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RESEARCH PAPER

Effect of weather conditions on growth, yield and quality of Menthol mint (*Mentha arvensis* L.) cultivars transplanted in different years on different dates under sub-tropical climate of North India

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Abstract

Menthol mint (*Mentha arvensis* L.) is grown as summer season crop in sub-tropical plains of north India for its valued essential oil. The productivity and quality of the essential oil is significantly influenced by weather parameters prevailed during cropping season. The studies conducted to assess the effect of different seasons, cultivars and dates of planting, revealed that growth, yield and quality of menthol mint was significantly better during hot and dry cropping season of 2010 than hot and humid season of 2011. Essential oil content in fresh herb was 39 % higher in 2010 over 2011; resulting 26.2 %, 9.5 % and 37.9 % increase in essential oil yield, menthol content and menthol yield, respectively. Maximum herb, oil and menthol yields were recorded when crop was planted on 15th March irrespective of cropping season and cultivars. Delay in the transplanting resulted in significant reduction in herb, oil and menthol yield. Cultivar Kosi produced maximum essential oil of better quality across different cropping seasons and date of transplanting; cultivar Saksham produced lowest oil during cropping season 2010. Net return in cropping season 2010 was 54.8 % higher than the cropping season 2011. Cultivar Kosi planted on 15th March gave maximum net returns of ₹ 80365 ha^{-1} in hot and dry cropping season of 2010. Menthol mint prefers hot and dry weather for producing maximum essential oil with better quality and it should be transplanted at early date in mid-March using cultivar Kosi, under sub-tropical climate of north India.

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Introduction

Mentha arvensis L. commonly known as Japanese mint or Menthol mint is an important essential oil bearing crop belongs to family Lamiaceae. Its oil is extensively used in perfumery and flavor industries. It is commercially cultivated in India, China, Brazil, Japan, USA, France, Australia, Thailand, Angola and Argentina for the production of essential oil which is rich in menthol. India is a leading producer of this crop in world having 1, 60,000 ha area with an annual production of 16000 t essential oil (Kumar *et al*., 2011). In India it is commercially grown in sub-tropical plains as a summer season crop after the harvest of winter season crops; potato, mustard and pea etc. Menthol mint is transplanted by farmers from mid-February to mid-April, depending upon the time of harvesting of preceding crop. It has been observed that environmental factors such as air temperature, relative humidity and precipitation during entire crop growth period in general and maturity phase in particular, play an important role on the yield and quality of essential oil. Indian monsoon is very erratic and uncertain. Early onset of monsoon rains in the year 2004, 2006, and 2008 caused heavy losses in the productivity of menthol mint as pre monsoon rains adversely effected growth, yield and quality of oil. More than 70 % of the cultivated area of menthol mint in India was affected by early onset of monsoon during these years. Although extents of losses due to vulnerability of monsoon rains were different under various locations under different planting dates due to variations in the temperature, humidity and soil type at different sites (Singh, 2005 and Singh *et al*, 2008). In view of the above, it was felt necessary to evaluate the influence of variation in weather conditions on growth, herb yield, oil content and oil yield of menthol mint transplanted at different dates as information on the effect of different weather parameters on the yield and quality of menthol mint oil are not available. The aims of these studies were to inform the scientific and farming community regarding change in yield and quality of menthol mint oil under varying weather conditions. The information on the optimum weather for harvesting more oil with better quality will benefit the grower of this valued crop.

Materials and methods

Experimental site and soil

The study was conducted at the research farm of CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow, India, situated at 26º 5' N latitude, 80 º 5' E longitudes with an elevation of about 120 m above mean sea level under the sub-tropical plains of north India. The soil (pH 7.7) of the experimental field was a sandy loam having organic carbon 0.32%, available N (alkaline $KMnO_4$ extractable) 177 kg ha^{-1}, available P (0.5 M Na HCO_3 extractable) 13.7.0 kg ha^{-1} and available K (1M NH_4OAc extractable) 168 kg ha^{-1}.

