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Bangladesh J. Sci. Ind. Res. **44(1)**, 137-145, 2009

Short Communication

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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Response of Different Levels of Nitrogen Fertilizer and Water Stress on the Growth and Yield of Japanese Mint (*Mentha Arvensis* L.)

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Abstract

The response of mint (*Mentha arvensis* L.) to different levels of nitrogen and different levels of water stress were investigated. Relative performances of different growth and yield parameters such as plant height and fresh weight of shoot as influenced by N-fertilizer and water stress were investigated. Pot experiment was conducted with five levels of N treatments- 0, 60, 120, 180, and 240 kg N ha^{-1} and four levels of water conditions 100, 75%, 50 and 25% field capacity. Plant growth (height and fresh herb (product) was affected by water stress and different N levels. At 100% field capacity, the highest dose of N- (240kg N/ha) Produced maximum plant height (46.33 cm) and fresh herb product. Lower dose of N treatment decreased the plant height and herb product. Compared to 100% field capacity the fresh herb product was drastically decreased from 103.54 -31.67 g pot^{-1} at 25% field capacity.

Key words: *Mentha arvensis,* Water stress, N-fertilization, Yield of mint.

Introduction

Mints are an important group of plants belonging to the family Labiate and the genus *Mentha.* Although, large-scale mint cultivation has come up only recently, mankind from ancient times has used these plants. *Mentha arvensis* popularly known as Japanese mint is one of the most important medicinal and aromatic plants. This is a very precious essential oil bearing crop in the world and a potential source of natural menthol. Menthol is extensively used in the pharmaceutical, cosmetic and perfumery industries (Atal and Kapur, 1982). Among the various agronomic practices used for higher production of herbage and oil adequate application of nitrogen plays an important role. The response of Japanese mint to different levels of nitrogen fertilizer differs remarkably because of the different availability and nutrient absorption efficiency of

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the crop (Atal and Kapur,1982).

Japanese mint is well adapted to climatic conditions in tropical and subtropical areas. A climate with adequate and regular rainfall and good sunshine during the period of its growth ensures a good yield. Mint is succulent crop that has a high water requirement during its active growth period in summer month. The water requirements of mints differ from location to location depending on soil type, soil fertility status and climatic factors. The favourable effects of irrigation in enhancing herb and essential oil yields of various mints species have been reported (Clark and Menary, 1980); (Singh *et al.,* 1982). But water stress in plants is one of the major factors limiting crop growth. Both high soil moisture content and high soil moisture tension (water stress) decrease the growth, herb and essential oil yields of mints.

Growth of Japanese mint (as revealed from height, number of branches, number of leaves, leaf area and herbage increment) was found to increase linearly up to a limit of N fertilizer application. But this limit varied from 60 kg N/ha to 225 kg N/ha in Indian reports (Gulati and Duhan, 1975); (Sarma *et al.,* 1975); (Shelke and Morey, 1978); (Chandra *et al.,* 1983); (Singh,1983). Application of nitrogen at rates lower or higher than these respective limits caused a reduction in growth and yield.

It is well established that water stress impairs numerous metabolic and physiological processes in plants such as nutrient uptake and transport (Mengel and Kirkby, 1996). Under water stress condition, the N-uptake by mint plant is considerably low. As a result, the vegetative growth of plant, their leaves area, total plant biomass production, leaves number, root length and root density decreases. It has been reported that water stress significantly decrease plant height, leaf area index (LAI), dry matter accumulation and oil content.

The effects of soil moisture stress on the uptake of nitrogen by different crops were reported to differ and even were opposite some times (Campbell *et al.,* 1977). So it appeared to be interesting to find out the effect of water stress and different rates of N application on the growth and yield of Japanese mint (*Mentha arvensis* L.).

Materials and Methods

The experiment was conducted in the net house in the premises of the Department of Soil, Water and Environment, University of Dhaka.

Planting material

The planting material (suckers of CIMAP/Hybrid 77) was brought from the Research field of the Bangladesh Council of Scientific and Industrial Research (BCSIR), Chittagong and suckers were transplanted after proper soil preparation The crops were hervested at 140 days after transplantation when the plants were at full blossom. The experiment was carried out from March 11, 2002 to July 28, 2002.

