of plant nutrients due to the use of biofertilizers, which confirms the results of this study. Fatex

(2023) stated that under Nitrogen deficiency conditions, the number of grains per row and the number of grains per ear significantly decrease. Who stated that the cause of seed loss under Nitrogen deficiency conditions was infertility, increased abortion, or failure to develop. Tarang *et al*. (2013) reported applications of Nitroxin bio-fertilizer and chemical fertilizer (400 $kg.ha^{-1}$ Urea with 300 $kg.ha^{-1}$ ammonium phosphate) had a significant effect on traits of root dry weight, number of seed per row (36.5), number of seeds per ear (458.56), 1000-grain weight, seed (13.23 $t.ha^{-1}$) and biological yield (26.4 $t.ha^{-1}$) , and harvest index (53.88%).

5. CONCLUSION

In this study, simultaneous use of biological fertilizer and Urea resulted in significant improvement in Corn crop production. The maximum and minimum amount of grain yield belonged to T_5 (3670 $kg.ha^{-1}$) and T_6 (2600 $kg.ha^{-1}$). Generally, the simultaneous use of biological fertilizers and Urea can be an effective step towards reducing the consumption of chemical fertilizers and sustainable agriculture, in addition to producing sufficient yields.

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FOOTNOTES

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Evaluation Effect of Seed Priming (Salicylic acid and Methyl jasmonate) on Crop Production and Biochemical Traits of Bread Wheat

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ABSTRACT

BACKGROUND: Salicylic acid and methyl jasmonate have been recognized as playing a pivotal role in regulating physiological processes and as an important molecular signal in plant oscillations in response to environmental stresses.

OBJECTIVES: Current research was done to assess response of biochemical characteristics and yield of Wheat varieties to use salicylic acid and Methyl jasmonate.

METHODS: This research was done in Lab via factorial experiment based on completely randomized design with four replications along 2019-2020 year. Also current study was done in farm according factorial experiment based on complete randomized block design with four replications. The treatments included seed priming (Control or seed treatment with distilled water, Seed treatment with 0.15 mM salicylic acid and 1.5 µM Methyl jasmonate) and Wheat Varieties (Chamran and Mehrgan).

RESULT: Result of analysis of variance revealed effect of seed priming, varieties and interaction effect of treatments (instead grain yield) on all measured traits was significant. Mean comparison result of different level of seed priming indicated that maximum amount of grain yield (0.445 $kg.m^{-2}$), leaf area ratio (0.833 $m^2.kg^{-1}$), Spike length (6.212 cm), Superoxide dismutase (339.603 gr leaf protein) and Glutathione peroxidase (4.548 gr leaf protein) were noted for Methyl jasmonate 1.5 micro molar and minimum amount of those belonged to control treatment. Also compare Wheat varieties revealed Chamran verity was superior in compare to Mehrgan verity. Evaluation mean comparison result of interaction effect of treatments indicated maximum leaf area ratio (0.846 $kg.m^{-2}$), spike length (6.375 cm), Superoxide dismutase (350.460 gr leaf protein) and Glutathione peroxidase (4.835 gr leaf protein) belonged to Methyl jasmonate 1.5 micro molar and Chamran variety and lowest ones belonged to control and Mehrgan variety.

CONCLUSION: Generally based on result of current study application salicylic acid and Methyl jasmonate led to improve grain yield and biochemical traits of Wheat verities and can be advised to farmer.

KEYWORDS: *Genotype, Grain Yield, Glutathione peroxidase, Leaf protein, Superoxide dismutase.*

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1. BACKGROUND

Salicylic acid is an organic acid that has wide applications in pharmaceuticals and industry. For years, it was known as a plant messenger molecule, and later its regulatory role was also identified. This regulator matter affects many biochemical characteristics of the plant under the stress conditions (Pirasteh-Anosheh, and Emam, 2018). Jasmonates are a new group of plant hormones that protect plants against environmental stresses by interfering with the expression of the various genes (Mahmud *et al*., 2017). Geetika *et al*. (2017) reported an increase in proline content of soybean seedlings under the influence of jasmonic acid. Jasmonic acid acts as a controller of the expression of osmotic regulatory genes such as theonin, osmotin, hydroxyl proline, and proline, and by upregulating them, especially proline, it increases the level of this amino acid under stress conditions. Abbasvand *et al* (2017) conducted an experiment to investigate the effect of priming basil seeds with salicylic acid on the rate of plant photosynthesis in a greenhouse at the University of Tabriz. The results of the experiment showed that the application of salicylic acid levels led to an increase in photosynthesis levels and plant yield. Ahmad *et al*. (2017) conducted an experiment in Pakistan to investigate the effect of priming corn seeds with salicylic acid on yield-related and morphological traits under field conditions. In this experiment, to prime corn seeds, the seeds were placed in a prepared salicylic acid solution for 24 hours and then the seeds were cultivated. The experimental results showed that priming seeds with salicylic acid led to increased grain yield, leaf area index, improved photosynthetic system, 1000-grain weight, plant height, and increased heat resistance in the field. Alamri *et al*. (2018) conducted an experiment to investigate the effect of priming wheat seeds with salicylic acid. In this experiment, they used 0 and 100 micro molar levels of salicylic acid, and the results showed that the application of salicylic acid accelerated germination, increased the percentage and speed of germination, and seedling length. Moghadam *et al*. (2017) conducted a study on the effect of priming fenugreek seeds with salicylic acid at Urmia University, and in this experiment, they used 0, 1700, and 2800 micro molar salicylic acid levels for treatment. The experimental results showed that priming seeds with 2800 µM salicylic acid treatment resulted in a significant increase in the percentage and rate of germination, seedling and root length. Hashemi *et al* (2018) reported the pretreatment of barley seeds with salicylic acid partially compensated for the increase in root and shoot sodium concentration and the activity of peroxidase, catalase, ascorbic peroxidase, and superoxide dismutase enzymes, and the decrease in root and shoot potassium concentration due to salt stress. Alizadeh *et al*. (2016) reported in an experiment investigating the effect of seed priming on the yield and yield components of two sesame genotypes that seed priming with salicylic acid increased the number of capsules per plant, thousand-seed weight, and seed yield of sesame cultivars.

2. OBJECTIVES

Current research was done to assess response of biochemical characteristics and yield of Wheat varieties to use salicylic acid and Methyl jasmonate.

3. MATERIALS AND METHODS

3.1. Field, Lab and Treatments Information

This research was carried out in Lab via factorial experiment based on completely randomized design with four replications along 2019-2020 year. Also current study was done in farm according factorial experiment based on complete randomized block design with four replications Place of research was located in Haftkel city at longitude 49°52'E and latitude 31°44'N in Khuzestan province (Southwest of Iran). The treatments included seed priming (Control or seed treatment with distilled water, seed treatment with 0.15 mM salicylic acid, seed treatment with 1.5 µM Methyl jasmonate) and Wheat Varieties (Chamran and Mehrgan). To prepare the priming solution, the seeds will be mixed with 0.15 mM salicylic acid and 1.5 µM methyl jasmonate. In this regard, 0.0207 grams of salicylic acid and 0.00336 grams of methyl jasmonate were dissolved in one liter of water, and then the seeds were treated with the prepared solutions (Fig.1). For cultivation in the field, plastic pots measuring 60 x 30 x 30 cm with a capacity of 10 kg of soil will be used. 30 wheat seeds were sown in each pot (number of pots: 24). (Fig.2). The physical and chemical properties of studied field was mentioned in table 1.

Table 1. Physical and chemical properties of studied field

Soil depth (cm)	Cd (ppm)	NO_3 (%)	K ($mg.kg^{-1}$)	P ($mg.kg^{-1}$)	N (%)	pH	Ec ($ds.m^{-1}$)
0-30	1.09	9.98	131	1.16	0.026	7.72	6.24

3.2. Farm Management

Chemical fertilizers were used based on the recommendations of the Khuzestan Agricultural and Natural Resources Research Center for wheat plants (including: 250 $kg.ha^{-1}$ of urea in divided at planting, end of tillering, end of stem elongation and spike emergence, 150 $kg.ha^{-1}$ of Triple Superphosphate and Potassium Sulfate at the basic stage). During the tillering stage, weaker plants were removed so that 20 plants would remain in each pot, which was calculated based on 400 plants per square meter. During the flowering stage, irrigation was stopped for two weeks.

3.3. Measured Traits

At the time of full maturity, the average weight of harvested seeds from each pot was calculated using a digital scale with an accuracy of 0.01. Five plants were harvested from each pot and their weight was calculated as biological yield. Then the spikes were threshed and the grain yield was determined.

Fig.1. Different stages of experiment

To calculate leaf area ratio (LAR) in wheat, you must first measure the total leaf area and the dry matter of the whole crop, then divide the total leaf area (in square meters) by the dry matter of the whole plant (in kilograms) to obtain the leaf area ratio (Gardner *et al*., 1985).

Equ.1. LAR (m^2/kg) = Total leaf area (m^2)/Total crop dry matter (kg)

Fig.2. Potted cultivation stage

To evaluate enzymatic changes, plant samples collected from the treatments were first stored at -80°C. The enzyme extract was prepared using 0.1 M phosphate buffer with pH 7, containing 0.2% polyvinylpyrrolidine, on ice and in a mortar. Three milliliters of extraction buffer were used per gram of wet material, the homogenized solution was centrifuged, and the supernatant extract was used to read the enzymatic activity (Bradford, 1976). The method for measuring superoxide dismutase enzyme activity is based on the ability of superoxide dismutase enzyme to prevent the oxidation of pyrogallol by superoxide radical. The absorbance changes of the samples were measured at a wavelength of 420 nm in the presence of pyrogallol. One unit of enzyme activity is the amount of enzyme protein that inhibits the oxidation of 2 micro molar pyrogallol per minute (Bradford, 1976).

3.4. Statistical Analysis

Analysis of variance and mean comparisons were done via SAS (Ver.9.1) software and Duncan multiple range test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. *Grain yield*

According result of analysis of variance effect of seed priming and varieties on grain yield was significant at 1% probability level but interaction effect of treatments was not significant (Table 2). Mean comparison result of different level of seed priming indicated that maximum grain yield (0.445 $kg.m^{-2}$) was noted for Methyl jasmonate 1.5 micro molar and minimum of that (0.230 $kg.m^{-2}$) belonged to control treatment (Table 3). Farooq *et al*. (2008) reported that priming Wheat seeds using potassium chloride and calcium chloride improved emergence, seedling establishment, tiller number, grain yield, biological yield, and harvest index in Wheat crop. In another study on rapeseed, the use of salicylic acid increased the number of capsules and seed yield by about 13.7% compared to the control treatment (Fariduddin *et al*., 2003). As for Duncan classification made with respect to different varieties maximum and minimum amount of grain yield belonged to Chamran Variety (0.364 $kg.m^{-2}$) and Mehrgan Variety (0.301 $kg.m^{-2}$) (Table 3). Nurbani (2017) conducted a study on Sesame with the aim of investigating the effect of priming treatment with methyl jasmonate and salicylic acid on performance characteristics in pasture. In this study, salicylic acid was used at a concentration of 0.1 mM and methyl jasmonate at a concentration of 1 μM. The results showed that salicylic acid and methyl jasmonate treatments increased grain yield, biological yield, and harvest index.

