Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(2): 49-53
Received: 07-01-2019
Accepted: 09-02-2019

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Effect of Herbicides on dry matter accumulation, fresh herbage yield, oil yield and profitability of Japanese mint (*Mentha arvensis* L)

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Abstract
An experiment was conducted during summer season of 2015 and 2017 at Agronomy Research Farm of N. D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.), to study the **"**Weed management studies in Japanese mint (*Mentha arvensis* L.). The experiment consisted of 14 treatment combination with propaquizafop **-** p - ethyl @ 40 g ha^{-1} as post-emergence (T_1), propaquizafop **-** p - ethyl @ 60 g ha^{-1} as post-emergence (T_2), propaquizafop **-** p - ethyl @ 80 g ha^{-1} as post-emergence (T_3), propaquizafop **-** p - ethyl @ 100 g ha^{-1} as post-emergence (T_4), clodinafop propargyl @ 40 g ha^{-1} as post-emergence (T_5), clodinafop propargyl @ 60 g ha^{-1} as post-emergence (T_6), clodinafop propargyl @ 80 g ha^{-1} as post-emergence (T_7), Pendimethalin @ 1000 g ha^{-1} as pre-emergence (T_8), oxyfluorfen @ 200 g ha^{-1} as pre-emergence (T_9), imazethapyr + imazamox @ 80 g ha^{-1} as post-emergence (T_{10}), imazethapyr + pendimethal in (RM) @1000 g ha^{-1} as pre-emergence (T_{11}), imazethapyr @ 60 g ha^{-1} as post-emergence (T_{12}), Weed free (Three hand weeding at 20, 45 and 65 DAP) (T_{13}) and weedy check (T_{14}). The treatments were replicated three times in a randomized block design.
All weed management practices proved effective in controlling the weeds in Japanese mint and gave significantly higher dry matter accumulation, fresh herbage yield and oil yield over weedy check. Pre emergence application of imazethapyr + pendimethalin at 1000 g ha^{-1} was found to be most effective control of all major weeds and recorded maximum dry matter accumulation, fresh herbage yield and oil yield (184.58 and 188.11 kg ha^{-1}) during 2015 and 2017, respectively, which was significantly superior to rest of the treatments while at par with post emergence application of imazethapyr + imazamox @ 80 g ha^{-1} as post emergence, pendimethalin @ 1000 g ha^{-1} as pre emergence and imazethapyr @ 60 g ha^{-1} as post-emergence. The net return (Rs. 155725) and B: C ratio (2.29) were also higher with pre emergence application of imazethapyr + pendimethalin at 1000 g ha^{-1} as pre-emergence.

Keywords: Japanese mint, herbicides, Weeds, dry matter, herbage yield, oil yield, Economics

Introduction
Japanese mint (*Mentha arvensis* L.) is an essential bearing family Lamiaceae, *Mentha* species are known for kitchen and medicinal herbs since time immemorial. There are about 40 species belonging to this genus, out of which, four viz. *Mentha arvensis* L. (Japanese mint or Corn mint or Field mint), *Mentha piperita* L. (Pepper mint, Black mint, Mitcham mint), *Mentha spicata* L. (Spearmint, Garden mint or Lamb mint) and *Mentha citrate Ehrh.* (Bergamot mint or Orange mint) are cultivated commercially in different parts of the world. Among the various types of mint, only Japanese mint is cultivated in tropics and subtropics. Mints are perennial aromatic herbs with quadrangular stem and bearing leaves with essential oil present in glands located in subcuticular region. Among these four species, *Mentha arvensis* L. has erect growth and its oil contains 70-85 % menthol, which is the highest among the four species. It is grown for medicinal and aromatic purposes. Brazil is the native place of Japanese mint. Commercially, Japan started producing mint around 1870. Previously, it was called Japanese mint and Japan was the leading mint producing country in the world. The production of mint was also reported in other countries of the world like China and India around 1960. Japanese mint is a long lasting, growing, hairy leaves herb that can even attain a height of 1.5 meter under favorable conditions. Mint oil is the main source of aromatic compounds such as menthol used as flavoring agent and as a constituent of medicinal preparations, especially in cough syrups, candies, beverages, chewing gums, hair lotions, toothpastes, mouthwashes and liquors. It is also employed as a soothing ingredients in cosmetic preparations, colognes, deodorants, aftershave lotions and perfume bases. The anti-microbial properties of menthol mint enhance the shelf of edible products and grains. India is the largest producer and exporter of Mentha oil in the world producing about 25,000 tonnes of mint oil and exporting 3,000

