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PHYSIOLOGICAL INFLUENCES OF SOME AGRICULTURAL PRACTICES ON THE GROWTH AND ESSENTIAL OIL PRODUCTION IN *MENTHA PIPERILA* L. PLANT

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ABSTRACT: ***Two field experiments were conducted at the Experimental Farm of the Faculty of Agriculture, Minufiya University during two successive seasons of 2006 and 2007 for studying the effect of inoculating the growing media of peppermint plants with different N_2-fixing bacterial strains such as Azospirillum lipoferum, Azatobacter chroococcum and / or Bacillus polymyxa individually or in combinations with urea fertilization rates of 0.0, 150, 300 and 450 kg/fed/season. The obtained results showed that, the inoculation treatments with the different bacterial strains resulted in significantly taller plants with more branches/plant and consequently heavier fresh weight of herb/plant in comparison with the uninoculated plants in the two growing seasons. The inoculation treatment with Azotobacter chroococcum gave generally the best results in this concern followed by Azospirillum lipoferum and Bacillus polymyxa, respectively in the three cuts in both growing seasons. The essential oil yield/plant followed the aforementioned trend in the two experimental seasons. In addition, the measured vegetative growth parameters as well as essential oil yield/plant in the different three harvesting cuts in both growing seasons was gradually increased with increasing urea fertilization also up to 300 kg/fed/season, meanwhile the control treatment without urea addition gave significantly the lowest values in this concern in the two season. Furthermore, the best growth parameters and essential oil yield were obtained by the combination treatment of Azotobacter chroococcum + the moderate urea fertilization rate (300 kg/fed/season) in comparison with the other interaction treatments and the control in the two growing seasons.***

Key words: ***Mentha piperita L., N_2-fixing bacteria, urea fertilization.***

INTRODUCTION

Mentha piperita **L. is one of the most famous Mentha hybrids which have been traditionally used in flavors, fragrances and medicines. Recent studies have supported these uses. Owing to the great importance of peppermint plants, several investigations for optimizing biomass production (herb yield) and improving its essential oil production were carried out by several investigators. In this regard, the herb yield and its essential oil content**

depend to a large extent on the application of proper agricultural practices such as supplying the plants with adequate nutrients, particulary nitrogen nutrition. Otherwise, nowadays there has been an increasing awareness of undesirable impact of using high doses from chemical fertilization, which have a dangerous effects on the environment and human health. Therefore, many attempts were carried out by several investigators to minimize the nonstop addition of high doses from chemical fertilization through the application of biofertilization by inoculating the seeds or the growing media with N_2-fixing bacteria such as *Azospirillum lipoferum, Azotobacter chroococcum* or *Bacillus polymyxa*, which are known to have a beneficial effects on the growth and chemical constituents of several medicinal and aromatic plants (Fayez *et al.,* 1985). In this regard El-Saway *et al.* (1998) and Nofal *et al.* (2001) on *Ammi visnaga* reported that, the application of Azotobacter and Azospirillum separately or in combinations with suitable doses from chemical fertilization enhanced plant growth and improved its chemical constituents. Furthermore, Kandeel *et al.* (2002) on *Ocimum basilicam*, Afify (2002) on *Foeniculum vulgare*, Kandeel and Sharaf (2003) and Mahfouz (2003) on *Majorana hortensis* found that the inoculation with different N_2-fixing bacterial strains in combinations will suitable chemical fertilization doses realized the best growth parameters and essential oil content of the investigated plants. In addition, Magahed *et al.* (2004) on celery plants, Youssef *et al.* (2004) on *Salvia officinalis* plants, Dewidar (2007) on *Rosmarinus officinalis*, *Origanum majorana* and *Mentha virids* and Mazrou (2008) on *Cymbopogon citrates*, concluded that, the application of N_2-fixing bacterial strains + suitable chemical fertilization rates enhanced the different vegetative growth parameters and improved essential oil content the plants as well as their content from other chemical constituents such as NPK percentages, total carbohydrate content and photosynthetic pigments concentrations in the leaves of studied plants. Therefore, the present investigation was conducted for studying the effect of inoculating the growing media of *Mentha piperita* L. plants with different N_2-fixing bacterial strains such as *Azospirillum lipoferum, Azotobacter chroococcum* and / or *Bacillus polymyxa* seperatly or in combinations with different urea fertilization rates on the vegetative growth and essential oil content of *Mentha piperita* L. plants grown under the environmental condition of El-Minufiya province.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of the Faculty of Agriculture, Minufiya University during two successive seasons of 2006 and 2007 for studying the effect of biofertilization with different N_2-fixing bacterial strains as well as the influence of different urea (46% N)