Table 2. Result analysis of variance of measured traits

S.O.V	df	Grain yield	Leaf area ratio	Spike length	Superoxide dismutase	Glutathione peroxidase
Replication	3	0.002	0.005	0.005	2.736	0.001
Seed priming (A)	2	0.092**	10.236**	1.980**	14490.483**	5.680**
Variety (B)	1	0.023**	0.814**	1.601**	3704.638**	1.215**
A × B	2	0.0001^{ns}	0.03*	0.92*	119.259**	0.024**
Error	15	0.001	0.003	0.005	0.992	0.875
CV(%)		3.43	2.063	1.350	0.332	0.589

$^{ns, * and **}$: no significant, significant at 5% and 1% of probability level, respectively.

4.2. *Leaf area ratio*

Result of analysis of variance revealed effect of seed priming and varieties on leaf area ratio was significant at 1% probability level also interaction effect of treatments was significant at 5% probability level (Table 2). Mean comparison result of different level of seed priming indicated that maximum leaf area ratio (0.833 $m^2.kg^{-1}$) was noted for Methyl jasmonate 1.5 micro molar and minimum of that (0.582 $m^2.kg^{-1}$) belonged to control treatment (Table 3). Ebrahimi and Jafari-Haghighi (2012) stated that the application of salicylic acid leads to the maintenance of leaf area index and leaf area ratio durability because salicylic acid leads to physiological changes such as the accumulation of proline in the crop. Also, the application of salicylic acid, through mechanisms such as increasing root height and length and increasing leaf proline, helps the plant maintain leaf area index by using more water available in the soil.

Table 3. Mean comparison different level of seed priming and variety on studied traits

Treatment	Grain yield ($kg.m^{-2}$)	Leaf area ratio ($m^2.kg^{-1}$)	Spike length (cm)	Superoxide dismutase (gr leaf protein)	Glutathione peroxidase (gr leaf protein)
Seed priming					
Control	0.230c	0.582c	5.225c	254.965c	2.863c
Salicylic acid 0.15 mM	0.323b	0.738b	5.612b	305.103b	3.735b
Methyl jasmonate 1.5 micro molar	0.445a	0.833a	6.212a	339.603a	4.548a
Variety					
Chamran	0.364a	0.736a	5.941a	312.315a	3.940a
Mehrgan	0.301b	0.699b	5.425b	287.466b	3.490b

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).

The use of salicylic acid exhibits desirable functions through its effect on the function of the hormone ABA and the control of cell respiration, which leads to an increase in yield components in crop. Between different varieties the maximum leaf area ratio (0.736 $m^2.kg^{-1}$) was observed in Chamran Variety and the lowest one (0.699 $m^2.kg^{-1}$) was found in Mehrgan Variety (Table 3). Evaluation mean comparison result of interaction effect of treatments indicated maximum leaf area ratio (0.846 $kg.m^{-2}$) was noted for Methyl jasmonate 1.5 micro molar and Chamran variety and lowest one (0.568 $kg.m^{-2}$) belonged to control and Mehrgan variety (Table 4). Khodary (2004) stated that the application of salicylic acid led to an increase in the leaf area index of Corn. In fact, the application of salicylic acid leads to an increase in the leaf area index by increasing the activity of the Rubisco enzyme and consequently improving photosynthesis.

Table 4. Mean comparison interaction effect of treatments on biochemical traits

Seed priming	Variety	Leaf area ratio ($m^2.kg^{-1}$)	Spike length (cm)	Superoxide dismutase (gr leaf protein)	Glutathione peroxidase (gr leaf protein)
Control	Chamran	0.596e	5.600d	271.787e	3.072e
	Mehrgan	0.568f	4.850f	238.142f	2.655f
Salicylic acid 0.15 mM	Chamran	0.766c	5.850c	314.697c	3.915c
	Mehrgan	0.710d	5.375e	295.510d	3.555d
Methyl Jasmonate 1.5 micromolar	Chamran	0.846a	6.375a	350.460a	4.835a
	Mehrgan	0.821b	6.050b	328.747b	4.262b

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).

4.3. *Spike length*

Result of analysis of variance revealed effect of seed priming and varieties on spike length was significant at 1% probability level also interaction effect of treatments was significant at 5% probability level (Table 2). Mean comparison result of different level of seed priming indicated that maximum spike length (6.212 cm) was noted for Methyl jasmonate 1.5 micro molar and minimum of that (5.225 cm) belonged to control treatment (Table 3). Between different varieties the maximum spike length (5.941 cm) was observed in Chamran Variety and the lowest one (5.425 cm) was found in Mehrgan Variety (Table 3). Evaluation mean comparison result of interaction effect of treatments indicated maximum spike length (6.375 cm) was noted for Methyl jasmonate 1.5 micro molar and Chamran variety and lowest one (4.850 cm) belonged to control and Mehrgan variety (Table 4). Shakirova *et al*. (2003) stated that the use of salicylic acid can improve the absorption of nutrients, which leads to increased growth and seedling height. Priming Wheat seeds with salicylic acid has led to increased spike size, thousand-grain weight, and plant height.

4.4. *Superoxide dismutase*

According result of analysis of variance effect of seed priming, varieties and interaction effect of treatments on Superoxide dismutase was significant at 1% probability level (Table 2). Antioxidant enzymes neutralize free radicals, which are harmful to cells because they inactivate photosynthetic enzymes. Researchers reported that methyl jasmonate increased the activity of some antioxidant enzymes in Arabidopsis (Jung, 2004) and rapeseed (Comparot *et al*., 2002). Mean comparison result of different level of seed priming indicated that maximum Superoxide dismutase (339.603 gr leaf protein) was noted for Methyl jasmonate 1.5 micro molar and minimum of that (254.965 gr leaf protein) belonged to control treatment (Table 3). As for Duncan classification made with respect to different varieties maximum and minimum amount of Superoxide dismutase belonged to Chamran Variety (312.315 gr leaf protein) and Mehrgan Variety (287.466 gr leaf protein) (Table 3). In a study on the effect of methyl jasmonate application on some characteristics, Karamat and Daneshmand (2012) stated that the application of methyl jasmonate led to an increase in photosynthetic pigments and a decrease in lipid peroxidation, as well as an increase in the activity of superoxide dismutase, catalase, peroxidase, and ascorbate peroxidase enzymes and the amount of phenolic compounds. Assess mean comparison result of interaction effect of treatments showed maximum Superoxide dismutase (350.460 gr leaf protein) was for Methyl jasmonate 1.5 micro molar and Chamran variety and lowest one (238.142 gr leaf protein) belonged to control and Mehrgan variety (Table 4).

4.5. *Glutathione peroxidase*

According result of analysis of variance effect of seed priming, varieties and interaction effect of treatments on Glutathione peroxidase was significant at 1% probability level (Table 2). Mean comparison result of different level of seed priming indicated that maximum Glutathione peroxidase (4.548 gr leaf protein) was noted for Methyl jasmonate 1.5 micro molar and minimum of that (2.863 gr leaf protein) belonged to control treatment (Table 3). Between different varieties the maximum Glutathione peroxidase (3.940 gr leaf protein) was observed in Chamran Variety and the lowest one (3.490 gr leaf protein) was found in Mehrgan Variety (Table 3). Evaluation mean comparison result of interaction effect of treatments indicated maximum Glutathione peroxidase (4.835 gr leaf protein) was noted for Methyl jasmonate 1.5 micro molar and Chamran variety and lowest one (2.655 gr leaf protein) belonged to control and Mehrgan variety (Table 4). Singh and Usha. (2003) reported Wheat plants grown from seeds primed with salicylic acid showed higher superoxide dismutase enzyme activity compared to the control. Salicylic acid plays an important role in inducing defense proteins, including superoxide dismutase and peroxidase, to protect cells. In primed corn seeds, antioxidant enzyme activity increased, which may be a reason for the superior yield of the treated seeds under normal and stress conditions compared to the control (Tabatabaee, 2013). Researchers have stated that jasmonic acid prevents the effects of free radicals resulting from stress on the membrane by maintaining high levels of antioxidant enzyme activity, such as catalase and peroxidase, and prevents the accumulation of malon dialdehyde and hydrogen peroxide (Comparot *et al*., 2002; Kumari *et al*., 2006; Jung, 2004). The metabolic changes caused by jasmonic acid lead to changes in the level of oxygen free radicals, which in turn stimulate the antioxidant defense system. It seems that jasmonic acid and reactive oxygen species, especially hydrogen peroxide, are involved in the cellular signaling system and stimulate antioxidant defense under stress conditions (Orozco-Cardenas *et al*., 2001).

5. CONCLUSION

Generally based on result of current study application salicylic acid and Methyl jasmonate led to improve grain yield and biochemical traits of Wheat verities and can be advised to farmer.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

CONFLICT OF INTEREST: Authors declared no conflict of interest.

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Assess Foliar Application of Iron and Zinc Fertilizers on Quantitative and Qualitative Traits of Sunflower in Warm and Dry Climate Condition (Southwest of Iran, Ahvaz Region)

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ABSTRACT

BACKGROUND: Nutrients play a very important role in chemical, biochemical, physiological, metabolic, geochemical, biogeochemical, and enzymatic processes.

OBJECTIVES: Current research was done to evaluated effect of foliar application of Microelements (Iron and Zinc) on crop production of Sunflower.

METHODS: This study was conducted in Ahvaz city (southwest of Iran) via a Factorial experiment based on randomized complete block design with three replications during 2022. The first factor included foliar application of Iron fertilizer (Zero or control, 0.003 and 0.005 concentration) and second factor consisted foliar application of Zinc fertilizer (Zero or control, 0.002 and 0.004 concentration).

RESULT: According result of analysis of variance effect of different level of Iron and Zinc fertilizer on all studied traits were significant but interaction effect of treatments on 1000-grain weight, oil content and oil yield was not significant. Evaluation mean comparison result of different level of Iron fertilizer revealed maximum amount of 1000-grain weight (65.27 gr), oil content (41.11%) and oil yield (116.87 $gr.m^{-2}$) belonged to 0.005 $L.ha^{-1}$ and lowest ones was control. Also compare different level of foliar application of Zinc showed that the maximum and the minimum amount of 1000-grain weight, oil content and oil yield belonged to 0.004 $L.ha^{-1}$ and control treatments. Evaluation mean comparison result of interaction effect of treatments indicated maximum number of grain per head (620.31), grain yield (298.6 $gr.m^{-2}$), protein content (19.3%) and protein yield (57.62 $gr.m^{-2}$) was noted for 0.005 $L.ha^{-1}$ foliar application of Iron and 0.004 $L.ha^{-1}$ foliar application of Zinc and lowest ones belonged to control treatment.

CONCLUSION: Finally according result of current research application 0.005 $L.ha^{-1}$ foliar application of Iron and 0.004 $L.ha^{-1}$ foliar application of Zinc had the highest amount of studied traits and it can be advice to producers in studied region.

