International Journal of Agriculture and Crop Sciences.
Available online at www.ijagcs.com
IJACS/2013/7-2/60-65
ISSN 2227-670X ©2013 IJACS Journal

Studying the effects of biological and chemical fertilizing systems on yield and yield components of cumin (*Cuminumcyminum* L.)

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ABSTRACT: In order to study the effect of Barvar-2 phosphate bio-fertilizer and chemical phosphorus fertilizer on yield and yield components of cumin (CuminumcyminumL.), this asymmetrical factorial experiment was arranged in randomized complete block design (RCBD) with three replications at the agricultural research farm of Lorestan University in the growing season of 2013. Studied factors included two levels of Barvar-2 phosphate bio-fertilizer [no inoculation (B_0) and inoculation (B_1)] and three levels of chemical super phosphate triple fertilizer [0 (P_0), 30 (P_1), and 60 (P_2) kg/ha]. The obtained results indicated that bio-fertilizer effect on some of the studied characteristics was significant and even competitive with that of chemical fertilizer.The highest seed yield (43.70 g/m^2), biological yield (95.14 g/m^2), and essential oil yield (1.58 g/m^2) were recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate triple chemical fertilizer at the level of 30 kg/ha. The lowest seed yield (21.04 g/m^2), biological yield (64.09 g/m^2), and essential oil yield (0.75 g/m^2) were obtained from the control treatment. Finally, it was shown that phosphate bio-fertilizer significantly improved quantitative and qualitative yields of cumin and, therefore, could be considered as an appropriate fertilizing system in reducing the application of chemical phosphorus fertilizer.
Keywords: cumin,bio-fertilizer, chemical fertilizer, essential oil yield

INTRODUCTION

Application of chemical fertilizers has many environmental hazards such as soil and water contamination and can endanger human health (Rahmani, 2010). Application of soil microorganisms as biological fertilizer is considered as the most natural and efficient solution for sustaining and activating soil bacterial life (SalehRastin, 2001).The main advantages of the growth stimulant bacteria include production of growth regulating hormones, expansion of root network, improvement of water and nutrient absorption, enhancement of germination and seedling emergence (Kloepperet al., 1998), increase of phosphorus availability, development of synergy with rhizobia, biological fixation of nitrogen (Ishizuka, 2002), and production of antibiotic agents, such as bacteriocins, for controlling plant disease agents (Tapia-hemandeet al., 1990).

Consumption of biological fertilizers is considered as the most efficient soil management method to sustain soil quality at a favorable level (Kokaliset al., 2006). Generally, biological fertilizers are microbial inoculants that induce nutrient availability through their biological mechanism. Biological fertilizers have been used as environmental-friendly inputs since the last decade. This resulted in reduction of the application of chemical fertilizers and improvement of soil fertility through biological activity in rhizosphere area (Mohammad Verziet al., 2010).

Phosphorus is an essential nutrient for plant's growth and reproduction. Second only to nitrogen, phosphorus is the most important factor in plant nutrition (Rafati, 2005). Phosphate solubilizing bacteria (PSB) are microorganisms that can solubilize soil's insoluble phosphorus. Bacillus and Pseudomonas are the most important species of PSB (Tilaket al., 2005).

Cumin(CuminumcyminumL.) is regarded as the most important medical herb in the country. It is a small and annual umbelliferous plant (Moraghebiet al., 2008) that has a short growing season, low water consumption, and a relatively high resistance to environmental tensions (Kafi, 2002). Its aromatic seeds have medical applications and contain 7% essential oil, 13% resin, 2.5 to 4% essence and aleurone (Saeidnezhad and Rezvani-Moghadam, 2009). It can be used in curing indigestion and dyspepsia and for increasing milk. It was also shown that cumin can affect gram-positive bacteria (Aniet al., 2006).

A research studying fennel(FoeniculumvulgareMill.) showed that the application of phosphate bio-fertilizer increased umbels, biological yield, and seed yield (Darziet al., 2008). Another research studying the effect of biological and chemical phosphorus fertilizerson yield and yield components of fennel showed that inoculation with Barvar-2 bio-fertilizer increased the number of umbels and clusters, plant and total dry biomass, and essential oil yield (Ramezani, 2009).

