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Effect of Plant Density and Nitrogen Rate on Herbage Yield of Marjoram under Mediterranean Conditions

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Abstract: Field experiments were conducted during the two growing seasons of 2000/01 and 2001/02 in Jordan University of Science and Technology (JUST) campus to determine the effects of plant densities (4, 6, 8 and 14 plants m^{-2}) and nitrogen rates (0, 50, 100 and 150 kg N ha^{-1}) on herbage yield of marjoram. Our results indicated that there was no interaction between nitrogen fertilizer rate and plant density, at the all harvests, indicating that the two factors act independently from each other. The higher plant densities produced higher fresh yield and resulted of significant increase in fresh weight of branches, number of leaves and fresh weight of leaves produced per unit area. The highest plant density (14 plants m^{-2}) gave significantly highest total fresh yield during the both growing seasons. In nutrient deficient (N) soils of the study area, marjoram plants responded significantly to the application of N nitrogen fertilizer rates. The highest rate 150 kg N ha^{-1} gave the highest total fresh yield.

Key words: Marjoram · plant density · nitrogen rate

INTRODUCTION

Marjoram (*Origanum syriacum* L.) an aromatic perennial herb belonging to *Labiatae*, is considered economically one of the most important *Origanum* species cultivated as culinary herbs and for medicinal purposes. Marjoram fresh yield that was produced at all harvests was an important indicator required by farmers to moderator the economic worth of its cultivation. A number of authors have examined the influence of plant density on growth and herbage yield in aromatic plants [1-3]. The effects of plant density on irrigated marjoram have been studied to a much lesser extent, particularly under Mediterranean conditions. On the other hand, nitrogen is generally considered as limiting factor for crop production under Mediterranean condition. A better understanding of plant nitrogen (N) dynamics in marjoram grown with prevailing management practices may help in the design of N management strategies that optimize N utilizationyields. Medicinal plants are produced on a wide range of soil types and in contrasting climatic conditions. Over the course of the last century, Medicinal plants nutrition were studied extensively and revisited as management practices [4, 5]. Thus, N requirements and N use efficiency may differ between locations and years. However there are no published research data on the nitrogen rate and sowing density response of marjoram in the region. The objective of this research work therefore was to investigate the effects of plant density and nitrogen rate on herbage yield of marjoram under Mediterranean conditions.

MATERIALS AN D METHODS

Site description: Field trial was carried out at the field site of Jordan University of Science and Technology (JUST) campus in Northern Jordan [32°34' N latitude, 36°01' E longitude and 520 m altitude] during the two growing seasons of 2000/01 and 2001/02. The location has Mediterranean climate of mild rainy winter and dry hot summer. The soil is fine-loamy, thermic, calcic paleargid.

Land preparation and crop culture: Experimental area was subject to two perpendicular chisel plow passes during the fall season. Field was disked before transplanting time to provide a proper seedbed. Experimental plots of

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2.25X1.8 m were established. The experiments were arranged in a Randomized Complete Block Design (RCBD) and replicated three times. Plowing operations were done, by chisel to a depth of 20 to 25 cm followed by rotary harrow to level soil surface. Four-month-old Marjoram seedlings with an average height of 20 cm were obtained from Nour Al Hussien Foundation. Hardening of seedlings before transplanting was accomplished by exposing them to low temperature and to adapt them to the JUST field condition during winter season. Transplanting was carried out to the experimental plots on 15 May, 2001; each plot was consisted of four rows, the outer ones considered as a border lines. Seedling plants were grown under irrigation using drip irrigation system. However, irrigation intervals and amount of water added were adjusted to maintain optimum moisture availability and the total amount of water was 800 m3/ha during the whole growing season. Three cuttings were done during the first growing season; the first, the second and the third harvest were on 6th July, 18th August and 14th October 2001, respectively. Whereas, the other three cuttings were done during the second season; the first, the second and the third harvest were on 25th May, 18th July and 10th September, 2002, respectively. Cutting height was around 7cm above soil surface.

Treatments: The treatments were factorial combinations of four plant densities (4, 6, 8 and 14 plant m^{-2}) and four rates of nitrogen fertilizer (0, 50, 100 and 150 kg N ha^{-1}). The plant densities were 4, 6, 8 and 14 plants m^{-2} were obtained by have 60, 45, 30 and 15cm between plants of the same row,respectively, while distance between rows was kept constant at 75 cm for all treatments. Nitrogen fertilizer was added in the form of Urea (NH2) Co (46% N) at transplanting time and a day after each harvest, all of which resulted in a total seasonal rate of (0, 50, 100 and 150 kg ha^{-1}). Nitrogen fertilizer treatments varied according to rate of application and were devised to provide for control with no fertilizer and various rates of split application.