fertilization rates separately or in combinations with the different N_2-fixing bacterial strains on the growth and essential oil production of *Mentha piperita* L. plants.

The experimental soil was carefully prepared and divided into plots 2 × 2 m and each plot contained 4 rows 50 cm apart, then uniformly rooted cuttings of *Mentha piperita* L. with 3 – 4 pairs of leaves, which were kindly obtained from El-Kanater El-Khairia Research Station were transplanted on the 5th of April in each growing season at a distance of 40 cm on the rows. Each row contained 5 plants and consequently each plot contained 20 plants.

The experimental soil was clay loamy and its physical and chemical properties are shown in Table (1).

Table (1): The physical and chemical properties of the experimental soil according to Jakson (1967).

a) Physical properties:

Water field capacity %	Organic matter %	Coarse sand %	Fine sand %	Silt %	Clay %	Texture grade
38.80	2.80	3.84	27.40	44.23	23.20	Clay loamy

b) Chemical properties:

PH	E.C. mm/hos/ cm at 25°C	C.E.C. mg/100 g	Total CaCo$_3$ %	Total N %	Total P_2O_5 %	Soluble ions mg/100 g			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}
7.90	1.73	25.60	2.32	0.12	0.26	0.42	0.68	0.60	0.12

During soil preparation, the recommended doses from calcium super phosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O) at rates of 270 kg/fed (El-Ghadban, 1998) from each fertilizer were added in the each growing seasons. The used inoculants in this investigation were active strains from *Azospirillum lipoferum, Azotobacter chroococcum* and *Bacillus polymyxa*, which were obtained kindly from Pharmaceutical Department, National Research Center, Giza, Egypt. The aforementioned N_2-fixing bacterial strains were prepared for application according to the method described by Mahfouz (2003). The prepared culture from each bacterial type contained 10^7 cell / ml. The grown plants were treated three times with 300 ml from each bacterial strains, which were added to irrigation water, one week after transplanting, one week after the first harvesting cut and the last addition was one week after the second harvesting cut in each experimental seasons. In this respect each plot of 2 × 2 m received (300 ml/plot/cut). Furthermore, inorganic N-fertilization in the form of urea (46% N) was applied at rates of 0.0 (N_0), 150 (N_1), 300 (N_2) and 450 (N_3) kg / fed / season. The used

amounts from urea fertilization were added in three equal side dressings during the growing period. The first addition was after two weeks after transplanting meanwhile, the second and the third doses were added two weeks after the first and the second harvesting cuts in the two growing seasons. The lay out of the experiment was a factorial complete randomized block design and each treatment was represented with three replicates (2×2m).

The treatments of bio and urea fertilization levels and their combinations were as follows:

[1] Control without bio (B_0) or urea biofertilization (N_0).
[2] Inoculation with *Azospirillum lipoferum* (B_1).
[3] Inoculation with *Azotobacter chroococcum* (B_2).
[4] Inoculation with *Bacillus polymyxa* (B_3).
[5] Urea application at 150 kg/fed/season (N_1) without inoculation.
[6] Urea application at 300 kg/fed/season (N_1) without inoculation.
[7] Urea application at 450 kg/fed/season (N_1) without inoculation.
[8] Inoculation with *Azospirillum lipoferum* (B_1) + 150 kg/fed/urea (N_1).
[9] Inoculation with *Azospirillum lipoferum* (B_1) + 300 kg/fed/urea (N_2).
[10] Inoculation with Azospirillum lipoferum (B_1) + 450 kg/fed/urea (N_3).
[11] Inoculation with *Azotobacter chroococcum* (B_2)+ 150 kg/fed/urea (N_1).
[12] Inoculation with *Azotobacter chroococcum* (B_2)+ 300 kg/fed/urea (N_2).
[13] Inoculation with *Azotobacter chroococcum*(B_2)+ 450 kg/fed/urea (N_3).
[14] Inoculation with Bacillus polymyxa (B_3) + 150 kg/fed/urea (N_1).
[15] Inoculation with Bacillus polymyxa (B_3) + 300 kg/fed/urea (N_2).
[16] Inoculation with Bacillus polymyxa (B_3) + 450 kg/fed/urea (N_3).

Harvesting:

During each experimental season the plants were cut three times at approximately full flowering. In each harvest the plants were cut leaving about 10 cm above the soil surface. The first cut was done on 25th of June, Meanwhile, the second and the third cuts were on 15th of September and 20th of November respectively in the two growing seasons. Furthermore, in each harvesting cut in the two growing seasons the following data were recorded and statistically analyzed according to Snedecor and Chochran (1980).

1. Vegetative growth parameters:

[1] Plant height in cm.
[2] Mean number of branches / plant.
[3] Fresh weight of leaves / plant.
[4] Fresh weight of stems / plant.
[5] Total fresh weight of herb / plant.
[6] Total fresh herb yield / fed / season.

[7] Dry weight of leaves / plant.
[8] Dry weight of stems / plant.
[9] Total dry weight of herb / plant.
[10] Total dry weight of herb / fed / plant.

2. The determination of the chemical constituents:

1. **Determination of the essential oil percentage in random samples obtained from the fresh herb of each treatment was carried out in each cut during the two experimental seasons according to the method described by British Pharmacopea (1963). The oil percentage (v/w) was calculated according to the following equation:**

$$\text{Essential oil percentage} = \frac{\text{Observed oil in graduated tube in ml}}{\text{Weight of sample in g.}} \times 100$$

2. **The essential oil yield / plant and per fed in liter for the three cuts and for season was calculated and statistically analyzed.**

RESULTS AND DISCUSSION

1. Vegetative growth parameters:

1.1. Plant height:

1.1.1. Effect of bio fertilization:

It is evident from the data in Table (2) that, the plant height was significantly increased as a result of inoculation the growing media of peppermint plants with the different N_2-fixing bacterial strains in the three harvesting cuts in both growing season in comparison with the uninoculated control. The mostly tallest plants were produced by the treatment of inoculation with *Azospirillum lipoferum* or *Bacillus polymyxa* during both experimental seasons. The uninoculated control treatment gave the significantly lowest values in this respect in the two experimental seasons.

The increment of plant height as a result of using the different N_2-fixing bacterial strains could be explained through their effect in providing peppermint plants plants with nitrogen required for protein and cytokinins synthesis and consequently enhancing cell division (Wagner and Michael, 1971). These results are in accordance with those obtained by Kandeel *et al.* (2003) on *Ocrmum basilicum*, Kandeel and Sharaf (2003) on *Majorana hortensis* and Dewidar (2007) on *Rosmarinus officinalis, Mentha viridis* and *Organum majorana*.

Table 2

1.1.2. Effect of urea fertilization:

The data in Table (2) show clearlythat, the plant height was gradually increased with increasing urea fertilization level up to 300 kg/fed/season. Otherwise, the application of the highest dose from urea (450 kg/fed/season) caused a reduction in this respect in the three harvesting cuts in the two experimental seasons. On the other hand, the significantly lowest values in this respect were obtained by the control plants grown without urea addition.