KEYWORDS: *Crop production, Nutrition, Oil, Protein, Seed yield.*

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1. BACKGROUND

Agricultural soils in Iran suffer from severe deficiencies of micronutrients, especially Iron and Zinc, due to reasons such as calcareous soils, none carbonate irrigation water, low organic matter in agricultural soils, drought stress and excessive use of phosphate fertilizers (Rahimizadeh *et al*., 2012). In agriculture, Zinc deficiency is common and widespread. This phenomenon arises due to the intense uptake of usable Zinc from the root penetration zone in the soil and, in some cases, due to the beneficial effect of soil organic matter in Zinc absorption by plants and surface erosion leading to Zinc deficiency. Additionally, in calcareous and alkaline soils, Zinc deficiency occurs due to the high soil acidity (Koochaki and Sarmadian, 1994). It appears that while foliar Zn spraying is more effective than soil N or Zn application to enrich wheat grains with Zn, the grain Zn bioavailability is influenced more by cultivar selection (Xia *et al*., 2018). The results of the research of Al-Murshidi and Halool Jassim (2023) showed that the superiority of Nano-Zinc at the level of 300 ppm on the flag leaf area and the number of grains in the spike, as the highest averages, while Zinc sulfate at the level of 200 ppm outperformed in the trait of plant height, as it recorded the highest average, as well as the superiority of Zinc Sulphate at the level of 300 ppm in the trait of spike length, number of branches, and grain yield, which recorded the highest averages. Iron is an essential but in short supply element in most plants. Its role in nitrogen fixation and the activity of some enzymes such as catalase, peroxidase, and cytochrome oxidase is well established (Ruiz *et al*., 2000). Nouraein *et al*. (2019) studied the effects of micronutrients on Sunflower crop production and stated that the highest number of seeds per head, thousand-seed weight, oil percentage, seed yield, harvest index, and head diameter were attributed to the combined application of Iron and Zinc. Lotha and Dawson (2021) studied the effects of micronutrients on Sunflower stated that the traits of plant height, head diameter, seed yield, harvest index and biological yield were obtained in the foliar application of Iron, Zinc and Boron, and the lowest amount of these traits were obtained in the treatment without foliar application of micronutrients.

2. OBJECTIVES

Current research was done to evaluated effect of foliar application of Microelements (Iron and Zinc) on crop production of Sunflower.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This research was conducted in Ahvaz City at longitude 48°40′E and latitude 31"20° N in Khuzestan province (Southwest of Iran) via a Factorial experiment based on randomized complete block design with three replications during 2022. The first factor included foliar application of Iron fertilizer (Zero or control, 0.003 and 0.005 concentration) and second factor consisted foliar application of Zinc fertilizer (Zero or control, 0.002 and 0.004 concentration). The experiment consisted of 27 plots. For the experiment, the distance between rows to rows was 75 cm with six rows per treatment. The size of each plot was 6×5 m². The distance between plots was two unplanted rows and the distance between blocks was 1.5 meters. Soil properties of studied field was listed in table (1).

Table 1. Physical and chemical properties of studied field

Soil depth (cm)	Soil texture	SP (%)	EC ($ds.m^{-1}$)	OC (%)	pH	P (ppm)	K (ppm)
0-15	Clay loam	47	3.89	0.77	7.2	9.1	190
15-30	Clay loam	45	3.71	0.64	7.1	8.8	178

3.2. Farm Management

Tillage and land preparation operations included irrigation before land preparation, one deep plowing and two disking, leveling, creating ridges and furrow, and plotting. The amount of phosphorus fertilizer was calculated and used based on 100 kg of phosphorus (P_2O_5) per hectare from triple superphosphate. All phosphorus fertilizer was distributed uniformly at the same time as final leveling. Nitrogen fertilizer from Urea source was applied at a rate of 200 $kg.ha^{-1}$, half of which was spread in the field with a disk before planting and the other half was distributed at the 8-leaf stage. The seed used was the Shams hybrid. The Shams hybrid, with an average yield of 3.5 tons per hectare, was identified as a superior and stable hybrid due to its equal yield to imported hybrids, lower height, early maturity, and more suitable head shape. Due to its desirable agronomic characteristics, this hybrid was introduced in January 2016 as a new Sunflower cultivar for spring cultivation in temperate and cold regions and summer cultivation in temperate regions (Ghafari, 2019). Seed sowing was done manually. The first irrigation was done one day after sowing. Foliar application of Iron and Zinc fertilizers in the mentioned amounts was carried out three times during the plant growth season at the 12-14 leaf stage, inflorescence emergence, and the beginning of pollination. The prepared solutions were sprayed in all plots was sprayed at early morning. Weed control was carried out by hand weeding, and effective pesticides and sprayers were used to combat possible pests and diseases.

3.3. Measured Traits

When 90% of heads turned yellowish-brown and the seeds moisture content was 20% (physiological maturity), the final harvest was carried out from an area equivalent to 2 square meters from lines three, four, and five. To calculate the number of seeds per head at the final harvest, 5 head were randomly selected and after separating the seeds from each head, seeds were counted using a seed counter and the average number of seeds per head was obtained. In order to determine grain yield, an area equivalent to two square meters was harvested and after separating the grains, the grain yield was weighed (Amini and Rushdi, 2013). To determine the percentage of grain protein, the percentage of grain nitrogen was first measured by Kjeldahl method, which includes digestion, distillation and titration. To measure the seed nitrogen content and straw nitrogen content the Kjeldahl method was used. So, to calculate the seed protein content the following formula was used (Bremner *et al*., 1983): **Equ.1.** Seed protein content (%)= Nitrogen percentage × 5.8. Prussic acid was determined according to the AOAC (1990) methods. Grain protein yield was also obtained by multiplying the protein percentage by grain yield. Oil content determine by Near Infrared Spectroscopy (Sato, 2002). Oil yield calculated by multiplying grain yield by oil content.

3.4. Statistical Analysis

Analysis of variance and mean comparisons were done via SAS (Ver.9) software and Duncan multiple range test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. *1000-grain weight*

Result of analysis of variance revealed effect of foliar application of Iron and Zinc on 1000-grain weight was significant at 1% probability level, but interaction effect of treatments was not significant (Table 2). As for Duncan classification made with respect to different level of foliar application of Iron maximum and minimum amount of 1000-grain weight belonged to 0.005 $L.ha^{-1}$ (65.27 gr) and control (56.03 gr) (Table 3). Compare different level of foliar application of Zinc showed that the maximum and the minimum amount of 1000-grain weight belonged to 0.004 $L.ha^{-1}$ (68.51 gr) and control (50.71 gr) treatments (Table 3). If the micronutrients (Iron and Zinc) are provided in sufficient quantities, the Sunflower can through increase vegetative growth and production of photosynthetic assimilates send a greater amount of carbohydrates to the seeds and increasing the seed weight (Al-Doori, 2019). Rahimi *et al*. (2003) reported consumption of micronutrients can activate and synthesize enzymes, thereby increasing the rate of photosynthesis. Increased photosynthesis also causes a greater amount of assimilates to the seeds, resulting in an increase seed weight. Kumar *et al*. (2010) reported use of micronutrients in Sunflower cultivation has a significant effect on stem height, head diameter, number of seeds per head, seed weight, seed oil percentage, number of leaves and crop production.

4.2. *Number of grain per head*

According result of analysis of variance effect of foliar application of Iron, Zinc and interaction effect of treatments on number of grain per head was significant at 1% probability level (Table 2). Evaluation mean comparison result of interaction effect of treatments indicated maximum number of grain per head (620.31) was noted for 0.005 $L.ha^{-1}$ foliar application of Iron and 0.004 $L.ha^{-1}$ foliar application of Zinc and lowest one (536.1) belonged to control treatment (Table 4). The results of Putran (2020) indicated a positive effect of microelements (Zinc and Iron) on Sunflower growth, yield, and its components, especially the number of seeds in the head, which was consistent with the results of this study.

Table 2. Result analysis of variance of measured traits

S.O.V	df	1000-grain weight	No. grain per head	Grain yield	Protein content	Protein yield	Oil content	Oil yield
Replication	2	5.67^{ns}	724.1^{ns}	741.3^{ns}	0.02^{ns}	19.3^{ns}	2.15^{ns}	32.1^{ns}
Foliar application of Iron fertilizer (I)	2	1821.42**	82361.5**	66428.5**	58.1*	21347.7**	351.33**	8206.4**
Foliar application of Zinc fertilizer (Z)	2	1505.3**	65039.1**	95433.4**	89.37**	1681.05**	199.2**	5271.5**
I × Z	4	7.16^{ns}	24387.8**	22147.01**	71.56**	1433.3**	0.05^{ns}	30.1^{ns}
Error	16	31.49	1721.32	1184.27	6.88	35.9	9.24	151.3
CV (%)		9.21	7.02	13.68	14.43	13	7.63	12.18

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

In studies by researchers, foliar spraying with micronutrients such as Iron and Zinc increases nitrogen absorption, yield components, including the number of grains per head, due to its positive effect on leaf area index and better absorption of some elements such as nitrogen (Baniabbass *et al*., 2012).

4.3. *Grain yield*

According result of analysis of variance effect of foliar application of Iron, Zinc and interaction effect of treatments on grain yield was significant at 1% probability level (Table 2). Evaluation mean comparison result of interaction effect of treatments indicated maximum grain yield (298.6 $gr.m^{-2}$) was noted for 0.005 $L.ha^{-1}$ foliar application of Iron and 0.004 $L.ha^{-1}$ foliar application of Zinc and lowest one (222.9 $gr.m^{-2}$) belonged to control treatment (Table 4). Increased yield in Sunflower can be due to an increase in any of the yield components. The number of seeds per head and seed weight in Sunflower are among the most important traits that affect seed yield, and an increase or decrease in any of them can increase or decrease seed yield (Dindoost Eslam *et al*., 2008). The results of Lotha and Dawson (2021) confirm that the highest grain yield trait was obtained in the foliar application of Iron, Zinc, and boron, and the lowest of this trait was obtained in the treatment without foliar application of micronutrients. By increasing the absorption capacity of macronutrients, micronutrients can store more photosynthetic materials in seeds and, by reducing the number of empty seeds, increase seed yield (Amini and Rushdi, 2013).

4.4. *Protein content*

Result of analysis of variance revealed effect of foliar application of Iron, Zinc and interaction effect of treatments on protein content was significant at 5%, 1% probability level, respectively (Table 2). Evaluation mean comparison result of interaction effect of treatments indicated maximum protein content (19.3%) was noted for 0.005 $L.ha^{-1}$ foliar application of Iron and 0.004 $L.ha^{-1}$ foliar application of

Zinc and lowest one (17.2%) belonged to control treatment (Table 4). Caliskan *et al*. (2008) revealed application of 400 gr.ha^{-1} Fe-EDTA along with 80 kg.ha^{-1} nitrogen had the best soybean yield. They emphasized application of coated nitrogen fertilizer along with Fe-EDTA as starter increased early plant growth. Janmohammadi *et al*. (2018) reported application of Iron and Zinc fertilizers along with manure had good results on pea yield. Like this maximum sweet corn seed yield obtained when enriched vermin compost with Iron sulfate and Zinc sulfate along with foliar application of Zinc and Iron sulfate applied 20 to 40 days after planting (Arabhanvi and Hulihalli, 2018).

Table 3. Mean comparison different level of foliar application of Iron and Zinc fertilizer on studied traits

Treatment	1000-grain weight (gr)	Oil content (%)	Oil yield (gr.m^{-2})
Foliar application of Iron			
None spray or control	56.03b	38.05b	81.84c
0.003 L.ha^{-1}	61.34ab	40.22ab	104.25b
0.005 L.ha^{-1}	65.27a	41.11a	116.87a
Foliar application of Zinc			
None spray or control	50.71b	37.24b	76.18c
0.002 L.ha^{-1}	63.44ab	39.85ab	104.99b
0.004 L.ha^{-1}	68.51a	40.76a	118.33a

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).

