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The Effect of Chemical and Biofertilizer on Grain Yield of Two Dill (*Anethum graveolens* L.) Cultivars [†]

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Abstract: To study the effect of the combined fertilizer management of bio-fertilizer and chemical fertilizers on the grain yield of two dill (*Anethum graveolens* L.) ecotypes, a field experiment was arranged in a factorial layout based on randomized complete block design with three replications in 2019 in Agricultural Research Farm of the University of Tabriz. The first factor includes two ecotypes (C1: Native of Tabriz and C2: Varamin), while the second factor was composed of five fertilizers levels, namely, control (N0), chemical fertilizers (N1), *Enterobacter cloacae* S16-3 bacteria + half a chemical fertilizer (N2), *Piriformospora indica* Fungi + half a chemical fertilizer (N3) and the combination of bacteria + fungi + half a chemical fertilizer (N4). Although the highest yield and yield components were obtained for chemical fertilizer treatment (N1), there was no statistically significant difference with the combined treatment (N4). The combined application of biofertilizers (growth-promoting bacteria and fungi), in addition to reducing chemical fertilizers (50%), led to a high grain yield. Accordingly, the application of combined treatment (N4) can be a suitable treatment for the cultivation of medicinal plants, including dill.

Keywords: bio-fertilizer; chemical fertilizer; dill; *Enterobacter cloacae*; grain yield; *Piriformospora indica*

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1. Introduction

Many of the herbs and spices used by humans to season food yielded useful medicinal compounds. The demand for medicinal plants is currently increasing in both developed and developing countries for various reasons. They are used in pharmacy, cosmetology, perfumes and the food industry, among others [1].

Dill (*Anethum graveolens* L.) is an annual plant of the Apiaceae family, which is grown as an important medicinal plant among the world. The uses of dill seeds are carminative, stomachic and diuretic. It can also be used to increase milk production for mothers who breastfeed, helped prevent colic, bad breath, coughing, cold, flu and menstrual. The treatment of potato tubers with the carvone of the essential oil extracted from dill seeds inhibited the growth of the potato spouts [2] (Sanli and Kardogan, 2019).

Biofertilizer, as an essential component of organic farming, plays a vital role in maintaining the long-term fertility and sustainability of soil [3]. Integrated nutrient management strategies involving chemical fertilizer and biofertilizer have been suggested to enhance the sustainability of crop production. Rhizosphere-associated nitrogen-fixing bacteria have been used as inoculum for non-legume crop species [4].

This research was conducted to study the effect of the combined fertilizer management of biofertilizer and chemical fertilizer on the grain production of two dill ecotypes in northwest Iran.

2. Materials and Methods

A field experiment was conducted in a factorial layout based on randomized complete block design with three replications in 2019 in Agricultural Research Farm of the University of Tabriz, which is located in northwest Iran (Longitude 46°17′ E, Latitude 38°05′ N, Altitude 1360 m above sea level).

The first factor included two ecotypes (C1: Native of Tabriz and C2: Varamin), while the second factor was composed of five fertilizers levels, namely, the control (N0), chemical fertilizers (N1), *Enterobacter cloacae* S16-3 bacteria + half a chemical fertilizer (N2), *Piriformospora indica* Fungi + half a chemical fertilizer (N3) and combination of bacteria + fungi + half a chemical fertilizers (N4).

Each plot consists of six rows with 25 cm distance from each other and 4 m length. Bacteria and fungi, used in this experiment as seed inoculums, were provided at Soil Biology Laboratory of the Soil Sciences Department of the University of Tabriz.

At maturity stage, plants of 1 m^2 in the middle part of each plot were harvested and grain yield per unit area was recorded. Then above-ground biomass was oven-dried at 75 °C for 48 h and weighed and, subsequently, plant biomass was calculated.

SPSS 9.4 software (IBM, New York, NY, USA) used for data analysis and the means of traits were compared using Duncan multiple range tests at $p \leq 0.05$.

3. Results

Analysis of variances showed the significant effects of fertilizer type on the biological yield, grain yield and harvest index of dill ecotypes. However, the dill ecotypes showed no significant differences in terms of grain production (Table 1).

Table 1. Analysis of variance in the data for grain production traits of two dill ecotypes under chemical and biofertilizer treatments.

