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Research Paper

Effect of date of planting and harvesting schedule on heat-unit accumulation and biomass production in Japanese mint (*Mentha arvensis*)

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ABSTRACT

The present investigation was carried out during the spring season of 2010 and 2011 at Ludhiana, Punjab, to study the effect of heat-unit accumulation on herb and oil productivity of Japanese mint (*Mentha arvensis* L.) under different dates of planting and harvesting schedules. The field experiment was laid out in split-plot design keeping 4 dates of planting 1 January, 15 January, 30 January and 15 February in main plots and 3 harvesting schedules (120, 135 and 150 days after planting) in subplots. Japanese mint planted on 15 February recorded the maximum fresh-herb and oil yields, which were statistically at par with that planted on 30 January, but were significantly higher than 15 January and 1 January plantings. The crop planted on 30 January and 15 February accumulated 456 and 624 and 222 and 390 units higher growing degree-days (GDD) than 1 January and 15 January planted crop respectively. The fresh-herb and oil yield of mint increased successively and significantly with delay in harvesting from 120 to 150 days after planting (DAP). The growing degree-days (GDD), photothermal units (PTU) and heliothermal units (HTU) accumulation were 649, 8,866 and 5,275 and 322, 4,480 and 2,548 units higher in crop harvested at 150 DAP than that harvested 120 and 135 DAP respectively. The interaction effects revealed that crop planted on 15 February and harvested at 150 DAP gave the maximum biomass and oil yield, which were statistically at par with that planted on 30 January and harvested at 150 days after planting, but was significantly better than all other combination because of higher accumulation of GDD, HTU and PTU. The multiple regression model was found to be well fit with P=0.0006, which revealed that fresh- herb yield of mint was significantly and positively correlated with GDD, HTU and PTU at multiple correlation value of 0.9636.

Key words **:** Date of planting, Growing degree-days, Harvesting schedule, Japanese mint, Oil yield

Japanese mint is an important essential oil-bearing industrial crop in which leaves are the principle site for synthesis of essential oil. The aerial parts of the herb on distillation yield essential oil containing a large number of aroma chemicals which are used in perfumery and cosmetic industries. In India Japanese/menthol mint is cultivated in Uttar Pradesh, Punjab, Himachal Pradesh, Haryana and Bihar. India is currently producing more than 18,000 tonnes of mint oil against world production of 22,000 tonnes annually and has emerged as a major world supplier of mint oil and menthol (Brar *et al.* 2014). In Punjab, mint is grown on an area about 15,000 ha and *Mentha arvensis* occupies more than 80% of total production of essential oil in Punjab (PAU, Ludhiana, 2014).

Herb and oil yields of Japanese mint are dependent on the prevailing climatic conditions. The chemical composition of oil is influenced by various factors such as geographical location (Rajeshwara Rao, 1990), environmental conditions (Chalchat *et al.,* 1997) and agro-climatic requirement (Chand *et al.,* 2004) of the crops. In North India, mint crop is generally cultivated during the spring and summer season. The bright sun light with 30˚C day temperature was found to be conducive for better leaf, stem and dry-matter production regardless of night temperature at various growth stages of Japanese mint (Duriyaprapan *et al*., 1986). Plant growth is an index to depict efficiency of living cells to harvest the solar radiations. The assimilates produced through conversion of solar energy to chemical energy are utilized for infrastructure buildup and are the principle source for oil because leaves are the major site for essential oil synthesis in mint. Among the climatic parameters, temperature and quantum of solar light availability are of paramount importance for proper plant growth and development and can be manipulated by adjusting the date of planting and time of harvest-

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ing. Thus, keeping in view the above facts the present investigation was planned to study the effect of heat-unit accumulation on herb and oil productivity of Japanese mint under different dates of planting and harvesting schedules.

MATERIALS AND METHODS

A field experiment was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during the spring seasons (mid-January to mid-June) of 2010 and 2011. The experimental region is situated in trans-gangetic agro-climatic zone, representing the Indo-Gangetic alluvial plains at 30° 56' N, 75° 52' E and at 247 m above mean sea-level. The climate of this region is characterized as sub-tropical semi-arid with hot summer and very cold winters. The soil (0–15 cm) of the experimental site was loamy sand with *p*H 8.20, electrical conductivity 0.29 dS/m, organic carbon 0.35%, available N 116.5 kg/ha, P 20.2 kg/ha and K 253.6 kg/ha. The experiment was laid out in a split-plot design keeping 4 dates of planting (1 January, 15 January, 30 January and 15 February) in main plots and 3 harvesting schedules (120, 135 and 150 days after planting) in sub-plots.