4.5. *Protein yield*

According result of analysis of variance effect of foliar application of Iron, Zinc and interaction effect of treatments on protein yield was significant at 1% probability level (Table 2). Evaluation mean comparison result of interaction effect of treatments indicated maximum protein yield (57.62 gr.m^{-2}) was noted for 0.005 L.ha^{-1} foliar application of Iron and 0.004 L.ha^{-1} foliar application of Zinc and lowest one (38.33 gr.m^{-2}) belonged to control treatment (Table 4). The results of research by Khalafi *et al*. (1401) showed that use microelements (Iron and Zinc) significantly increased grain protein. They reported that these elements play a role in the structure of enzymes involved in the synthesis of amino acids, which are the basis of protein synthesis. Therefore, the consumption of these elements increased the amount of grain protein, which was consisted with the results of this study. The researchers concluded that Zinc and Iron deficiency may prevent the activity of a number of antioxidant enzymes, which in turn causes oxidative damage to protein molecules, chlorophyll, and nucleic acids, so led to reduces crop protein production (Daniel and Triboi, 2008).

4.6. *Oil content*

Result of analysis of variance revealed effect of foliar application of Iron and Zinc on oil content was significant at 1% probability level, but interaction effect of treatments was not significant (Table 2). As for Duncan classification made with respect to different level of foliar application of Iron maximum and minimum amount of oil content belonged to 0.005 $L.ha^{-1}$ (41.11%) and control (38.05%) (Table 3). Compare different level of foliar application of Zinc showed that the maximum and the minimum amount of oil content belonged to 0.004 $L.ha^{-1}$ (40.76%) and control (37.24%) treatments (Table 3). Roshdi *et al.* (2008) based on their two-year research stated that inoculation of seed with Nitroxin plus 50% of urea required the most positive effect in increasing seed and oil yield and the use of biological fertilizers can improve the characteristics of the oil seed be useful. Research by Babulkar *et al.* (2010) found that the effect of micronutrients significantly increased the percentage of protein and oil content. These results indicate that the application of micronutrients can have a significant impact on increasing quantitative and qualitative yield.

Table 4. Interaction effect of treatments on studied traits

Foliar application of Iron	Foliar application of Zinc	No. Grain per head	Grain yield ($gr.m^{-2}$)	Protein content (%)	Protein yield ($gr.m^{-2}$)
None spray or control	**None spray or control**	536.1e	222.9f	17.2e	38.33d
	0.002 $L.ha^{-1}$	575.1d	231.6e	17.5d	40.53cd
	0.004 $L.ha^{-1}$	582cd	232.18e	17.8cd	41.33cd
0.003 $L.ha^{-1}$	**None spray or control**	590.4c	240.05de	18c	43.2c
	0.002 $L.ha^{-1}$	601.4b	248.2d	18.4bc	45.66bc
	0.004 $L.ha^{-1}$	606.23ab	261.4c	18.8c	49.14b
0.005 $L.ha^{-1}$	**None spray or control**	596.5bc	254.1cd	18.1c	45.99bc
	0.002 $L.ha^{-1}$	609.1ab	275.11b	19ab	52.27ab
	0.004 $L.ha^{-1}$	620.31a	298.6a	19.3a	57.62a

*Mean which have at least once common letter are not significant different at the 5% level using (DMRT).

4.7. *Oil yield*

According result of analysis of variance effect of foliar application of Iron and Zinc on oil yield was significant at 1% probability level, but interaction effect of treatments was not significant (Table 2). Evaluation mean comparison result revealed in different level of foliar application of Iron the maximum oil yield (116.87 $gr.m^{-2}$) was noted for 0.005 $L.ha^{-1}$ and minimum of that (81.84 $gr.m^{-2}$) belonged to control treatment (Table 3). Between different level of foliar application of Zinc the maximum oil yield (118.33 $gr.m^{-2}$) was observed in 0.004 $L.ha^{-1}$ and the lowest one (76.18 $gr.m^{-2}$) was found in control treatment (Table 3). The results of experiments by Kumar *et al.* (2010) showed that the use of micronutrients in Sunflower cultivation has a significant effect on oil percentage, which was similar to the results of this study. Also in the experiment of Rahimizadeh *et al.* (2010), the highest oil yield was obtained in fertilizer treatments containing Zinc and Iron, which was consistent with the results of this study.

5. CONCLUSION

Finally according result of current research application 0.005 $L.ha^{-1}$ foliar application of Iron and 0.004 $L.ha^{-1}$ foliar application of Zinc had the highest amount of studied traits and it can be advice to producers in studied region.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

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Evaluation Combined Effect of Sulo Potash and Zinc Chelate on Corn Crop Production under Water Deficit Stress Conditions in Southwest of Iran (Shoushtar Region)

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ABSTRACT

BACKGROUND: Management of balanced fertilizer application according to plant growth requirements and soil testing is one of the strategies for improving the quality and quantity of agricultural products.

OBJECTIVES: This study was done to assess effect of different level of macro elements and Microelements on Corn crop production affected drought stress.

METHODS: This research was conducted via analysis split plot experiment based on randomized complete blocks design during 2018 with three replications. The main factor included water deficit stress (60 mm, 90 mm and 120 mm evaporation from the Class A evaporation pan). The sub factor consisted different type of fertilizer (Control, 10 $kg.ha^{-1}$ Solu Potash, Combined Solu Potash and Chelated Zinc, 0.004 $L.ha^{-1}$ Chelated Zinc).

RESULT: According result of analysis of variance effect of water deficit stress and fertilizer on all measured traits was significant, but interaction effect of treatments on number of grain per row, 1000-grain weight and chlorophyll index was not significant.
Mean comparison result of different level of water deficit stress indicated that maximum number of grain per row (35.08), 1000-grain weight (180.50 gr) and Chlorophyll index (48.08) was noted for 60 mm evaporation from the class A evaporation pan and minimum of those traits belonged to 120 mm. As for Duncan classification made with respect to different level of fertilizer maximum and minimum amount of number of grain per row (36.57), 1000-grain weight (179.28 gr) and Chlorophyll index (48.08) belonged to Combined use of Solu Potash and Chelated Zinc (49.13) and control treatment.

CONCLUSION: Generally according result of current study combined use of Solu Potash and Chelated Zinc fertilizer with irrigation at 60 mm evaporation from the class A evaporation pan had the highest amount of crop production, so it can be advice to farmers.

KEYWORDS: *Chlorophyll, Biological yield, Grain weight, Maize, Micronutrient.*

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1. BACKGROUND

Increasing fertilizer consumption has led to the growth of food production, and scientific sources have shown that by increasing one or more of the 16 essential nutrients, the yield has also increased. The 16 chemical elements primarily recognized as essential for plant growth include Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulfur, Iron, Zinc, Copper, Manganese, Molybdenum, Boron, and Chlorine (Sharafizadeh, 2001). In agriculture, Zinc deficiency is common and widespread. This phenomenon arises due to the intense uptake of usable Zinc from the root penetration zone in the soil and, in some cases, due to the beneficial effect of soil organic matter in Zinc absorption by plants and surface erosion leading to Zinc deficiency. Additionally, in calcareous and alkaline soils, Zinc deficiency occurs due to the high soil acidity (Koochaki and Sarmadian, 1994). Potassium is an essential nutrient that affects most of the biochemical and physiological processes are involved in plant resistance to biotic and abiotic stresses (Ashfaq *et al.*, 2015). Potassium known to increase pest resistance, as well as resistance to diseases and other biotic and abiotic environmental stresses (Zafar and Athar, 2013). Recent studies in Iran have shown the rate of decline in soil Potassium has increased, and the Potassium balance in many wheat fields has become negative. The reasons are intensive cropping, use of cultivars with a high nutrient demand, excessive application of Nitrogen and Phosphorous fertilizers and negligible use of Potassium fertilizers. These have increased rates of Potassium removal from soils faster than the rate of its release from minerals (Olfati *et al*., 2010). Foliar application is a method to reduce the fixation of chemical fertilizers in the soil and as a result reduce environmental risks, including reducing soil and water pollution, and it makes nutrients available to plants in a controlled manner (Kannan, 2010). Today, in addition to high-consumption food elements, the use of micronutrient elements as an important tool to achieve maximum yield per unit area is considered (Mosavi *et al*., 2007). Zinc plays an important role in reducing ROS generation and protects cells from the damaging effects of ROS (Cakmak, 2000). Zinc deficiency in cases caused by the limitations of the subsoil, dryness of the surface soil and diseases cannot be completely and definitively resolved through the consumption of fertilizers containing Zinc. Therefore, the use of effective genotypes for the absorption of Zinc can be an effective and sustainable solution for the production of more crops in conditions of Zinc deficiency (Sadeghzadeh, 2013). It appears that while foliar Zinc spraying is more effective than soil Nitrogen or Zinc application to enrich wheat grains with Zinc, the grain Zinc bioavailability is influenced more by cultivar selection (Xia *et al*., 2018). The results of the research of Al-Murshidi and Halool Jassim (2023) showed that the superiority of Nano-Zinc at the level of 300 ppm on the flag leaf area and the number of grains in the spike, as the highest averages, while Zinc sulfate at the level of 200ppm outperformed in the trait of plant height, as it recorded the highest average, as well as the superiority of Zinc Sulphate at the level of 300 ppm in the trait of spike length, number of branches, and grain yield, which recorded the highest averages.

2. OBJECTIVES

This study was done to assess effect of different level of macro elements and Microelements on Corn crop production affected drought stress.

3. MATERIALS AND METHODS

3.1. *Field and Treatments Information*

This research was conducted via analysis split plot experiment based on randomized complete blocks design during 2018 with three replications. The main factor included water deficit stress (60 mm, 90 mm and 120 mm evaporation from the class A evaporation pan). The sub factor consisted different type of fertilizer (Control, 10 $kg.ha^{-1}$ Solu Potash, Combined Solu Potash and Chelated Zinc, 0.004 $L.ha^{-1}$ Chelated Zinc). Place of research was located in Shoushtar city at longitude 48°49'E and latitude 32°14'N in Khuzestan province (Southwest of Iran). The average annual rainfall, temperature, and evaporation in the region is 245 mm, 21 C and 2995 mm, respectively. Before the land preparation operation, sampling was carried out to identify the soil condition and deliver the samples to the soil science laboratory. The physical and chemical properties of studied soil mentioned in table 1. The size of each plot was 6×5 m^2 and each block has 12 treatments. For the experiment, the distance between rows to rows was 75 cm with six rows per treatment.

Table 1. Physical and chemical properties of studied field

Soil depth (cm)	Soil texture	pH	EC ($ds.m^{-1}$)	OC (%)	Phosphorus (ppm)	Potassium (ppm)	Zinc (ppm)	Nitrogen (ppm)
0-30	Silty clay	7.70	3.88	0.32	10.74	105	0.34	0.12
30-60	Silty clay	7.54	3.70	0.30	9.06	92	0.31	0.09

3.2. *Farm Management*

Land preparation operations included plowing to a depth of 30 cm, double-sided disking, leveling with a leveler, and creating furrows and ridges with appropriate spacing. The basic fertilizer used in the farm included nitrogen fertilizer from Urea at a rate of 150 $kg.ha^{-1}$ in two stages (50% at the time of planting and 50% after stem elongation consumed) and phosphorus fertilizer based on 60 kg of pure phosphorus from Triple Superphosphate during land preparation. Solu Potash fertilizer was applied at a rate of 10 kg/ha, first dissolved in water before use, and then applied with the first irrigation in the field. The Zinc chelate fertilizer (Green Drop) used contains 7.5% Zinc in chelate form and is completely stable over a wide range of acidity and is used to compensate for Zinc deficiency in all crops. Seeds are disinfected with the fungicide Carboxin Thiram before planting. The first irrigation was performed one day after planting, and irrigation was performed according to regional custom until the four to five leaf stage. The first irrigation was done one day after planting, and irrigation was done according to regional custom until the four to five leaf stage. Subsequent irrigations were done based on daily evaporation reported from the meteorological station. The stress application time lasted about 60 days, from 30 days after planting to about 25 days before harvest. Solu Potash was applied in the field in two stages. The first stage was done simultaneously with planting and the second stage at the six-leaf stage. Foliar spraying of Zinc chelate was carried out at the six-leaf and twelve-leaf stages and between 6 and 8 pm. The amount of Zinc fertilizer was based on 4 per thousand (4 cc per thousand cc of water). The prepared solution was sprayed in all plots using a backpack pump sprayer. Weed control was carried out by hand weeding.