tonnes and earn exchange with of Rs.100 crores annually. In India, *M. arvensis* L. is cultivated in the semi- temperate regions in the foot hills of Himalayas i.e. Uttar Pradesh, Punjab, Haryana, Bihar and Assam. Among various mint species, Japanese mint accounts for 86 % of total area under mint cultivation in India. The area under this crop in the country is estimated at about 2,50,000 hectares (Anonymous 2016a) [1]. Japanese mint crop requires frequent irrigations for quick sprouting and better growth which encourage the growth of weeds. Thus, the crop is affected from weeds of both winter and summer seasons. Due to poor initial growth rate, field is usually dominated by the weeds, resulting in poor quality and quantity of oil (Skrubis, 1971) [9]. Reduction in herbage yield by 80% and essential oil yield by 74% due to weedy condition has been reported by Gulati and Bhan (1971) [2]. The presence of weeds reduces the photosynthetic efficiency and crop dry matter production. The weeds, if not controlled during critical period of crop-weed competition, i.e., 30 to 45 days in cutting leads to 76 and 80 % reduction in fresh herb and essential oil as compared with crop free from weeds (Singh *et al* 1993a) [10]. The weeds can be managed by cultural, mechanical and chemical methods. Manual weeding being costly and time consuming is not possible on a large scale. Moreover, peak period of weed removal from *Mentha* crop coincides with the harvesting period of many winter season crops, thus posing a serious problem of labor availability which delays the removal of weeds. Under such situation, use of herbicides for weed control holds a great promise. The chemical method involving use of selective herbicides is generally effective and economical and the farmers are adopting this method extensively. Now - a - days a number of high potency herbicide molecules have been developed which proved highly efficient to control the different types of weed flora in Japanese mint. Weeds are considered to be major enemy of crop plants and have been found to cause considerable economic loss due to their luxuriant growth accelerating the intensity of their competition for space, CO_2, nutrients, moisture and light without leaving obvious sign of distress. Successful weed management for Japanese mint crop becomes much more important in order to exploit its maximum production potential as it is a serious constraint. The control of weeds at critical stages of crop-weed competition turns the growth factor in favor of crop plants. Better use of growth factors by Japanese mint plant in the plots receiving weed control treatments due to less crop-weed competition was reflected on plant growth characters viz., plant height, dry matter accumulation, fresh herbage yield, oil yield etc.

Material and Methods

The field experiment was conducted at Agronomy Research Farm of N. D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during summer season of 2015 and 2017. The farm is located 42 km away from Faizabad on Raebareily road at 26.47˚ N latitude and 82.12˚ E longitude and about 113 meters above the mean sea level. Summer is hot and dry. Generally, the mean maximum temperature during the hottest month (May) vary from 33.0 to 41.7 ^{0}C and minimum during the coolest month (December and January) varies from 4.5 to 8.8 0C. The soil of experimental field was Silty loam in texture, low in organic carbon and available nitrogen, medium in available phosphorus and potassium with near to neutral in reaction. The experiment consisted of 14 treatment combination with Propaquizafop **-** p - ethyl @ 40 g ha^{-1} as post-emergence (T_1), Propaquizafop **-** p - ethyl @ 60 g ha^{-1} as post-emergence (T_2), Propaquizafop **-** p - ethyl @ 80 g ha^{-1} as post-emergence (T_3), Propaquizafop **-** p - ethyl @ 100 g ha^{-1} as post-emergence (T_4), Clodinafop propargyl @ 40 g ha^{-1} as post-emergence (T_5), Clodinafop propargyl @ 60 g ha^{-1} as post-emergence (T_6), Clodinafop propargyl @ 80 g ha^{-1} as post-emergence (T_7), Pendimethalin @ 1000 g ha^{-1} as pre-emergence (T_8), Oxyfluorfen @ 200 g ha^{-1} as pre-emergence (T_9), Imazethapyr + Imazamox @ 80 g ha^{-1} as post-emergence (T_{10}), Imazethapyr+ Pendimethalin (RM) @1000 g ha^{-1} as pre-emergence (T_{11}), Imazethapyr @ 60 g ha^{-1} as post-emergence (T_{12}), Weed free (Three hand weeding at 20, 45 and 65 DAP) (T_{13}) and weedy check (T_{14}). The herbicides were applied with the help of manually operated Knapsack sprayer fitted with flat fan nozzle using 500 liters of water per hectare. Data on dry matter accumulation was recorded at different growth stage of crop in each plot. Weed samples were sun dried before oven drying at 70^{0}C until constant weight was attained.