	Mean Squares		
Source of Variation	**Biological Yield**	**Grain Yield**	**Harvest Index**
Replication	496,175.09 ^{**,1}	55,729.4 ^{ns}	102.18 *
Ecotype	203,321.72 ^{ns}	37,619.07 ^{ns}	0.44 ^{ns}
Fertilizer	587,672.97 **	142,688.7 **	186.06 *
Replication * Ecotype	140,856.73 ^{ns}	23,443.9 ^{ns}	181.3 ^{ns}
Error	52,528.52	15,882,368	63.49
Cv (%)	15.25	22.82	21.49

[1], ^{ns}, *, **: Not significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.

Biological yield of Tabriz ecotype was a little higher than that of the Varamin ecotype; however, the difference was not significant (Table 2).

Table 2. Mean comparison of grain production traits of two dill ecotypes under chemical and biofertilizer treatments.

Ecotype	Biological Yield g/m^2	Grain Yield g/m^2	Harvest Index %
Tabriz	1585.01 a [1]	587.66 a	37.19 a
Varamin	142,036 a	516.83 a	36.95 a

[1] Different letters indicate significant differences at $p \leq 0.05$ (Duncan test).

Dill biological yield significantly increased due to the application of fertilizers; the highest yield and yield components were obtained for chemical fertilizer treatment (N1), but there was no statistically significant difference with the combined treatment (N3, fungi + half a chemical fertilizer and N4, combination of bacteria + fungi + half a chemical fertilizer) (Figure 1).

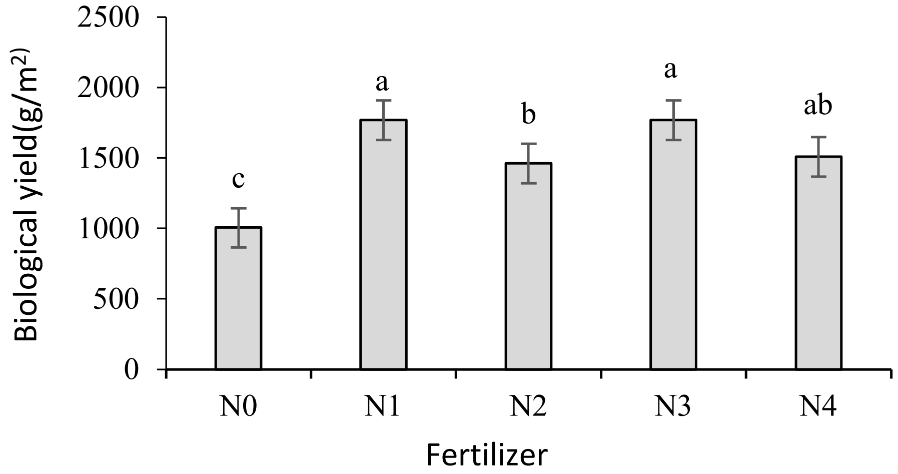

Figure 1. Dill biological yield affected by chemical and bio-fertilizer treatments. Different letters indicate significant difference at $p \leq 0.05$ (Duncan test). Control (N0), chemical fertilizers (N1), *Enterobacter cloacae* S16-3 bacteria + half a chemical fertilizer (N2), *Piriformospora indica* fungi + half a chemical fertilizer (N3) and combination of bacteria + fungi + half a chemical fertilizer (N4).

The grain yield of dill ecotypes considerably increased with chemical and bio-fertilizers, although the highest yield and yield components were obtained for chemical fertilizer treatment (N1), but there was no statistically significant difference between the combined treatment (N4, combination of bacteria + fungi + half a chemical fertilizers) (Figure 2).