Experimental soil media

The soil samples collected for the study belong to the ‘‘Sonatala series’’. Bulk soil samples from 0-15 cm were collected from Unarpur in the District, of Mymensing. According to Reconnaissance Soil Survey Report of Mymensing district, Sonatala series textured, ridge soils developed in Brahmaputra alluvium. These soils have a mixed dark comprises intermittently and seasonally flooded, imperfectly to poorly drained, medium yellowish brown to olive-brown and grey, friable, silt loam subsoil with usually moderate prismatic structure and grey ped cutans. The morphological properties of the soil are presented in Table I.

Physical and chemicals analysis of soil plant samples

Soil samples were air dried and sieved by a 2mm sieve and stored for physical and chemical analysis. Moisture at field capacity and wilting point were determined by pres sure membrane apparatus at 0.33 bar and 15 bar, respectively. The collected plant samples were dried at 65^{0}C and dry weights were

Table I. Morphological characteristics of the soil

Morphological Characteristics	
1. Soil series	Sonatala
2. Soil tract	Brahamaputra alluvium
3. Topography	Summit of very gently undulating ridge
4. Drainage	Intermittent flooded, imperfectly to poorly drained.
5. Present land use	Mainly Aus, Jute and rabi crops.
6. Land capability subclass	IIDw
7. General soil type	Non calcareous Gray Floodsplain Soils
8. FAO-UNESCO soil subunit	Areni-Eutric Gleysols
9. USDA Soil Taxonomy	Inceptisols
Order	Aquepts
Suborder	Haplaquepts
Great group	Aeric Hapaquepts
10. Limitations	Droughtiness late in dry season, intermittent wetness in rainy season.

Table II. Physical and chemical properties of the soil

Properties	**Values**
1. Moisture at field capacity	25.47%
2. Moisture at wilting point	5.2%
3. Particle density	2.17 g/cc
4. Particle size distribution	
Sand	36.09%
Silt	56.08%
Clay	07.73%
5. Textural class	Silt loam
6. pH (soil :water= 1:2.5)	5.4
7. EC (soil :water= 1:2)	0.1 mmhos/cm
8. Organic carban	0.71%
9. Organic matter	1.2%
10.Cation exchange capacity (CEC)	10.82meq/100g soil
11. Total nitrogen (N)	0.092%
12. Total phosphorus (P)	0.06%
13. Total potassium (K)	0.152%
14. Total sulfur (S)	0.04%
15. Total sodium (Na)	0.034%
16. C:N ratio	7.72

recorded. Then the samples were ground in a grinder and preserved in plastic bottle for analysis. Standard methods were followed to analyze the soil and plant samples. The physical and chemical properties of the soil are presented in Table II.

Experimental setup

The experiment was divided into two sections e.g. experiment-1 and experiment-2. In experiment-1, only one nitrogen level (60 kg N/ha) was used under 4 soil moisture levels W_{100} (100% field capacity), W_{75} (75% field capacity), W_{50} (50% field capacity) and W_{25} (25% field capacity). In experiment-2, five N level N_0 (without nitrogen), N_{60} (60 kg N/ha), N_{120} (120 kg N/ha), N_{180} (180 kg N/ha) and N_{240} (240 kg N/ha) were used for only two soil moisture levels (100% and 50%). All treatments had three replications. The pots (18cm diameter and 15 cm depth) were arranged in a completely randomized design. Nitrogen was added in three installments based dose (during pot preparation), at 40 days after transplanting (DAT), 80 DAT. All the pots were kept at field capacity till 60 DAT and after that water status was maintained according to the treatments.

5 kg of air-dried soil samples was taken in each pot. During pot preparation, Triple Super Phosphate (TSP) at a rate of 40 kg P/ha and Muriate of Potash (MP) at a rate of 40 kg K/ha were applied as a source of P and K in the soil. Urea was applied as N-treatments and 1/3 amount of each N treatment was used as basal dose. About one litter (1L) of tap water was added in each pot during the pot preparation and then the pots were kept for over night. Every pot was marked in accordance with the treatments.

Table III. Height (cm) of mint plants with ± SEM under different treatment combinations.

