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Biofertilizers and Superabsorbent polymers enhance cumin yield under water limitation

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ABSTRACT

Biological fertilizers are regarded as a viable substitute for chemical fertilizers in sustainable agriculture. Conversely, drought stress constitutes a significant impediment to the development and growth of crops. Large quantities of rainwater or irrigation water can be absorbed by superabsorbent polymers, preventing their deep infiltration and resupplying the plant in dry conditions. The present study investigated the impact of superabsorbent polymer and fertile biofertilizers-2, in addition to Nitroxin, on the quantitative and qualitative yield of cumin when subjected to drought stress conditions. To examine the impact of superabsorbent polymers Barvar2 and bio-fertilizers Nitroxin on cumin seed yield and yield components during drought stress, a factorial split experiment was conducted in a randomized complete block design with three replications at the field during the 2014-2015 crop year. This study focused primarily on drought stress, including two levels of stress and non-stress. The experimental setup consisted of two levels of non-consumption and consumption of superabsorbent polymers (Nixin and Barvar2), as well as biofertilizers Nitroxin and Barvar2. The subfactors were represented in the subplots using a 2×2×2 factorial design. Under conditions of drought stress, the integrated application of bio-fertilizers Nitroxin and Barvar2, along with the utilization of a superabsorbent polymer, produced the highest seed weight (3.133 gr), seed yield (46.09 grm^{-2}), and biological yield (106.8 grm^{-2}). The optimal treatment combination, which consists of Barvar2 with superabsorbent polymer and Nitroxin integrated treatments, has been identified as the most effective method for increasing grain yield and yield components under wet conditions. Overall, the outcomes of these experiments indicated that the application of bio-fertilizers and superabsorbent polymers might be viable options for enhancing the productivity of cumin manufacturing. In drought-stressed conditions, such as dry farming, the application of biofertilizers Barvar2 and Nitroxin in conjunction with superabsorbent polymer consumption reduced the effects of drought stress on yield components, grain yield, and biological yield in comparison to the control treatment. When moisture limitation is present, the application of bio-fertilizers containing superabsorbent polymer can significantly enhance the productivity of rainfed cumin cultivation.

Highlights

- Application of superabsorbent is effective to resist drought stress.
- Biological fertilizers such as Nitroxin and fertilizing phosphate can help meet the nutritional needs of the cumin plant and increase its yield.
- Application of superabsorbent along with bio-fertilizers in cumin rainfed cultivation improved yield under drought stress conditions

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1. Introduction

Cumin cientifically known as *Cuminum cyminum*, is classified as a member of the umbel family. Aside from its fruit, it is aromatic and hairless. Its stem is herbaceous in nature and may consist of two or three branches. This plant has a grooved stem, peripheral collapsible tissue, divided leaves or very thin incisions, a green coloration, and thread-like ribs. The flowers are pink or white compound umbels. This small herbaceous plant ranges in height from 10 to 50 centimeters; its long, slender, and white-colored roots (Sastry and Anandraj, 2013). It has been reported that irrigated crops can produce as much as 900 kgha-1 on average, while rainfed cumin crops can yield up to 400 kg/ha. (Kafi, 2006).

In the realm of plant nutrition, it is critical not only that each element be adequately accessible to the plant, but also that equilibrium be maintained and nutritional elements be observed. In recent years, the country's agriculture has suffered severe setbacks due to the excessive application of chemical fertilizers, particularly nitrogen and phosphorus, without regard for the nutrient balance in the plant. These include the depletion of soil essential elements, interference with the solubility and absorption of food components, contamination of underground and river water, and the introduction of toxic elements into the soil via fertilizer (Zahedi and Isma

Biological fertilizers have the potential to enhance the quality and quantity of medicinal plants and are a viable substitute for chemical fertilizers in sustainable agriculture. Cumin yields were enhanced both quantitatively and qualitatively through the application of biological fertilizers (Rezaei Chianeh et al., 2014). The study demonstrated that by minimizing environmental risks and ensuring the stability and health of the agricultural system, combined treatments utilizing bioorganic and chemical fertilizers can effectively address the nutritional requirements of plants to a significant degree. Additionally, these treatments promote the establishment of soil microorganisms for subsequent cycles (Movafaghian et al., 2014). Rai et al. (2018) found that the incorporation of bio-fertilizers in conjunction with minimal quantities of chemical fertilizers improved atmospheric conditions and human health. According to research (Azizi, 2017), the application of superabsorbents in conjunction with phosphate barvar2 biofertilizers and nitrogen has a beneficial impact on a variety of quantitative and qualitative characteristics of the fennel plant. Appropriate application of animal and biological fertilizers, in addition to their combination, can result in an increase in wheat yield and yield components that is comparable in magnitude to the yield increase induced by chemical fertilizers. Additionally, reducing the use of chemical fertilizers contributes to environmental health. Hence, for optimal results and environmental enhancement, it is recommended to utilize animal manures in conjunction with biological fertilizers (Lotfi Jalalabadi et al., 2013).