Measurements: During both growing seasons, measurements and samples were collected from plants labeled randomly from the two central rows of each plot to avoid any border effect. The following parameters were recorded: total fresh weight per m^2 and total fresh weight of leaves (g $plant^{-1}$).

Statistical Analysis: The data was analyzed as RCBD with two factors (plant density and nitrogen fertilizer rate). The means were separated by using Fisher least significant differences (LSD) according to Steel and Torri [6] by using MSTAT-C software (Michigan State University, 1988.

RESULTS AND DISCUSSION

The effects of plant density and nitrogen fertilizer on yield of marjoram were studied at JUST during 2000/2001 and 2001/2002 growing seasons. The data presented are the results of F-tests performed to examine the main and interaction effects. There was no interaction between the two factors (density and nitrogen rate) at all harvests for all characters.

Total Fresh yield: Marjoram total fresh yield is an important indicator required by growers to judge the economic value of its cultivation. Comparing marjoram fresh yield at three harvest dates for each season, there was an increase in fresh yield with age (Tables 1 and 2). At first harvest, plants developed the root system, having little foliage and thus very low yield was obtained. Similar results were obtained by Putievsk and Basker [7] and Abu Al-Rub [8]. After the first harvest, plants were well established, produced good canopy and thus an increase in yield was obtained (Table 1). After the second harvest (two months), another flush of leaves was produced but it was lower than first harvest. Because the plant was at the flowering stage and most of the reserved food was directed toward the production of flowers [9].Fresh yield at the third harvest (562.0 g m^{-2}) was much higher than that of the second (365.0 g m^{-2}), which in turn was higher than that of the first (100.5 g m^{-2}). The increase in fresh yield after the first harvest was probably due to the increase in number of branches. A similar trend was obtained at the second season but the differences were lower than those of the first season. The increment in biomass of plant was increased until mid summer (from 100.5 to 365.0 g m^{-2}) after that the increment in biomass was decreased (from 365.0 to 562.0 g m^{-2}) this is attributed to the lower temperature and the shorter photoperiod during autumn regrowth as marjoram is a long day plant [10]. Total fresh weight decreased slightly on the late of the growing season. This could be attributed to the withering of stems and inflorescences or the withering and falling of the basal leaves at this stage of growth.

Plant density effect: Fresh yield significantly increased as plant density was increased in both second and third harvest during the first season (Table 1). However,

Table 1: Effect of planting density and nitrogen fertilizer rate on the total fresh weight (g\m^2) of marjoram at three harvests on the first season 2000/01

Nitrogen Fertilizer (kg ha^{-1})	Planting density (plant m^{-2}) 14	8	6	4	Mean
First Harvest					
0	81.45	83.26	76.56	87.16	82.11
50	95.67	98.90	99.82	94.77	97.29
100	106.84	106.28	109.71	105.69	107.13
150	115.73	109.50	119.69	116.75	115.42
Mean	99.92	99.49	101.45	101.09	LSD=5.75
Second Harvest					
0	332.89	328.79	425.10	323.74	327.63
50	366.97	356.29	345.33	344.09	353.17
100	384.57	379.76	398.63	368.97	382.98
150	412.23	411.46	376.91	384.03	396.16
Mean	374.16	369.07	361.49	355.21	LSD=13.8
Third Harvest					
0	514.78	525.55	517.65	506.36	516.08
50	564.59	548.31	539.05	529.65	545.40
100	589.52	382.56	578.94	564.01	576.76
150	638.90	623.04	575.85	574.23	605.76
Mean	576.95 ab	569.87 b	552.87 c	548.31 a	LSD=11.8
Total Yield					
0	929.12	938.60	934.44	953.26	938.85
50	1027.23	1003.50	984.50	1004.51	1004.86
100	1080.93	1068.60	1053.95	1074.67	1069.54
150	1166.96	1144.01	1105.78	1130.68	1136.86
Mean	1051.06	1038.68	1019.59	1040.78	LSD=14.75

Table 2: Effect of planting density and nitrogen fertilizer rate on the total fresh weight (g\m^2) of marjoram at three harvests on the second season 2001/02