	Days after transplantation (DAT)		
Treatment	**60**	**90**	**120**
$W_{100}N_0$	31.00 ± 0.82	37.33 ±2.05	41.33 ±0.94
$W_{100}N_{60}$	31.33 ± 0.47	42.00 ±2.16	43.67 ±2.05
$W_{100}N_{120}$	32.67± 0.47	35.66 ±1.90	44.67 ±3.39
$W_{100}N_{180}$	34.00± 0.82	37.00 ±1.41	41.00 ±4.32
$W_{100}N_{240}$	34.67± 0.47	40.67 ±1.24	46.33 ±4.49
$W_{50}N_0$	30.67 ± 0.47	33.33 ±1.25	36.67 ±1.69
$W_{50}N_{60}$	31.00 ± 0.00	33.67 ±0.47	37.00 ±0.81
$W_{50}N_{120}$	32.33 ± 0.47	35.33 ±1.69	37.33 ±1.24
$W_{50}N_{180}$	32.67 ± 0.47	35.00 ±2.16	38.67 ±1.69
$W_{50}N_{240}$	33.00± 0.00	35.33 ±1.24	38.00 ±1.63

Treatments were made as follows

N_0= Nitrogen 0 kg/ha
N_{60}= Nitrogen 60 kg/ha
N_{120}= Nitrogen 120 kg/ha
N_{180}= Nitrogen 180 kg/ha
N_{240}= Nitrogen 240 kg/ha

The pots were irrigated to maintain 4 constant soil moisture levels as follows

W_{100}= Soil supplied with tap water to attain 100% field capacity (F.C)
W_{75}= Soil supplied with tap water to attain 75% field capacity
W_{50}= Soil supplied with tap water to attain 50% field capacity
W_{25}= Soil supplied with tap water to attain 25% field capacity

The treatment combinations for N-effects were :
$W_{100}N_0$= 0 kg N/ha at 100% F.C.
$W_{100}N_{60}$= 60 kg N/ha at 100% F.C.
$W_{100}N_{120}$= 120 kg N/ha at 100% F.C.
$W_{100}N_{180}$= 180 kg N/ha at 100% F.C.
$W_{100}N_{240}$= 240 kg N/ha at 100% F.C.
$W_{50}N_0$= 0 kg N/ha at 50% F.C.
$W_{50}N_{60}$= 60 kg N/ha at 50% F.C.
$W_{50}N_{120}$= 120 kg N/ha at 50% F.C.
$W_{50}N_{180}$= 180 kg N/ha at 50% F.C.
$W_{50}N_{240}$= 240 kg N/ha at 50% F.C.

The treatment combinations of water stress were :

$W_{100}N_{60}$= 60 kg N/ha at 100% F.C
$W_{75}N_{60}$= 60 kg N/ha at 75 % F.C.
$W_{50}N_{60}$= 60 kg N/ha at 50% F.C.
$W_{25}N_{60}$= 60 kg N/ha at 25% F.C.

Statistical analysis:

Probability values were derived using type III sum of squares (SS) from a one way anova model with factors of nitrogen level, water stress and their interaction on plant height using SPSS for windows Version 11. (SPSS, 2001).

Table IV. Plant height and fresh herb product of mint plants with ± SEM under different soil moisture conditions.

Treatment	Plant height (cm) Days after transplantation (DAT)			Fresh herb (g/pot)
	60	90	120	
$W_{100}N_{60}$	31.33 ± 0.47	42.00 ±2.16	43.67 ±2.05	103.54 ±22.08
$W_{75}N_{60}$	31.50 ± 0.40	35.67 ±1.25	39.33 ±0.47	59.63 ±1.60
$W_{50}N_{60}$	31.00± 0.00	33.67 ±0.47	37.00 ±0.81	59.43 ±12.51
$W_{25}N_{60}$	30.33 ± 0.47	30.67 ±0.94	31.00 ±0.82	31.67 ±2.08

Table V. Analysis of variance for the height of mint plant at 60, 90 and 120 DAT under different treatment combination.

S.V	d.f	SS	M.S	F calc.
		02.87	01.43 a	05.03*
Replication	2	08.07	04.03 b	0.795 ns
		40.07	20.03 c	01.39 ns
		48.67	05.41 a	18.98 **
Treatment	9	205.64	22.85 b	04.51 **
		306.80	34.08 c	02.37 ns
		04.80	04.80 a	16.84 **
Water stress (A)	1	108.30	108.30 b	21.36 **
		192.54	192.54 c	13.40 **
		41.33	10.33 a	36.24 **
Nitrogen (B)	4	55.14	13.78 b	02.72 ns
		25.47	06.37 c	00.44 ns
		02.54	0.63 a	02.23 ns
AXB	4	42.20	10.55 b	02.08 ns
		88.79	22.197 c	01.55 ns
		05.13	0.285 a	
Error	18	91.26	05.07 b	
		258.60	14.36 c	
		56.67 a		
Total	29	304.97 b		
		605.47 c		

a represents 60 DAT , b represents 90 DAT and c represents 120 DAT

**Significant at 1% level, *Significant at 5% level, ns not Significant

Results and Discussion

In this study relative performances of different growth and yield parameters such as height of the plants at regular intervals and weight of fresh shoot as influenced by N-fertilizer and water stress have been recorded. The results obtained from this study are presented in the following sections. Data presented here are the mean of three replications.

