Vol. 14, No. 1, pp. 37-43 (2014)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Effect of Drip Fertigation on Yield, Water Use Efficiency and Water Productivity of Mint (*Mentha arvensis* L.)

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ABSTRACT

Field experiments were conducted on a sandy loam soil to study the effect of drip irrigation and fertilizer on herbage and oil yields, water use efficiency, water productivity and consumptive use of water by mint (*Mentha arvensis* L.) in rice based cropping system. The experiment was laid in a factorial randomized block design and was replicated thrice. The treatments consisted of three irrigation regimes (I_1- drip irrigation at 100% pan evaporation (PE); I_2 at 80% PE; and I_3 at 60% PE) combined with three fertility levels (F_1 -100, F_2-75 and F_3 - 50% recommended dose of NPK), and a control with surface irrigation and soil application of fertilizer. The soil was acidic (pH 5.7), low in organic carbon and nitrogen; medium in available phosphorus and potassium. The highest herbage (35,798 kg ha^{-1}) and oil yields (260 kg ha^{-1}) of mint were obtained with fertigation at 100% PE and 100% NPK application. The crop used 777 mm of water with the use efficiency of 0.338 kg ha^{-1}cm^{-1}.

Key words: Consumptive water use, Oil yield, Water use efficiency, Water productivity, Drip fertigation, *Mentha arvensis*

Introduction

Importance and use of traditional medicines are gaining momentum, and about 60% of world's population are presently using them (Chevallier, 1996; Dubey *et al*., 2004). International market for medicinal plants is estimated at US $65 billion per year (Ghosh, 2000; Singh, 2006), which is growing at the rate of 7% each year. While the traditional medicines are prepared from plants, minerals and organic matter, the herbal drugs are prepared from medicinal plants only (Duke *et al*., 1999).

Japanese mint, corn mint or menthol mint (*Mentha arvensis* L.) is one of the cultivated commercial and important essential oil-bearing crops in northern semi-arid and sub-tropical regions of India (Singh *et al.,* 2005). It is a potential source of natural menthol and other constituents like mint terpenes, menthone, isomenthone, menthyl acetate etc., which are

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widely used in various pharmaceutical and cosmetic products. India is currently producing more than 18,000 t of mint oil every year and had emerged as a major supplier of mint oil and menthol (Anwar *et al.,* 2010). Mint is a shallow rooted, high water demanding crop, and potential shortage of water can severely reduce its productivity. Irrigation and fertilization are the key inputs for securing optimum productivity and quality of the crop. By providing optimum irrigation and fertilizer through drip-fertigation in exact quantity, the yield, water use efficiency and water productivity of the medicinal crops could be increased to sustain the ever-increasing demand. Keeping this in view, a field experiment was conducted to evaluate the influence of drip fertigation on yield, water use efficiency and water productivity of mint.

Materials and Methods

The experiment was conducted at Central Experimental Farm, Directorate of Water Management, Bhubaneswar during *rabi* (October-June) of 2005-06 and 2006-07. The site is located at 20^o 30' N latitude and 87^o 48' E longitude at an elevation of 45 m above the mean sea level. It has a warm and moist climate with hot and humid summer and mild winter, and a mean annual rainfall of 1439 mm. Total evaporation from open pan was 572 and 541 mm, respectively during the experimental periods.