Results and Discussion

Weeds are considered to be major enemy of crop plants and have been found to cause considerable economic loss due to their luxuriant growth accelerating the intensity of their competition for space, CO_2, nutrients, moisture and light without leaving obvious sign of distress. Successful weed management for Japanese mint crop becomes much more important in order to exploit its maximum production potential as it is a serious constraint. The control of weeds at critical stages of crop-weed competition turns the growth factor in favor of crop plants. Better use of growth factors by Japanese mint plant in the plots receiving weed control treatments due to less crop-weed competition was reflected on plant growth characters viz., initial plant population, plant height, dry matter accumulation, fresh herbage yield, oil yield etc.

Dry matter accumulation (g m^{-2})

Dry matter accumulation of Japanese mint increased with the advancement of crop age and reached maximum at harvest stage during both the years of crop period and their result have been presented in Table-1, indicate that all the weed management practices increased the dry matter significantly over weedy check at all the stages of crop growth except 30 DAP, during both the years. Among the herbicides pre-emergence application of imazethapyr + pendimethalin @ 1000 g ha^{-1} was found most effective for increasing the dry matter of Japanese mint which was significantly superior to rest of the treatments while at par with post emergence application of imazethapyr + imazamox @ 80 g ha^{-1}, pendimethalin @ 1000 g ha^{-1} as pre emergence and imazethapyr @ 60 g ha^{-1} as post- emergence at all the stages of crop growth except 30 DAP where imazethapyr + pendimethalin @ 1000 g ha^{-1}applied as pre emergence was at par with pre-emergence application of pendimethalin @ 1000 g ha^{-1} and oxyfluorfen @ 200 g ha^{-1} during both the years. Similar results were also noticed by Singh (1983) [7], Tuti *et al*. (2007) [12] and Hossain *et al.* (2014) [4]

Fresh herbage yield

Fresh herb yield recorded significantly higher with weed management practices over weedy check at 60 DAP and at harvest stage of crop growth during both the years. Among the herbicides pre-emergence application of imazethapyr + pendimethalin @ 1000 g ha^{-1} was found most effective for increasing the fresh herbage yield of Japanese mint which was

significantly superior to rest of the treatments while at par with post emergence application of imazethapyr + imazamox @ 80 g ha^{-1}, pendimethalin @ 1000 g ha^{-1} as pre emergence and imazethapyr @ 60 g ha^{-1} as post-emergence at 60 DAP and at harvest stage of crop growth. This is might be due to effective weed control resulted in maximum plant growth and development. Similar results were also noticed by Randhawa *et al.* (1982) [6], Singh (1991b) [8], Gupta *et al.* (2017) [3] and Singh *et al.* (2017) [11]

Oil yield

The data pertaining to essential oil yield are presented in Table-1, indicate that all the weed management practices increased the oil yield significantly over weedy check at harvest stage of crop growth during both the years. Among the herbicides pre-emergence application of imazethapyr + pendimethalin @ 1000 g ha^{-1} was found to be most effective in increasing the oil yield of Japanese mint fallowed by post emergence imazethapyr + imazamox @ 80 g ha^{-1}, pendimethalin @ 1000 g ha^{-1} as pre emergence and imazethapyr @ 60 g ha^{-1} as post-emergence at harvest stage of crop growth. The lowest oil yield obtained in weedy check treatment was associated with values of yield attributes. It might be due to heavy crop weed competition where weeds shared a major part of inputs with crop which suffered a lot of these. Jaidev *et al.* (1993) [5], Yadav *et al.* (2015) and Yadav *et al.* (2017) [13]

Economics

Among the herbicides pre-emergence application of imazethapyr + pendimethalin @ 1000 g ha^{-1} provided its superiority over all management practices by giving highest mean gross return of (Rs.223614 ha^{-1}) which was at par with imazethapyr + imazamox @ 80 g ha^{-1} as post emergence (Rs. 205974 ha^{-1}), pendimethalin @ 1000 g ha^{-1} as pre emergence (Rs. 205146 ha^{-1}) and imazethapyr @ 60 g ha^{-1} as post-emergence (Rs. 201924 ha^{-1}), whereas the lowest gross return of (Rs 64518 ha^{-1}) was recorded in weedy check, respectively. Highest mean net return was recorded with pre-emergence application of imazethapyr + pendimethalin @ 1000 g ha^{-1} (Rs.155725 ha^{-1}) which was at par with imazethapyr + imazamox @ 80 g ha^{-1} as post emergence (Rs. 140977 ha^{-1}), pendimethalin @ 1000 g ha^{-1} as pre emergence (Rs. 139433 ha^{-1}), and imazethapyr @ 60 g ha^{-1} as post-emergence (Rs. 136054 ha^{-1}). The lowest net return was found in weedy check (Rs. 8266 ha^{-1}), respectively. Highest mean benefit cost ratio was found with pre-emergence application of imazethapyr + pendimethalin @ 1000 g ha^{-1} (2.29) was at par with imazethapyr + imazamox @ 80 g ha^{-1} as post emergence (2.17), pendimethalin @ 1000 g ha^{-1} as pre emergence (2.12) and imazethapyr @ 60 g ha^{-1} as post-emergence (2.07). The lowest benefit cost ratio (0.15) was observed in weedy check, respectively.