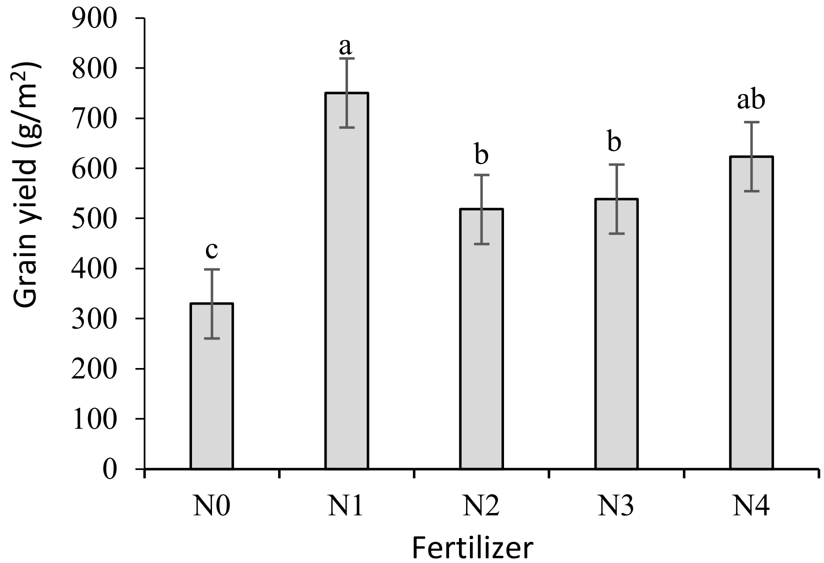

Figure 2. Changes in dill grain yield under chemical and bio-fertilizer treatments. Different letters indicate significant difference at $p \leq 0.05$ (Duncan test). Control (N0), chemical fertilizers (N1), *Enterobacter cloacae* S16-3 bacteria + half a chemical fertilizer (N2), *Piriformospora indica* fungi + half a chemical fertilizer (N3) and combination of bacteria + fungi + half a chemical fertilizer (N4).

The harvest index of dill ecotypes was also significantly affected by chemical and bio-fertilizers; the highest harvest index was obtained from chemical fertilizer treatment (N1), but there was no statistically significant difference when compared with the combined treatment (N4, combination of bacteria + fungi + half a chemical fertilizers) (Figure 3).

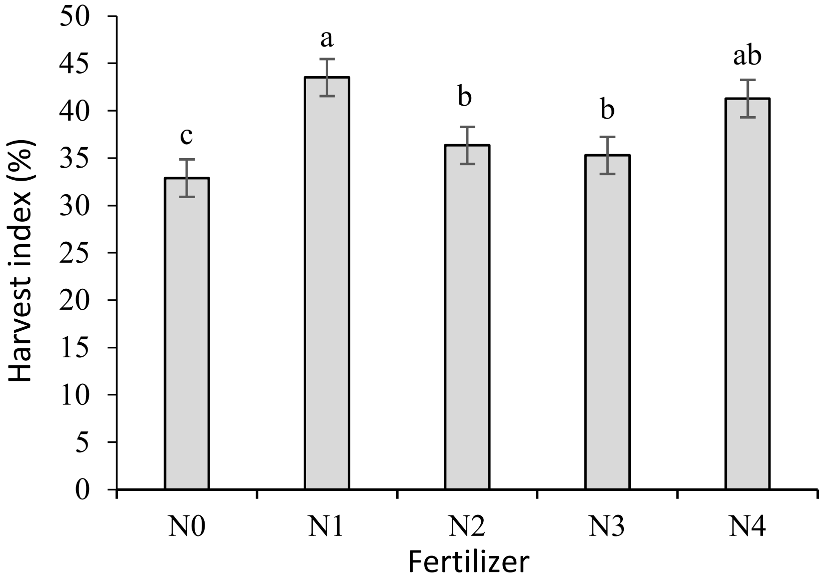

Figure 3. Harvest index of dill ecotypes affected by chemical and bio-fertilizer treatments. Different letters indicate significant difference at $p \leq 0.05$ (Duncan test). Control (N0), chemical fertilizers (N1), *Enterobacter cloacae* S16-3 bacteria + half a chemical fertilizer (N2), *Piriformospora indica* fungi + half a chemical fertilizer (N3) and combination of bacteria + fungi + half a chemical fertilizer (N4).

4. Discussion

The biological and grain yield of dill ecotypes was significantly increased by chemical and bio-fertilizers; our results show that although *Enterobacter cloacae,* the nitrogen fixing bacteria, or *Piriformospora indica* fungi could enhance the grain production of dill, the combined treatments of bacteria + fungi + half of chemical fertilizer showed a better performance (Figures 1 and 2). Biological yield enhancement by plant-growth-promoting rhizobacteria (PGPR) and mycorhizal fungi were reported by other researchers (Shaharona et al. 2006).

Optimizing dill grain yield under integrated treatments could be related to increases in photosynthesis and plant shoot growth improvements caused by soil microorganisms. It seems that the application of mycorhizal fungi has a symbiotic effect on dill grain production, with improvements due to nitrogen-fixing bacteria. Accordingly, the application of combined treatment (N4) can be a suitable treatment for the cultivation of medicinal plants, including dill.

Supplementary Materials: The presentation material can be downloaded at: https://www.mdpi.com/article/10.3390/IOCAG2022-12333/s1.

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