Nitrogen Fertilizer (kg ha^{-1})	Planting density (plant m^{-2}) 14	8	6	4	Mean
First Harvest					
0	388.80	413.20	417.48	389.82	402.33
50	403.47	392.66	409.89	413.05	404.77
100	440.01	433.36	398.94	436.68	427.25
150	427.81	459.00	468.38	456.51	452.93
Mean	415.02	424.56	423.67	424.02	LSD=12.4
Second Harvest					
0	575.64	553.46	553.92	556.82	559.96
50	563.10	570.33	575.12	571.16	569.93
100	576.98	560.58	580.24	578.50	574.08
150	586.16	589.61	590.88	594.77	590.36
Mean	575.47	568.50	575.04	575.32	LSD=13.9
Third Harvest					
0	586.82	606.46	587.17	576.23	589.17
50	601.02	602.13	592.96	601.02	599.28
100	675.41	623.86	627.08	625.86	633.55
150	646.89	644.02	640.12	636.90	641.98
Mean	623.03	619.12	611.83	610.00	LSD=13.8
Total Yield					
0	1517.93	1506.46	1525.24	1542.87	1523.12
50	1567.58	1565.14	1577.97	1585.14	1573.96
100	1641.06	1631.04	1639.59	1641.04	1638.18
150	1694.19	1793.64	1700.05	1688.19	1719.02
Mean	1605.19	1624.07	1610.71	1614.02	LSD=37.73

14 plants per m^2 gave the highest yield and was 374.2 g m^{-2} and significantly higher than 4 plants m^{-2} by 5.3 %. No significant differences were found between the other densities. Similar trend was observed for the effect of plant density on third harvest, the highest density (14 plants m^{-2}) gave significantly the highest fresh yield than other densities and was 576.95 g m^{-2}. The increase was 4.4 % over 6 plants m^{-2} and 5.2 % over 4 plants m^{-2}. No significant differences were found when 8 plants m^{-2} was used. Several investigators working in different crops in different parts of the world reported similar results; [1, 2,8]. These studies were reported through their work with, *Majorana hortensis, Mentha* species and *Origanum syriacum*, respectively. The increase in total fresh weight may be due to increase in plant density, which was reflected as an increase in the number of basal branches, total branches, leaves number and yield. Consequently the total yield per unit area was increased, especially in absence of competition between plants for water and nutrients [8]. The absence of significant effect of plant density on fresh yield during the second season (Table 2) was probably due to the interplant competition among plants for water, nutrients and light.

Nitrogen Effect: The differences in total fresh weight at different nitrogen rate treatments were highly significant (P=0.01). The highest fresh weight recorded (468.9 g m^{-2}) was obtained from the highest nitrogen rate (150 kg N ha^{-1}), as the nitrogen rate increased the total weight was increased. These results agreed with those reported by Singh *et al.* [11], Zljazkov *et al.* [12], Jeliazkova *et al.* [13], through their work with mint species, peppermint *Mentha piperita* wild Egyptian oregano *Origanum syriacum* L. var. *aegyptiacum* Tackh, peppermint *Mentha piperita*, sweet marjoram *Majorana hortensis* and *Tagetes minuta.* Fresh yield significantly increased as nitrogen rate was increased in both seasons (Tables 1 and 2). However in the second harvest, 150 kg N ha^{-1} produced the highest yield, it was 396.2 g m^{-2} and significantly higher than 50 kg N ha^{-1} by 12.2 % and 0 kg N ha^{-1} by 20.9 %. No significant differences were found between 100 and 150 kg N ha^{-1}.Concerning harvest number three, the highest nitrogen rate (150 kg N ha^{-1}) gave significantly the highest fresh yield than other densities and was 605.76 g m^{-2}. The increase was 5.0 % over 100 kg N ha^{-1}, 14.3 % over 50 kg N ha^{-1} and 17.4 % over 0 kg N ha^{-1}. With regard to, harvest number four (harvest 1 in the second season 2002), the highest nitrogen rate