Utilizing biofertilizer Phosphate Barvar2 is comprised of beneficial phosphate-dissolving bacteria that facilitate soil acidification and the secretion of phosphatase enzymes, which liberate phosphate ions from phosphorous compounds for plant absorption (Tohidinia et al., 2014). Utilizing biofertilizer Auxin can be produced in greater quantities using phosphate Barvar2 than nitrogen fertilizers. Conversely, Nitroxin bio-fertilizer, comprising species of Azotobacter and Azospirillum, facilitates the synthesis of auxin and other hormones that promote plant growth in agriculture (Ansari et al., 2014). According to the findings of the study, supplementing chamomile with either animal manure in its unmodified form or with the mycorrhizal fungus can enhance the quality of dried flowers, increase the production of chamomile's secondary compounds and essential oils, and serve as a foundation for minimizing the application of chemical fertilizers while ensuring consumer food safety, economic viability, and environmental health (Kohan Mo and Agha Alikhani, 2014). Utilizing biofertilizer According to Azizi (2017), the application of phosphate Barvar2 and Nitroxin fertilizers on fennel plants results in favorable outcomes across several plant parameters, including harvest index, total dry matter, seed yield, plant height, essential oil percentage, and yield. Conversely, drought stress constitutes a significant impediment to the growth and development of agricultural plants, and one potential strategy for augmenting agricultural plant production is to enhance water utilization efficiency. The research findings indicate that black cumin, a low-water-use plant, maintains its phenol content even when subjected to drought stress conditions. Overall, the findings of this study suggest that drought has a beneficial impact on the antioxidant capacity of seeds derived from drought-resistant plants (Saeidnejad et al., 2013). Due to the irregular rainfall patterns in various regions of the country over the past few decades, agricultural products have been subjected to severe drought stress. Elevated temperatures and inadequate nutrition frequently exacerbate the consequences of drought stress. Drought resistance is enhanced in plants that have been adequately nourished and supplied with low-use elements (Mortazavi et al., 2015). Large quantities of water from precipitation or irrigation can be absorbed by superabsorbent polymers, which prevent the water from penetrating deeply and recirculate it to the plant in dry conditions. A material with exceptional absorbency can absorb a substantial volume of water and alleviate the strain associated with water scarcity. The water absorption capacity of these materials is approximately 400 times their weight. This enables them to readily supply the plant with stored water during periods of water scarcity, thereby substantially preventing stress and yield reduction (Azizi, 2017). According to research (Sajedinia et al., 2018), it was possible to increase the frequency of irrigation in tomato plants without negatively impacting fruit yield and quality by employing superabsorbent polymers.

In light of the growing interest in utilizing medicinal plants that have low water demands and the country's water constraints, the current study aimed to determine the impact of superabsorbent polymer and Nitroxin and Phosphate Barvar2 under conditions of drought stress on the cumin yield, both quantitatively and qualitatively.

2.Materials and methods

During the 2018 agricultural harvest, a split factorial experiment was conducted at the research farm of the Faculty of Agriculture, Lorestan University, situated in the vicinity of Khorram Abad (33° 26′ N latitude and 45° 27′ E longitude; height 1210 meters above sea level). The experiment followed a basic design of randomized complete blocks with three repetitions. March was chosen as the month to conduct the land preparation operation due to the favorable climatic conditions at that time. The ground was covered with a 1.5 3 square meter surface area subsequent to its leveling. Each plot comprises six rows of crops, spaced at 20 cm between rows and 2 cm between plants. Additionally, the separation between the plots and the blocks was assumed to be 1 meter for the former and 2.5 meters for the latter. Prior to sowing, soil samples were collected and subjected to physical and chemical analysis at various depths (between 0 and 25 centimeters and 25 and 50 centimeters) at the experimental site (Table 1).

Table 1. Physical and chemical characteristics of farm soil

Soil Texture	Sand	Silt	Clay	pH	EC	Mg	Ca	K	p	Organic carbon	Total nitrogen
		(%)			(dS/m)			p.p.m		(%)	
Loomy clay	24	44	32	8.5	0.47	2.9	3.3	410	9.4	0.55	0.98

Drought stress (W) was the primary determinant in this study; in the main plots, it was classified into two levels: no stress (W0) and stress (W1). The experimental secondary factors comprised superabsorbent polymer (S), Nitroxin (N), and Barvar2 (B). These bio-fertilizers were arranged in subplots according to two factorial levels: consumption and non-consumption. Both quantitative and qualitative characteristics were assessed in this study. Two square meters were taken in order to determine yield and yield components, two side rows were eliminated, and a half-meter was added to the beginning and end of each plot as a marginal effect.