Soil was a sandy clay (*Aeric Haplaquept*); acidic in nature (pH 5.7) (Jackson, 1973), low in organic C (0.46%) (Walkley and Black, 1934) and available N (159 kg ha^{-1}) (Subbiah and Asija, 1956), medium in available P (21 kg ha^{-1}) (Olsen *et al*., 1954) and K (183 kg ha^{-1}) (Jackson, 1973). The experiment was laid in a factorial randomized block design with three replications. Three levels of drip irrigation [(I_1- irrigation at 100% pan evaporation, PE); I_2- irrigation at 80% PE); I_3-irrigation at 60% PE)] were combined with three levels of fertilizer [F_1- 100% of the recommended dose (RD) of N, P and K); F_2-75% RD of NPK; F_3-50% RD of NPK]. The control was the farmers' practice with surface furrow irrigation and soil application of fertilizer. In control, surface irrigation of 6 cm depth was applied in furrows at 60 mm PE with application of 100% RD of fertilizers. The mint variety '*Koshi*' was sown at a spacing of 30 cm X 10 cm and a fertilizer dose of 150-60-60 kg N-P_2O_5-K_2O ha^{-1} through urea, single super phosphate and muriate of potash, respectively was applied. Fertigations were given in equal splits at the fortnight interval from 15 days after planting (DAP) up to 30 days before harvest. Full dose of phosphorus was applied as basal. Required amount of urea and potash was dissolved in water and fed to the drip using ventury system. Fertigation was made by regulating the taps of the laterals by allowing the solution to the specified plots as per the treatments. The first harvesting was done at 115 and final harvesting at 75 DAP. The herbage was dried for 2 days in shade for extraction of oil. The freshly harvested herbage from net plot was weighed by an electronic balance and the data were converted to kg ha^{-1}. The oil was extracted by water and steam distillation method using Clevenger`s type essential oil extracting apparatus made of glass and expressed in percentage of oil on fresh weight basis. The harvest index (HI) was calculated as per the formula suggested by Donald, 1962.

The consumptive use of water by the crop under different treatments was worked out following Dastane (1972). Water use efficiency was calculated as:

WUE = Economic yield (kg ha^{-1}) / Consumptive use of water (cm)

The water productivity was calculated considering the gross return and amount of total water used by the crop and expressed in Rs. mm^{-1}.

Water productivity = Gross returns (Rs ha^{-1}) / Total water used (mm)

Data were analysed using the F-test according to Gomez and Gomez (1984). Least significant difference (LSD) values at p = 0.05 were used to determine the significance of differences between treatment means.

Table 1. Effect of irrigation and fertility levels on herbage yield, oil yield and harvest index of mint

Treatment	Herbage yield (kg ha^{-1})		Oil yield (kg ha^{-1})		Harvest index	
	2006	2007	2006	2007	2006	2007
Method of irrigation						
Control	27546	27798	201.88	202.64	0.738	0.728
DF	31925	32142	232.47	239.49	0.728	0.745
SE(m)±	108.0	485.4	0.608	0.840	0.006	0.004
LSD(0.05)	320.9	1455.2	1.807	2.510	NS	0.012
Irrigation levels (I)						
I_1 = 100% PE	35132	34463	249.47	256.84	0.710	0.745
I_2 = 80% PE	32626	32588	236.69	241.76	0.725	0.741
I_3 = 60% PE	28079	29010	211.24	219.80	0.752	0.757
SE(m)±	187.1	283.0	1.053	1.111	0.010	0.008
LSD(0.05)	555.8	840.7	3.130	3.302	0.029	NS
Fertility levels (F)						
F_1 = 100% RD	32558	32586	241.43	249.51	0.741	0.765
F_2 = 75% RD	31870	32054	232.16	240.04	0.728	0.748
F_3 = 50% RD	31326	31596	223.82	228.85	0.714	0.724
SE(m)±	187.1	283.0	1.053	1.111	0.010	0.008
LSD(0.05)	555.8	840.7	3.130	3.302	NS	0.024
Interaction (I x F)						
SE(m)±	324.1	490.1	1.825	1.925	0.017	0.013
LSD(0.05)	962.7	NS	NS	5.720	NS	NS