Plant height

The analysis of variance for the height of mint plant at 60, 90 and 120 DAT under different treatment combinations has been presented in Table V. Plant height varied from 30.67cm to 46.33 cm. Height of mint plant was significantly affected by various levels of N-fertilizers. Generally, plant height was increased as the level of nitrogen increased.

The maximum plant height 46.33 cm was obtained at 120 DAT with the treatment of $W_{100}N_{240}$ (240 kg N/ha^{-1} Under 100%) F./C) that significantly differed from other treatments. Under the same soil moisture condition plant height was increased as the level of nitrogen increased. (Rahman, 1999) reported that plant height of mint was increased as the level of nitrogen increased from 0 to 200 kg ha^{-1}. However, further increase in nitrogen did not always increase plant height.

Table IV shows plant height and fresh herb products under different soil moisture conditions. At 100% field capacity condition

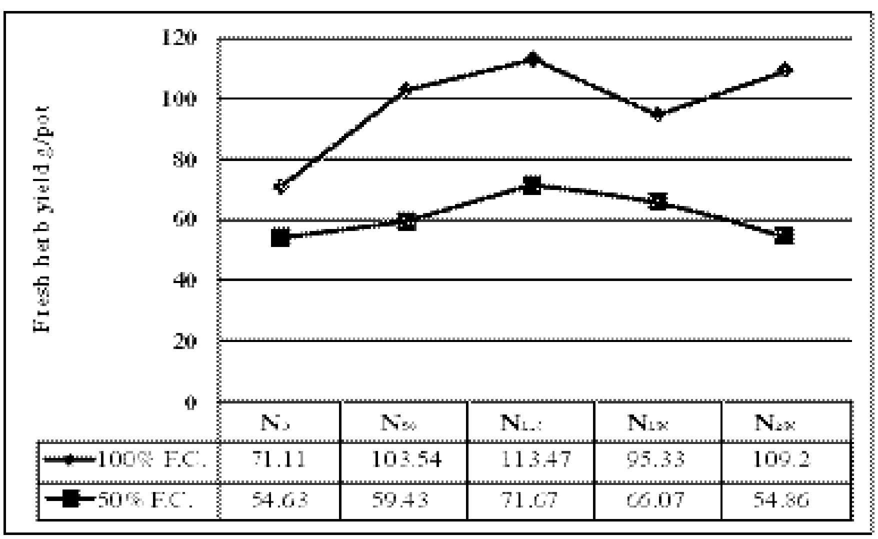

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Figure 1 : Fresh herb product of mint plants at 100 and 50% field capacity.

plant height varied from 41.33 cm to 46.33 cm while at 50% field capacity condition it varied from 36.67 cm to 38 cm. The lowest plant height was found in the treatment of

25% field capacity. (Arnon and Gupta, 1995) stated that the reduction in plant height due to water stress.

Fresh herb product

Fresh herb yield was measured at harvesting. Mean values of fresh herb yield (fresh leaf + stem) under different treatments are shown in Fig. 1. Values ranged from 54.63 ($W_{50}N_0$) to 113.47 ($W_{100}N_{120}$) g/pot. In most instances fresh herb yield was increased with increasing nitrogen rates. The maximum value (103.54g) of fresh herb product was obtained with the treatment of 120 kg N/ha. Generally herb product was increased as the level of nitrogen increased from 0 to 120 kg/ha.

Fresh herb product was drastically decreased due to water stress (Table IV). The lowest yield (31.67g) was obtained at 25% field capacity.

The variance analysis indicated that there were significant differences among the treatment combinations used in this experiment (Table V). However, there was no nitrogen x water stress treatment interaction for plant height at different DAT.

Conclusion

Data shows that the detrimental effect of water stress on herb yield can not be compensated with high nitrogen doses. Data on this experiment may be helpful develop the cultivars to be cultivated under water stress conditions or water limiting areas. So further research is necessary in this direction.

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Received : August, 26, 2008;
Accepted : February, 11, 2009.