In the study of essential oil yield and chamazulene percentage in German chamomile (MatricariarecutitaL.) the highest values were recorded in the interaction of 40 kg/ha phosphorus chemical fertilizer and Barvar-2 phosphate bio-fertilizer (Alijaniet al., 2011). Annamalaiet al. (2004) reported that the application of PSB significantly increased the biological yield of a medical plant belonging to Euphorbiaceaefamily(phyllanthusamarus)in comparison with the control treatment. Studying sugar cane (Saccharumofficinarum), Sandra et al. (2001) also showed that the application of a particular species of PSB along with phosphate stone increased the quantity and quality of sucrose in comparison with the control treatment.

Regarding the necessityresearches onthe use ofthe alternative methods for chemical fertilization and the limited researches on the effect of bio-fertilization in Iran's medical plants on one hand and the economic and medical importance of cumin on the other hand, this experiment was conducted to study the effect of Barvar-2 phosphate bio-fertilizer and chemical phosphorus fertilizer (super phosphate triple)on yield and yield components of cumin.

METHODS AND MATERIALS

This study was conducted on the agricultural research farm of Lorestan University inKhoramabad in 2013. The experimental site was located at latitude 33°26′ N, longitude 45°17′ E, and an altitude of 1210 m with semi-arid climate, mean annual precipitation of 462.8 mm, mean annual evaporation of 1842.52 mm, and mean annual temperature of 16.6°C. Regarding the climatic conditions of the experimental site, seedbed preparation started in March 2012 (Annual Meteorological Statistics of Lorestan, 2012).A soil sample was collected in a zigzag pattern from the depth of 30 cm to determine the chemical and physical properties of the soil (Table 1). This asymmetrical factorial experiment was arranged in randomized complete block design (RCBD) with three replications. Sowing was done in a linear pattern in March 2012. The designed plots were 3 m long and 1.5 m wide and consisted of 6 lines. There was a 75 cm space between the plots and a 2.5 m space between the replications. There was a 2 cm space between the plants and a 20 cm space between the rows. Studied factors included two levels of Barvar-2 phosphate bio-fertilizer [no inoculation (B_0) and inoculation (B_1)] and three levels of triple superphosphate chemical fertilizer [0 (P_0), 30 (P_1), and 60 (P_2) kg/ha] applied as a thin strip 4 cm away of the seeds.

Table 1. Soil test results

Location	Khoramabad
Depth (cm)	30
Nitrogen (%)	98
OC	1.03
Absorbable Phosphorus (PPM)	9.4
K (PPM)	410
Fe (PPM)	2.2
Mn (PPM)	5.2
Zn (PPM)	0.32
B (PPM)	0.05
Mg (PPM)	2.9
Ca (PPM)	3.3
EC (ds/m)	0.47
pH	8.5
Soil texture	loam-clay

40 g seed were collected from each treatment and ground into powder. The essential oil was obtained throughhydro distillationof the powder using a Clevenger type apparatus for 3h at 100°C. The essential oil percentage was multiplied by seed yield to obtain essential oil yield. The two border lines and 0.5 m of both ends were discardedin each plot as border effect and the remaining area was harvested to obtain seed yield, biological yield, and harvest index. 10 plants were randomly collected from each plot at harvest and the number of umbels per plant, the number of seeds per umbel, the number of lateral branches per plant, and 1000-seed weight were measured. After sampling and measuring the characteristics, the obtained data was subjected to statistical analysis according to statistical model of factorial experiments using MSTAT-C and SPSS statistical

software packages (Table 2). Means were compared using Duncan's multiple range test (Table 3). Microsoft Office Word and Excel were employed to design the tables and draw the charts.

RESULTS AND DISCUSSION

The analysis of variance for Barvar-2 phosphate bio-fertilizer showed that the yield components including the number of umbels per plant, the number of seeds per umbel, the number of seeds per plant, 1000-seed weight, and the number of plants per unit area were significantly affected (Table 3). The yield components were improved in most of the treatments and, as a result, seed yield was increased in comparison to the control treatment.