Weather parameters

The data recorded on different weather parameters during the period of experimentation are given in Fig. 1. In this region monsoon normally sets from last week of June and continues until the end of September with an average annual precipitation of 1000 mm. About 80 % of the monsoon rains are received in July and August. Winter also experience some rains due to cyclonic disturbances in the Arabic sea. Mean maximum temperature fluctuated from 26.1 to 44.5 ºC, whereas mean minimum temperature varied from 7.8 to 29.5 ºC. Rainfall and relative humidity during the cropping season in 2011 were higher than 2010. Thus, weather conditions during second year were more humid than first year.

Treatment and experimental design

Twenty four treatments having combination of two cropping years (2010 and 2011), three dates of transplanting (15 March, 30 March, 15 April) and four cultivars (Kushal, Himalya, Saksham and Kosi) were tested in a factorial randomized block design with three replications.

Raising of crop

Forty days old plantlets, having 20 cm height, raised in nursery beds by cutting suckers (stolen) in small pieces at different dates were transplanted in flat beds with row to row spacing of 50 cm and plant to plant spacing of 15 cm as per treatments i.e. on 15 March, 30 March and 15 April in 2010 and 2011, after flooding in individual bed before transplanting. The number of irrigation applied after establishments were 5, 4 and 2 during 2010 and 4, 3 and 2 during 2011 in 15 March, 30 March and 15 April transplanted mint, respectively. The depth of water for each irrigation kept as 50 mm. Other cultural practices were followed as prescribed by Khanuja *et al* (2006).Crop was harvested at maturity i.e. when 2-3 lower leaves became yellow and upper leaves became small. The data on fresh herb yield were recorded immediately after harvest.

Plant sampling and biometric observations

For recording observations on plant height, plant spread and number of branches, five plants were randomly selected in each plot at the time of harvest. For the estimation of leaves to stem ratio and essential oil content in fresh herb; 200 g green shoot biomass was used for each. For estimation of essential oil 200 g fresh biomass was hydro- distilled by Clevenger's apparatus (Clevenger, J.F, 1928). To obtain oil yield, fresh herb yield was multiplied with corresponding oil content (v/w %) and 0.9 (approximate specific gravity of oil).

Quality analysis

Essential oil samples were analyzed using a Varian CP 3800 gas chromatograph (USA) fitted with CP Wax 52 CB column (30 m x 0.25mm, film thickness 0.25 µm, Supelco, USA), column temperature 70-250°C was programmed at 3°C/minute with initial and final hold of 2 and 10 minutes, respectively, using H_2 as carrier gas at 10 psi constant pressure, split ratio 1:40, injection size 0.03 µl; injector and detector temperatures were 250°C. Characterization of constituents was done on the basis of retention indices using index calculating software, co injection with standards (Sigma), MS Library spectra (NIST/ NIH Version 2.1& Wiley-Registry of mass spectral data – 7th edition) and by comparing with mass spectral literature data.

Statistical analysis

The data on different growth, yield and quality attributes were analyzed separately as well as combined for both the years statistically by using the analysis of variance technique for factorial randomized block design of field experimentation as suggested by Panse and Sukhatme (1985). Differences between the treatment means were compared by critical difference at 5% ($P \leq 0.05$) level of significance.

Economics

Economics of different treatments was calculated on the basis of average yield and prevailing market price of inputs and outputs. Net return was calculated as follows, Net return = Gross return- cost of cultivation.

Results

Crop growth and yield attributing characters

Most of the growth parameters like plant spread, leaf area index and leaf: stem ratio were significantly higher ($P \leq 0.05$) during first year (2010) than 2011 (Table 1 and 2). However reverse trend was observed for plant height.

Menthol mint plants attained maximum height, spread and leaf area index (LAI) when transplanted on 15 March, delay in transplanting resulted in reduction in plant height, spread and leaf area index and reverse trend was observed for leaf : stem ratio during both the years (Table1and 2).