The previously obtained results reflected the important role of N-nutrition at suitable doses, which are very necessary for proteinsynthesis and formation similar results were obtained by Nofal *et al.* (2001) on *Ammi visnaga*, Kandeel *et al.* (2003) and Mahfouz (2003) on *Majorana hortensis* and Dewidar (2007) on *Rosmarinus officinalis, Mentha viridis* and *Organum majorana*.

1.1.3. Effect of interaction between bio- and urea fertilization levels:

The data in Table (2) indicate that, the plant was markedly improved as a result of the application of the different combinations treatments between biofertilization and the different urea fertilization levels in comparison with the control in the three cuts in both growing seasons. The tallest plants were obtained by the treatment of inoculation with Azotobacter or Bacillus plus the moderate urea fertilization dose (300 kg/fed/season) during both experimental seasons.

These results could be supported by the findings of Gomaa *et al.* (1989) on tomato, Maheshwari *et al.* (1992) on *Cymbopogon martini* var. *notia*, Afify (2002) on fennel plants and Kandeel *et al.* (2002) on *Ocimum basilicum* L.

1.2. Mean number of branches / plant:

The reported data in Table (3) clearly indicate that, the mean number of branches / plant was significantly increased as a result of inoculation with the different N_2-fixing bacterial strains in the three harvesting in both growing seasons in comparison with the uninoculated control. The best results in this concern were obtained in the case of inoculation with *Azotobacter chroococcum*, followed by the tratmetns of using *Azospirillum* lipoferum and *Bacillus polymyxa*, respectively.

The effective role of the application of biofertilization in increasing the mean number of branches / plant could be attributed to the role of the applied N_2-fixing bacteria in producing endogenous phytohormones such as IAA, GA_3 and cytokinins and consequently stimulating cell division and building more vascular tissues (Youssef *et al.,* 2004). In addition the aforementioned trend was found also by Maheshwari *et al.* (1992) on lemon grass, Abd El-Latif *et al.* (2002) on *Matricaria chamomilla* and Dewidar (2007) on *Rosmarinus officinalis, Mentha viridis* and *Origanum majorana*.

Table 3

Regarding the effect of the application of urea fertilization, it could be noticed that, the mean number of branches/plant was significantly increased in the three harvesting cuts in both growing season as a result of using the different urea fertilization doses in comparison with the control. The best results in this respect were obtained by providing the plants with the moderate rate (300 kg/fed/season) of urea fertilization (Table (3).

These results are in agreement with the findings of Singh *et al.* (1983) on *Mentha citrate*, Kandeel *et al.* (2002) on *Ocimum basilicum* and Mahfouz (2003) on *Majorana hortensis*.

Furthermore, the data in Table (3) indicate that the mean number of branches/plant was significantly increased as a result of the application of the different interaction treatments between biofertilization and addition of the different urea fertilization doses in comparison with the untreated plants in the three cuts in both experimental seasons. The highest number of branches/plant was obtained by the treatment of inoculation with *Azotobacter chroococcum* + 300 kg/fed/season of urea (46% N) fertilization in the two growing seasons.

These results are in accordance with those obtained by Kandeel *et al.* (2002) on *Ocimum basilicum*, Mahfouz (2002) on *Majorana hortensis* and Mazrou (2008) on *Cymbopogon citratus*.

1.3. Total fresh herb yield/plant:

The data in Table (4) indicate that, the mean fresh weight of herb/plant/cut was significantly increased as a result of inoculating the growing media with the different N_2-fixing bacterial strains in comparison with the uninoculated peppermint plants in the three harvesting cuts in the two experimental seasons. The inoculation treatment with Azotobacter resulted in the best results in this respect in comparison with those of inoculation with Azospirilum or Bacillus in the two growing season. These results could be attributed to the increment in both the plant height (Table 2) and the obtained mean number of branches/plant (Table 3).

The previously stated trend was assured by the finding of Afify (2002) on fennel, Kandeel *et al.* (2002) on *Ocimum basilicum* and Dewidar (2007) on *Rosmarinus officinalis, Mentha viridis* and *Origanum majorana*.