3.3. *Measured Traits*

In order to measure total dry matter above the ground level, five crops within 0.5–0.6 m of a row section in each plot were cut at the ground level at ripening stage. Crop samples were dried at the 65°C until constant weight was achieved. The final harvesting area was equal to 4.8 m^{-2} that was done from two middle lines of planting. The yield components including the seed weight, number of seed per row and number of seed per ear were measured separately from the final harvest plants per plot. Corn seed yields were determined by hand harvesting the 8 m sections of three center rows in each plot. Then, seed yield values were adjusted to 15.5% moisture content. Chlorophyll content of five ear leaves in each plot was measured at anthesis stage by SPAD 502 device, accurately three points of leaf measured and the average of three numbers was considered.

3.4. *Statistical Analysis*

Analysis of variance and mean comparisons were done via SAS (Ver.9.1) software and Duncan multiple range test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. *Number of grain per row*

Result of analysis of variance revealed effect of water deficit stress and fertilizer on number of grain per row was significant at 1% probability level, but interaction effect of treatments was not significant (Table 2). Mean comparison result of different level of water deficit stress indicated that maximum number of grain per row (35.08) was noted for 60 mm evaporation from the class A evaporation pan and minimum of that (23.18) belonged to 120 mm (Table 3). As for Duncan classification made with respect to different level of fertilizer maximum and minimum amount of number of grain per row belonged to Combined use of Solu Potash and Chelated Zinc (36.57) and control (24.81) (Table 3). Foliar application of micronutrients, due to its nutritional effect and deficiency elimination, increased growth balance and regulated developmental processes in the plant, which led to an increase in the number of seeds per ear and ultimately improved grain yield (Karimi *et al*., 2012).

Application of Potash (70 kg $K.ha^{-1}$) as Potassium Nitrate was better than Potassium Sulphate and Potassium Chloride for plant height, number of boll, boll weight, seed Cotton yield, lint percentage and earliness in Cotton (Armin and Hajinezhad, 2016).

Table 2. Result analysis of variance of measured traits

S.O.V	df	No. grain per row	No. grain per ear	1000-grain weight	Chlorophyll index	Grain yield	Biological yield
Replication	2	2.54^{ns}	1001.03^{ns}	90.6^{ns}	150.1^{ns}	3571^{ns}	600.1^{ns}
Water stress (W)	2	153.14^{**}	35260.4^{**}	2184.4^{**}	604.02^{*}	509137^{**}	801590^{**}
Error I	4	10.73	904.7	189.32	81.78	2057.51	8010
Fertilizer (F)	3	90.42^{**}	28206.5^{**}	1893.06^{**}	413.08^{*}	102764^{**}	541518^{**}
F × W	6	3.54^{ns}	15025.8^{**}	35.21^{ns}	19.75^{ns}	51287^{**}	153607^{**}
Error II	18	7.65	851.74	177.38	40.24	1600.2	7500.5
CV (%)		9.36	7.05	8.26	14.35	8.41	6.56

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

4.2. *Number of grain per ear*

According result of analysis of variance effect of water deficit stress, fertilizer and interaction effect of treatments on number of grain per ear was significant at 1% probability level (Table 2). Evaluation mean comparison result of interaction effect of treatments indicated maximum number of grain per ear (510.12) was noted for 60 mm evaporation from the class A evaporation pan and Combined use of Solu Potash and Chelated Zinc and lowest one (318.12) belonged to 120 mm evaporation and none use of fertilizer (Table 4). The increase in the number of grains per spike may be attributed to the treatment of the plant with Zinc, which was characterized by its physiological role in increasing the work of the leaf and its efficiency and reducing its aging in terms of photosynthesis and chlorophyll formation and increasing the production of dry matter and this is what was indicated by Ali and Sharqi (2010), accounted for the effect of Zinc during the flowering period, spraying reduces competition between the flowers to absorb Zinc, and this increases the percentage of pollinated flowers that develop into grains. In this study, the lack of grain formation due to drought stress is due to insufficient photosynthetic materials available at the time of pollination, grain filling, or the stages before it. Water stress affects the growth of embryonic cells at these stages (Cakir, 2004).

4.3. *1000-grain weight*

Result of analysis of variance revealed effect of water deficit stress and fertilizer on 1000-grain weight was significant at 1% probability level, but interaction effect of treatments was not significant (Table 2). According result of mean comparison maximum of 1000-grain weight (180.50 gr) was obtained for 60 mm evaporation from the class A evaporation pan and minimum of that (145.03 gr) was for 120 mm treatment (Table 3). Evaluation mean comparison result indicated in different level of fertilizer the maximum 1000-grain weight (179.28 gr) was noted for Combined use of Solu Potash and Chelated Zinc and minimum of that (143.72 gr) belonged to control treatment (Table 3). Savaghebi and Malakouti (1999) reported applying Potassium has significant effects on canola yield, and use of Potassium sulfates at the rate of 150 $Kg.ha^{-1}$ as the base fertilizer and 100 $Kg.ha^{-1}$ Potassium chloride for topdressing led to achieve maximum yield. Moreover, application of Potassium reduced Zinc deficiency resulting from applying phosphorous (Mirzashahi *et al*., 2010). Tabatabaei *et al*. (2014) reported effect of Potassium sulphate was significant on number of spike per m^2, number of grain per spike, number of spikelet per spike, protein content, biological yield, seed yield and straw yield also highest of seed yield (6523 $kg.ha^{-1}$) was obtained from 160 $kg.ha^{-1}$ Potassium sulphate application.

Table 3. Mean comparison effect of on water stress and Fertilizer on studied traits

Treatment	No. grain per row	1000-grain weight (gr)	Chlorophyll index
Water stress			
60 mm	35.08a*	180.50a	48.08a
90 mm	30.34b	158.15b	43.94b
120 mm	23.18c	145.03c	40.84c
Fertilizer			
Control	24.81c	143.72c	39.48c
Solu Potash	27.14bc	159.47b	43.26b
Combined Solu Potash and Chelated Zinc	36.57a	179.28a	49.13a
Chelated Zinc	30.6b	161.8b	44.96b

*Similar letters in each column show non-significant difference at 5% probability level via Duncan test.

4.4. *Chlorophyll index*

Result of analysis of variance revealed effect of water deficit stress and fertilizer on chlorophyll index was significant at 5% probability level, but interaction effect of treatments was not significant (Table 2). Mean comparison result of different level of water deficit stress indicated that maximum chlorophyll index (48.08) was noted for 60 mm evaporation from the class A evaporation pan and minimum of that (40.84) belonged to 120 mm (Table 3). As for Duncan classification made with respect to different level of fertilizer maximum and minimum amount of chlorophyll index belonged to Combined use of Solu Potash and Chelated Zinc (49.13) and control (39.48) (Table 3). In this study, low chlorophyll content under water deficit stress conditions is a sign of oxidative stress, which may cause photo oxidation of the pigment and chlorophyll degradation. This argument is consistent with the findings of other researchers (Giancarla *et al*., 2013). It seems that the higher chlorophyll index in fertilizer treatments is due to the fact that Zinc and Potassium elements activate many enzymes, which are necessary for chlorophyll synthesis and carbohydrate formation. Ganjipour (2007) studies confirmed these results.

Table 4. Mean comparison interaction effect of treatments on studied traits

Water stress	Fertilizer	No. grain per ear	Grain yield ($kg.ha^{-1}$)	Biological yield ($g.m^{-2}$)
60 mm	Control	420.14c*	4701.7c	1332.1c
	Solu Potash	442.56b	5294.8b	1365.1b
	Combined Solu Potash and Chelated Zinc	510.12a	5940.12a	1461.4a
	Chelated Zinc	450.4b	5311.11b	1380.2b
90 mm	Control	379.4d	4350.4d	1260.29d
	Solu Potash	410.14c	4694.92c	1338.75c
	Combined Solu Potash and Chelated Zinc	502a	5890.3ab	1450.9ab
	Chelated Zinc	425.06c	4775.5c	1330.29c
120 mm	Control	318.12f	3750.2e	1170.11e
	Solu Potash	350.04e	5040.7de	1230.2de
	Combined Solu Potash and Chelated Zinc	392.14cd	4500.9cd	1265.8d
	Chelated Zinc	358.04e	4280.2d	1250.9de

*Similar letters in each column show non-significant difference at 5% probability level via Duncan test.

4.5. *Grain yield*

According result of analysis of variance effect of water deficit stress, fertilizer and interaction effect of treatments on grain yield was significant at 1% probability level (Table 2). Evaluation mean comparison result of interaction effect of treatments indicated maximum grain yield (5940.12 $kg.ha^{-1}$) was noted for 60 mm evaporation from the class A evaporation pan and Combined use of Solu Potash and Chelated Zinc and lowest one (3750.2 $kg.ha^{-1}$) belonged to 120 mm evaporation and none use of fertilizer (Table 4). Woldesenbet and Tana (2014) also reported that the highest grain yield was obtained from the treatment receiving the micronutrient Zinc. The use of micronutrients, considering their impact on chlorophyll synthesis and the increase in growth regulators, enhances the photosynthesis of young leaves, increases the transport of substances to storage sites, and consequently increases grain weight. Therefore, it directly influences grain yield.

4.6. *Biological yield*

According result of analysis of variance effect of water deficit stress, fertilizer and interaction effect of treatments on biological yield was significant at 1% probability level (Table 2). Evaluation mean comparison result of interaction effect of treatments indicated maximum biological yield (1461.4 gr.m^{-2}) was noted for 60 mm evaporation from the class A evaporation pan and Combined use of Solu Potash and Chelated Zinc and lowest one (1170.11 gr.m^{-2}) belonged to 120 mm evaporation and none use of fertilizer (Table 4). The increase in dry weight of maize plants with the simultaneous use of iron and Zinc fertilizers was also reported in the studies of Ebrahimi and Hassanpour (2002) and Zarea and Karimi (2023). So the utilization of micronutrients leads to an increase in dry matter accumulation, and under nutrient deficiency conditions, the enhancement of biological yield in plants will be restricted.

5. CONCLUSION

Generally according result of current study combined use of Solu Potash and Chelated Zinc fertilizer with irrigation at 60 mm evaporation from the class A evaporation pan had the highest amount of crop production, so it can be advice to farmers.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

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Evaluation Correlation between Traits and Stepwise Regression of Corn Affected Different Level of Chemical and Biological Fertilizer under Warm and Dry Climate Conditions

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ABSTRACT

BACKGROUND: The combined use of chemical and biological fertilizers is recommended due to the reduction in the cost of chemical inputs, alignment with sustainable agriculture goals, and prevention of environmental pollution.

OBJECTIVES: Current study was done to assess the effect of Fertilizer and biological fertilizer on grain yield, its components and morphological traits of Corn.