To ascertain the quantity of essential oil present in the seeds, a 50-gram sample was extracted from each of the test plots. Following a three-hour grinding period, the essential oil was extracted through water distillation utilizing a Clevenger apparatus. The essential oil yield was determined using a percentage-based method (Zeinali et al., 2008). The yield of the substance in question was calculated by multiplying the seed yield by the essential oil yield (Tasdighi et al., 2015). The statistical software SPSS was utilized to analyze the sampling data. The graphs were created utilizing Excel 2013. The mean of the data was calculated utilizing Duncan's multiple range test.

3. Results and discussion

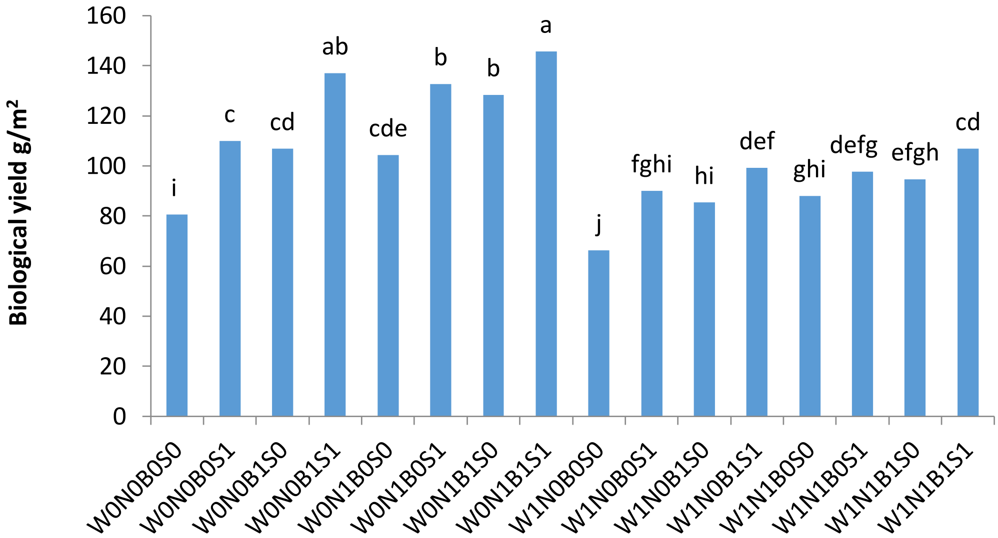
3.1. Biological yield

The findings of the study indicate that there is a statistically significant relationship ($P<0.01$) between the mutual effects of Nitroxin and Barvar2 bio-fertilizers and super absorbent polymers, and drought stress, with respect to biological yield (Table 2). The treatment involving the four mutual effects of Nitroxin, Barvar2, and superabsorbent polymer bio-fertilizers produced the highest biological yield (145.7 grams per square meter) in the absence of drought stress. Conversely, the treatment without Nitroxin, Barvar2, and superabsorbent polymer bio-fertilizers resulted in the lowest biological yield (66.33 grm^{-2}) under drought stress conditions (Figure 1). The findings of this study indicate that the application of superabsorbent polymers, both individually and in combination with biofertilizers, leads to a decrease in biological yield during periods of drought stress, as compared to the control treatment. As a result, taking into account recent droughts and humidity restrictions, the application of superabsorbents under conditions of drought stress enhances the plant's absorption of water and nutrients and improves the soil's physical properties. The findings of the current study align with those of previous research (Karami and Sepehri, 2013). Recent studies have demonstrated that under drought stress conditions, the application of Barvar2 bio-fertilizers in conjunction with 50% chemical fertilizers (urea, triple superphosphate, and potassium sulfate) not only enhances biological yield but also mitigates the adverse effects of dehydration stress while concurrently augmenting biological yield.

