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Effect of Nitrogen and Phosphorus Fertilizers on Growth and Oil Yield of Indigenous Mint (*Mentha longifolia* L.)

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Abstract: A field study was conducted to determine the effect of different rates of application of N and P fertilizers at different time intervals on the growth and essential oil yield of indigenous mint (*Mentha longifolia*) during 2000-2001 and 2001-2002 cropping seasons. The response of growth and essential oil yield of crop to different fertilizer treatments was consistent in both the years. The Leaf Area Index (LAI) increased significantly with the increasing the rate of fertilizer application from 75/50 kg N/P_2O_5/ha (F_4) to 100/75 kg N/P_2O_5/ha (F_5) than the control and the lower rates of fertilizer application. Application of 75/50 kg N/P_2O_5/ha significantly increased the total dry matter and essential oil yield. Essential oil yield increased with the corresponding increase in the total number of leaves/plant and leaf area. The time of fertilizer application did not affect significantly the essential oil yield in both the cropping seasons. Overall, the essential oil yield of indigenous (wild) mint was maximum in F_4 treatment (75/50 kg N/P_2O_5/ha) under the agro-ecological conditions of Al-Hassa, Saudi Arabia.

Key words: Nitrogen, phosphorus, oil contents, leaf area index, indigenous, plant growth, dry-matter

INTRODUCTION

Mint is a perennial plant and productive up to 15 years. Primarily, it is grown for oil production from its leaves. The life span of a commercial mint field is 3-5 years and mainly depends on genetic and environmental factors.

Generally the growth, development and the quality of aromatic plants are affected by the genetic background, environment and cultivation practices as well as the processing and storage of plant tissues (Clark and Menary, 1980a, b). The concentration of secondary metabolites such as essential oils in plants result from their continuous formation and breakdown during plant growth. The total oil accumulation depends on the genetic composition of the plant and it varies between genera and species (Franz *et al*., 1984).

However, for a newly introduced crop, it is important to assess the appropriate production technology under different environments. Among many plant growth factors, the nutritional requirements of the crop are considered to be the most important factor (Singh *et al*., 1989). Nitrogen (N) and phosphorus (P) fertilizers play a vital role in enhancing crop yield. A high rate of N application increases leaf area development and increases overall crop assimilation, thus contributing to increased seed yield (Bhardwaj and Kaushal, 1989). Patra *et al*. (1993) reported that straw mulching significantly affected the fertilizer nitrogen use efficiency and essential oil yield in Japanese mint (*Mentha arvensis* L.) Alkire and Simon (1996) and Piccaglia *et al*. (1993) concluded that N increases essential oil yield of peppermint by influencing a variety of growth parameters such as tillers per plant, the total plant dry weight and the Leaf Area Index (LAI). The purpose of this research was to evaluate the response of indigenous mint *Mentha longifolia* to different rates of N and P fertilizers applied in split doses at various growth stages of plant.

MATERIALS AND METHODS

The experiment was carried out on indigenous mint at the Agricultural and Veterinary Training and Research Station, King Faisal University, Al-Hassa, Saudi Arabia during 2000-2002 seasons. A split plot design was used, with the time of fertilizer application as the main plot and different fertilizer rates as the sub-plots. The experimental treatments were replicated four times. The net plot size was 2.70×5.00 m (13.50 m^2). The detail of experimental treatments is given in Table 1. Soil samples were analyzed for physical and chemical properties before planting in both the years (Table 2). The climatic conditions during the experiment period are presented in Table 3.

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Table 1: Detail of nitrogen and phosphorus experimental treatments

Treatments	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	Time of fertilizer application
T_1	100	75	2 weeks after sowing
T_2	50	75	2 weeks after sowing
	50	-	45 days after sowing
T_3	50	75	2 weeks after sowing
	50	-	At flowering stage
F_0	0	0	
F_1	50	0	
F_2	0	25	
F_3	50	25	
F_4	75	50	
F_5	100	75	

Table 2: Initial physical and chemical analysis of experimental soils

	Cropping season	
Soil parameters	2000-2001	2001-2002
Sand (%)	69	60
Silt (%)	12	15
Clay (%)	19	25
Texture	Sandy loam	Sandy loam
EC (dS m^{-1})	7.3	6.9
pH	7.6	7.5
Organic matter (%)	0.09	0.13
Total N (%)	0.75	0.93