The number of umbels per plant

The highest number of umbels per plant (22.6) was recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate chemical fertilizer at the level of 30 kg/ha.Generally, the number of umbels per plant is one of the main yield components andits improvement can increase the number of seeds per plant and seed yield (AminiDehaghi, 2011). It can be inferred that in addition to sufficient phosphorus availability, production of growth stimulant hormones by the bacteria increases the number of umbels per plant (Kafi, 2002).

It was shown that the application of phosphate bio-fertilizer increased the number of umbels in PimpinellaanisumL. by increasing plant's phosphorus absorption and improving flowering (Darziet al., 2010). Mahfouz and Sharaf-Edin (2007) also reported that the number of umbels per plant significantly increased in FoeniculumvulgareMill. by application of bio-fertilizer.

The number of seeds per umbel

The highest number of seeds per umbel (8.917) was recorded in treatment with triple superphosphate chemical fertilizer at the level of 60 kg/ha. However, the second highest numbers of seeds per umbel (8.69) was recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate chemical fertilizer at the level of 30 kg/ha and significantly differed from the control treatment. Phosphate bio-fertilizer functionality capitalizes on its PSB which increase phosphorus availability that is crucial for the improvement of root network, vegetative growth, flowering, seeding, maturation, and plant's qualitative properties. PSB can release soil's insoluble phosphorus in the form of organic phosphorous acid and light phosphorus throughtheirenzymatic process and by affecting soil acidity (Sarokhaniet al., 2000).

The number of seeds per plant

Since the number of umbels per plant and the number of seeds per umbel can't be regarded as reliable factors for evaluation of seed yield by themselves, the number of seeds per plant was also measured through multiplying the number of umbels per plant by the number of seeds per umbel (Saeidnezhad and ResvaniMoghadam, 2009). The highest number of seeds per plant (173.4) was recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate chemical fertilizer at the level of 30 kg/ha.

Bacillus and Pseudomonas present in the phosphorus bio-fertilizer increase phosphorus availability and, therefore, improve nutrient absorption by decreasing soil's pH (Rasipor and Asgharzadeh, 2007). Annamalaiet al. (2004) also reported a significant increase of seed yield in Phyllanthusamarusby application of PSB.

1000-seed weight

The highest 1000-seed weight (3.893) was recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate chemical fertilizer at the level of 30 kg/ha. This can be attributed to the increase of nutrient absorption and photosynthesis by PSB (Darziet al., 2008).

Biological and seed yield

The highest biological and seed yields (95.14 and 43.7 g/m^2, respectively) were both recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate chemical fertilizer at the level of 30 kg/ha. The lowest biological and seed yields (64.09 and 21.04 g/m^2, respectively) were both recorded in the control. This can be attributed to the increase of phosphorus absorption and photosynthesis by application of phosphate bio-fertilizer. This is in agreement with the results obtained by Rattiet al. (2001) studying lemongrass (lemon verbena). They reported that in addition to the positive effect of phosphorus absorption on dry mass, the production of growth stimulant hormones by PSB may probably lead to the improvement of biological yield (Darziet al., 2008).

Bio-fertilizers can also provide plants with soluble nutrients through the secretion of solubilizing bacteria and decrease of soil's acidity (Rademacher, 1994). The results obtained by Mirshekariet al. (2007) indicated that the simultaneous presence of PSB and micronutrients would show the highest effect on increasing seed yield in cumin. Congruently, the results obtained by Gad(2001) showed that the application of bio-fertilizers is necessary for increasing growth and seed yield in fennel and dill. Another study on fennel also revealed that the application of phosphate bio-fertilizer would lead to the increase of the number of umbels in plant, biological yield, and seed yield in comparison to the control (Darziet al., 2004).

Harvest index

The highest harvest index (45.95%) was recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate chemical fertilizer at the level of 30 kg/ha. The lowest harvest index (32.81%) was recorded in the control. Ramshwar and Sing (1998) attributed this to improved nutrient absorption under the application of bio-fertilizer. Improved nutrient absorption increases the proportion of seed to dry mass by developing leaf area index and, therefore, supplying more photosynthetic materials to seeds.