METHODS: This research was done via split plot experiment based on randomized complete blocks design during 2016 with three replications. The main factor included chemical fertilizers and manure (C_1: 100%, C_2: 50%, C_3: 25% NPK according recommended consumption amount and C_4: Animal manure [Cow manure]). The sub factor consisted three types of biological fertilizer (B_1: Control [none inoculation], B_2: Seed inoculation with a mixture of biological fertilizers such as Peta Barvar2, Phosphate Barvar2 and Azotobacter Barvar2, B_3: Seed inoculation with a mixture of biological fertilizers such as Peta Barvar2, Phosphate Barvar2 and Azotobacter Barvar2 and *Aspergillus niger*).

RESULT: According result of analysis of variance effect of different level of chemical fertilizers and manure (instead number of leaf up of ear, 1000-grain weight and harvest index), biological fertilizer (instead number of leaf up of ear, leaf area index and biological yield) on all measured traits was significant but interaction effect of treatments (instead cob diameter) on all measured traits was not significant. The traits of biological yield (0.85^{**}), number of grain per row (0.84^{**}), number of grain per ear (0.78^{**}), 1000-grain weight (0.83^{**}) and ear length (0.72^{**}), ear diameter (0.70^{**}), cob diameter (0.69^{**}), number of active leaf per plant (0.68^{**}) and leaf area index (0.68^{**}) had significant correlation with grain yield at 1% probability level, also harvest index (0.52^{*}) and dry matter (0.51^{*}) had significant correlation with grain yield at 5% probability level.

CONCLUSION: According results of stepwise regression, traits of number of grains per row, leaf area index, and ear diameter were identified as the most effective traits determining grain yield. Corn grain yield changed with decrease or increase in these traits due to changes in the amount of chemical fertilizer, Cow manure and biofertilizer application.

KEYWORDS: *Aspergillus*, *Azotobacter*, *Cow manure*, *Maize*, *Phosphate*.

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1. BACKGROUND

Seed yield, as the most important quantitative characteristic, will be a result of genotype, environment and genotype-environment interaction effects (Marjanovic-Jeromela *et al*., 2009). Multivariate analyses are useful for characterization, evaluation and classification of plant genetic resources when a number of accessions are to be assessed for several characters of agronomic, morphological and physiological importance. Different types of multivariate analysis such as regression analysis, path analysis, principal component analysis can be used to identify groups of genotypes that have beneficial traits for breeding and instructing the patterns of variation in genotype accession, to recognize relationships among accessions and possible gaps. Correlation coefficients describe the mutual relationships between different pairs of characters without providing the nature of cause and effect relationship of each character (Sharifi *et al*., 2020). Correlation coefficient, which is used as a standard of measuring linear relationship between two variables, only has one mathematical interpretation, and does not refer to cause and effect relationships (Abozary Gasaforodi, 2002). In this method, Correlation coefficient which exists between two traits is divided in to components which measure direct and indirect effects. Making use of this method requires the knowledge about cause and effect relations which exist between traits, and assuredly must determine the direction of causes according to previous information and experimental evidences (Garcia del Moral *et al*., 1999). Correlation analysis describes the mutual relationship between different pairs of characters without providing the nature of cause and effect relationship of each character. Significant positive correlations were detected between faba bean seed yield and each of number of pods per plant, number of seeds per plant, seed weight per plant and biological yield (Alghamd, 2007). Understanding of interrelationship between component characters helps in determining which character to select when improvement of the related complex character is desired. The correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for the improvement in associated complex character yield (Sokoto *et al*., 2012; Mohammadi *et al*., 2012). Seed yield is a quantitative trait, which expression is the result of genotype, environmental effect and genotype-environment interaction (Gunasekera *et al*., 2006). Sadat Mohajerani *et al* (2018) by study the effect of irrigation regime and biological fertilizer on seed yield, its components and correlation between traits of Red Bean confirm the relationship between photosynthesis efficiency and seed yield, because seed yield increases when plants can have higher photosynthetic material accumulation. Also, there was a significant correlation between the number of seeds per pod and the number of pods per plant. Mentioned traits are the most important characteristics that constituted the bean yield. A positive and significant correlation between seed yield and harvest index was expected, given that seed yield is one of the components in the seed harvest index. So that when the seed yield increases by the number of seeds per pod and the number of pods per plant, itis a factor to achieve higher harvest index. Soltani Howyzeh *et al*. (2018) by compare seventh spring canola reported the correlation coefficients among the seed yield and 1000-seed weight, number of seed per pod, harvest index and days to maturity were positive and significant. Results of stepwise regression analysis revealed that 1000-seed weight, number of pods per plant and days to maturity had significantly effects on seed yield.

2. OBJECTIVES

Current study was done to assess the effect of chemical and biological fertilizer on grain yield, its components and morphological traits of Corn.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This research was conducted in research farm of Ramhormoz, according split plot experiment based on randomized complete blocks design during Summer 2016 with three replications. The main factor included four Chemical Fertilizers (C_1: 100%, C_2: 50%, C_3: 25% NPK according recommended consumption amount and C_4: Animal manure [Cow manure]). The sub factor consisted three types Biological Fertilizer (B_1: Control [none inoculation], B_2: Seed inoculation with a mixture of biological fertilizers such as Peta Barvar2, Phosphate Barvar2 and Azotobacter Barvar2, B_3: Seed inoculation with a mixture of biological fertilizers such as Peta Barvar2, Phosphate Barvar2 and Azotobacter Barvar2 and *Aspergillus niger*). Place of research was located in Ramhormoz at longitude 49°36'E and latitude 31°16'N in Khuzestan province (Southwest of Iran). The metrological parameters such as average annual rainfall, temperature, and evaporation in the region is 267 mm, 24 C and 3000 mm, respectively (Table 1). Also the physical and chemical properties of studied soil was mentioned in table 2.

Table 1. Meteorological information for Ramhormoz city during the summer corn growing period in 2016

Month	Average temperature (degrees Celsius)		Average Relative Humidity (Percentage)	Average evaporation (mm/day)	Precipitation (mm)
	Minimum	Maximum			
July	31.7	47.5	18	16	0
August	32.2	47.2	21	14.8	0
September	29.7	45.1	19	13	0
October	22.7	38.4	22	9.1	0
November	18.0	32.2	32	5.7	3
December	10.1	21.1	55	2.5	64.5

Table 2. Soil properties of studied field

Soil texture	Potassium ($mg.kg^{-1}$)	Phosphorus ($mg.kg^{-1}$)	Nitrogen (%)	O.C (%)	pH	EC ($ds.m^{-1}$)
Silty clay loam	224	16.9	0.13	1.5	7.37	**3.4**

3.2. Farm Management

Based on the results of the chemical analysis of the soil at the research site, the application of 250 $kg.ha^{-1}$ of Urea (115 $kg.ha^{-1}$ of Nitrogen), 50 $kg.ha^{-1}$ of Triple Superphosphate (23 $kg.ha^{-1}$ of P_2O_5), and 150 $kg.ha^{-1}$ of Potassium Sulfate (75 $kg.ha^{-1}$ of K_2O) was considered equivalent to 100% of the recommended NPK application. The manure used in this study was three-year-old rotted cow manure, the results of the chemical analysis of this manure are presented in table (3).

Table 3. Chemical properties of the cow manure

Total Potassium (%)	Total Phosphorus (%)	Nitrogen (%)	O.C (%)	pH	EC ($ds.m^{-1}$)
0.93	2.10	1.05	12.10	7.25	**2.58**

The amount of manure used (with 15% moisture) to provide 115 kg of Nitrogen per hectare was estimated to be 25 tons per hectare, assuming that 50% of the total Nitrogen in cow manure was available to the plant (Van Castle and Rios, 2002; Pourazizi *et al*., 2013) and based on Equation (1). **Equ.1.** Amount of kilograms of nitrogen required per hectare= Dry weight of fertilizer (kg) × Percentage of nitrogen available to plants in manure × Percentage of nitrogen in manure. Biofertilizers such as Peta Barvar 2, Phosphate Barvar 2, and Azotobacter Barvar2 were purchased from "Zistfanavar Sabz" Company. Each gram of Peta Barvar 2 biofertilizer contained 10^7 to 10^8 *Pseudomonas vancouverensis* strain 26 and *Pseudomonas koreensis* strain 104. Each gram of Phosphate biofertlizer by commercial name of Barvar 2 contained 10^7 to 10^8 Phosphate-solubilizing bacteria *Pantoea agglomerans* strain P_5 and Pseudomonas putida strain P_{13}. Each gram of Azotobacter biofertlizer contained 10^7 to 10^8 *Azotobacter vinelandii* strain O_4. The manufacturer recommended using each 100-gram package of the aforementioned biofertilizers to soak the required seeds in one hectare. The Aspergillus fungus used in this study was extracted from the rhizosphere of sugarcane and was obtained from the Khuzestan Province Agricultural and Natural Resources Research Institute, Phytosanitary Research Department (Biological Products Production Laboratory) in the form of talc powder containing the fungus. The amount of Aspergillus fungus used, based on the laboratory's recommendation, was 20 grams of powder for three kilograms of seeds. The field was irrigated regularly in a way that did not cause the plant to affected water stress. Weeds in the field were also weeded manually.

3.3. *Measured Traits*

In this study, seven plants from rows two and four of each experimental unit were randomly selected at the corn tassel stage and marked with ribbons. These seven plants were used to measure traits such as plant height, number of active leaves per plant, number of leaves on the top of the ear, ear length, ear diameter and cob diameter. Three plants were also used in rows two and four of each experimental unit to evaluate leaf area index and dry matter weight at the silk emergence stage. In order to evaluate ear yield, grain yield, biological yield, and yield components, 30 plants belonging to rows two, three, and four of each experimental unit, covering an area of 4.6 m^2 at harvest time were used. At the milky stage (Zadox code 75), the total number of green leaves and the number of green leaves above the ear were counted and recorded in seven marked plants in rows two and four of each experimental unit. In order to determine the yield and yield components, two side rows and a half meters from the beginning and end of the plot were removed as marginal effects. The final harvest was done in an area equivalent to two square meters in each plot. In order to calculate the weight of 1000 seeds, two groups of 500 seeds were separated and if their difference was less than six percent, their total weight was determined as the weight of 1000 seeds. To determine the biological yield, an area of two square meters was taken from each plot and a section of about 500 grams was separated and after transferring the samples to the laboratory, they were placed in a oven dryer at 75°C for 48 hours. And after drying, their weight was calculated. Harvest index (HI) was calculated according to formula of Gardner *et al*. (1985) as follows: **Equ.2.** HI= (Seed yield/Biologic yield) ×100. To determine the leaf area of the linear relationship S= K. L.W was used in which S, L and W were the leaf area, L and W respectively, the maximum length and width of each leaf and K= 0.75 correction coefficient. The leaf area index was calculated from leaf area ratio to ground level.

3.4. *Statistical Analysis*

Analysis of variance and mean comparisons were done by SAS (Ver.9.1) software and LSD test at 5% probability level. The simple correlation coefficients between studied traits were calculated by using SAS software (Ver.9.1). Stepwise regression method was used to study the effect of each trait on grain yield (dependent variable).

4. RESULT AND DISCUSSION

4.1. *Analysis of variance*

Result of analysis of variance revealed effect of different level of chemical fertilizer and cow manure on number of leaf per plant, leaf area index, ear length, cob diameter, number of grain per row, number of grain per ear, grain yield and biological yield was significant at 1% probability level but on dry matter, ear dimeter and number of row per ear was significant at 5% probability level and on number of leaf up of ear, 1000-grain weight and harvest index was not significant (Table 4).