Also, the data in Table (4) clearly show that, application of the different urea fertilization rates separately or in combination with the different N_2-fixing bacterial strained gave significantly heavier fresh weight/plant/cut than the untreated control during both experimental seasons. The best results in this concern were obtained by using the moderate dose from urea fertilization (300 kg/fed/season) individually or when combined with *Azotobacter chroococcum* during both growing season.

Table 4

These results are similar with those obtained by Afify (2002) on fennel, Kandeel *et al.* (2002) on *Ocimum basilicum* and Mahfouz (2003) on *Majorana hortensis*.

2. Essential oil content:

It is evident from the data in Tables (5 and 6) that the essential oil percentage as well as its yield obtained from *Mentha piperita* L. plants was clearly improved as a result of the application of either biofertilization or urea addition at its different rates separately or in combinations in comparison with the untreated plant in the two growing season. The relativelyhgiher essential oil percentages in fresh herb of peppermint plants were obtained by inoculation with *Bacillus polymyxa* followed by the inoculation treatments with either *Azotobacter chroococcum* or *Azospirillum lipoferum* during the two growing season. Otherwise, the highest essential oil yield/plant/cut was obtained by inoculation with *Azotobacter chroococcum* and / or by using the moderate urea fertilization rate individually or when combined together in the three cuts of both growing seasons. On the other hand, the lowest essential oil content was found in the case of the control plants grown without bio- or urea-fertilization addition in the three harvesting cuts in the two seasons.

The aforementioned results indicated that, there was a closely relationship between the produced fresh herb yield/plant (Table 4) and the produced oil yield/plant (Table (6). Therefore, the occurred increment in essential oil production as a result of using bio- or urea-fertilization separately or in combination could be mainly explained through their beneficial effects in enhancing plant growth and improving essential oil percentages in the produced fresh herb/plant.

Similar results were obtained by Afify (2002) on fennel plants, Mahfouz (2003) on *Majorana hortensis*, Dewidar (2007) on *Rosmarinus officinales, Mentha viridis* and *Origanum majorana* and Mazrou (2008) on *Cymbopogon citrates*.

Generally, the second harvesting cut in the two experiemntial season gave better growth and higher essential oil yield/plant than those obtained from the first or the third harvesting cuts (Tables, 4 & 6).

CONCLUSION

From aforementioned results it could be concluded that, the application of biofertilization, especially inoculation of the growing media of peppermint plant with *Azotobacter chroococcum* and using urea fertilization dose at 300 kg/fed/season realized the best growth and essential oil production when compared with the other fertilization treatments and the control.

TABLE 5

TABLE 6

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التأثيرات الفسيولوجية لبعض المعاملات الزراعية على النمو وإنتاج الزيت الطيار فى نبات النعناع الفلفلى

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الملخص العربى :

تم في هذه الدراسة إجراء تجربتين حقليتين بمزرعة الأبحاث الخاصة بكلية الزراعة جامعة المنوفية خلال موسمين متتاليين ٢٠٠٦ ، ٢٠٠٧ وذلك بهدف دراسة استجابة نباتات النعناع الفلفلي للتغذية بالنيتروجين من مصادر حيوية وأخري غير عضوية . وفي هذه الدراسة قد تم تلقيح بيئة نمو النباتات بواسطة ثلاث سلالات مختلفة من البكتريا المثبتة للأزوت الجوي (بتركيز $١٠^{٧}$ خلية/لتر) هي ازوسبيريلليم ليبوفورم ، أزوتوباكتر كروكوكم ، باسلس بولي ميكسا والتي تم إضافتها ثلاث مرات لنمو الحشات الثلاث في كل من موسمي التجربة . وبالإضافة إلي ذلك فقد تم دراسة تأثير التسميد باليوريا (٤٦٪ ن) بمعدلات صفر، ١٥٠ ، ٣٠٠ ، ٤٥٠ كجم /للفدان/الموسم والتي تم توزيعها بالتساوي علي ثلاث دفعات للحشات الثلاث في كل من موسمي التجربة . وقد تم دراسة تأثير كل من نوعي الأسمدة المضافة بصورة منفردة أو متداخلة . وقد أوضحت النتائج المتحصل عليها أن استعمال كل من نوعي الأسمدة بصورة منفردة أو متداخلة قد أدت إلي حدوث زيادة معنوية في الصفات الخضرية التي تم تسجيلها مثل طول النبات ، عدد الأفرع للنبات ، الوزن الطازج للنبات / الحشة مقارنة بالكنترول (بدون إضافة سماد) وذلك في الثلاث حشات المتحصل عليها في كل من عامي التجربة . كما أشارت نتائج تلك الدراسة أيضا إلي إن استعمال البكتريا المثبتة للآزوت الجوي وكذلك التسميد بمعدلات ا ليوريا المختلفة بصورة منفردة أو متداخلة قد أدي إلي حدوث تحسن معنوي في محتوي النبات من الزيت الطيار ومحصوله .