Among the mint cultivars Saksham was significantly taller ($P \leq 0.05$) and plants of cultivar Kushal were shortest. Plant spread and leaf area index of all the varieties were statistically at par. Leaf: stem ratio of cultivar Kosi and Kushal were significantly higher than Saksham during both the years.

Herb yield, oil content and oil yield

Fresh herb yield recorded during cropping year 2010 was significantly higher ($P \leq 0.05$) over the 2011, irrespective of cultivars and transplanting dates. Similar trend was observed in essential oil content in fresh herb and oil yield (Table 1 and 3).

Early transplanted Menthol mint (15 March) gave maximum herb and oil yield; delay in transplanting resulted in consecutive decline in yield during both the years (Table 1 and 3). Mean essential oil content (0.64 %) in fresh herb across different dates of transplanting during 2010 (hot and dry season) was 39 % higher than 0.46 % in hot and humid weather of 2011.

Fresh herb produced by the different cultivars of menthol mint was statistically at par, however cultivar Kosi gave significantly higher oil content and oil yield during both the years over all other cultivars. Cultivar Saksham gave lowest yield during 2010 but it was at par to Himalaya and Kushal during 2011.

Table 1. Growth, yield attributes, yield and quality of menthol mint as influenced by cropping seasons, dates of transplanting and cultivars.

Treatments	Plant height (cm)	Plant spread (cm)	Leaf area index (cm)	Leaf: stem	Fresh herb yield (t ha^{-1})	Oil content (% V/W Fresh herb)	Oil yield (kg ha^{-1})	Menthol content (%)	Menthol Yield (kg ha^{-1})
Cropping season (Y)									
2010	53.1	50.6	3.2	1.3	22.4	0.6	117.1	75.1	88.4
2011	58.4	46.0	3.1	1.2	20.4	0.5	92.8	68.6	63.9
Date of transplanting (D)									
15-Mar	65.7	51.0	3.6	1.2	23.8	0.5	113.5	72.8	83.1
30-Mar	51.6	49.9	3.1	1.2	21.4	0.5	103.5	72.6	75.9
15-Apr	49.9	44.1	2.8	1.4	19.0	0.6	97.9	70.0	69.3
Cultivars (V)									
Kushal	43.8	46.6	3.1	1.3	21.3	0.5	102.5	71.0	73.8
Himalya	57.0	49.0	3.2	1.2	21.0	0.5	101.1	71.9	73.3
Saksham	68.2	50.1	3.1	1.1	21.6	0.5	99.7	71.5	72.0
Kosi	53.9	47.6	3.3	1.4	21.7	0.6	116.5	72.8	85.6
LSD at 5%									
Cropping season (Y)	3.1	2.3	NS	0.1	0.8	0.01	2.2	0.6	1.8
Date of transplanting (D)	3.8	2.8	0.3	0.1	0.9	0.02	2.7	0.7	2.2
Cultivars (V)	4.4	NS	NS	0.1	NS	0.02	3.1	0.8	2.6

Table 2. Growth and yield attributes of menthol mint as influenced by the interaction effect of cropping seasons, dates of transplanting and cultivars.