Table 3: Some of the clmate parameters during the crop growing seasons

Climate factors	Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Air temp. (°C)	2000	35.0	28.2	24.7	20.9	23.2	27.9	30.8
	2001	33.2	30.2	26.6	21.3	22.1	26.0	31.3
Relative humidity (%)	2000	76.4	74.6	78.0	81.6	78.5	70.9	66.4
	2001	72.7	70.3	82.0	84.2	73.6	65.4	69.5
Rainfall (mm)	2000	-	-	5.4	3.7	7.0	-	-
	2001	-	-	-	6.7	8.5	12.0	-
Evaporation	2000	7.8	5.6	4.9	4.8	5.6	8.5	9.6
(mm day^{-1})	2001	6.0	5.9	4.3	4.1	5.8	8.7	9.8

Mint plants were transplanted during the 1st week of October in both the cropping seasons. A plant population of 15 plants m^{-2} was maintained with inter-row distance of 45 cm and intra-row spacing of 15 cm. Nitrogen (N) and P_2O_5 were applied in the form of Urea and triple super phosphate, respectively. Fertilizers were broadcast by hand. In order to minimize the loss of N by volatilization, the plots were irrigated immediately by applying 10 mm depth of water after fertilization. The crop was irrigated on weekly basis during the whole growing season. Two hoeings were done to remove weeds from the crop.

All the measurements related to growth and essential oil yield were the same in both the years. An area of 1 m^2 was harvested randomly at different time intervals from each plot for the determination of leaf area and dry matter yield. Leaf area was measured using a leaf area meter (Licor, Model 3100, LICOR Ltd., Lincoln, NE). The LAI was calculated as the ratio of leaf area to land area (Zheljazkov and Margina, 1996). The total dry weight was determined by oven drying at 80°C to a constant weight.

Oil analysis: Essential oil contents were extracted from the top 10 cm leaf/stem tissues (leaves, floral parts and new branches) by steam distillation in a mixture of hexane and petroleum ether. Plant tissues were weighed accurately before oil extraction. The extraction time, temperature and number of washes were consistent for all the plant tissue samples. Solvent was removed using a rotary vacuum evaporator and the concrete was weight to calculate oil yield.

Statistical analysis: The data were analyzed by Analysis of Variance (ANOVA) using SAS (SAS, 2000). Whereas, the Least Significant Difference (LSD) was calculated as 5% level of significance according to Steel and Torrei (1996) to evaluate fertilizer treatments.

RESULT AND DISCUSSION

Leaf Area Index (LAI): Application of nitrogen and phosphorus at different time intervals did not significantly affect the plant growth and the essential oil yield in both the cropping seasons.

Mean maximum value of LAI increased gradually to 2.26 in 2000-2001 and 2.49 in 2001-2002 cropping season till the harvesting on 30th January and then decreased. During the winter months (November to January), LAI values were low probably due to low temperatures. Later on, the values of LAI increased rapidly with the increase in temperature.

The sharp decrease in LAI values towards the end of seasons could be associated with the senescence of leaves. This type of LAI curve is common in many species, such as mustard (Kjellström, 1993; Kumar *et al.*, 1999) and mint (Duriyaprapan *et al.*, 1986) and Dill (Halva, 1993).

In 2000-2001 cropping season, the F_5 fertilizer treatment (maximum rate of fertilizer application i.e., 100/75 kg ha^{-1}) produced significantly higher LAI values than all the treatments except F_4 (75/50), where LAI values were not significantly different from those of F_5 treatment (Fig. 1a). Both these treatments gave maximum LAI value (>3.0) at the January, 15th harvesting, while none of the other fertilizer treatments gave LAI value of 3.0 at any harvest during the season. However, the LAI values decreased consistently for all the other fertilizer rates.

During 2001-2002 cropping season, the LAI curve (Fig. 1b) followed similar pattern to that obtained in 2000-2001. The highest fertilizer treatments (F_4 and F_5) significantly increased the LAI as compared to the control (F_0) and the lower fertilizer treatments (F_1-F_3) throughout the cropping season. Mean maximum values of LAI were 3.3 and 3.5 for F_4 and F_5 treatments, respectively at the 30th January harvest.