Summary and Conclusions

All weed management practices proved effective in controlling the weeds in Japanese mint and gave significantly higher dry matter accumulation, fresh herbage yield and oil yield over weedy check. Pre emergence application of imazethapyr + pendimethalin at 1000 g ha^{-1} was found most effective for control of all major weeds and recorded maximum dry matter accumulation (570.2 and 579.24 gm^{-2}) , fresh herbage yield(214.63 and 216.22 q ha^{-1}) and oil yield (184.58 and 188.11 kg ha^{-1}) which was significantly superior to rest of the treatments while at par with post emergence application of imazethapyr + imazamox @ 80 g ha^{-1} as post emergence, pendimethalin @ 1000 g ha^{-1} as pre emergence and imazethapyr @ 60 g ha^{-1} as post-emergence. The net return (Rs. 155725) and B: C ratio (2.29) were also higher with pre emergence application of imazethapyr + pendimethalin at 1000 g ha^{-1} as pre-emergence. On the basis of results obtained in this study it may be concluded that application of imazethapyr + pendimethalin at 1000 g ha^{-1} as pre-emergence should be adopted for maximum dry matter accumulation, herbage yield , oil yield, net return and B: C ratio in Japanese mint.

Table 1.1: Dry matter accumulation (g m^{-2}) at various growth stages as influenced by weed management practices

Treatments	30 DAP		60 DAP		90 DAP		120 DAP		At harvest	
	2015	2017	2015	2017	2015	2017	2015	2017	2015	2017
Propaquizafop-p-ethyl @ 40 g ha^{-1} as post-emergence	13.05	13.58	82.52	84.69	223.34	229.70	388.70	398.13	433.23	447.23
Propaquizafop-p-ethyl @ 60 g ha^{-1} as post-emergence	13.74	14.27	84.60	86.77	228.11	234.47	394.47	403.90	447.20	461.20
Propaquizafop-p-ethyl @ 80 g ha^{-1} as post-emergence	14.15	14.68	86.59	88.76	234.86	241.22	398.22	407.65	455.15	469.15
Propaquizafop-p-ethyl @ 100 g ha^{-1} as post-emergence	14.42	14.95	89.65	91.82	244.95	251.31	417.31	429.74	478.14	492.14
Clodinafop propargyl @ 40 g ha^{-1} as post-emergence	14.23	14.76	87.06	89.23	241.14	247.50	406.50	415.93	467.43	481.43
Clodinafop propargyl @ 60 g ha^{-1} as post-emergence	14.35	14.88	88.87	91.04	243.19	249.55	411.55	420.98	473.18	487.18
Clodinafop propargyl @ 80 g ha^{-1} as post-emergence	14.62	15.15	90.30	92.47	246.26	252.62	421.62	436.05	489.75	497.75
Pendimethalin @ 1000 g ha^{-1} as pre-emergence	16.43	16.51	99.79	102.66	273.81	278.04	464.31	468.38	527.77	546.37
Oxyfluorfen @ 200 g ha^{-1} as pre-emergence	15.81	15.94	92.37	95.17	252.14	256.76	437.43	449.19	501.43	505.43
Imazethapyr + Imazamox @ 80 g ha^{-1} as post-emergence	15.13	15.43	102.07	104.60	279.64	286.20	479.47	481.66	549.53	557.93
Imazethapyr+ Pendimethalin (RM) @1000 g ha^{-1} as pre-emergence	17.13	17.43	104.61	107.51	287.31	293.19	490.72	498.46	570.20	579.54
Imazethapyr @ 60 g ha^{-1} as post-emergence	14.75	15.15	95.21	98.97	260.24	264.33	450.61	457.41	512.06	523.27
Weed free	17.82	18.13	108.02	110.40	291.81	297.20	498.63	507.39	580.10	594.60
Weedy check	14.12	14.42	25.40	26.60	56.75	58.62	99.39	102.77	116.31	118.24
SEm±	0.65	0.58	3.56	3.57	9.97	10.39	15.97	15.99	21.02	22.02
CD (P=0.05)	1.90	1.69	10.34	10.38	28.97	30.21	46.43	46.49	61.09	64.02