NS= Not significant

Results and Discussion

Yield and harvest index

The herbage yield of mint was higher in 2007 than 2006 except that of I_1 and I_2 (Table 1). The yield reduced by 1-3% in 2006 as compared to 2007. The method of irrigation and fertilizer application significantly affected the herbage yield (Table 1). Maximum yield of 31925 kg ha^{-1} in 2006 and 32142 kg ha^{-1} in 2007 were recorded in I_1. Drip fertigation at 100% PE increased the yield by 15.9 and 15.6% in 2006 and 2007, respectively. Maximum herbage yield (35132 and 34463 kg ha^{-1}, respectively in 2006 and 2007) was obtained from I_1, while the minimum yields of 28079 and 29010 kg ha^{-1} in the respective years were recorded under I_3. I_1 increased yields from 7.7% (I_2) to 25.1% (I_3) in 2006 and 5.8% (I_2) to 18.8% (I_3) in 2007. Reduction in herbage yield ranged 7.1-20.1% in 2006 and 6.3-18.0% in 2007 in case of I_3 and I_2, as compared to I_1. In 2006, I_1 and I_2 produced higher yield and I_3 less yield than the same in 2007. The herbage yield decreased by 11 to 14% in I_3 as compared to I_2.

Similarly, fertilizer levels also affected the herbage yield of mint during both the years (Table 1). The F_1 produced maximum yield (32558 and 32586 kg ha^{-1} in 2006 and 2007, respectively). There was a significant reduction in yield in F_2 and F_3 during 2006 as compared to F_1. But in 2007, only F_3 resulted in significant reduction in yield. Reduction of fertilizer from the recommended dose (F_1) decreased the total yield by 1.6-2.1% and 3.0-3.8% F_2 and F_3, respectively. However, the herbage yield decreased only by 1.4-1.7% with further reduction of 25% fertilizer from F_2.The interaction effects of irrigation and fertilizer were not significant.

The oil yield of mint was affected by irrigation method, level and fertility in both the seasons (Table 1). In drip fertigation, application of more water and fertilizer increased the oil yield. The oil yield was 0.4 to 4.0% higher in 2007 than in 2006. Method of irrigation also affected the oil yield (Table 1). Maximum yield (249.47-256.84 kg ha^{-1}) was recorded in I_1, which was 5.4-6.2% and 16.9-18.1% higher than I_2 and I_3, respectively. On average, reduction of yield in I_2 and I_3 were 5.5 and 14.9% in comparison to I_1. Application of 100% RDF (F_1) produced maximum oil (245.47 kg ha^{-1}) yield followed by F_2 (236.10 kg ha^{-1}) and F_3 (226.34 kg ha^{-1}). This was 4.0-7.9% in 2006 and 3.9-9.0% in 2007 higher compared to F_2 and F_3. The oil yield increased significantly from 3.7 to 4.9% by 75% RDF compared to 50% RDF. The interaction effect of irrigation and fertilizer was significant during 2007 only. Harvest index (HI) of mint was affected by irrigation but not by fertilizer dose (Table 1). It was higher in 2007 than 2006 except for surface irrigation. Drip irrigation showed higher HI (0.74) than surface irrigation (0.73). I_1 reduced HI (0.73) as compared to other irrigation regimes. Fertilizer dose had significant effect on HI only in 2007. It decreased from 0.75 to 0.72 with reduction in fertilizer dose. All the interactions were non-significant.

Randhawa *et al.* (1984) recorded low herbage and oil yields in mentha under low moisture supply conditions. In our study, increase in herbage and oil yields and harvest index with irrigation at 100 and 60%PE were due to favourable soil moisture conditions maintained throughout the crop growth period. Mentha is a succulent, multi-cut crop that has high water requirement during its growth period especially in summer months when the evaporation demand is relatively high. The favourable effect of irrigation in enhancing herb and oil yields of various mint species have been reported by Singh *et al*. (1989); Ram *et al*. (1993) and Hanson and May (2003). Similar findings were also reported by Aujla *et al*., 2005 with cotton.