Table (2). Effect of bio-and urea fertilization and their interaction on the plant height (in cm) of *Mentha piperita* L. plants during the growing seasons of 2006 and 2007.

Harvesting cuts	The first cut					The second cut					The third cut				
N. Fert. / Bio. Fert.	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
The first season 2006															
B_0	43.48	48.66	55.30	51.40	49.71	60.89	63.89	68.50	55.30	62.15	27.94	33.89	38.23	36.00	34.02
B_1	53.07	59.01	62.66	58.16	58.22	60.50	70.28	75.66	61.05	66.87	31.66	44.02	49.66	34.33	39.92
B_2	54.07	59.83	63.72	62.45	60.02	59.94	78.13	83.11	70.83	73.01	34.00	39.00	44.55	39.39	39.24
B_3	59.39	61.43	63.86	51.78	59.11	63.94	67.86	74.66	62.27	67.18	31.59	34.98	44.83	42.66	38.51
Mean	52.50	57.23	61.39	55.95	-	61.32	70.04	75.48	62.36	-	31.29	37.97	44.32	38.10	-
The second season 2007															
B_0	39.77	44.97	50.10	46.07	45.23	56.11	60.20	63.52	51.62	57.86	24.23	30.20	33.26	31.27	29.74
B_1	48.22	55.00	59.88	53.66	54.19	55.61	66.29	72.14	57.12	62.79	27.59	30.99	41.30	37.77	34.41
B_2	49.53	55.44	60.11	59.66	56.19	55.44	74.12	80.33	65.98	68.97	29.81	40.02	41.88	29.83	35.39
B_3	55.44	57.44	60.33	46.88	55.02	61.22	63.38	71.05	57.76	63.35	29.48	34.61	40.94	36.60	35.41
Mean	48.24	53.21	57.61	51.56	-	57.10	66.00	71.76	58.12	-	27.78	33.95	39.35	33.87	-

LSD at 5%	The first season 2006			The second season 2007		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
Bio-fertilization (B.)	2.65	1.86	2.12	1.97	2.88	2.49
N-fertilization (N.)	2.65	1.86	2.12	1.97	2.88	2.49
Interaction (B. × N.)	5.30	3.72	4.24	3.94	5.76	4.98

Table (3). Effect of bio-and urea fertilization and their interaction on the mean number of branches plant of *Mentha piperita* L. during the growing seasons of 2006 and 2007.

