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Impact of Biofertilization Treatments on The Growth of Different Cultivars of Flax (Linum usitatissimum L.)

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ABSTRACT
During the winter season of 2022-2023, a field experiment was carried out in the Al-Mahawil region of Babylon province to determine the effect of biological Fertilization on the development of several flax kinds. The experiment incorporated two variables: first, three distinct varieties of flax (Giza 8, Indian, Polony), and second, four levels of biological Fertilization. (azotobacter bacteria, mycorrhizal fungi, azotobacter + mycorrhizal fungi, without addition). The outcomes were as follows: The field was organized in accordance with a wholly randomized block design with three replications. The treatment containing Azotobacter and mycorrhizal organisms exhibited notable improvements in the following parameters: plant height (in centimeters), number of primary branches (plant branch-1), number of capsules (plant capsule^{-1}), and number of seeds in the capsule (seed capsule^{-1}). The maximum values were obtained for the weight of 1000 seeds (g), the percentage of oil in the seeds (%), and the number of plant containers (66.30, 88.32 cm, 4.91 branches, 8.74 ́H³, 10.78 g, 44.51%). The Giza 8 cultivar exhibited a marked advantage over the remaining varieties across all the characteristics that were examined. The cultivar known as Giza 8 was shown to have a considerable advantage over the other kinds in all of the characteristics that were investigated. The interaction treatment (Azotobacter bacteria + mycorrhizal fungi + Giza 8 cultivar) performed significantly better in terms of plant height (cm), number of main branches (plant branch^{-1}), number of capsules (plant capsule^{-1}), and number of seeds in the capsule (Seed capsule^{-1}). The best results were achieved by calculating the weight of 1000 seeds (g) and the percentage of oil in the seeds (%). The values obtained were as follows: 91.00 cm, 5.19 branches, 68.44 plant capsules -1, 8.92 plant seeds -1, 11.29 g, and 44.85%.

KEYWORDS: Biofertilization, growth, Flax, Linum usitatissimum L.

INTRODUCTION

Flax (Linum usitatissimum L.), a member of the Linaceae family, is among the earliest commodities that humans have cultivated for the production of fiber, oil, or both (Reddy et al., 2013). Since flax (Linum usitatissimum L.) may be farmed for either oil fiber or both, it is a crop with several uses. The dry oil, which

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is used to make varnish, wood polish, and colors, has a proportion of oil in the seeds that varies from 30 to 45. According to Singh et al. (2016), it is also used in the soap and printing ink industries. Canada is thought to be the world's top producer of linen, followed by China, India, the United States, Ethiopia, and Egypt (FAO STATA, 2019).

Regarding Iraq, there are hardly any cultivated flax areas. This could be for a number of reasons, the primary ones being the emphasis on the production and cultivation of strategic winter crops, the need for more interest from experts in the crop's productivity, and the absence of specialized factories to extract flax's oil and fiber. Its seeds have an oil content that varies from around 30 to 45% (Nadaf, 2017) (.One of the latest methods to lessen the reliance on chemical fertilizers is to include microbial inoculants, which are additions derived from biological sources, into the soil. These inoculants take the form of bacteria. In soil treated with them, they establish colonies in the vicinity of the roots and promote the growth of plants by means of Through the provision of essential nutrients, including those transformed from non-absorbable to absorbable forms by means of vital processes, the provision of substances that promote and stimulate plant growth, including growth regulators and hormones, and the fixation of atmospheric nitrogen via symbiotic relationships, thereby aiding in the reduction of chemical fertiliser usage. Azotobacter and basil bacteria may fix nitrogen and phosphate and release stimulants that promote root development, including gibberellins, cytokinins, and auxins (Al-Rawi, 2010; Saleh, 2015). Considering those above, the objective of the studies is to examine how various kinds of flax are affected by biofertilization.