Date of transplanting (D)	Cultivars (V) Cropping Season (Y)	Plants heights (cm)		Plants spread (cm)		Leaf area index		Leaf : stem ratio	
		2010	2011	2010	2011	2010	2011	2010	2011
15 March	Kushal	50.0	55.0	47.0	51.8	3.4	3.6	1.3	1.2
	Himalya	62.5	68.8	49.0	54.0	3.5	3.7	1.2	1.1
	Saksham	75.0	82.5	50.0	55.0	3.4	3.6	1.1	1.0
	Kosi	62.5	68.9	48.0	52.8	3.5	3.7	1.3	1.2
30 March	Kushal	37.5	41.3	46.0	50.7	3.0	3.1	1.3	1.2
	Himalya	50.0	55.5	48.0	52.8	3.1	3.2	1.3	1.2
	Saksham	62.5	68.5	49.0	54.0	3.0	3.1	1.1	1.0
	Kosi	46.5	51.2	47.0	51.8	3.1	3.2	1.4	1.3
15 April	Kushal	37.5	41.5	40.0	44.0	2.7	2.8	1.5	1.4
	Himalya	50.0	55.0	43.0	47.3	2.8	2.9	1.3	1.2
	Saksham	57.5	63.3	44.0	48.4	2.7	2.8	1.3	1.2
	Kosi	45.0	49.5	41.0	45.1	2.9	3.0	1.5	1.4
LSD at 5%									
Y X D			5.3		4		0.4		0.02
Y X V			6.2		4.6		0.4		0.02
D X V			7.5		5.6		0.5		0.03
Y x V x D			10.7		7.9		0.7		0.04

Menthol content and yield

Menthol content in essential oil and menthol yield was significantly influenced by weather conditions. Menthol content was significantly superior ($P \leq 0.05$) and 9.5 % higher during hot and dry weather of 2010 as against 68.6%, recorded in hot and wet weather of 2011 (Table 1 and 3). Similar to oil yield, menthol yield was significantly higher in 2010 than 2011, as menthol yield was a function of oil yield x menthol content in oil (Table 1 and 3). Menthol yield (88.4 kg ha^{-1}) recorded during 2010 was 37.9 % higher than 63.9 kg ha^{-1} obtained during 2011.

Essential oil of cultivar Kosi planted on 30 March contained significantly higher (P ≤ 0.05) menthol during 2010, whereas during 2011 it contained higher menthol in 15 March planting. Essential oil of cultivar Kushal planted on 15 April contained lowest menthol. Cultivar Kosi planted on 15 March produced significantly higher (P ≤ 0.05) menthol and cultivar Saksham planted on 15 April produced significantly lowest menthol during both the years of study (Table 1 and 3).

Table 3. Fresh herb yield, oil content, oil yield, menthol content and menthol yield of menthol mint as influenced by the interaction effect of cropping seasons, dates of transplanting and cultivars.

Date of transplanting (D)	Cultivars (V) Cropping season (Y)	Fresh herb yield (t ha^{-1})		Oil content (% v/w) in fresh herb		Oil yield (kg ha^{-1})		Menthol content (%)		Menthol yields (kg ha^{-1})	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
15 March	Kushal	25.0	22.7	0.6	0.4	120.7	97.8	75.4	69.3	91.3	68.0
	Himalya	24.4	22.2	0.6	0.4	118.3	95.9	75.6	70.2	89.6	67.5
	Saksham	25.2	22.9	0.6	0.4	121.7	98.6	75.5	69.5	92.1	68.7
	Kosi	25.1	22.8	0.7	0.5	140.9	114.1	75.7	70.9	106.8	81.1
30 March	Kushal	22.4	20.4	0.6	0.4	111.6	87.7	75.8	68.3	84.8	60.2
	Himalya	22.0	19.4	0.6	0.4	108.8	85.9	76.1	68.6	83.0	59.1
	Saksham	22.5	20.4	0.6	0.4	111.9	87.9	75.9	68.4	85.0	60.3
	Kosi	22.8	20.6	0.7	0.5	131.3	103.1	78.6	69.2	103.4	71.6
15 April	Kushal	19.4	17.7	0.7	0.5	111.7	85.4	71.3	66.0	82.1	56.4
	Himalya	19.5	17.8	0.7	0.5	112.1	85.8	73.4	67.3	82.5	57.8
	Saksham	20.2	18.4	0.6	0.4	99.5	78.8	72.9	67.0	72.7	52.8
	Kosi	20.5	18.6	0.7	0.5	117.4	92.5	74.4	67.9	87.5	63.0
LSD at 5%											
Y X D		1.3		0.02		3.8		1.0		3.1	
Y X V		1.5		0.02		4.4		1.2		3.6	
D X V		1.9		0.03		5.3		1.4		4.5	
Y x V x D		2.6		0.04		7.5		2.0		6.3	

Economics

Relative economics of different treatment combination during both the years is presented in Fig. 2 and Table 4. Net return during 2010 was 54.8 % higher than 2011. It was due to 26.2 % higher oil yield as cost of cultivation was almost same but gross return in 2010 was higher than 2011 in proportion to oil yield.

