

Effect of irrigation and fertility levels on yield, quality and economics of Japanese mint (*Mentha arvensis*) under drip irrigation system

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ABSTRACT

An experiment was conducted during *rabi* seasons of 2005-06 and 2006-07 to study the effect of fertigation on yield and net return of Japanese mint (*Mentha arvensis* L.). The treatments consisted of three irrigation regimes (I_1 —drip irrigation at 100%, I_2 — at 80% and I_3 — at 60% Pan Evaporation) and three fertility levels (F_1 — 100%, F_2 — 75% and F_3 — 50% of recommended dose of NPK) with an extra (control) treatment having surface irrigation and soil application of fertilizer. The soil was acidic in reaction and sandy clay loam in texture. It was low in organic carbon (0.46%), available N, medium in available P and K. Fertigation produced maximum herbage yield of 32.0 t/ha and oil yield of 236 kg/ha, which was 16% and 17% more than the surface irrigation. It gave higher net return of ₹ 60,666/ha than the latter. Irrigating the crop at 100% PE with 100% RD produced highest herb (32.0 t/ha) and oil yield (260 kg/ha), net return (₹ 66, 480 /ha) and benefit-cost ratio (1.88) as compared to other combinations of irrigation and fertility levels. The menthone content in the oil was doubled (9.33%), Isomenthone, Neomenthol and menthol contents were reduced while limonene and menthyl acetate contents were increased under fertigation.

Key words : Fertigation, Herbage yield, Japanese mint, Net returns, Pan evaporation

Mint is currently cultivated in 0.15 million ha and has emerged as a major industrial crop in India. It is a potential source of natural menthol and other ingredients viz. mint terpenes, menthone, isomenthone and menthyl acetate, which are extensively used in pharmaceutical, cosmetic, food and flavour industries. Essential oil and their valuable commercial constituents obtained from menthol mint have great export potential. Presently India is the largest producer of *Mentha* oil (18,000 tonnes per year) in the world contributing about 85% of the total production (Anwar *et al.*, 2010). It is extremely popular among small farmers. It is believed that over one million farmers grow this crop regularly contributing 75 to 80 % of global menthol mint oil and get a profit of about ₹ 30,000 to 40,000/ha. About 15,000 20,000 tonnes of *Mentha* oil per annum and its derivatives, valued at ₹ 6,000–8000 million are exported from India (Anonymous, 2010).

Mint is a shallow rooted and high water demanding crop. The water requirement of this crop varies from location to location depending upon soil and climatic factors. Both high soil moisture content and low leaf water potential decrease the oil yield (Shormin *et al.*, 2009). Irrigation

should be scheduled at 35% depletion of available soil moisture to get good yield (Mitchell *et al.*, 1993). The crop responds well to high levels of fertilizer (150 to 250 kg N/ha) depending on agro-climatic conditions (Patra *et al.*, 2000 and Shormin *et al.*, 2009). Water and nitrogen are important to influence the essential oil production in mint besides phosphorous and potassium. The studies on fertilizer management on other crops, whose economic part is leaf, revealed that optimum availability of nutrients throughout the growing period increases leaf production when applied through fertigation due to placement of fertilizer in effective crop root zone and less leaching loss (Rao *et al.*, 1988). Keeping this in view, the present investigation was carried out to assess the effect of fertigation on mint in an acid soil with sandy clay loam in texture.

MATERIALS AND METHODS

The field experiment was conducted in Research farm at Directorate of Water Management, Bhubaneswar, Odisha during *rabi* seasons of 2005-06 and 2006-07 to study the effect of drip irrigation regimes and fertigation levels on menthol mint grown in the rice fallow. It was laid out in factorial randomized block design with three replications. The treatments consisted of three irrigation regimes (I_1 - drip irrigation at 100%, I_2 - 80% and I_3 - 60% Pan

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Evaporation) and three fertility levels (F_1 -100%, F_2 - 75% and F_3 - 50% of the recommended dose of NPK) with an extra treatment having surface irrigation taken as control and soil application of fertilizer. The experimental soil was sandy clay in texture with pH 5.7, low in organic carbon (0.46%), available nitrogen (159 kg/ha); medium in phosphorus (21 kg/ha) and potassium (183 kg/ha).