3.2. Grain yield

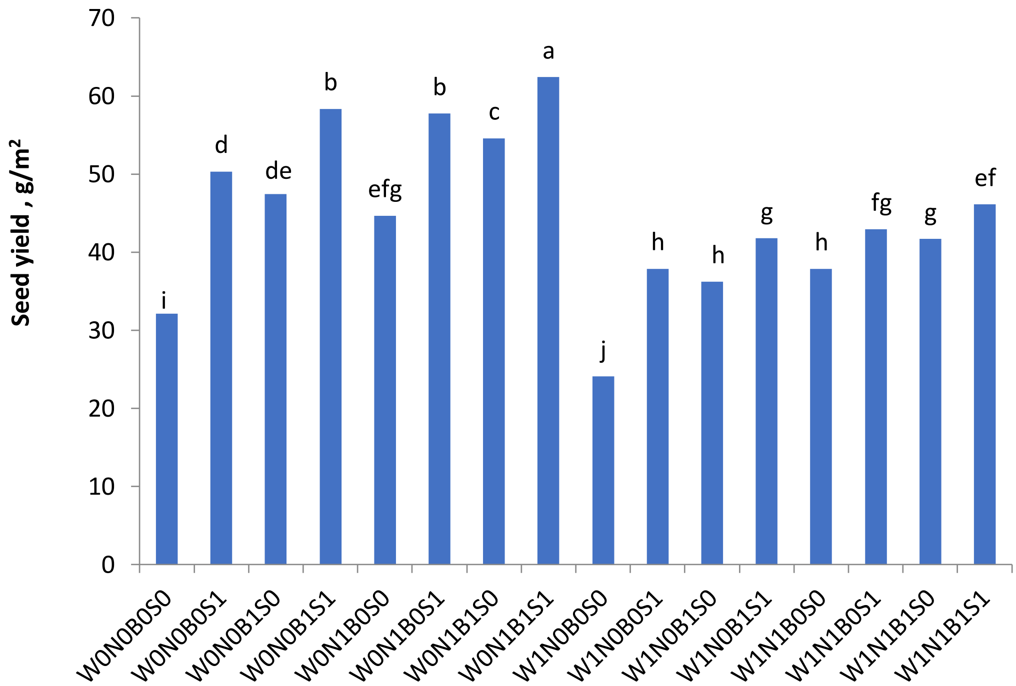
The results obtained from the variance analysis regarding the four interaction effects of drought stress, superabsorbent polymer, Nitroxin biofertilizers, and Barvar2 on grain yield do not exhibit statistical significance (Table 2). After conducting a comparison of the means of the four previously mentioned mutual effects, it was ascertained that the treatments labeled W0N1B1S1 and W1N0B0S1 generated the greatest grain yield (64.37 grm^{-2}) and the least (24.07 grm^{-2}), respectively (see Figure 2). According to the results obtained, it seems that the W1N0B0S1 treatment, which employed superabsorbent to maintain adequate moisture levels for the plant, did not effectively provide the plant with vital nutrients, resulting in a substantial reduction in grain yield. Based on the results obtained, it can be concluded that the decrease in grain yield during drought stress conditions in the W1N0B0S1 treatment can be attributed to the absence of Nitroxin Phosphate Barvar2 biofertilizers. This conclusion is reached despite the application of superabsorbent and the provision of moisture necessary for the plant. The augmented grain yield that is evident subsequent to biological fertilizer inoculation can be ascribed to the heightened nutrient accessibility for the plants. As a result, the increased availability of nutrients promotes the production of photosynthetic materials that are utilized by the seeds. Through the retention and storage of the super absorbent in the soil during periods of water scarcity, the plant was able to obtain the necessary water, resulting in an enhanced yield when compared to when the super absorbent was not employed. Superabsorbent polymers

(SAPs) have been found to be practical and highly effective in arid and semi-arid regions for the storage of water and specific nutrients (Jahan and Nassiri Mahallati, 2020). Zafarian et al. (2011) conducted an investigation to assess the effects of biofertilizers Nitroxin, Azotobacter, and Phosphate Barvar 2 on safflower seed yield and its constituents. The study's results validated that the optimal seed yield was achieved through the combined application of Azotobacter, Nitroxin, and Phosphate Barvar 2. This finding aligns with the results obtained in the current research.



W_0: No drought stress, N: Non- use Nitroxine, B_0 :Non- use Barvar$_2$, S_0 : Non- superabsorbent polymer w_1: drought stress, N_1: Use- Nitroxine, B_1: Use- Barvar$_2$, S_1 :Use- superabsorbent

Figure 1. Comparison of the average quadruple effects of Nitroxin and fertile biofertilizers with superabsorbent under drought stress on the total dry matter of cumin



W_0: No drought stress, N: Non- use Nitroxine, B_0 :Non- use Barvar$_2$, S_0 : Non- superabsorbent polymer w_1: drought stress, N_1: Use- Nitroxine, B_1: Use- Barvar$_2$, S_1 :Use- superabsorbent

Figure 2. Comparison of the mean quadruple interactions of Nitroxin and fertile biofertilizer application with superabsorbent under drought stress conditions on cumin grain yield

Table 2. Analysis of variance of the effect of nitroxin, phosphate-2 and superabsorbent polymers under drought stress conditions on cumin