Harvesting cuts	The first cut					The second cut					The third cut				
N. Fert. / Bio. Fert.	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
The first season 2006															
B_0	24.16	26.44	27.77	22.22	25.15	42.70	66.83	77.50	61.59	62.15	50.07	54.50	63.97	52.47	55.25
B_1	34.14	35.50	40.89	34.89	36.36	61.05	70.29	75.66	60.50	66.88	64.10	64.65	69.32	66.15	66.05
B_2	34.39	37.50	44.78	30.22	36.72	76.00	78.13	83.05	59.94	74.28	68.03	70.10	72.39	68.35	69.72
B_3	18.44	23.47	35.89	24.48	25.57	62.27	67.86	71.66	63.94	66.43	48.07	50.17	66.37	63.80	57.10
Mean	27.78	30.73	37.33	27.95	-	60.51	70.78	76.97	61.49	-	57.57	59.85	68.01	62.69	-
The second season 2007															
B_0	21.99	27.02	39.44	28.03	29.12	46.25	70.38	81.05	65.13	65.70	57.68	59.22	67.03	64.44	62.10
B_1	37.69	39.05	44.44	38.44	39.91	65.82	71.41	79.88	67.49	71.15	66.10	68.78	70.71	66.28	67.97
B_2	37.94	41.05	48.33	33.77	40.27	79.55	81.68	86.60	63.49	77.83	68.37	69.40	72.44	70.40	70.15
B_3	27.71	29.99	32.99	25.77	29.12	64.60	73.83	71.21	64.05	68.42	50.17	68.20	70.20	62.42	62.75
Mean	31.33	34.28	41.30	31.50	-	64.06	74.33	79.69	65.04	-	63.58	66.40	70.95	65.89	-

LSD at 5%	The first season 2006			The second season 2007		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
Bio-fertilization (B.)	2.01	1.91	2.17	1.99	2.89	3.21
N-fertilization (N.)	2.01	1.91	2.17	1.99	2.89	3.21
Interaction (B. × N.)	4.02	3.82	4.34	3.98	5.78	6.42

Table (4). Effect of bio-and urea fertilization and their interaction on the fresh weight of *Mentha piperita* L. in g / plant during the growing seasons of 2006 and 2007.

Harvesting cuts	The first cut					The second cut					The third cut				
N. Fert. / Bio. Fert.	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
The first season 2006															
B_0	58.68	103.49	149.43	129.57	110.29	177.22	213.30	244.97	182.75	204.56	115.86	146.17	165.26	145.80	143.27
B_1	138.47	217.13	246.99	200.57	200.79	248.83	283.88	302.26	274.98	277.49	172.09	215.66	233.80	188.26	202.46
B_2	213.46	263.80	296.01	192.94	241.56	275.89	298.97	350.11	211.76	284.18	163.14	207.89	257.05	234.27	215.59
B_3	160.38	196.63	231.80	195.65	196.12	225.49	243.45	310.04	271.42	262.60	107.24	180.75	214.69	199.98	176.67
Mean	142.75	195.26	231.06	179.68	-	231.86	259.90	301.84	235.23	-	139.58	187.62	217.70	192.08	-
The second season 2007															
B_0	59.37	92.05	139.83	82.16	93.36	86.61	91.33	129.87	120.19	107.00	80.95	118.46	151.23	129.75	120.10
B_1	160.20	176.26	210.17	188.04	183.67	167.30	192.33	228.02	199.79	196.86	148.00	157.65	195.96	148.08	162.42
B_2	129.58	166.27	180.05	171.72	161.91	215.90	221.86	224.09	215.61	219.37	125.73	170.30	204.22	183.05	170.83
B_3	121.95	159.23	174.45	138.72	148.58	137.44	188.63	208.79	190.66	181.38	128.95	149.11	169.80	136.13	146.00
Mean	117.78	148.45	176.12	145.17	-	151.81	173.54	197.69	181.56	-	120.91	148.88	180.30	149.25	-

LSD at 5%	The first season 2006			The second season 2007		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
Bio-fertilization (B.)	8.84	4.49	2.87	7.16	4.04	4.81
N-fertilization (N.)	8.84	4.49	2.87	7.16	4.04	4.81
Interaction (B. × N.)	17.97	8.98	5.74	14.32	8.08	9.62

Table (5). Effect of bio-and urea fertilization on the essential oil percentage in the fresh herb of *Mentha piperita* L. plants during the growing seasons of 2006 and 2007.