The suckers of variety 'Kosi' were transplanted at a spacing of 60 cm $\times$ 10 cm on 10 December, 2005 and 11 December, 2006. The total amount of rainfall received during the cropping season was 464 mm in 2005-06 and 359 mm in 2006-07 in 42 and 23 rainy days, respectively. Mint received 105 mm more rainfall in 2005-06 than 2006-07. The recommended dose of NPK was 150-60-60 kg N, P_2O_5 and K_2O /ha. Full dose of phosphorus (through SSP) was applied as basal at the time of planting. It was placed in open furrows about 2.5 cm below the suckers and mixed well with the soil by a small stick. Nitrogen and potassium were given through drip irrigation in equal splits (10 times) at fortnightly interval from 15 days after planting (DAP) up to 30 days before final harvest as per treatment. Required amount of urea and potash was dissolved in water and fed to the drip system through a venturi. Fertigation was made by regulating the taps of the laterals by allowing the solution to spread to the specified plots as per fertilizer levels. The weighed amount of 35 g Urea and 11 g MOP/plot (Net plot size-4.60 m $\times$ 2.40 m) was applied through drip irrigation in one split. As per treatment, differential amount of water was applied on the basis of two days cumulative pan evaporation (CPE) through meteorological approach. Cumulative pan evaporation for different treatments was computed using data from a standard US Weather Bureau Class-A open pan evaporimeter. The depth of irrigation water was 60 mm in case of surface irrigation applied through a Parshall Flume. The water was drawn from the secondary reservoir. First irrigation was given one day prior to planting. Subsequent irrigations were given at two days interval in drip irrigation. If rainfall event occurred between irrigation cycles, then the effective rainfall amount was taken into consideration while applying irrigation.

The crop was harvested by taking the first cut at 115 days after planting and the second cut at 75 days after the first cut during both the years. It was done in bright sunny weather with the help of a sickle from 2 to 3 cm above the ground level when the lower leaves start yellowing. The fresh harvested herbage from net plot was weighed by an electronic balance and the data were converted to kg/ha. Similar procedure was also followed in second harvest. Both the yields were added to obtain the total herbage yield. The herbage was dried for two days. The essential oil was extracted from the fresh herbage through steam

distillation method using Clevenger's type extracting apparatus made up of glass (Clevenger, 1928). The volume of oil was recorded and oil per cent was computed by the following formula.

Oil content (w/w %) on fresh weight basis =

$$\frac{\text{Weight of oil}}{\text{Weight of fresh herb}} \times 100 \text{ (w/w) basis}$$

The oil percent was multiplied with corresponding fresh herbage yield of each treatment to get the oil yield. The oil was analysed at CIMAP, Lucknow by gas liquid chromatography (Hewlett Packard 5890, column AT 1000, temperature from 100°C to 170°C raised to 5° per minute, carrier gas-nitrogen @ 1ml/min) for principal chemical constituents such as limonene, menthone, isomenthone, methyl acetate, neo-menthol and menthol. Cost of laying-out of drip irrigation system and cultivation charges were worked out per hectare. The life of drip system was assumed to be ten seasons (Narayanamoorthy, 2008). For working out the economics, prevailing market prices for mint oil, cost of labour and other inputs were considered. The data were statistically analysed and the results of individual years as well as pooled data were presented.

RESULTS AND DISCUSSION

Herbage yield

The Herbage yield was higher in 2006-07 than 2005-06 except that of I_1 and I_2 (Table 1). It was more (39.0% to 53.0%) in the second harvest than the first one. The yield was marginally reduced by 1.0% to 3.0% in 2005-06 as compared to 2006-07 due to drainage congestion. The irrigation method significantly affected the herbage yield. The yield increased from 14.2% to 14.4% during the first and from 16.5% to 17.1% during the second harvest under drip irrigation as compared to surface irrigation. Maximum yield of 32.0 t/ha was recorded with drip irrigation, which was 15.8% more than that of surface irrigation