MATERIALS AND METHODS

A field experiment was conducted in the Al-Mahawil region of Babylon province from 2022 to 2023 in the winter season in order to assess the effects of biofertilization on the growth and development of various cultivars of flax plants. The experiment contained two factors: the first, three flax cultivars (Giza 8, Indian, and Polony), and the second, bio fertilization at four levels (without addition, azotobacter bacteria, mycorrhizal fungus, and azotobacter + mycorrhizae). Biofertilizers were obtained from the Department of Agricultural Research, Ministry of Science and Technology. The addition was (10 g) per pit, the strength of the spores for the fungus was (40 spores.g-^{1}), and the strength of the inoculum for the bacteria was (2.8*10 per g), where the inoculum was loaded onto the peat moss agricultural medium (35 grams per 1 g of soil), taking into account that it was close to the seed, inside the neighborhood. The experimental land was plowed in two perpendicular plows using a rotary plow, and then smoothing and leveling operations were conducted on it for the purpose of preparing a suitable bed for the seeds. An entirely randomized block design (RCBD) was utilized to organize the field, consisting of three replicates, each comprising 12 experimental units. Including the following, the experimental unit measured 6 m2 (3 m x 2 m) in area: Every experimental unit consisted of ten lines, with a 20 cm separation between each line. The treatments were physically separated from one another by shoulders that were 1 m wide. The soil was fertilized by adding half the fertilizer recommendation of 90 kg ha-1 nitrogen fertilizer in the form of urea fertilizer (46%) in two batches at planting and the second one a month after planting. (Hassan and Shaker, 2013). Before planting, 45 kg ha^{-1} of phosphate fertilizer (46% P2O5) was sprinkled, and 60 kg ha^{-1} of potassium fertilizer K2SO4 in the form of potassium sulfate was applied in a single batch (Grant et al., 2010). Seeds were planted on November 15 in the first site for the year 2022, and crop maintenance operations were carried out, including irrigation, hoeing, and weeding, as needed. After the plants showed symptoms of maturity, such as the complete loss of leaves, overall yellowing of the plant, and dried capsules, they were collected.

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Studied traits:

Plant height (cm): The mean plant height was determined by measuring the distance from the soil surface to the highest point of 10 randomly selected plants located along the central rows of each experimental plot.

The number of the main branches in the plant (plant branch^{-1}): The mean number of primary branches observed in each experimental unit's ten plants at the time of harvest was computed. Ten plants were randomly chosen from the middle lines.

The number of capsules per plant (plant^{-1} capsule): Utilising the midlines of each experimental unit, the average number of capsules on ten plants selected at random was determined.

The number of seeds in the capsule (seed capsule^{-1}): The approach included dividing the number of seeds in plant capsules by the number of capsules in the ten randomly chosen plants from each experimental unit's middle lines.

The weight of 1000 seeds (g): Following the mixing of the plant seeds collected from every experimental unit, 1000 seeds were selected at random, weighed, and their average was determined.

Percentage of oil in seeds (%): Estimated using the Soxhlet device (A.O.C.S, 1990) and according to the following equation:

Percentage of oil in seeds (%) = (weight of oil extracted from sample seeds/weight of dry sample) x 100

RESULTS AND DISCUSSION

Plant height(cm)

The findings of Table (1) revealed that biofertilization had a considerable impact on plant height. It performed much better on the treatment (Azotobacter bacteria + mycorrhizal fungus). It achieved the greatest plant height of (88.32 cm), whereas the treatment without addition resulted in the lowest plant height of 69.45 cm. Regarding the cultivars, the findings indicated that the Polony cultivar produced the lowest plant height of (75.58 cm). In comparison, the Giza 8 cultivar substantially excelled and produced the maximum plant height of (78.71 cm). As for the interaction between the cultivars and biofertilization, the interaction treatment (Azotobacter + Mycorrhiza + Giza 8) excelled and recorded the highest height of (91.00 cm). In contrast, the control treatment (without addition + Polony cultivar) provided the highest height and recorded (62.11 cm).

Table (1) The impact of cultivars, biofertilization, and their interactions on plant height (cm) of flax plants

average Biofertilization	cultivars			Biofertilization
	Polony	Indian	Giza 8	
69.46	62.11	74.92	71.36	Without adding
71.55	78.91	68.01	67.72	Azotobacter bacteria
78.56	77.09	73.83	84.76	Mycorrhizal fungi
88.32	84.19	89.78	91.00	Azotobacter * Mycorrhizae
	75.58	76.635	78.71	cultivars average
interaction7.58=		cultivars3.25=	Biofertilization5.26=	LSD 0.05

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The number of main branches (plant branch-1)

According to the findings of Table (2), biofertilization had a considerable influence on the number of major branches. The treatment (Azotobacter bacteria + mycorrhizal fungus) performed much better, resulting in the maximum number of major branches (4.91), whereas the treatment without addition produced the lowest average number of main branches (3.30). In terms of cultivars, the findings indicated that the Giza 8 cultivar outperformed and produced the main branches, representing (4.23) branches, while the Polony cultivar produced the fewest, totaling (3.93) branches.

As for the interaction between the cultivars and biofertilization, the interaction treatment (Azotobacter + Mycorrhizal + Giza 8) excelled and recorded the highest number of main branches, reaching (5.19) branches. In contrast, the combined interaction treatment (without addition + the Polony cultivar) gave the highest number and recorded the lowest number of main branches, amounting to (3.11) branches.