Harvesting cuts	The first cut					The second cut					The third cut				
N. Fert. / Bio. Fert.	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
The first season 2006															
B_0	0.598	0.615	0.614	0.618	0.611	0.573	0.584	0.575	0.580	0.578	0.586	0.598	0.588	0.602	0.594
B_1	0.632	0.641	0.635	0.646	0.639	0.631	0.635	0.598	0.633	0.624	0.620	0.645	0.638	0.643	0.637
B_2	0.642	0.646	0.638	0.651	0.644	0.682	0.737	0.725	0.744	0.722	0.594	0.648	0.627	0.634	0.626
B_3	0.641	0.651	0.653	0.657	0.651	0.624	0.684	0.643	0.651	0.651	0.630	0.645	0.639	0.642	0.639
Mean	0.628	0.638	0.635	0.643	-	0.628	0.660	0.635	0.652	-	0.608	0.634	0.623	0.630	-
The second season 2007															
B_0	0.675	0.695	0.632	0.680	0.671	0.682	0.687	0.666	0.688	0.681	0.575	0.621	0.615	0.618	0.607
B_1	0.650	0.710	0.694	0.715	0.692	0..682	0.724	0.714	0.744	0.716	0.586	0.628	0.592	0.625	0.608
B_2	0.725	0.739	0.732	0.728	0.731	0..732	0.746	0.740	0.742	0.740	0.703	0.716	0.710	0.712	0.710
B_3	0.792	0.811	0.805	0.809	0.804	0.784	0.802	0.797	0.793	0.794	0.650	0.695	0.685	0.688	0.680
Mean	0.711	0.739	0.716	0.733	-	0.720	0.740	0.729	0.742	-	0.629	0.665	0.651	0.661	-

Table (6). Effect of bio-and urea fertilization and their interaction on the essential oil yield of *Mentha piperita* L. plants in cc / plant during the growing seasons of 2006 and 2007.

Harvesting cuts	The first cut					The second cut					The third cut				
N. Fert. / Bio. Fert.	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
The first season 2006															
B_0	0.351	0.636	0.917	0.801	0.676	1.020	1.246	1.408	1.060	1.184	0.679	0.874	0.972	0.878	0.851
B_1	0.875	1.392	1.568	1.296	1.283	1.570	1.800	1.810	1.740	1.730	0.067	1.391	1.492	1.210	1.290
B_2	1.370	1.704	1.890	1.256	1.555	1.882	2.203	2.538	1.575	2.050	0.969	1.347	1.612	1.485	1.353
B_3	1.028	1.280	1.514	1.285	1.277	1.410	1.670	1.990	1.770	1.710	0.676	1.166	1.372	1.284	1.125
Mean	0.906	1.253	1.472	1.160	-	1.470	1.730	1.937	1.540	-	0.848	1.195	1.362	1.214	-
The second season 2007															
B_0	0.401	0.640	0.884	0.559	0.621	0.591	0.627	0.865	0.827	0.728	0.465	0.736	0.930	0.802	0.733
B_1	1.040	1.250	1.460	1.340	1.270	1.220	1.430	1.690	1.480	1.460	0.867	0.990	1.160	0.926	0.986
B_2	0.939	1.229	1.318	1.250	1.184	1.472	1.606	1.600	1.604	1.571	0.884	1.219	1.450	1.303	1.214
B_3	0.970	1.290	1.400	1.120	1.200	1.080	1.510	1.660	1.510	1.440	0.838	1.036	1.163	0.937	0.994
Mean	0.837	1.102	1.266	1.067	-	1.091	1.293	1.454	1.356	-	0.764	0.995	1.176	0.992	-

LSD at 5%	The first season 2006			The second season 2007		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
Bio-fertilization (B.)	0.055	0.039	0.029	0.053	0.030	0.034
N-fertilization (N.)	0.055	0.039	0.029	0.053	0.030	0.034
Interaction (B. × N.)	0.110	0.078	0.058	0.12	0.060	0.068