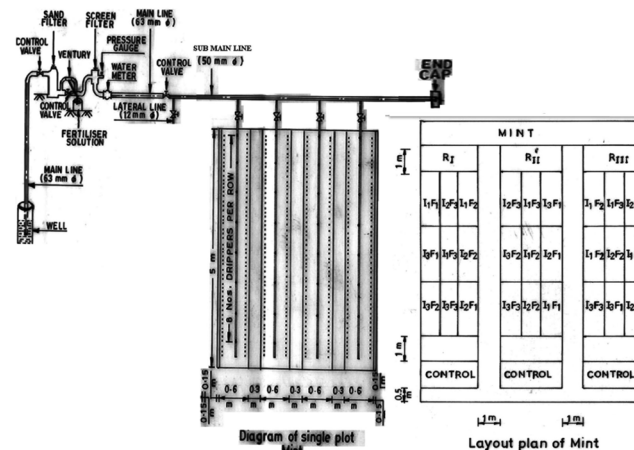


Fig. 1. Layout plan and design of drip irrigation for Japanese mint

(control). Different irrigation levels significantly affected the herbage yield during both the years (Table 1). Maximum total herbage yield of 35.1 and 34.5 t/ha were obtained from irrigation at 100% PE during first and second year respectively. The minimum yield of 28.1 to 29.0 t/ha was recorded with 60% PE (I_3). Application of irrigation at 100% PE increased the total yield by 6.7% and 21.9% compared to 80% and 60% PE. The favourable effect of irrigation in enhancing herb yield of various mint species have also been reported by Clark and Menary (1980), Ram *et al.* (2006) and Shormin *et al.* (2009).

Application of 100% recommended dose of fertilizer (RD) produced significantly maximum herb yield (32.5 t to 32.6 t/ha) with a mean yield of 32.5 t/ha (Table 1). Adequate supply of nutrients increased herbage yield due to production of taller plants, more branches and leaves per plant, superior leaf-stem ratio and increased dry matter accumulation and crop growth rate. An increase in leaf number increased the photosynthetic area. It facilitated the crop for more vegetative growth and accumulation of secondary metabolites to develop more oil (Russel, 1973). Higher yield of menthol mint with higher rate of NPK application has been reported on soils with low N content by Kumar and Sood (2011). The interaction effect of irrigation and fertilizer was not significant during both the years.

Oil content

Higher oil content was recorded with the first harvest than the second one (Table 1). Application of increasing

levels of irrigation water decreased the oil content, whereas higher fertilizer dose increased it. Drip irrigation increased the oil content due to optimum supply of nutrients throughout the crop growth period (Abbass, 2009). Oil content was maximum (0.71% to 0.82%) with irrigation at 60% PE. It decreased by 0.01% to 0.03% in case of I_1 and I_2 respectively as compared to I_3 . Different doses of fertilizer affected oil content in plants. The oil content was more (0.70% to 0.83%) with application of 100% recommended dose of fertilizer (RD) than 75% RD and 50% RD due to more vegetative growth resulting in accumulation of more metabolites to form more oil (Russel, 1973).

Oil Yield

Drip fertigation produced significantly maximum oil of 236 kg/ha (Table 1). Balanced application of water and fertilizer through drip irrigation increased the oil yield by 34 kg/ha (16.7%). Singh *et al.* (1989) recorded significant increase in herbage and oil yields due to N application in Japanese mint under optimum moisture conditions. Highest quantity of oil (253 kg/ha) was recorded at higher irrigation regime (100% PE) due to adequate availability of soil moisture to the crop. The favourable effect of irrigation on oil yield was reported by Singh *et al.* (1989) and Ram *et al.* (1993 and 2006). Oil yield decreased by 5.5% with irrigation at 80% PE and 15% at 60% PE due to inadequate moisture availability under reduced irrigation frequency (Shormin *et al.*, 2009).

The crop showed positive response to N, P and K application. Application of 100% RD (F_1) produced maximum

Table 1. Effect of irrigation and fertility on herbage, oil yield, oil content and economics of mint (Pooled mean of 2 years)

Treatment	Herbage yield (t/ha)			Oil yield (kg/ha)	Oil content (%)		Gross returns (×10 ³ ₹/ha)	Net Returns (×10 ³ ₹/ha)	Benefit : cost ratio
	2005-06	2006-07	Mean		At first harvest	At second harvest			
<i>Method of irrigation</i>									
Control	27.55	27.80	27.6	202	0.77	0.70	80.9	51.6	1.77
Drip fertilization	31.92	32.15	32.0	236	0.81	0.69	94.3	60.6	1.81
SEm±	0.11	0.49	0.12	0.57	0.002	0.003	0.22	0.26	0.009
CD(P=0.05)	0.32	1.46	0.37	1.70	0.007	0.009	0.68	0.79	0.027
<i>Irrigation (I)</i>									
I ₁ = 100% PE	35.13	34.46	34.7	253	0.79	0.68	101.2	65.8	1.88
I ₂ = 80% PE	32.63	32.59	32.6	239	0.81	0.68	95.6	61.7	1.82
I ₃ = 60% PE	28.08	29.01	28.5	216	0.82	0.71	86.2	54.4	1.72
SEm±	0.19	0.28	0.22	0.99	0.004	0.006	0.39	0.46	0.016
CD (P=0.05)	0.56	0.84	0.65	2.94	0.012	0.016	1.17	1.36	0.047
<i>Fertility (F)</i>									
F ₁ = 100% RD	32.55	32.59	32.5	246	0.83	0.70	98.1	64.0	1.88
F ₂ = 75% RD	31.87	32.05	31.9	236	0.81	0.69	94.4	60.4	1.79
F ₃ = 50% RD	31.33	31.60	31.4	226	0.79	0.68	90.5	57.5	1.75
SEm±	0.19	0.28	0.22	0.99	0.004	0.006	0.39	0.46	0.016
CD (P=0.05)	0.56	0.84	0.65	2.94	0.012	0.016	1.17	1.36	0.047