Essence percentage

The highest essence percentage (3.787) was recorded in the treatment with triple superphosphate chemical fertilizer at the level of 30 kg/ha. The lowest harvest index (3.538) was recorded in the control. In addition to improving quantitative yields, the presence of sufficient nutrients in soil can increase the secondary metabolites and quality of the product (Valadabadiet al., 2010). However, Moradiet al. (2011) reported that essence percentage was not significantly affected by the application of biological and organic fertilizers in fennel.

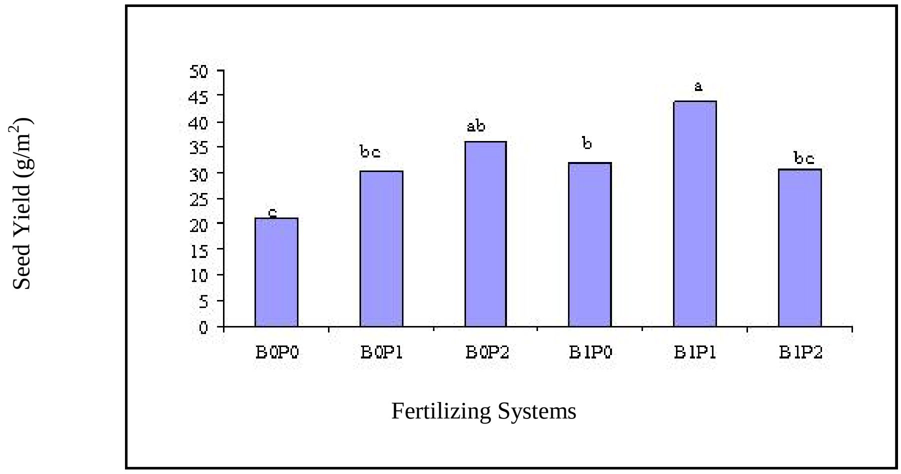

Figure 1.Comparison of means for seed yield of cumin under biological and chemical fertilizing systems

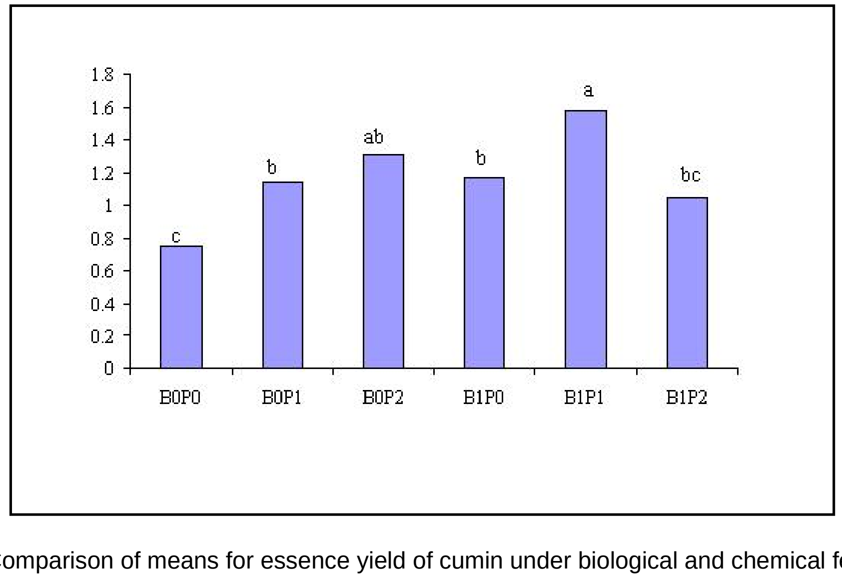

Figure 2.Comparison of means for essence yield of cumin under biological and chemical fertilizing systems

B_0: no inoculation, B_1: inoculation, withBarvar-2 phosphate bio-fertilizer : P_0:0, P_1: 30, P_2: 60 [kg/ha],triple superphosphate chemical fertilizer