Consumptive use of water, water use efficiency and water productivity

Irrigation and fertilizer affected the consumptive use of water in both the seasons (Table 2). Irrigation significantly affected the water consumption in the individual years. When applied through furrow irrigation, the mint crop used more water than drip irrigation. Drip irrigation saved 34.5 and 24.0% water in 2006 and 2007, respectively. The use was higher at I_1 than I_2 and I_3. Maximum water (730 to 812 mm) was used in I_1 followed by I_2 (623 to 681 mm) and I_3 (521 to 556 mm). Thus, I_1 consumed 18.3-43.0% more water than I_2 and I_3. Irrigating at 80% PE (I_2) used 19.6 and 22.5% more water than that of 60% PE (I_3) during 2006 and 2007, respectively. Variation in fertilizer application rate also affected the consumptive use of water. A total of 655 mm water was used in F_1, which was equal to F_2 and at par with F_3 (652 mm). All the interactions were non-significant.

Drip fertigation increased WUE by 65.3% as compared to furrow irrigation (Table 2). Average WUE was 0.362 kg ha^{-1} mm^{-1} water for drip irrigated and 0.219 kg $ha^{-1}mm^{-1}$ for furrow irrigated crops. The WUE decreased significantly with increase in irrigation rate during 2007, but was as par in 2006 (Table 2). Maximum WUE of 0.40 kg oil $ha^{-1}mm^{-1}$ water was recorded with I_3 followed by I_2 (0.368 kg ha^{-1} mm^{-1}) and I_1 (0.329 kg $ha^{-1}mm^{-1}$). Application of irrigation to the crop at 100% PE decreased the WUE by 8.0 to 17.7% as compared to 60% PE. Similarly, irrigation at 80% PE increased the WUE by 11.9% as compared to 100% PE. The WUE was higher in 2006 than 2007. The WUE decreased with reduction in fertilizer dose. Maximum WUE of 0.385 and 0.365 kg ha^{-1} mm^{-1} were recorded at F_2 followed by F_3 (0.360 and 0.335 kg ha^{-1} mm) during 2006 and 2007, respectively. It decreased by 3.7 and 7.2% under F_3 and F_2, respectively compared to F_1. The interaction between irrigation and fertilizer was also significant (Table 3).

Water productivity increased by drip irrigation and high level of fertilizers, but decreased with an increase in irrigation level, and was higher in 2006 than 2007 (Table 2). Drip fertigation increased the water productivity by 77.2 and 57.1% in 2006 and 2007, respectively. It had the highest productivity value of Rs. 150.3 and 142.2 mm^{-1}. Water productivity value was

Table 2. Effect of irrigation and fertility levels on consumptive use and water use efficiency of mint

Treatment	Consumptive use (mm)		Water use efficiency (kg oil ha^{-1} mm)		Water productivity (Rs. mm^{-1})	
	2006	2007	2006	2007	2006	2007
Method of irrigation						
Control	953	896	0.212	0.226	84.8	90.5
DF	625	683	0.372	0.351	150.3	142.2
SE(m)±	0.844	1.544	0.013	0.001	0.46	0.48
LSD(0.05)	2.508	4.589	0.039	0.003	1.35	1.42
Irrigation levels (I)						
I_1 = 100% PE	730	812	0.342	0.316	136.7	126.5
I_2 = 80% PE	623	681	0.380	0.355	151.9	142.0
I_3 = 60% PE	521	556	0.405	0.395	162.2	158.0
SE(m)±	1.462	2.675	0.022	0.002	0.79	0.83
LSD(0.05)	4.344	7.948	0.068	0.006	2.34	2.47
Fertility levels (F)						
F_1= 100% RD	627	684	0.385	0.365	156.0	148.0
F_2= 75% RD	627	683	0.370	0.351	149.4	142.8
F_3= 50% RD	621	683	0.360	0.335	145.4	135.7
SE(m)±	1.462	2.075	0.022	0.002	0.79	0.83
LSD(0.05)	4.344	NS	0.088	0.006	2.34	2.47
Interaction (I x F)						
SE(m)±	2.532	4.634	0.039	0.004	1.37	1.44
LSD(0.05)	NS	NS	0.117	0.011	4.06	4.27

NS=Not significant

maximum with I_3, which were greater by 11.1 and 18.7% in 2006 and by 12.3 and 24.9% in 2007 than I_2 and I_1, respectively. The I_3 increased the productivity by 8.9% as compared to I_2. The F_1 had highest productivity, which was 4.4 and 7.3% (2006), and 3.6 and 9.0% (2007) higher than F_2 and F_3, respectively. F_2 decreased the productivity by 3.9% and F_3 further by 7.5%. The interaction effect was significant.