S. O. V	df	MS									
		Plant height	Number of umbrellas per plant	Number of seeds per umbel per plant	Thousand weights of seeds	Number of seeds per plant	Total dry matter	Seed yield	Harvest index	Percentage of essential oils	Essential oil yield
R	2	22.490^{ns}	14.432^{ns}	4.163^{ns}	1.651^{ns}	504.596^{ns}	962.803*	513.004*	84.958^{ns}	5.240*	2.755*
A	1	43.225*	238.655**	33.117*	2.480*	5044.167**	8855.790**	1701.701**	1.619^{ns}	2.189*	0.239^{ns}
ERORR$_1$	2	1.352	0.935	1.926	0.155	457.933	32.476	18.617	5.529	0.222	0.031
B	1	40.498**	78.976**	10.954**	1.783**	18524.843**	2836.995**	857.350**	55.320**	1.744**	1.721**
AB	1	0.910*	13.157**	^{ns}0.199	0.083**	2424.368**	172.445**	22.963*	4.184^{ns}	0.194**	0.005^{ns}
C	1	1.837**	156.855**	21.561**	3.198**	36378.692**	3383.857**	912.286**	35.82**	0.263**	1.095**
AC	1	4.266**	14.008**	0.189^{ns}	0.129**	3321.178**	402.405**	105.851**	0.287^{ns}	^{ns}0.001	0.074^{ns}
BC	1	5.103**	15.019**	2.965**	0.628**	2118.559**	154.012**	90.256**	29.873**	0.220**	0.279**
ABC	1	0.531^{ns}	0.160^{ns}	0.160^{ns}	0.007^{ns}	23.144^{ns}	3.010^{ns}	2.746^{ns}	0.025^{ns}	0.012^{ns}	0.003^{ns}
D	1	18.563**	61.812^{ns}	11.535**	0.788**	15914.447**	5080.390**	1047.201**	7.979*	0.263**	1.041**
AD	1	0.115^{ns}	0.001^{ns}	0.001^{ns}	0.004^{ns}	1.006^{ns}	397.786**	54.060**	4.054^{ns}	0.023^{ns}	0.005^{ns}
BD	1	9.639**	8.526**	2.240**	0.413**	1567.168**	165.689**	16.333^{ns}	0.257^{ns}	0.004^{ns}	0.001^{ns}
ABD	1	0.239^{ns}	1.790**	0.102^{ns}	0.039**	288.463^{ns}	0.559^{ns}	20.306^{ns}	17.388**	0.000^{ns}	0.021^{ns}
CD	1	6.938**	8.526**	2.258**	0.245**	1837.316**	58.919^{ns}	31.493*	13.579**	0.146**	0.093*
ACD	1	1.304*	0.127^{ns}	1.303^{ns}	0.002^{ns}	0.002^{ns}	1.621^{ns}	4.404^{ns}	9.461**	0.064**	0.015^{ns}
BCD	1	2.063**	13.515**	3.791**	0.243**	3903.675**	0.069^{ns}	6.366^{ns}	10.935**	0.015^{ns}	0.000^{ns}
ABCD	1	0.105^{ns}	7.076**	0.173**	0.010^{ns}	1612.749**	107.461**	16.497^{ns}	0.349^{ns}	0.006^{ns}	0.001^{ns}
ERORR$_2$		0.195	0.286	0.090	0.004	88.767	16.853	4.905	1.433	0.007	0.015
	C. V	2.65	3.18	3.21	2.02	5.69	3.93	4.98	2.84	3.10	11.14

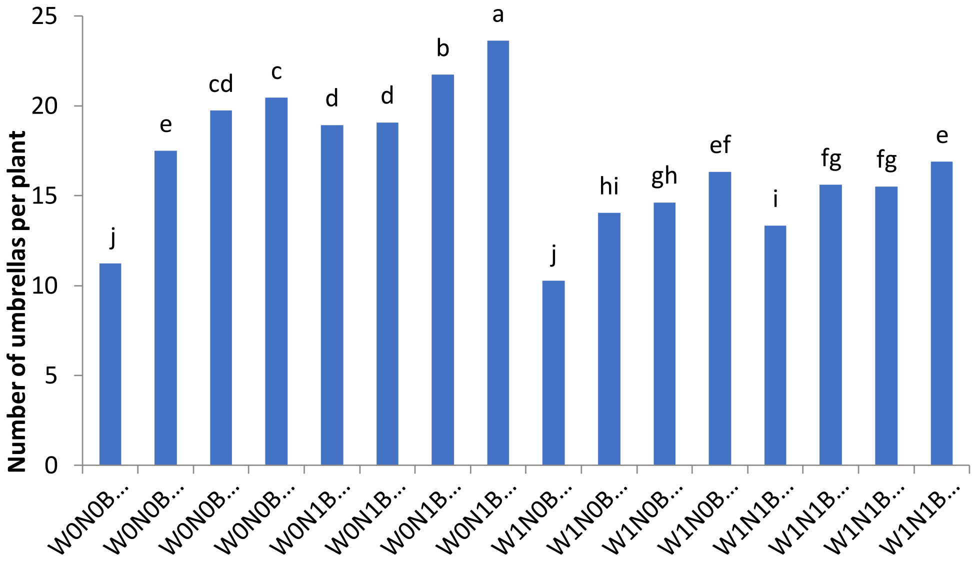
Significant at 1% level, * significant at 5% level and ns: Non-significant, R: repeat, A: drought stress, B: nitroxin, C: fertile phosphate, D: superabsorbent