Cultivar Kosi planted on 15 March gave highest net return whereas cultivar Saksham planted on 15 April gave lowest return during both the years.

Table 4. Economics of menthol mint as influenced by the interaction effect of cropping seasons, dates of transplanting and cultivars.

Date of transplanting (D)	Cultivars (V) Cropping season (Y)	Cost of cultivation (☐ ha^{-1})		Gross return (☐ ha^{-1})		Net return(☐ ha^{-1})	
		2010	2011	2010	2011	2011	2010
15-Mar	Kushal	68218	64072	132810	107602	64592	43530
	Himalya	66811	62795	130071	105457	63260	42662
	Saksham	68732	64557	133819	108420	65087	43863
	Kosi	74592	74716	154957	125481	80365	50765
30-Mar	Kushal	63048	57444	122749	96466	59701	39022
	Himalya	61489	56271	119717	94505	58228	38234
	Saksham	63201	57594	123046	96719	59845	39125
	Kosi	69156	67531	144379	113406	75223	45875
15-Apr	Kushal	63105	55904	122855	93889	59750	37985
	Himalya	63331	56166	123303	94325	59972	38159
	Saksham	56229	51634	109476	86717	53247	35083
	Kosi	61320	60568	129114	101717	67794	41149
LSD at 5%							
Y X D		4065.9		5145.5		6028.7	
Y X V		4694.9		4786.8		6961.4	
D X V		5750.1		5862.6		8525.9	
Y x V x D		8131.8		8291.0		12057.4	

Discussion

Better growth of plants in terms of crop spread and leaf area index during first year (2010) was due to favorable weather conditions required for crop i.e. higher air temperature, lower relative humidity and these factors enhanced the ratio of leaves to stem resulting in higher oil content. Lower oil content in fresh herb in humid weather of 2011 was on account of heavy rains during maturity and harvesting time, which ruptured and washed off oil glands of leaves.

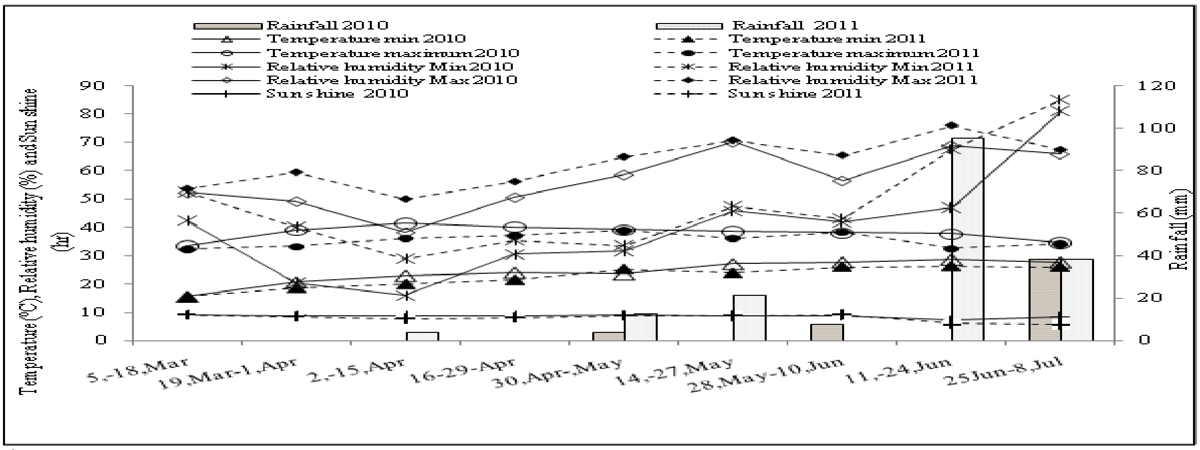

Fig. 1. Mean bi-weekly air temperature, relative humidity, sun shine hours and total rainfall over the cropping season 2010 and 2011.