The planting of Japanese mint was done using 0.5 t/ha suckers at 4–5 cm depth in rows 45 cm apart. Well-rotten farmyard manure @ 10 t/ha was thoroughly mixed in to the soil 2 weeks before the planting. A basal dose of 37.5 kg N/ha, 40 kg P_2O_5/ha and 40 kg K_2O/ha were applied through urea, dia-ammonium phosphate and muriate of potash and 37.5 kg/ha N was applied at 40 days after planting as top-dressing. Pendimethalin @ 750 g a.i./ha was applied after planting as pre-emergence and 2 manual weedings were also done to keep the proper check on weeds during both the years. To check the attack of termite and cutworm, Chloropyriphos 20 EC @ 5.0 litre/ha was applied twice with irrigation water during both the years. The crop was harvested manually with sickle about 5 cm above the ground level as per the harvesting schedules. The essential oil content in 500 g fresh-herb from each plot was extracted in Clevenger's type apparatus at harvesting of the crop. Oil percentage was calculated on v/w basis on fresh-weight basis. Oil yield was computed by multiplying the fresh-herb yield at harvest with respective essential oil content and expressed in litre/ha.

Growing degree days (GDD) were calculated with following formula:

$$\text{Growing degree-days} = \frac{T_{max} + T_{min}}{2} - T_{base}$$

where, T_{max}, daily maximum temperature (˚C), T_{min}, daily minimum temperature (˚C), T_{base}, base temperature or minimum threshold temperature (˚C) and taken as 4, 6 and 10˚C for months of January–March, April and May to harvesting respectively. The heliothermal units (HTU) and photothermal units (PTU) were calculated by multiplying the growing degree-days to the actual sunshine hours and maximum possible sunshine hours of the day, respectively, recorded at Meteorological Observatory of the University at Ludhiana.

Analysis of variance was performed on fresh-herb and oil yield using Procedure Generalized Linear Model of Statistical Analysis System software version 9.3 for windows. The difference between means of various treatments was compared with Fisher's least significant difference test at 5% probability level. Since trends in results were similar during both the years, data were pooled, keeping years as main factor to increase the precision for main plot (Main plot = date of planting). A multiple linear regression analysis was done keeping fresh-herb yield as dependent variable and GDD, PTU and HTU as independent variable assuming all the 3 independent variables affect the dependent variable in a linear fashion and independently of one another.

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots. + b_kX_k + e$$

where b_0, b_1, b_2…. b_k are regression coefficients, $X_{1,}$ X_2…..X_k are independent variable.

Path analysis was done to access the direct and indirect effects of independent variable on dependent variable (fresh-herb yield) as per procedure given by Akintunde (2012).

RESULTS AND DISCUSSION

Date of planting

Fresh-herb and oil yields of Japanese mint increased successively with delay in planting from 1 January to 15 February, though the differences were statistically non-significant between 30 January and 15 February (Table 1). The crop planted on 30 January and 15 February gave 35.5 and 18.7 and 38.1 and 21% higher fresh-herb yield than 1 January and 15 January plantings respectively. The corresponding values for oil yield were 29.5 and 13.7 and 31.7 and 15.7% respectively. The oil content in biomass did not vary significantly among different dates of planting. Higher shoot-biomass production in 30 January and 15 February-planted crop resulted from favourable temperature and photo-period conditions which is evident from GDD, PTU and HTU accumulation data (Table 2). The crop planted on 30 January and 15 February accumulated 456 and 624 and 222 and 390 units higher GDD than 1 January and 15 January planted crop respectively. Similarly, 30 January and 15 February planted crop accumulated 456 and 624 and 222 and 390 and 456 and 624 and

222 and 390 units higher PTU and HTU than 1 January and 15 January planted crop respectively. The higher accumulation of GDD, PTU and HTU in later planting dates resulted in better photosynthesis rate which ultimately resulted in higher biomass production in the form of leaves and stem. Mahal (1991) observed significantly higher number of sprouts/unit area in 23 February planted spearmint as compared to 25 December and 24 January plantings and mentioned that 23 February planted crop consumed 2,471 heat units as against 1,972 and 1,517 heat-units consumed by 24 January and 25 December planted crop at PAU, Ludhiana

Table 1. Fresh-herb yield, oil content and oil yield as influenced by planting date and harvesting schedule of Japanese mint (pooled mean of 2010 and 2011)

Treatment	Fresh-herb yield (t/ha)	Oil content (% fresh-weight basis)	Oil yield (litre/ha)
Planting date			
1 January	21.57	0.67	141.9
15 January	24.61	0.66	161.6
30 January	29.22	0.63	183.7
15 February	29.78	0.63	186.9
SEm±	0.48	0.03	3.23
CD (P=0.05)	1.37	NS	9.2
Harvesting schedules			
120 DAP	22.93	0.66	150.2
135 DAP	26.19	0.65	169.1
150 DAP	29.77	0.63	186.3
SEm±	0.31	0.02	2.67
CD (P=0.05)	0.89	NS	7.6

DAP, days after planting

Harvesting schedule

Fresh-herb and oil yields increased significantly and successively with delay in harvesting from 120 DAP to 150 DAP. Harvesting at 150 DAP resulted in 13.7% and 29.8% higher fresh-herb yield than harvested 135 and 120 DAP respectively. The crop harvested at 150 DAP remained in field for longer period, resulting in better growth and development of plants. The crop harvested at 150 DAP accumulated 649, 8,866 and 5,275 and 322, 4,480 and 2,548 units higher GDD, PTU and HTU than the crop harvested 120 and 135 DAP respectively. Sekhon (1995) also reported significantly higher fresh-herb yield from *mentha citrata* crop harvested at 150 DAP as compared to early harvesting because of longer field duration and higher consumption of heat units.