3.3. Number of umbels per plant

The findings indicated that the interplay between bio-fertilizers, superabsorbent polymers, and drought stress significantly ($P<0.01$) impacted the umbel count of cumin plants (Table 2). Based on the average comparison results, the treatment containing super absorbent polymer, Nitroxin, Barvar2, and Barvar2 produced the greatest number of umbels per plant (23.63 umbels) in the absence of drought stress. Conversely, the treatment lacking biological fertilizers and super polymer yielded the fewest umbels (10.27). The adsorbent was acquired in conditions of drought stress (see Figure 3). Under conditions of drought stress, the number of umbels produced per plant is diminished among the treatments. In contrast to the control, the combined application of Barvar2 bio-fertilizers and Nitroxin with super absorbent resulted in the greatest number of umbels per plant. The superabsorbent polymer appears to mitigate the impacts of drought stress through its ability to retain moisture, create an optimal environment for bacterial activity in bio-fertilizers, and enhance the solubility of soil nutrients. Azizi (2017) demonstrated that the application of superabsorbents in conjunction with phosphate barvar2 biofertilizers and nitrogen had a beneficial impact on a variety of quantitative and qualitative characteristics of the fennel plant. These findings corroborate the results obtained in the present study.

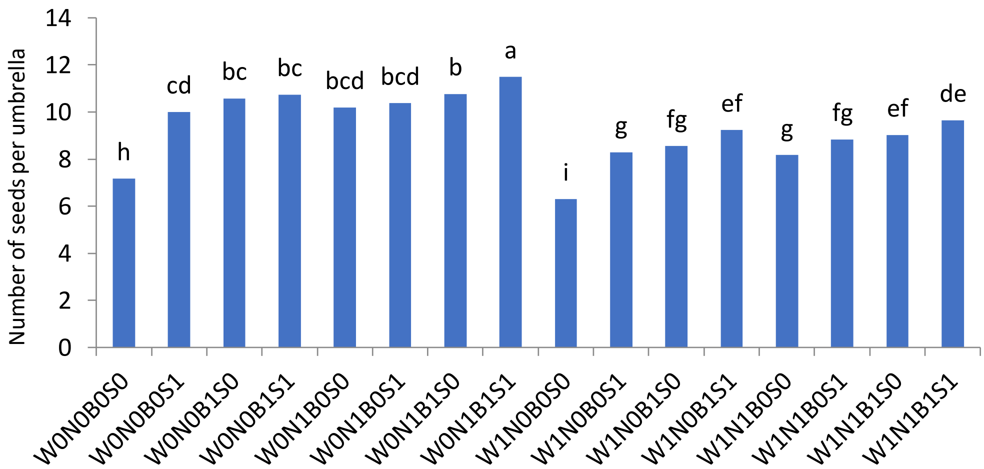
3.4. The number of seeds in the umbel

The findings of the investigation indicate that the interplay between Nitroxin biofertilizers, Phosphate Barvar2, superabsorbent polymer, and drought stress significantly impacts the quantity of seeds in the umbel (Table 2). In the absence of drought stress, the highest number of seeds in the umbel, as determined by the average comparison results, is 11.49, which is attributable to the mutual effects of superabsorbent polymer, Nitroxin biofertilizer, and Phosphate Barvar2. The umbel contains a minimum of 6.30 seeds, which can be attributed to the reciprocal effects of forgoing the application of bio-fertilizers and superabsorbent polymer under conditions of drought stress (see Figure 4). Drought stress consistently influences the number of seeds in the umbel, an attribute that is also genetically determined. Reducing the quantity of seeds contained within the umbrella will invariably result in a decline in the seed yield. The findings indicated that the application of superabsorbent polymer-containing biofertilizers Nitroxin and Barvar2 in drought-stressed treatments increased seed production and mitigated the negative effects of drought stress in comparison to the other treatments. This can be construed to mean that the plant maximizes umbel production under irrigation conditions by capitalizing on all available environmental factors, including adequate development of vegetative organs and suitable synthesis of photosynthetic materials. Sufficient seeds are acquired at this level as a consequence. Due to the reduction in production and storage of photosynthetic materials and the occurrence of drought stress, the quantity of umbels decreased, and consequently, so did the number of seeds contained within each umbel. Rahimi (2012) reported that an increase in drought stress led to a reduction in both the number of umbels per plant and the number of seeds per umbel of cumin. These findings align with the results obtained in the present research.