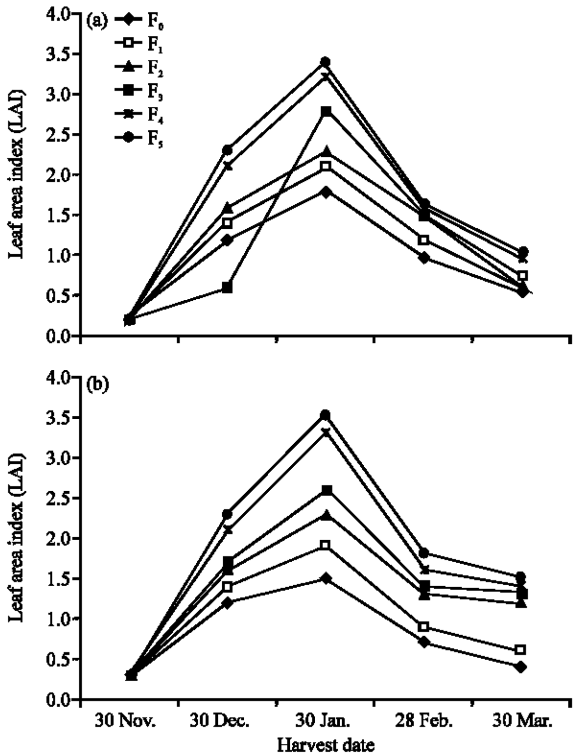

Fig. 1: Effect of the rate of fertilizer application on leaf area index of mint in (a) 2000-2001 and (b) 2001-2002

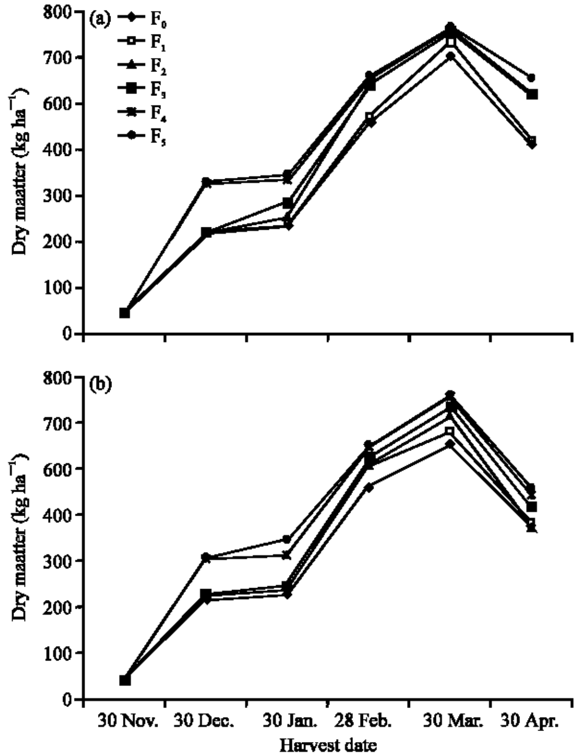

Fig. 2: Effect of the rate of fertilizer application on dry matter of mint in (a) 2000-2001 and (b) 2001-2002

The importance of LAI as a determinant of radiation interception has been recognized in field crops, including Brassica (Kumar *et al*., 1999). They reported a linear relationship between light interception and LAI and found an optimum LAI of 3.11. These results agree with findings of the present study where identical LAI values were obtained. In the present study, the increase in LAI with the increased rate of fertilizer application was similar to those reported by Kumar *et al*. (1999) in India and by Lacy *et al*. (1981) in the United States.

Zheljazkov and Margina (1996) concluded that LAI is a major factor determining the difference in yield between species caused by different agronomic treatments. Similarly, Jeliazkova *et al*. (1999) reported that LAI in peppermint markedly increased by N application and the results are similar to those found in this study.

Dry matter accumulation: Generally, the Dry Matter (TDM) continuously increased up to 25th February harvest in both the years (Fig. 2a, b). Later on, there was a gradual decrease in the TDM until the final harvest (6 April) irrespective of different fertilizer treatments. Similar growth curves for TDM were reported by Clark and Menary (1980a) in peppermint, Duriyaprapan *et al*. (1986) in Japanese mint and Halva (1993) in dill (*Anethum graveoliens* L.). The highest rate of fertilizer application (F_5) gave significantly higher TDM than the control (F_0) and the lower rates of fertilizer application (F_1-F_4) in both the years (Fig. 2a, b). In 2000-2001 at the final harvest, the mean TDM yield was 470 g m^{-2} (F_0), 478 g m^{-2} (F_1), 590 g m^{-2} (F_2), 594 g m^{-2} (F_3), 595 g m^{-2} (F_4) and 634 g m^{-2} (F_5). In different fertilizer treatments. In 2001-2002 season, the equivalent values varied from 430 g m^{-2} in F_0 (control) to 523 g m^{-2} in F_5 (120/90) treatments.