Table (2) The impact of cultivars, biofertilization, and their interactions on the number of main branches (branch plant-1) of the flax plant

average Biofertilization	cultivars			Biofertilization
	Polony	Indian	Giza 8	
3.30	3.11	3.46	3.33	Without adding
3.72	3.82	3.37	3.98	Azotobacter bacteria
4.26	4.03	4.33	4.43	Mycorrhizal fungi
4.91	4.75	4.8	5.19	Azotobacter * Mycorrhizae
	3.93	3.99	4.23	cultivars average
interaction=0.87		cultivars=0.36	Biofertilization= 0.50	LSD 0.05

The number of capsules (plant capsule ⁻¹)

As it is revealed in Table (3), the amount of capsules was mainly influenced by biofertilization. The combination of Azotobacter bacteria and mycorrhizal fungi produced the most effective treatment, with 66.30 plant capsules observed, compared to the control group, which received just 39.14 plant capsules $^{-1}$ on average.

The results of Table (3) showed that biofertilization had a considerable impact on the number of capsules. The treatment (Azotobacter bacteria + mycorrhizal fungi) significantly excelled and recorded the highest number of capsules, amounting to (66.30) plant capsules $^{-1}$. In contrast, the treatment without addition gave the lowest average number of capsules, (39.14) plant capsules. $^{-1}$ As for the cultivars, the results showed that the Giza 8 cultivar significantly excelled and gave the highest number of capsules, amounting to (53.79) plant capsules $^{-1}$. In contrast, the Polony cultivar gave the lowest number of capsules, amounting to (49.76) plant capsules $^{-1}$. As for the interaction between the cultivars and biofertilization, the interaction treatment (Azotobacter + Mycorrhiza + Giza 8) excelled and recorded the highest number of capsules, amounting to (68.44) plant capsules $^{-1}$. In contrast, the combination interaction treatment (without addition + Polony cultivar) gave the highest number of capsules, amounting to (36.72) capsules. Plant $^{-1}$

Table (3) The impact of cultivars, biofertilization, and their interactions on the number of capsules (plant capsule $^{-1}$) of flax plants

average Biofertilization	cultivars			Biofertilization
	Polony	Indian	Giza 8	
39.14	36.72	40.89	39.82	Without adding
46.77	43.21	45.72	51.39	Azotobacter bacteria
56.36	53.2	60.37	55.51	Mycorrhizal fungi
66.30	65.89	64.58	68.44	Azotobacter * Mycorrhizae
	49.76	52.89	53.79	cultivars average
interaction9.87=		cultivars4.58=	Biofertilization6.6=	LSD 0.05

The number of seeds (seed capsule-1)

The findings of Table (4) demonstrated that biofertilization had a considerable influence on seed production. The treatment (Azotobacter bacteria + mycorrhizal fungus) resulted in the maximum number of seeds, (8.74) plant seeds $^{-1}$, whereas the treatment without addition yielded the lowest average of (5.42) plant seeds. Regarding the cultivars, the findings indicated that the Giza 8 cultivar was the most successful and produced the greatest number of seeds, (7.32) plant seeds $^{-1}$; in contrast, the Polony cultivar produced the fewest seeds, (6.87) plant seeds $^{-1}$.

As for the interaction between the cultivars and biofertilization, the interaction treatment (Azotobacter + Mycorrhiza + Giza 8) excelled and recorded the highest number of seeds, amounting to (8.92) plant seeds $^{-1}$. In contrast, the control treatment (without addition + the cultivar Polony) gave the highest number of seeds, amounting to (5.17) seeds. Plant $^{-1}$

Table (4) The impact of cultivars, biofertilization, and their interactions on the number of seeds (seed capsule-1) of flax plants

average Biofertilization	cultivars			Biofertilization
	Polony	Indian	Giza 8	
5.42	5.17	5.85	5.24	Without adding
6.64	6.08	6.61	7.24	Azotobacter bacteria
7.77	7.54	7.9	7.87	Mycorrhizal fungi
8.74	8.7	8.59	8.92	Azotobacter * Mycorrhizae
	6.87	7.24	7.32	cultivars average
interaction2.03=		cultivars0.87=	Biofertilization1.25=	LSD 0.05

The weight of 1000 seeds (g)

As with the findings of Table (5), biofertilization had a substantial influence on the weight of 1,000 seeds. The treatment consisting of Azotobacter bacteria and mycorrhizal fungus exhibited superior performance, resulting in a maximum weight of 1000 seeds (10.78 g). In contrast, the treatment without any additional components gave the lowest weight of 1000 seeds (5.75 g). In terms of cultivars, the findings revealed that the Giza 8 cultivar outperformed the others, with the maximum weight of 1000 seeds (8.56 g),

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while the Polony cultivar yielded the lowest weight (7.83 g). In terms of cultivar-biofertilization interaction, the interaction treatment (Azotobacter + Mycorrhiza + Giza 8) outperformed and recorded the highest weight of 1000 seeds (11.29 g), while the combination interaction treatment (without addition + cultivar Polony) produced the best results and recorded the lowest weight of 1000 seeds, (5.29 g).