(150 kg N ha^{-1}) gave significantly the highest fresh yield and was 452.93 g m^{-2} and significantly higher than100 kg N ha^{-1} by 6.0 %, 50 kg N ha^{-1} by 12.0 % and 0 kg N $ha^{-1}$by 12.6 %.No significant differences were found when 0 and 50 kg N ha^{-1} were used. With regard to, harvest number five, the highest nitrogen rate (150 kg N ha^{-1}) gave significantly the highest fresh yield and was 590.36 g m^{-2} and significantly higher than100 kg N ha^{-1} by 2.8 %, 50 kg N ha^{-1} by 3.6 % and 0 kg N $ha^{-1}$by 5.4 %. With regard to, harvest number six, the highest nitrogen rate (150 kg N ha^{-1}) gave significantly the highest fresh yield and was 641.98 g m^{-2} and significantly higher than 50 kg N ha^{-1} by 7.1 % and 0 kg N $ha^{-1}$by 9.0 %. No significant differences were found when 0 and 50 kg N ha^{-1} or 100 and 150 kg N ha^{-1} were used. Nitrogen fertilization significantly affected total weight of marjoram plants in all cuttings in both seasons. Plant biomass responded linearly to nitrogen application, because the nitrogen fertilization supply the plant with the most essential element for the plants, this leads to the production of extra protein and allows the leaves of the plant to grow larger and hence to have larger surface available for synthesis [14]. The absence of further significant increase in total fresh yield by adding 150 kg N ha^{-1} over adding 100 kg N ha^{-1} in harvest two during the first season and harvest three during the second season may be due to the significant impact of this element on the interference relationship between marjoram and weed, increasing interspecific competition in *Origanum* by weeds. Thus, loss in marjoram yield due to those weeds could be expected to be greater as nitrogen fertilization increased. Payan *et al.* [15] working with cilantro (*Coriandrum sativum*) reported similar results.

Leaves fresh weight: Leaves are the main edible part of marjoram plant, used excessively for human consumption; thus their weight is a good indicator on plant productivity. Leaves fresh weight per plant at the third harvest (58.176 g m^{-2}) was much higher than that of the second harvest (42.862 g m^{-2}) by 71.91%, which in turn was higher than that of the first harvest (12.040 g m^{-2}) by 26.32 %. The increase in fresh weight after the first harvest was probably due to the increase in number of branches developed (Data not shown). A similar trend was obtained at the second season but the differences were lower than those of the first season (47.938, 66.393 and 70.559 g m^{-2}, at the first, second and third harvest, respectively.

Table 3: Effect of planting density and nitrogen fertilizer rate on total fresh weight of leaves (g $plant^{-1}$) of marjoram at three harvests on the first season 2000/01

Nitrogen Fertilizer	Planting density (plant m^{-2})				
(kg ha^{-1})	14	8	6	4	Mean
First Harvest					
0	5.609	9.068	10.167	15.120	9.99
50	6.189	10.580	12.598	17.603	11.74
100	6.664	11.421	13.815	19.600	12.87
150	7.176	12.038	13.670	20.590	13.36
Mean	6.40	10.78	12.73	18.22	LSD=1.51
Second Harvest					
0	19.835	34.228	44.110	64.935	40.78
50	20.398	35.626	46.560	67.670	42.52
100	20.964	36.654	47.118	69.583	43.58
150	21.536	37.178	48.597	70.630	44.48
Mean	20.71	35.92	46.59	68.21	LSD=0. 89
Third Harvest					
0	27.029	46.540	61.042	90.135	56.187
50	27.592	48.045	63.067	92.585	57.822
100	28.089	48.891	63.830	95.378	58.836
150	28.601	49.538	65.102	95.545	59.697
Mean	27.828	48.254	63.260	93.365	LSD=0.78

The increment in leaves fresh weight per plant in the first growing season was increased until mid summer (from 12.040 to 42.862 g m^{-2}). After that the increment in leaf weight was decreased (from 42.862 to 58.176 g m^{-2}) this was a result of increasing of total number of leaves per plant early in the season later on, it was decreased (Data not shown). This was probably due to the lower temperature and the shorter photoperiod during autumn regrowth as marjoram is a long day plant [10].

Plant density effect: Leaves weight per plant has been significantly (P=0.05) affected by planting density. The lowest density (4 plants m^{-2}) gave the highest weight per plant for all harvests in both seasons. As planting density decreased, the weights of leaves per plant in both seasons were increased (Table 3 and 4). Several previous studies indicated similar results. These studies reported by Piccaglia, *et al.* [10] and Arisha and Bardisi [14], through their work with sweet marjoram, peppermint and common bean, respectively. The simulative effect of wide spacing (low plant density) on morphological characters, such as leaves weight per plant, might be due to more exposing to solar radiation, meanwhile, prevent stem etiolation and consequently gave more branching and higher number of leaves per plant due to large amounts of nutrients available to each plant. With regard to, the leaves dry and fresh weights (per unit area), results show that, as number of plants per unit area decreased, the yield

Table 4: Effect of planting density and nitrogen fertilizer rate on total fresh weight of leaves (g plant^{-1}) of marjoram at three harvests on the second season 2001/02