Application of irrigation at 100% PE increased consumptive use of water and decreased the water use efficiency. It could be due to high herbage and oil yields that utilized more water for soil nutrient absorption and trapping the CO_2 for photosynthesis. The water use efficiency was low due to dilution effect of water. Saxena and Singh (1996) reported that crop needed 300 to 400 mm of water at IW/CPE ratio of 0.5 and 250 mm at 0.3 IW/CPE ratio under shallow water table conditions (62 to 119 cm). High moisture regimes maintained up to 1.2 IW/CPE ratio increased the water use efficiency in mint (Patel and Rajput, 2003; Ram *et al.,* 2006).

Nutrient management both at first and second harvest during 2006 and 2007 significantly influenced the herbage as well as oil yields of Japanese mint. The crop showed positive response to NPK application. The N promotes vegetative growth through cell enlargement, multiplication and increase in the rate of photosynthesis. Singh *et al.* (1989) recorded significant increase in herbage and oil yields due to N application in Japanese mint. Application of adequate amount of phosphorus helps in ramification of the root system, which increased the number of suckers in the plant (Rahman *et al.,* 2003). More sucker production resulted in higher herbage and oil yield. Similar findings were also reported by Patra *et al.,* 2000, 2003; Kattimani and Jayadev, 2003.

Table 3. Interaction effect of irrigation and fertility levels on mean water use efficiency (kg ha^{-1} mm^{-1}) of mint

Irrigation levels	Fertility levels			
	F_1	F_2	F_3	Mean
I_1	0.338	0.329	0.320	0.329
I_2	0.379	0.366	0.357	0.367
I_3	0.424	0.400	0.377	0.400
Mean	0.380	0.365	0.351	

SE(m) =0.003; LSD(P=0.05) =0.009

The increased herbage and oil yields and harvest index obtained with higher 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 (1998) proved that mentha was a heavy demander of N. Inadequate application of N affected the yield. In the present study, 150:60:60 kg NPK ha^{-1} was found to be optimum dose for enhancing economic yield. Studies conducted in other regions revealed that 150 kg N ha^{-1} was the optimum dose for obtaining maximum herbage and oil yield in Japanese mint (Mukesh, 1996; Shormin *et al.,* 2009). Adequate supply of nutrients increased both herbage and oil yields due to production of taller plants, more branches and leaves, superior leaf-stem ratio and increased dry matter (Li and Zhang, 2003). Increase in oil yield could be mainly due to high herbage yield. An increase in leaf number increased the photosynthetic area. It facilitated the crop for more vegetative growth and accumulation of secondary metabolites to form more oil (Mukesh, 1996).

The crop receiving irrigation at 100% PE and full-recommended dose of fertilizer gave maximum herbage and oil yields. Reduction in fertility level from 100 to 50% RD of fertilizers did not affect the consumptive use, but increased the water use efficiency. Drip irrigation increased the water productivity by 69%. The productivity decreased with increased in irrigation level but it increased with increased in fertility level. Corak *et al*. (1991); Hatfield *et al*. (2001) and Kumar and Sood (2011) reported similar findings.

Conclusions

Drip fertigation resulted in higher herbage and oil yields, harvest index and WUE of mint. Application of water at 100% PE and 100% RD recorded highest herbage and oil yields. although irrigation at 60% PE with 100% RD of fertilizers resulted in the highest water use efficiency.

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Received: 2 June 2014; Accepted: 30 June 2014