oil yield (246 kg/ha) followed by F_2 (236 kg/ha) and F_3 (226 kg/ha). Reduction of 25% fertilizer (F_2) decreased the yield by 3.9% and that of 50% fertilizer (F_3) by 7.8% compared to 100% RD. Nitrogen plays an important role in plant growth and development. It promotes vegetative growth through cell enlargement, multiplication and increase in the rate of photosynthesis. Application of adequate amount of phosphorus helps in ramification of the root system, which increased the number of suckers in the plant. More sucker production resulted in higher herbage and oil yield.

Increased herbage and oil yields with high dose of N clearly indicated that the crop is a heavy feeder of N and showed good response to increased N application. Saxena and Singh (1996) made similar observation. In the present study, application of 150-60-60 kg NPK/ha was found to be optimum for enhancing the economic yield. The studies conducted in other regions revealed that 150 kg N/ha was the optimum dose for obtaining maximum herbage and oil yield in Japanese mint (Saxena and Singh, 1996; Patra *et al.*, 2000). Anwar *et al.*, 2010 reported favourable effect of graded levels of NPK fertilizers on oil yield of mint. The interaction of irrigation and fertilizer was found significant in case of total oil yield. Application of irrigation at 100% PE with 100% RD produced 260 kg oil/ha because of optimum supply of moisture and nutrients.

Quality of essential oil

Fertigation at 100% PE with 100% RD allowed the crop plants to synthesize more menthol (71.53%) than control (Table 2). It also increased the terpinoids such as menthone, isomenthone and neomenthol contents as compared to control. Surface irrigation with 100% RD (control) increased the limonene (4.53%) and menthyl acetate (6.56%) contents. Anwar *et al.* (2010) reported that menthol content was not significantly affected due to NPK application but neo-menthol, menthyl acetate, isomenthone and menthone were considerably affected by fertilizer levels.

Economics

Drip irrigation recorded 16.7% and 17.4% higher gross

Table 2. Effect of irrigation and fertility on quality of essential oil (kg/ha) (Pooled mean of 2 years)

Sl. No	Constituents (%)	Control	I_1F_1
1	Limonene	4.53	2.92
2	Menthone	5.10	9.33
3	Isomenthone	3.54	3.91
4	Menthyl acetate	6.56	1.41
5	Neomenthol	1.97	2.19
6	Menthol	67.15	71.53

and net return, respectively than that of surface irrigation (control). The former gave ₹ 9,000/ha more net return than the latter (Table 1). The benefit-cost ratio was more (1.81) with drip irrigation. Application of irrigation at 100% PE gave highest gross and net return of ₹ 1,01,261 and ₹ 65, 805/ha respectively with benefit-cost ratio of 1.88. Reduction in frequency of irrigation reduced the gross, net return and benefit-cost ratio due to low herbage and oil yield. Application of full dose of fertilizer (100% RD) recorded highest gross and net return of ₹ 98,188 and ₹ 64, 020/ha respectively and cost-benefit ratio of 1.88. The interaction effect was not significant. However, application of irrigation at 100% PE with 100% RD maximized the net return (₹ 66,480/ha) and benefit-cost ratio (1.88). It was because of better plant growth, higher oil content and oil yield as reported by Clark and Menary (1980) and Anwar *et al.* (2010).

Mint requires favourable soil moisture condition as it is a succulent multi-cut crop. High frequency irrigation at 100% pan evaporation with full dose of recommended fertilizer (150 kg N, 60 kg P_2O_5 and 60 K_2O kg/ha) through drip system except P should be given to the crop to exploit its full potential to the extent of 260 kg/ha oil and net return of ₹ 66,480/ ha.

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