Nitrogen Fertilizer (kg ha^{-1})	Planting density (plant m^{-2}) 14	8	6	4	Mean
First Harvest					
0	21.950	41.466	53.291	70.875	46.89
50	23.104	39.171	49.565	72.573	46.10
100	24.166	49.526	53.250	77.808	51.18
150	25.239	43.701	55.588	74.550	49.77
Mean	23.61	41.38	52.92	73.82	LSD=6.01
Second Harvest					
0	30.507	52.592	69.153	111.615	65.96
50	31.431	54.928	71.570	104.905	65.70
100	31.829	55.131	71.653	106.956	66.39
150	32.432	55.708	73.808	108.073	67.50
Mean	31.55	54.59	71.54	107.88	LSD=1.02
Third Harvest					
0	31.676	56.576	73.345	108.038	67.40
50	33.246	56.689	74.768	110.630	68.83
100	34.241	59.796	77.062	122.468	73.39
150	34.610	60.424	78.895	116.370	72.57
Mean	33.46	58.37	76.01	114.37	LSD=3.59

Table 5: Effect of planting density and nitrogen fertilizer rate on total fresh weight of leaves (g m^{-2}) of marjoram at three harvests on the first season 2000/01

Nitrogen Fertilizer (kg ha^{-1})	Planting density (plant m^{-2}) 14	8	6	4	Mean
First Harvest					
0	78.53	72.54	65.50	60.48	69.16
50	86.65	84.64	75.59	70.41	79.32
100	93.30	91.37	82.89	78.40	86.49
150	100.47	96.30	82.02	82.36	90.29
Mean	89.73	86.21	76.40	72.91	LSD=3.86
Second Harvest					
0	277.69	273.82	264.66	259.81	269.00
50	285.57	285.01	279.36	270.68	280.65
100	293.49	293.23	282.71	278.33	286.94
150	301.50	297.42	291.58	282.52	293.26
Mean	290.06	287.37	279.58	272.84	LSD=2.8
Third Harvest					
0	378.40	372.32	366.25	360.54	369.38
50	386.29	384.36	378.40	370.34	379.85
100	393.25	391.13	382.98	381.51	387.22
150	400.42	396.30	390.61	382.18	382.38
Mean	389.59	386.03	379.56	373.46	LSD=3.18

of leaves was subsequently decreased (data not shown); this was true to certain extent. Fresh yield of leaves at the second harvest during the first season at 14 plant density was 290.06 g m^{-2}. It was higher than 6 plant m^{-2} by 3.61 % and than 4 plant m^{-2} by 5.94 %. Similarly, at the third harvest, the highest density (14 plants m^{-2}) gave higher fresh yield of leaves than 8 plants m^{-2} and by 0.91 %, than 6 plants m^{-2} by 2.57 % and than 4 plants m^{-2} by 4.14 % (Table 5).

Nitrogen effect: Highly significant differences (P=0.01) in leaves dry and fresh weight were recorded between the nitrogen rate treatments. As nitrogen rates increased both dry and fresh weights increased, these results agreed with Zheljazkov *et al.*[12] and Arisha and Bardisi [14]. Data presented in table 3 illustrated that increasing nitrogen level up to 150 kg ha^{-1} significantly increased leaf fresh weight per plant in the first growing season at the two harvesting dates; harvest two and harvest three. However, this trend was not so clear in the second growing season (Table 4). The stimulating effect of nitrogen on morphological characters of marjoram plants may be due to that nitrogen increases the meristematic activity of the plant tissues; also nitrogen plays an important role in building protein molecules. The response of the plant characteristics to the rates of nitrogen fertilization may due to the increase ability of the plant to produce the dry matter and/or increase meristemic cells growth and retardation of cell differentiation.

CONCLUSIONS

Marjoram (*Origanum syriacum* L.) is a perennial herb, grows wild in hilly regions and under cultivation it can be harvested repeatedly. It has extensive domestic uses besides its uses as herbal remedies by infusions. The effect of four plant densities (14, 8, 6 and 4 plant m^{-2}) and four nitrogen fertilizer rates (150, 100, 50 and 0 kg N ha^{-1}) on fresh weight of leaves and of the whole plant were investigated for marjoram grown in the field under irrigation conditions.

The following conclusions can be drawn from the study:

- There was no interaction between nitrogen fertilizer rate and plant density, at the all harvests, indicating that the two factors act independently from each other.
- Higher plant densities produced higher fresh yield and resulted of significant increase in fresh weight of branches, number of leaves and fresh weight of leaves produced per unit area. The highest plant density (14 plants m^{-2}) gave significantly highest total fresh yield during the both growing seasons.
- In nutrient deficient (N) soils of the study area, marjoram plants responded significantly to the application of N nitrogen fertilizer rates. The highest rate 150 kg N ha^{-1} gave the highest total fresh yield.

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