Interaction effect

The interaction between planting dates and harvesting schedules was also significant (Table 3) and the maximum fresh-herb and oil yields were obtained when crop planted on 15 February and harvested at 150 DAP which was statistically at par with crop planted on 30 January and harvested at 150 DAP, but was significantly better than all other combination of planting dates and harvesting schedules. Data further manifested that crop planted on 15 February and harvested at 135 DAP gave significantly higher fresh-herb yield than the crop planted on 15 January and harvested at 150 DAP despite the 15 days less field duration (Table 3). This resulted from favourable temperature and radiation conditions which is evident from the highest accumulation of GDD, PTU and HTU units in crop planted on 15 February and harvested at 150 DAP.

Table 2. Effect of dates of sowing on accumulated heat, photo-thermal and helio-thermal units at 3 harvesting schedules in Japanese mint (pooled mean of 2010 and 2011)

Planting date	Harvesting schedule			Mean
	120 DAP	135 DAP	150 DAP	
		Heat units		
1 January	1,680	2,002	2,347	2,010
15 January	1,908	2,253	2,571	2,244
30 January	2,146	2,464	2,789	2,466
15 February	2,319	2,640	2,942	2,634
Mean	2,013	2,340	2,662	
		Photo-thermal units		
1 January	19,899	24,195	28,853	24,316
15 January	23,164	27,826	32,280	27,757
30 January	26,722	31,176	35,764	31,221
15 February	29,712	34,249	38,470	34,144
Mean	24,874	29,362	33,842	
		Helio-thermal units		
1 January	13,377	16,062	18,854	16,098
15 January	15,689	18,445	21,747	18,627
30 January	17,904	21,206	23,552	20,887
15 February	20,428	22,595	24,348	22,457
Mean	16,850	19,577	22,125	

DAP, Days after planting

Regression and path analysis

A multiple regression was performed keeping fresh-herb yield as dependent and GDD, HTU, PTU as independent variables. The model found to be well fit with P=0.0006 and multiple correlation value of 0.9636. The data depicted in Table 4 on correlation matrix revealed that fresh-herb yield of mint significantly and positively correlated with GDD, HTU and PTU. Path analysis was also performed to access the nature of association of fresh-herb yield with GDD, HTU and PTU and their direct as well as indirect effects under different dates of planting and harvesting schedules (Table 5). The data indicated that GDD and HTU showing negative direct as well as indirect coef-

Table 3. Interactive effect of planting dates and harvesting schedules on fresh-herb and oil yield of Japanese mint (pooled mean of 2010 and 2011)

Planting date	Fresh-herb yield (t/ha)			Oil yield (litres/ha)		
	Harvesting schedule (DAP)			*Harvesting schedule (DAP)*		
	120	135	150	120	135	150
1 January	18.79	21.50	24.44	114.3	150.8	160.8
15 January	22.82	24.18	26.83	155.7	158.6	170.5
30 January	24.92	29.34	33.40	163.8	181.7	205.6
15 February	25.19	29.73	34.41	167.2	185.3	208.3
Interaction						
SEm±		0.60			0.51	
CD (P=0.05)		1.79			15.2	

DAP, Days after planting

Table 4. Correlation matrix depicting the relationship between fresh-herb yield (FHY), growing degree-days (GDD), helio-thermal-units (HTU) and photo-thermal units (PTU) during crop season under different dates of planting and harvesting schedules (mean of 2010 and 2011)

Characters	FHY	GDD	HTU
GDD	0.9545		
HTU	0.9503	0.9885	
PTU	0.9610	0.9975	0.9924

Table 5. Nature of association of GDD, HTU, PTU and fresh-herb yield (FHY) of mint and their path coefficient showing the direct (diagonal bold ones) and indirect effects (mean of 2010 and 2011)

Characters	FHY	GDD	HTU
GDD	-0.1184	-0.0042	0.0189
HTU	-0.1170	-0.0042	0.0188
PTU	0.1181	-0.0042	0.0190

ficients, while PTU having positive direct and indirect effects on fresh-herb yield of mint.

Thus, Japanese mint should be planted from 30 January to 15 February and harvested at 150 DAP for realizing maximum herb and oil yield under Punjab condition. The fresh-herb yield of mint is positively correlated with GDD, PTU and HTU. The GDD and HTU having negative while PTU having positive direct and indirect effects on fresh-herb yield of Japanese mint.

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