Table 4. The results of analysis of variance of measured traits

S.O.V	df	No. leaf per plant	No. leaf up of ear	Leaf area index	Dry matter	Ear length
Replication	2	0.266^{ns}	0.070^{ns}	0.086^{ns}	45.36^{ns}	0.113^{ns}
Chemical Fertilizer and Cow Manure (A)	3	1.718**	0.135^{ns}	1.005**	1015.94*	9.639**
Error I	6	0.179	0.058	0.124	187.23	0.913
Biological Fertilizer (B)	2	0.347*	0.030^{ns}	0.183^{ns}	346.07*	5.315**
A × B	6	0.070^{ns}	0.054^{ns}	0.041^{ns}	128.33^{ns}	0.701^{ns}
Error II	16	0.0896	0.098	0.118	79.50	0.853
CV (%)	-	2.11	5.83	10.28	8.21	4.53

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

Continue table 4.

S.O.V	df	Ear dimeter	Cob diameter	No. row per ear	No. grain per row	No. grain per ear
Replication	2	0.025^{ns}	0.0063^{ns}	0.216^{ns}	0.263^{ns}	456.67^{ns}
Chemical Fertilizer and Cow Manure (A)	3	0.086*	0.0443**	0.352*	41.07**	12225.24**
Error I	6	0.011	0.0051	0.052	3.22	1197.79
Biological Fertilizer (B)	2	0.085**	0.0435**	0.835**	36.53**	13833.72**
A × B	6	0.024^{ns}	0.0143*	0.169^{ns}	2.37^{ns}	1229.56^{ns}
Error II	16	0.014	0.0045	0.148	2.48	768.65
CV (%)	-	2.32	2.40	2.55	4.01	4.69

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

Continue table 4.

S.O.V	df	1000-grain weight	Ear yield	Grain yield	Biological yield	Harvest index
Replication	2	17.69^{ns}	167128.5^{ns}	470577.96^{ns}	1282633^{ns}	18.09^{ns}
Chemical Fertilizer and Cow Manure (A)	3	433.96^{ns}	36902786.8**	22097622.70**	108493535.7**	8.43^{ns}
Error I	6	557.32	1335698.2	642004.43	4870148.6	17.74
Biological Fertilizer (B)	2	955.11**	7222540.5*	7870248.47**	906349.6^{ns}	133.24**
A × B	6	86.41^{ns}	1177389.9^{ns}	685112.38^{ns}	1539003.4^{ns}	17.19^{ns}
Error II	16	153.67	1630393.5	1196263.5	1495441.3	6.54
CV (%)	-	4.33	8.6	9.8	5.7	4.9

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

According result of analysis of variance effect of different level of Biological Fertilizer on ear length, ear dimeter, cob diameter, number of row per ear, number of grain per row, number of grain per ear, 1000-grain weight, grain yield and harvest index was significant at 1% probability level but on number of leaf per plant, dry matter, cob diameter and ear yield was significant at 5% probability level and on number of leaf up of ear, leaf area index and biological yield was not significant (Table 4). Interaction effect of treatments on all measured traits (instead cob diameter at 5% probability level) was not significant (Table 4).

4.2. *Correlation between traits*

Knowledge of relationship among yield components is essential for the formulation of breeding programs aimed at achieving the desired combinations of various components of yield. The estimates of correlation coefficients among different characters indicate the extent and direction of association. The correlation co-efficient provide a reliable measure of association among the characters and help to differentiate vital associations useful in breeding from those of the non-vital ones (Falconer, 1981). The traits of biological yield (0.85**), number of grain per row (0.84**), number of grain per ear (0.78**), 1000-grain weight (0.83**) and ear length (0.72**), ear diameter (0.70**), cob diameter (0.69**), number of active leaf per plant (0.68**) and leaf area index (0.68**) had significant correlation with the grain yield at 1% probability level (Table 5). Also the traits of harvest index (0.52*) and dry matter (0.51*) had significant correlation with the grain yield at 5% probability level (Table 5). According to the result of correlation coefficients, the trait of number of grains per ear had a highly significant positive correlation with the number of grains per row (r=0.95**), number of rows per ear (r=0.68**), ear length (r=0.80**), ear diameter (r=0.77**) and cob diameter (r=0.56*) (Table 5). Ears with greater length and diameter had a higher number of grains per row and number of rows per ear, and had a higher number of grains per ear. Increases in ear length, ear diameter, cob diameter and number of grains per ear were associated with increases in ear yield and biological yield. Previously, a significant positive correlation between grain yield and the number of grains per ear, thousand-grain weight, and ear length was reported by Kafi Ghasemi and Isfahani (2005). In a study of correlations between various agronomic traits by Kurdi *et al*. (2016), a significant positive correlation was observed between Corn grain yield and ear weight, 100-grain weight and number of grains per row. They reported ear weight and the number of grains per row to be the most important factors to determine Corn yield. Khodarahmpour and Hamidi (2012) reported the positive and significant correlation between the number of grains per ear and grain yield of Corn. Based on the results presented in table 5, a significant positive correlation was observed between the 1000-grain weight and number of grains per ear ($p<0.05$, r=0.51*), which was consistent with the results of Keihani and Modhej (2014). In addition, leaf area index had a highly significant positive correlation with the number of active leaves per plant ($p<0.01$, r=0.61*), but it had no significant correlation with the number of leaves up of the ear (Table 5).

Table 5. Correlation between studied traits

Traits	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	-													
2	0.94**	-												
3	0.91**	0.85**	-											
4	0.27^{ns}	0.27^{ns}	0.13^{ns}	-										
5	0.77**	0.84**	0.70**	0.43^{ns}	-									
6	0.71**	0.78**	0.61**	0.68**	0.95**	-								
7	0.39*	0.83**	0.31^{ns}	0.23^{ns}	0.38^{ns}	0.51*	-							
8	0.66**	0.72**	0.63**	0.40^{ns}	0.82**	0.80**	0.32^{ns}	-						
9	0.64**	0.70**	0.56*	0.52*	0.74**	0.77**	0.42^{ns}	0.77**	-					
10	0.54*	0.69**	0.43^{ns}	0.47^{ns}	0.50*	0.56*	0.16^{ns}	0.65**	0.72**	-				
11	0.60**	0.68**	0.49*	0.46^{ns}	0.57*	0.62**	0.30^{ns}	0.46^{ns}	0.42^{ns}	0.56*	-			
12	0.31^{ns}	0.28^{ns}	0.23^{ns}	0.16^{ns}	0.21^{ns}	0.23^{ns}	0.007^{ns}	0.27^{ns}	0.22^{ns}	0.28^{ns}	0.37^{ns}	-		
13	0.64**	0.68**	0.65**	0.30^{ns}	0.43^{ns}	0.36^{ns}	0.28^{ns}	0.35^{ns}	0.25^{ns}	0.33^{ns}	0.61*	0.14^{ns}	-	
14	0.54*	0.52*	0.59*	0.20^{ns}	0.25^{ns}	0.27^{ns}	0.25^{ns}	0.26^{ns}	0.23^{ns}	0.31^{ns}	0.43^{ns}	0.13^{ns}	0.76**	-
15	0.14^{ns}	0.51*	-0.20^{ns}	0.27^{ns}	0.33^{ns}	0.36^{ns}	0.25^{ns}	0.20^{ns}	0.31^{ns}	0.25^{ns}	0.24^{ns}	0.11^{ns}	-0.05^{ns}	-0.20^{ns}

$^{ns,\ *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

1: Ear yield, **2**: Grain yield, **3**: Biological yield, **4**: Number of row per ear, **5**: Number of grain per row, **6**: Number of grain per ear, **7**: 1000-grain weight, **8**: Ear length, **9**: Ear diameter, **10**: Cob diameter, **11**: Number of active leaf per plant, **12**: Number of leaf above of ear, **13**: Leaf area index, **14**: Dry matter, **15**: Harvest index.

Goldani and Nassiri Mahallati (2011) reported leaf area index and number of active leaves per plant had a positive and significant relationship with ear yield, grain yield, biological yield, number of grains per row, number of grains per ear, and ear length, such that treatments with more leaves had a higher leaf area index and ultimately had higher yield. By increasing the number of active leaves and leaf area index, the amount of light received increases and photosynthesis increases, which results in improved growth indices and crop production. The positive and significant correlation between leaf area index and dry matter (r=0.76**) is also consistent with current results (Table 5). Al-Salim *et al*. (2017) reported all studied traits except grain weight were highly significantly correlated with grain yield and about 35% of variation in grain yield could be explained by the level of nitrogen fertilizer, and the traits of Plant height and dry and green fodder weight were the major contributors towards grain yield since these traits explained about (57, 52, 50)% respectively of the variation of grain yield, which might be a good traits for breeders to develop high yielding cultivars in sorghum, followed by stem diameter and grain number then leaf area index. The increase of total dry weight and its direct relation with seed yield show the relations between photosynthesis efficiency of plant and seed yield, therefore varieties which have gained more profit of production factor according to growth conditions and they keep more photosynthesis materials in their sinks, have more efficiency. This status was in conformity with the results of some other researchers (Qulipor *et al*., 2004).

4.3. *Stepwise regression analysis*

In Stepwise regression analysis, grain yield was considered as a dependent variable, while other traits were considered as independent variables (Shiapchan, 2012). In order to investigate the effect of each of the evaluated traits on grain yield as a dependent variable and to eliminate variables that have a negligible effect on the dependent variable, stepwise regression method was used. In this study, the traits number of rows per ear, number of grains per row, thousand-grain weight, number of active leaves per plant, number of leaves above the ear, ear length, ear diameter, cob diameter, leaf area index and dry matter were considered as independent variables and grain yield as dependent variable. Based on the results obtained, the number of seeds per row was the first trait to enter the model and remained in the model due to its significant regression coefficient. The number of seeds per row alone explained 73% of the variation in seed yield. In the second stage, the leaf area index trait and in the third stage, ear diameter were entered into the model. These traits remained in the model due to the significance of their regression coefficients and explained about 82% of the grain yield variations. According to the final coefficient of explanation of the model, a multiple correlation coefficient of 91% was obtained, which indicates a strong multiple correlation between the variables in the model (number of grains per row, leaf area index, and ear diameter) and corn grain yield (Table 6). In a study of different cropping systems by Jahan *et al*. (2009), the variables of leaf area index, canopy temperature, chlorophyll meter number, specific root length, and ear number remained in the model and were identified as the main factors affecting corn grain yield. While in the study of Kurdi *et al*. (2016), ear weight and number of grains per row were identified as the most important factors determining corn yield. Keihani and Modhej (2014) also stated, based on the results of stepwise regression in the study of various morphological traits, yield, and yield components of corn, that the two traits, number of grains per row and grain weight, determine the most variation of grain yield. Using the obtained regression model, the grain yield response can be evaluated based on the increasing or decreasing effect of experimental treatments on the independent variables in the model. According to the model obtained in table 6, Corn grain yield will change by decreasing or increasing the number of grains per row, leaf area index, and ear diameter due to changes in the amount of Cow manure fertilizer and biofertilizer application. The increase of biologic yield and its direct relation with seed yield show the relations between photosynthesis efficiency of plant and seed yield, therefore genotypes which have gained more profit of production factor according to growth conditions and they keep more photosynthesis materials in their sinks, have more efficiency. This status was in conformity with the results of some other researchers (Mardin, 2017; Tian, 2017). Ghalejoughi *et al*. (2013) studied regression and correlation between grain yield and related traits of corn hybrids, and revealed a positive significant correlation between grain yield and the weight of grain, stem diameter and the total number of grains. The equation of regression of grain yield indicates that the effective roles of vegetative organs growth and biological yield in grain yield within this experiment.