W_0: No drought stress, N: Non- use Nitroxine, B_0 :Non- use Barvar$_2$, S_0 : Non- superabsorbent polymer w_1: drought stress, N_1: Use- Nitroxine, B_1: Use- Barvar$_2$, S_1 :Use- superabsorbent

Figure 3. Comparison of the mean of the four interactions of Nitroxin and fertile bio-fertilizers with superabsorbent under drought stress conditions on the number of umbrellas per cumin plant

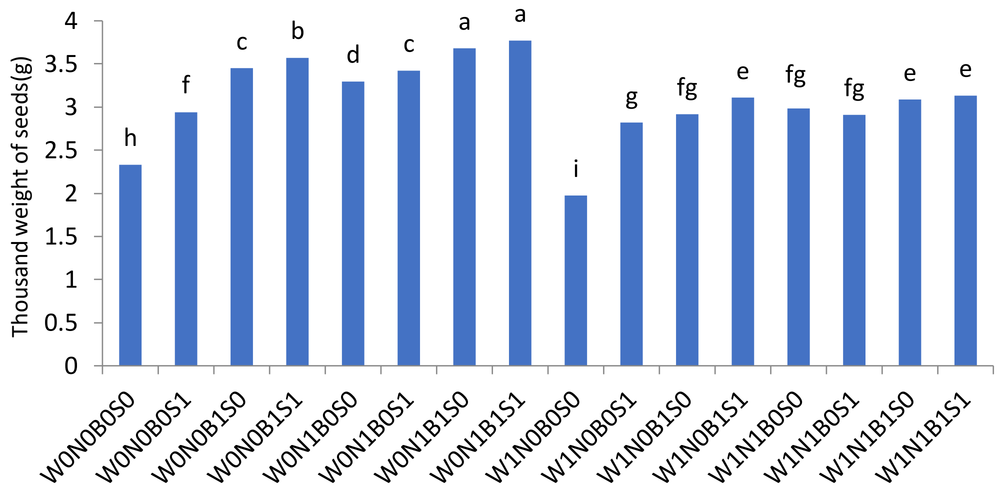


W_0: No drought stress, N: Non- use Nitroxine, B_0 :Non- use Barvar$_2$, S_0 : Non- superabsorbent polymer w_1: drought stress, N_1: Use- Nitroxine, B_1: Use- Barvar$_2$, S_1 :Use- superabsorbent

Figure 4. Comparison of the mean of the four interactions of nitroxin and fertile biofertilizers with the use of superabsorbent under drought stress conditions on the number of seeds per cumin