Table (5) The impact of cultivars, biofertilization and their interactions on the weight of 1000 seeds (g) of flax plants

average Biofertilization	cultivars			Biofertilization
	Polony	Indian	Giza 8	
5.75	5.29	6.07	5.89	Without adding
7.19	6.63	6.88	8.06	Azotobacter bacteria
8.80	8.59	8.83	8.98	Mycorrhizal fungi
10.78	10.8	10.26	11.29	Azotobacter * Mycorrhizae
	7.83	8.01	8.56	cultivars average
interaction1.02=		cultivars0.50=	Biofertilization0.89=	LSD 0.05

Oil percentage (%)

The findings of Table (6) revealed that biofertilization has a considerable impact on oil percentage. The treatment (Azotobacter + Mycorrhizal fungus) performed much better, with the greatest oil percentage of 44.51%, whereas the treatment without addition produced the lowest oil percentage of 36.77%. In terms of cultivars, the findings revealed that the Giza 8 cultivar outperformed and produced the highest oil percentage (41.74%), while the Polony cultivar produced the lowest oil percentage (40.51%).

As for the interaction between the cultivars and biofertilization, the interaction treatment (Azotobacter + Mycorrhiza + Giza 8) excelled and recorded the highest oil percentage, amounting to (44.85%). In contrast, the combination interaction treatment (without addition + Polony cultivar) gave and recorded the lowest oil percentage, amounting to (36.27%).

Table (6) The impact of cultivars, biofertilization and their interactions on Oil percentage (%)of flax plants

average Biofertilization	cultivars			Biofertilization
	Polony	Indian	Giza 8	
36.77	36.27	36.62	37.41	Without adding
40.06	39.22	39.43	41.53	Azotobacter bacteria
42.73	42.37	42.64	43.17	Mycorrhizal fungi
44.51	44.17	44.52	44.85	Azotobacter * Mycorrhizae
	40.51	40.80	41.74	cultivars average
interaction6.78=		cultivars2.65=	Biofertilization4.69=	LSD 0.05

Cultivars in traits studied are often due to the genetic ability of the cultivar to express itself in its growing environment, such as differences in weather conditions. This is shown in the results of Tables (1-5). The moral superiority of the Giza 8 genotype over the other genotypes may be due to this noticeable discrepancy. To the nature of the genetic potential of the cultivar (Jhala & Hall, 2010). These findings agree with what was obtained by (Al-Sudani, 2018), (Al-Samarrai, 2019), (Al-Azzawi, 2020), and (Al-Hiti, 2021), who indicated in their study the difference in flax genotypes in vegetative growth traits. The findings in Tables 1-5 also demonstrated that adding biofertilizers had a substantial influence on vegetative attributes, with the mixture treatment (Azotobacter + Mycorrhizae) outperforming all other treatments and yielding the highest values for the variables tested. This may be attributed to the efficiency of biofertilization in increasing nutrient readiness.

Moreover, increasing their concentration in the soil, in addition to the role of mycorrhizae in improving metabolic processes and absorbing water and nutrients such as nitrogen, phosphorus, potassium, calcium, sulfur and iron from the soil and transporting them to the plant through the roots. The bio fertilization also can secrete growth-stimulating substances such as auxins, cytokines, and gibberellins, which contribute to increasing cell division, expansion, and elongation of plant tissues (Utobo et al., 2011) (Abu Al-Saud et al., 2017) .Consequently, the height of the plant increases, Table (5). The increase in the number of main branches may be due to the role of azotobacter bacteria, which work to secrete or stimulate signals in a process called Rhizocoenosis. These signals cross the plant cell wall and are organized in the cellular membranes, which in turn are sensitive to any change, which stimulates Surface absorption of nutrients by cortex cells (Klopper et al., 1991); these results are consistent with the findings of (Elayan et al., 2015), (Gupta et al., 2017), who indicated in their study that biofertilization (bacterial and fungal) had a significant effect on the vegetative growth traits of flax.

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