Table 6. Stepwise regression analysis of grain yield of single cross 703 Corn

Step	Regression equation	Partial R^2	Model R^2
1	**GY**= −10135 + 544.07 NGpR	0.73	0.73
2	**GY**= −10661 + 462.46 NGpR + 1116.19 LAI	0.07	0.82
3	**GY**= −18327 + 360.33 NGpR + 2274.42 ED + 1181.78 LAI	0.02	0.91

GY: Grain yield, **NGpR**: Number of grain per row, **LAI**: Leaf area index, **ED**: Ear Diameter

5. CONCLUSION

According to the results of stepwise regression analysis, the traits of number of grains per row, leaf area index, and ear diameter were identified as the most effective traits determining grain yield. Corn grain yield changed with a decrease or increase in these traits due to changes in the amount of chemical fertilizer and Cow manure and biofertilizer application.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

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Assess Effect of Growth Regulator (Gibberellin Hormone) on Crop Production under Abiotic Stress

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ABSTRACT

The development and growth of plants are influenced by a variety of factors, including phytohormones with their designated roles. Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimately enhance productivity of the crop. Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of accumulates from source to sink in the field crops. Gibberellic acid (GA) a well-known phytohormone, has numerous physiological effects on plants including seed germination, growth, stem elongation, leaf expansion, photosynthesis, flowering and cell expansion. In recent years, growth hormones have attracted much attention to enhance yield and its related traits of crops. The synthesis and regulation of gibberellins in plants involve complex biosynthetic pathways that integrate both endogenous and environmental signals. Additionally, GA play a role in stress response, helping plants adapt to challenging conditions like salinity and water scarcity. Research continues to explore the biotechnological applications of GA, including their use in floriculture, fruit production, and improving plant resilience under stress conditions, making them essential for sustainable agriculture. It can be concluded that the exogenous application of gibberellic acid improves the morphological characteristics, physiological and metabolic processes, in addition to increasing the yield and quality of plants grown under different environmental conditions.

KEYWORDS: *Metabolic pathways, Organic compounds, Physiological processes, Phytohormone, Yield.*

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1. BACKGROUND

Growth regulators are organic substances besides nutrients, synthesized in plants, causing alteration in their cellular metabolism. Synthesis of some plant hormones is adversely affected by environmental factors, which causes restriction on physiological processes of the plant and ultimately, limits their growth potential (Copur *et al*., 2010). The application of these hormones in low concentration regulates growth, differentiation and development, either by promotion or inhibition (Naeem *et al*., 2004), and allows physiological processes to occur at their normal rate (Gulluoglu, 2004). Major plant growth regulators (PGRs) significantly enhanced fiber yield in cotton (Copur *et al*., 2010), protein content in pea (Bora and Sarma 2006), chemical constituents in *Croton* (Soad *et al*., 2010), fruit size in *Molina* (Vwioko and Longe 2009), seed germination rate in black gram and horse gram (Chauhan *et al*., 2009), floral buds in *Jojoba* (Prat *et al*., 2008) and other growth parameters in different plants. Thus, to overcome the production constraints, chemical manipulation could be done to improve yield and growth parameters. Gibberellins are numerous groups of plant hormones that in addition to auxins are one of the main groups of plant regulators (Bethke and Jones, 1998). Gibberellins, (GA) a group of diterpenoid plant hormones, have an important role in regulation of diverse developmental processes in plants such as seed germination, cell and organ elongation as well as flowering and have wide applications in modern agriculture (Taiz and Zeiger, 2010). Extensive studies have been conducted on the research of GA in which (Khatri *et al*., 2005) reported that GA extremely significant phytohormones for multiple processes in which stem elongation, leaf extension, pollen maturation and flowering induction are well known instances. A very a smaller number of studies have been conducted on the foliar application of GA to understand that how this hormone reacts with such kind of application. But it is clear that a diluted GA is used in very small amounts in the form of foliar application to speed up favorable conditions for the growth and development of plants at a proper time in canola (Shah *et al*., 2008). Gibberellins are produced in plants through the terpenoid route, which requires three enzymes for the production of bioactive GA from GGDP: terpene synthase (TPSs), cytochrome P450 monooxygenase (P450s), and 2-oxoglutarate dependent dehydrogenase (2 ODDs) (Fig.1.). Also, Gibberellins biosynthesis pathway is presented in Fig. 2. Gibberellins (GA) are the most important natural growth regulators and generally involved in the growth and development of different plant. They control seed germination, leaf expansion, stem elongation, and flowering (Kumar *et al*., 2018).

2. OBJECTIVES

Current research was done to evaluation effect of gibberellin acid on physiological process and effective traits on crop production under abnormal situation.

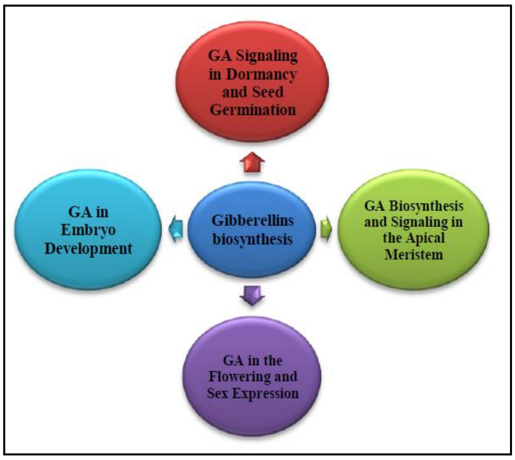

Fig. 1. Gibberellins Biosynthesis, a (Roopa *et al*., 2023).

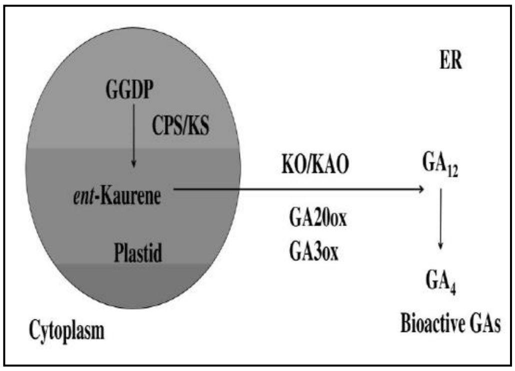

Fig. 2. Gibberellins biosynthesis pathway, b; residing in three different cellular compartments (cytoplasm, endoplasmic reticulum, and plastid). *ent*-CDP: ent-copalyl diphosphate; GGDP: geranylgeranyl diphosphate; KS: *ent*-kaurene synthase; CPS: *ent*-copalyl diphosphate synthase; KAO: *ent*-kaurenoic acid oxidase, KO: *ent*-kaurene oxidase (Azizi *et al*., 2023).

3. EVIDENCE ACQUISITION

Current research was conducted according evaluate results of valid researcher.

4. RESULT AND DISCUSSION

Gibberellins are plant growth hormones which promote cell division and regulate numerous physiological processes including seed germination, stem elongation, leaf, root and reproductive organs expansion (Colebrook *et al*., 2014). Several studies described the inhibition of gibberellin biosynthetic pathway by growth retardants in order control crop production. Growth retardants were employed to reduce the shoot system, thereby lowering the risk of lodging in cereal crops, also used in making ornamental plants more compact with better canopy structure as well as improving the formation of reproductive structures in many other crops (Rademacher, 2016). El-Khourya *et al*. (2019) suggested that it is very useful in commercial horticulture for betterment of plant growth and yields. They further added that effective cell growth and cell elongation were caused by GA effects on stem and root growth. Nizamani *et al*. (2018) further said that sustainable improvement of yield has been a big challenge for plant breeders to secure food in upcoming years in which fertilization is a very critical challenge. George *et al*. (2008) explained that GA might have participated in the formulation of seeds and a greater number of seed is produced in pods when their nourishment normal, but when their nourishment is abnormal more aborted seeds come into being. For the modification of crop plants, both natural as well as artificial phytohormones are used in agriculture so that better and most useful cultivation of plants can be put into practice for unlike processes of development (Wang *et al*., 2020). Similar results for seed index were in conformity with Mir *et al*. (2009). Moreover, many studies have shown that GA3 plays an important role in seed quality. According to Hedden and Sponsel (2015), GA is one of the most vital endogenous hormones in plants, because they bring development in the body of a plant for the regulation of lots of physiological mechanisms. In the plant growth phase, gibberellins trigger cell division and elongation processes, meristem transcription for shoot development, the change of leaf stage from juvenile to adult, flowering and sexual expression (Khan *et al.*, 2020). Gibberellins mitigate the negative impacts of salinity by improving the efficiency of nutrient use and absorption, enzymatic activity and chlorophyll content, resulting in better physiological performance of plants. Research indicates that the exogenous application of GA promoted improvements in several cultivated plants, strengthening their physiological and biochemical attributes. GA not only improves metabolic attributes but also increases plant yield where it increases the number of flowers, fertile seeds, fruit weight and total fruit/plant through foliar spray processes (Kuchi *et al.*, 2017). Abiotic stresses, such as soil salinity or drought, negatively affect plant growth and productivity, causing osmotic, ionic and oxidative stress. GA helps protect plants from salinity damage by maintaining membrane stability, ionic homeostasis and upregulating antioxidant enzymes. Furthermore, it promotes the concentration of compatible solutes, protects photosystems, and induces the expression of stress-related genes. In general, exogenous application of gibberellic acid improves the morphological characteristics, physiological and metabolic processes, in addition to increasing the yield and quality of plants grown under different environmental conditions (Isayenkov and Maathuis, 2019). Water stress is an acute environmental condition that affects several plant processes, leading to reduced productivity in different crops around the world (Seleimann *et al.*, 2021). It can generate physical-biochemical disorders, interrupting the plant's cellular metabolism, and causing damage due to ionic and oxidative stress, generating rapid loss of water through the stomata, leading to cellular dehydration and tissue death. Evidence suggests GA plays an important role in improving plant development in this water stress condition, showing exogenous GA reduces the effects generated (Shah *et al.*, 2023). Gibberellic acid effect on growth, photosynthesis and antioxidant defense of crops mentioned in Fig.3.

5. CONCLUSION

Gibberellins play a key role in many metabolic pathways affecting these characteristics, such as chlorophyll production and degradation, translocation of assimilates, nitrogen metabolism, and nitrogen redistribution. As stated above, these effects can vary greatly among different species, growth stages, application dose and methods, and cultivation techniques. It can be concluded that the exogenous application of gibberellic acid improves the morphological characteristics, physiological and metabolic processes, in addition to increasing the yield and quality of plants grown under different environmental conditions.

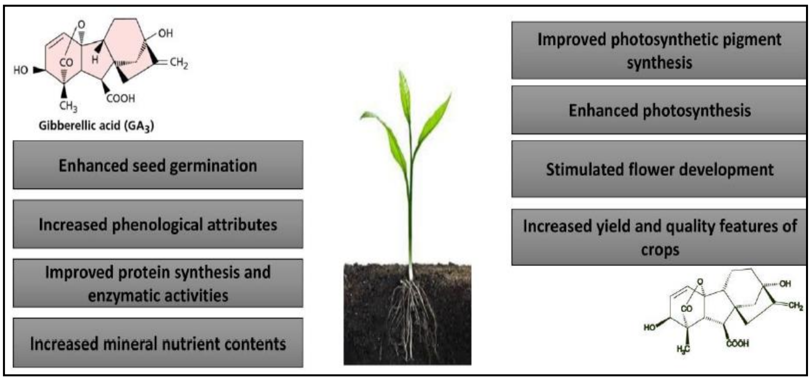

Fig. 3. Effects of gibberellic acid on growth, photosynthesis and antioxidant defense of crops (Azizi *et al*., 2023).

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