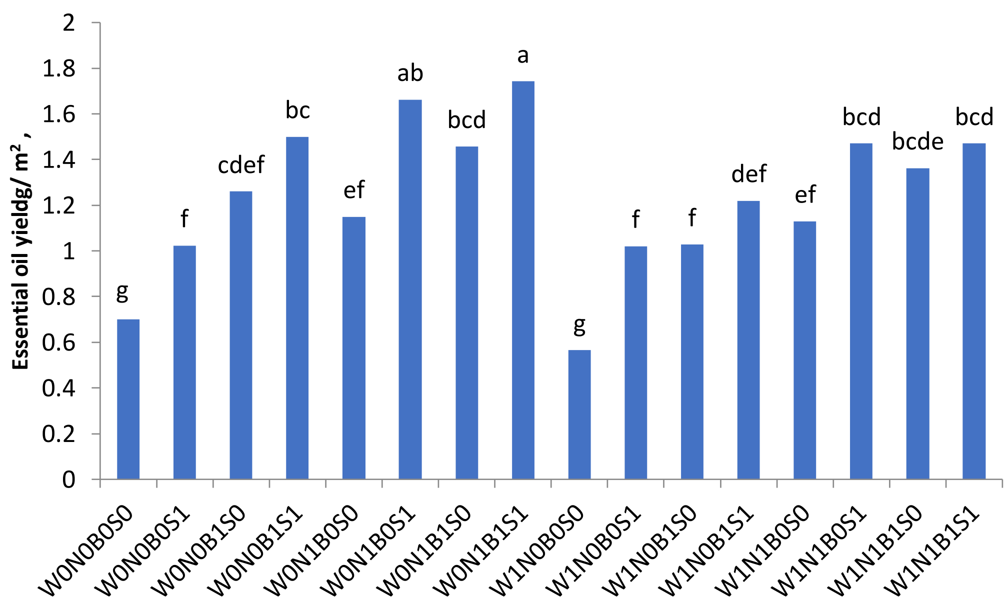
3.5. Weight of one thousand seeds

The findings indicate that the weight of one thousand seeds is not significantly impacted by the four interaction effects between superabsorbent polymers and Nitroxin and Phosphate Barvar2 bio-fertilizers under stress conditions (Table 2). To examine the impact of experimental treatments on the weight of one thousand seeds, the mean values of four interaction effects were compared. The findings indicated that the treatment involving the use of nitroxin, phosphate barvar2, and super absorbent polymer under drought stress conditions produced the heaviest weight of one thousand seeds (3.773 grams). Conversely, the treatment involving the absence of biological fertilizers and super absorbent polymer under drought stress conditions resulted in the lightest weight of one thousand seeds (1.973 grams) (Figure 5). Drought stress significantly impacted the weight of one thousand cumin seeds, resulting in a reduction in seed weight. In comparison to the other treatments subjected to drought stress, the combined application of Barvar2 with superabsorbent polymer and Nitroxin bio-fertilizers yielded a greater thousand seed weight. Drought stress appears to impede the transpiration of essential water and the transportation of nutrients to the seeds. Conversely, by diminishing the transfer of photosynthetic materials to the seeds, one thousand seeds undergo shriveling and their weight decreases. Utilizing animal manure and growth-stimulating bacteria increased the number of umbels per plant, the weight of one thousand seeds, and the seed yield of the medicinal coriander plant, according to the findings of Darzi et al. (2006). According to their statement, the co-administration of Azospirillium bacteria and animal manure likely facilitated nutrient uptake in the soil, thereby contributing to the weight augmentation of one thousand seeds.



W_0: No drought stress, N: Non- use Nitroxine, B_0 :Non- use Barvar$_2$, S_0 : Non- superabsorbent polymer w_1: drought stress, N_1: Use- Nitroxine, B_1: Use- Barvar$_2$, S_1 :Use- superabsorbent

Figure 5. Comparison of the mean of the four interactions of nitroxin and fertile biofertilizers with superabsorbent under drought stress conditions on 1000-seed weight of cumin



W_0: No drought stress, N: Non- use Nitroxine, B_0 :Non- use Barvar$_2$, S_0 : Non- superabsorbent polymer w_1: drought stress, N_1: Use- Nitroxine, B_1: Use- Barvar$_2$, S_1 :Use- superabsorbent

Figure 6. Comparison of the mean of the four interactions of nitroxin and fertile biofertilizers with superabsorbent under drought stress conditions on cumin essential oil yield

3.6. Essential oil yield

The findings indicate that the four interaction effects between superabsorbent polymers and Nitroxin and Phosphate Barvar2 bio-fertilizers do not exert a statistically significant impact on the yield of essential oil when subjected to stress conditions (Table 2). The highest essential oil yield (1.743% per square meter) was observed in the treatment of Nitroxin and Barvar2 biofertilizers utilizing superabsorbent polymer under drought-free conditions, as determined by a comparison of the averages. The minimum value, which corresponds to 0.566 grams per square meter, is associated with the treatment of the quadruple mutual effects resulting from the absence of superabsorbent polymers and Nitroxin and Barvar2 biofertilizers under drought stress conditions (Figure 6). It appears that biofertilizer treatments have significantly created more favorable conditions for enhancing beneficial microbial activities in the soil, increased biological yield via the roots' favourable absorption of macro and micro mineral elements, and increased the yield of essential oils in comparison to the control treatment. Biofertilizers increase the yield of essential oil from fennel, according to some researchers (Mona et al., 2008).

4. Conclusion

The findings of the study indicate that the implementation of a superabsorbent polymer, phosphate Barvar2, and Nitroxin biofertilizers combined under drought stress conditions, particularly in the rainfed cultivation of cumin plants, improved nutritional conditions (by supplying moisture to the plant and increasing the solubility of nutrients). This combination effectively mitigates the detrimental impacts of drought stress conditions and yields favorable outcomes for both seeds and biological production. Hence, in accordance with the advancement of sustainable agriculture and the well-being of agricultural commodities, while also mitigating the detrimental environmental impacts of chemical fertilizers and optimizing water usage, it is advisable to encourage and cultivate cumin plant in conjunction with the utilization of biofertilizers and superabsorbent materials, given the recent drought scarcity and the minimal moisture requirements of cumin plants.

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