Table 1.2 Fresh herb yield (60 days after planting and at harvest stage) and oil yield (at harvest stage) as influenced by weed management practices

Treatments	Fresh herb yield (q ha^{-1})				Oil yield (kg ha^{-1})	
	60 DAP		At harvest			
	2015	2017	2015	2017	2015	2017
Propaquizafop-p-ethyl @ 40 g ha^{-1} as post-emergence	85.55	87.12	154.79	157.28	128.48	130.54
Propaquizafop-p-ethyl @ 60 g ha^{-1} as post-emergence	88.58	90.10	156.26	159.73	129.70	134.17
Propaquizafop-p-ethyl @ 80 g ha^{-1} as post-emergence	91.49	93.16	161.00	164.46	135.24	138.15
Propaquizafop-p-ethyl @ 100 g ha^{-1} as post-emergence	94.25	96.81	172.66	175.75	145.03	149.39
Clodinafop propargyl @ 40 g ha^{-1} as post-emergence	92.78	94.40	164.96	168.35	136.92	141.41
Clodinafop propargyl @ 60 g ha^{-1} as post-emergence	93.34	95.16	166.65	169.84	139.99	144.36
Clodinafop propargyl @ 80 g ha^{-1} as post-emergence	95.64	97.13	175.16	176.45	147.13	149.98
Pendimethalin @ 1000 g ha^{-1} as pre-emergence	104.78	109.51	194.28	198.72	169.02	172.89
Oxyfluorfen @ 200 g ha^{-1} as pre-emergence	96.28	99.28	183.22	186.85	153.90	158.82
Imazethapyr + Imazamox @ 80 g ha^{-1} as post-emergence	106.78	111.91	197.43	199.42	169.79	173.50
Imazethapyr + Pendimethalin (RM) @1000 g ha^{-1} as pre-emergence	110.59	113.77	214.63	216.22	184.58	188.11
Imazethapyr @ 60 g ha^{-1} as post-emergence	101.15	106.29	192.61	196.48	167.57	168.97
Weed free	115.71	117.53	216.52	218.38	186.21	189.99
Weedy check	34.05	36.73	63.54	65.23	52.74	54.79
SEm±	4.13	3.17	7.73	7.45	6.33	6.80
CD (P=0.05)	12.00	9.21	22.47	21.67	18.39	19.76

Table 1.3: Economics of various weed management practices of Japanese mint crop during 2015 and 2017.

Treatments	Mean Oil yield (kg ha^{-1})	Common cost (Rs.)	Treatments cost (including application charges 645 Rs. ha^{-1})	Oil extraction including transport cost (Rs.)	Total cost (Rs.)	Gross return (Rs.)	Net profit (Rs.)	B:C Ratio
Propaquizafop-p-ethyl @ 40 g ha^{-1} as post-emergence	129.51	52757	1285	8418	62460	155412	92952	1.49
Propaquizafop-p-ethyl @ 60 g ha^{-1} as post-emergence	131.94	52757	1605	8576	62938	158322	95384	1.52
Propaquizafop-p-ethyl @ 80 g ha^{-1} as post-emergence	136.70	52757	1925	8885	63567	164034	100467	1.58
Propaquizafop-p-ethyl @ 100 g ha^{-1} as post-emergence	147.21	52757	2245	9569	64571	176652	112081	1.74
Clodinafoppropargyl @ 40 g ha^{-1} as post-emergence	139.17	52757	1515	9046	63318	166998	103680	1.64
Clodinafoppropargyl @ 60 g ha^{-1} as post-emergence	142.18	52757	1946	9241	63944	170610	106666	1.67
Clodinafoppropargyl @ 80 g ha^{-1} as post-emergence	148.56	52757	2383	9656	64796	178266	113470	1.75
Pendimethalin @ 1000 g ha^{-1} as pre-emergence	170.96	52757	1844	11112	65713	205146	139433	2.12
Oxyfluorfen @ 200 g ha^{-1} as pre-emergence	156.36	52757	2463	10163	65383	187632	122249	1.87
Imazethapyr + Imazamox @ 80 g ha^{-1} as post-emergence	171.65	52757	1083	11157	64997	205974	140977	2.17
Imazethapyr+ Pendimethalin (RM) @1000 g ha^{-1} as pre-emergence	186.35	52757	3020	12112	67889	223614	155725	2.29
Imazethapyr @ 60 g ha^{-1} as post-emergence	168.27	52757	2175	10938	65870	201924	136054	2.07
Weed free	188.10	52757	32250	12227	97234	225720	128487	1.32
Weedy check	53.77	52757	0	3495	56252	64518	8266	0.15

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