Essence yield

The highest essence yield (1.58 g/m^2) was recorded in the interaction of Barvar-2 phosphate bio-fertilizer and triple superphosphate chemical fertilizer at the level of 30 kg/ha which significantly differed from the control that recorded the lowest essence yield (0.75 g/m^2).The production of essence is considered as one of the main reasons for cultivating cumin. Essence yield depends on essence percentage and seed yield (Valadabadiet al., 2010). Since seed yield is relatively affected more than essence percentage, it can be inferred that essence yield is more affected by seed yield (Mirshekariet al., 2009). Ajimoddinet al. (2005) reported that the highest vegetative and essence yield were both recorded in the interaction of biological fertilizer and 75% of the required chemical fertilizer in basil.

Table 2. Analysis of variance for theeffect of biological and chemical fertilizing systems on yield and yield components of cumin

		Mean squares										
Source of variation	Df	Umbel/plant	Seed/umbel	Seed/plant	1000-seed weight	Lateral branch	Plant height	Seed yield	Biological yield	Harvest index	Essence percentage	Essences yield
Replication	2	12.354*	3.429ns	1084.844*	0.014ns	0.494ns	1.501ns	70.391*	46.358ns	44.754ns	0.185ns	0.065ns
A (Barvar-2 phosphate bio-fertilizer)	1	22.178**	1.417ns	2278.125**	0.276ns	0.180ns	0.436ns	177.410**	437.981**	54.149ns	0.000ns	0.184*
B (triple superphosphate chemical fertilizer)	2	22.640**	3.232ns	3932.230**	0.242ns	0.101ns	0.987ns	173.817**	387.808**	52.149ns	0.009ns	0.239*
A x B	2	28.224**	10.067**	7585.781**	0.107ns	0.585ns	5.401ns	152.386**	237.093**	81.687*	0.040ns	0.237*
Error	10 17	1.708	0.857	189.203	0.164	0.308	1.806	14.995	24.311	15.632	0.223	0.035
C V (%)		6.32	11.97	9.52	11.20	11.83	8.6	11.99	5.83	10.51	12.84	15.92

* Significant at 5%, ** significant at 1%, and ^{ns} not significant.

Table 3. Comparison of means for the effect of biological and chemical fertilizing systems on yield and yield components of cumin

Treatments	Umbel/plant	Seed/umbel	Seed/plant	1000-seed weight(g)	Lateral branch	Plant height(cm)	Seed yield (g/m^2)	Biological yield(g/m^2)	Harvest index	Essences percentage	Essence yield(g/m^2)
B_0P_0	14.97b	5.373b	67.85c	3.173a	4.133a	13.93a	21.04c	64.09b	32.81b	3.583a	0.750c
B_0P_1	22.13a	8.060a	162.6ab	3.513a	4.833a	16.33a	30.42bc	85.55a	35.31b	3.787a	1.140b
B_0P_2	21.57a	8.917a	169.4a	3.787a	4.800a	16.13a	36.03ab	89.23da	39.57ab	3.640a	1.307ab
B_1P_1	22.13a	8.490a	166.6a	3.597a	5.033a	16.43a	31.87b	86.67a	36.67b	3.763a	1.173b
B_1P_2	22.60a	8.690a	173.4a	3.893a	4.833a	15.63a	43.70a	95.14ca	45.95a	3.640a	1.580a
B_1P_3	20.60a	6.853ab	127.4b	3.727a	4.500a	15.27a	30.75bc	86.67a	35.47b	3.633a	1.050bc

Treatments with at least one letter in common showno significant difference

B_0: no inoculation, B_1: inoculation, withBarvar-2 phosphate bio-fertilizer : P_0:0, P_1: 30, P_2: 60 [kg/ha],triple superphosphate chemical fertilizer

CONCLUSION

The obtained results indicated that the interaction of phosphate bio-fertilizer and 50% of required phosphorus chemical fertilizer increased essence yield, biological yield, seed yield, and some yield components. Therefore, regarding the reduction of application of chemical fertilizers for promoting sustainable agriculture, it can be concluded that biological fertilizer can supply a large part of the required nutrients in cumin.

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