In the present study, the significant differences in TDM yield among different rates of fertilizer application, especially between low and high rates, were probably due to the differences in LAI (Fig. 1a, b). Jeliazkova *et al*. (1999) reported higher TDM production with increasing rate of NPK fertilizer application. Thus, at any given harvest, the DM accumulation is a physiological index closely related to the photosynthetic activity of leaves.

At final harvest, the average TDM yield ranged from 4.30 t ha^{-1} in 2001-2002 to 6.34 t ha^{-1} in 2000-2001 cropping season which increased to 7.60 t ha^{-1} in highest rate of fertilizer application (F_5). These TDM values were appreciably lower than those of 10-14 t ha^{-1} reported in the literature (Asare and Scarisbrick, 1995; Gammellvind *et al*., 1996; Hocking *et al*., 1997; Kumar *et al*., 1999).

Leaf/stem ratio: Mint, in early vegetative growth, is mostly composed of leave and very little stem mass. This stage is followed by a rapid growth of both the leaves and stem and a dramatic increase in total dry matter production. Leaf formation is reduced at the flowering stage. At this stage, the quantity of leaves is at its peak and the proportion of leaf to stem is nearly one (i.e., same proportion of leaf and stem).

Mean leaf/stem ratio increased with the increasing the rate of fertilizer application up to the F_4 treatment in both the years, but it decreased significantly at the highest rate of fertilizer application (F_5). In 2000-2001 cropping season, the leaf/stem ratio ranged from 0.70-0.84 and from 0.68-0.85 in 2001-2002 in different fertilizer treatments (Table 4). He further concluded that the combined effect of nitrogen and phosphorus at the rate of 100 and 60 kg ha^{-1}, respectively showed maximum beneficial effect in Japanese mint cultivation.

Essential oil yield: The essential oil yield increased significantly with increasing the rate of fertilizer application only up to the F_4 treatment in 2000-2001 cropping season. But later on, the essential oil yield decreased significantly with the highest rate of fertilizer application (F_5). The lowest essential oil yield was found in F_0 (control) treatment. Similar trend of variation in essential oil yield was observed in different fertilizer treatments in 2001-2002 cropping season (Table 4). The higher essential oil yield with increasing rate of fertilizer application was probably due to higher growth rate. Similar results were also reported by Piccaglia *et al.* (1993), who reported that some agronomic factors alos affect the essential oil contents of mint. The essential oil yields of 112-140 kg ha^{-1} obtained in the present study are slightly lower than the yields reported by Lacy *et al.* (1981), Matovc and Lavadinovic (1999) and Stream (2001).

Essential oil content: The time of fertilizer application did not affect the essential oil content in both the cropping seasons. However, the rate of fertilizer application significantly affected essential oil contents in both the seasons (Table 4). During 2000-2001 crop, the highest essential oil content of 1.46% was found in F_0 (control) and was significantly higher than the values found in all others fertilizer treatments except F_2, where the difference was non-significant. Similar trend was observed in essential oil content in different fertilizer treatments. The results showed that the increasing rates of fertilizer application decreased the essential oil content relative to the lower rates of fertilizer application. Similar results were reported for *Mintha arvensis* (Kumar *et al*., 1999), Mintha x Piperita L. (Piccaglia *et al*., 1993).

Table 4: Effect of different rates of fertilizer application on leaf/stem ratio, essential oil yield and oil contents of mint

	Fertilizer rate						
Traits	F_0	F_1	F_2	F_3	F_4	F_5	LSD (0.05)
Leaf/stem ratio							
2000	0.70	0.73	0.77	0.82	0.84	0.80	0.018
2001	0.68	0.76	0.80	0.83	0.85	0.83	
Essential oil yield (kg ha^{-1})							
2000	112	120	122	128	141	133	0.021
2001	110	117	115	120	133	126	
Essential oil content (%)							
2000	1.46	1.41	1.44	1.40	1.40	1.33	0.036
2001	1.46	1.41	1.42	1.40	1.38	1.35	

CONCLUSIONS

The application of nitrogen and phosphorus fertilizers at different time intervals (different growth stages) did not significantly affect the essential oil yield of indigenous mint wildly growing under the climatic conditions of Al-Hassa. But the different rates of N and P fertilizers significantly affected the growth and yield of mint. A fertilizer dose of 75 kg N and 50 kg P_2O_5/ha significantly increased the essential oil yield in both the years. The study provided useful information regarding the value of indigenous mint for further investigation.

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