Higher growth of plants under early planting was due to moderate temperature at the time of transplanting, which favored better establishment and growth of shoots and root, thus plants could utilize above and underground resources more efficiently (Farrav and Williams, 1991). Higher leaf: stem ratio and oil content under delayed (15 April) planting was due to comparatively more foliage growth than stem due to higher mean maximum and minimum temperature prevailed during active crop growth stage. This observation is in agreement to those reported by Duriyaprapan *et al* (1986), Singh *et al* (1995), Singh *et al* (1997), Singh *et al* (1998) and Singh *et al* (2003) who noted that oil content in leaves of *Mentha species* was a direct function of mean temperature prevailing during growth period.

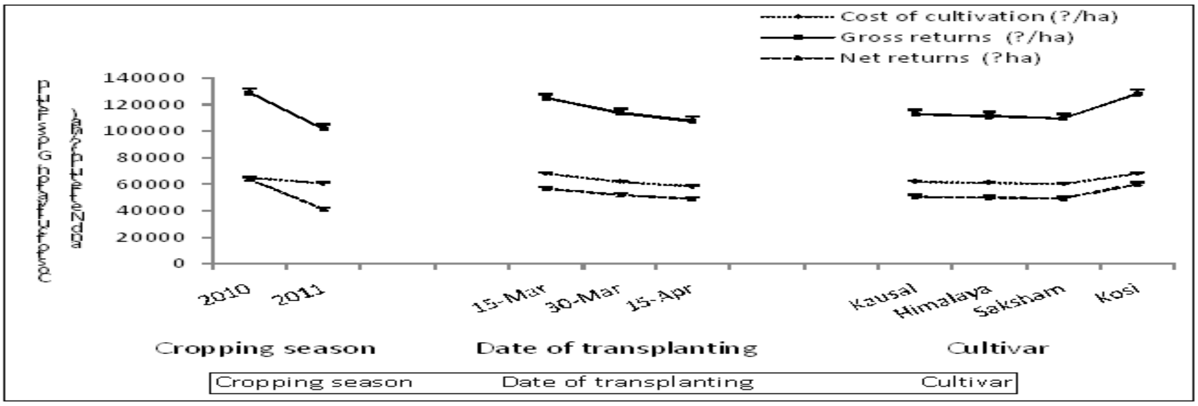

Fig. 2. Economics of menthol mint as influenced by cropping season's dates of transplanting and cultivars.

Higher herb yield during 2010 was due to better growth of plant in terms of, crop spread leaf area index and leaf: stem ratio, similarly higher oil yield was due to 20 % higher recovery of essential oil in herb than 2011 which resulted in 26.2 % increase in oil yield. Similar results were also obtained by Ram and Kumar (1998) in menthol mint. Higher herb, oil and menthol yield in early planted crop was due to better plant growth in terms of plant height, spread and leaf area index resulting in higher fresh herb yield. Higher herb yield was the sole reason for higher oil yield.

Conclusions

The field studies with menthol mint in which different cultivars of this crop were evaluated for the first time under different weather conditions prevailed during two different cropping seasons, clearly showed that hot and dry weather will benefit menthol mint growth, yield and quality. The crop experienced hot and dry weather conditions in the first experimental season. Menthol mint yield and quality benefited by hot and dry weather mainly due to balanced crop growth and more biosynthesis of better quality essential oil in leaves. The findings also indicate that menthol mint prefers hot and dry weather for producing maximum essential oil with better quality and it should be transplanted at early date in mid-March using cultivar Kosi under sub-tropical climate of North India.

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