Journal of Crop and Weed, 18(2): 126-133 (2022)
ISSN- O : 2349 9400 ; P : 0974 6315

http://cwssbckv.org
www.cropandweed.com

Influence of plant growth regulators on yield and quality of Mint (*Mentha arvensis* L.)

U. SINGHA, *N.CHATTOPADHYAY, D.K. GHOSH (LKN) AND A. BANDYOPADHYAY

Department of Plantation, Spices, Medicinal and Aromatic crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur- 741252, Nadia, West Bengal

Received : 10.02.2022 ; Revised : 30.06.2022 ; Accepted : 10.07.2022

DOI: https://doi.org/10.22271/09746315.2022.v18.i2.1582

ABSTRACT

An experiment was conducted during the pre-kharif season (Feb to May) of 2020 and 2021to study the influence of plant growth regulators on yield and quality of Mint (Mentha arvensis L.*) at the H R S, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. Total 13 number of treatments including control were imposed in RBD with three replications. Necessary agricultural operations were adopted. Among different treatments mean maximum plant height (47.25cm), number of primary branches (8.30), secondary branches (21.55), leaf length (4.30cm), width (3.30cm) , plant spread in North-South (50.30cm) , East-West (44.10cm) , fresh herbage yield/plot (2.14kg/2.7m^2), dry yield/plot (730.57g), projected yield (79.24 q ha^{-1}),net return (Rs.142452.00ha $^{-1}$) and B:C ratio of 2.51: 1 were evident under T_6i.e.. pre-planting cutting treatment with GA_3 100 ppm + spraying with $GA_3$100 ppm at 30, 60 and 90 DAT). However, the mean maximum essential oil yield (1.98ml100g^{-1} dry leaves sample) was found from T_{13} (e.g.No pre-planting cutting treatment + spraying with IAA 125 ppm at 30, 60 and 90 DAT) Depending upon the above results it may be concluded that pre-planting cutting treatment with $GA_3$100 ppm + spraying with $GA_3$100 ppm (i.e. T_6) at 30, 60 and 90 DAT may be recommended. However, the experiment should be carried out for at least 2-3 years to confirm the results.*

Keywords: BC ratio, mint, PGR, quality, yield

Mint (*Mentha arvensis* L, family- Lamiaceae.) is a genus of aromatic perennial distributed mostly in the temperate and sub-temperate regions of the World. Several Mentha species are considered as an industrial crop as they are a source of essential oil enriched in certain monoterpenes, widely used in food, flavour, cosmetic and pharmaceutical industries. In 1952, the Regional Research Laboratory, Jammu obtained a few live stolons of this crop from Japan (Kapoor *et al.*,1955) which laid down the foundation of a flourishing chemical industry in India. It's cultivation in India has spread to an area of 80,000 to 1,00,000 ha with a production of more than 15,000 tonnes of essential oils which worth more than Rs.150 crores (Varshney *et al.,* 1998). Among Asian, Europe and American countries, India occupies first position with respect to area and production of Japanese mint followed by China (Watts, 1997). Japanese mint (*Mentha arvensis* L.), pepper mint (*Mentha piperita*) and spear mint (*Mentha spicata*), contains isolates like menthol, carvone, linalylacetate and linalool which are used in pharmaceutical, food flavour, cosmetics, beverages and allied industries. Other mints *viz*., water mint or marsh mint (*Mentha aquatica*), horse mint (*Mentha longifolia*), apple mint or round leaved mint (*Mentha rotundifolia*), English or European pudding grass (*Mentha pulegium*) were also cultivated in India. Due to less menthol content in their essential oils, they were considered to be uneconomical on commercial scale (George., 1994). The cooling effect is also exploited in making certain cosmetic products like lipsticks, face creams, hair lotions and shaving creams. The various uses of mint in pharmaceutical industries are as tooth pastes, mouth fresheners, aerosols and shoe polish (George, 1994). Menthol's refreshing aroma and cooling action along with its stimulant and antiseptic properties have led to its wide spread use for medicinal purposes such as inhales, cough syrups and ointments. India dominates in mint production and it supplies 80 per cent of mints globally, followed by China and Japan. About 90 per cent of Indian mint production comes from Uttar Pradesh and remaining 10 per cent coming from smaller parts of Punjab, Rajasthan *etc*. Four main species of mentha (*Mentha arvensis* L. -Japanese mint, *Mentha perperita*-pepper mint, *Mentha spicata* -spear mint, and *Mentha citrate* bergamot) are presently cultivated in India. According to a survey, about 2,50,000 hectares are put in the farming of mentha in India. The large scale commercial cultivation of mentha is going on in different states of India like Uttar Pradesh (Bilaspur, Rampur, Chandausi, Sambhal, Barabanki, Bareilly, Sitapur etc.), Punjab (Jalandhar), Haryana (Ambala), Himachal Pradesh and Bihar (Muzuffarpur). India produces about 27,600 tonnes of mentha crude oil per annum (average for last five years). The output is increasing in recent years and a record production is close to 38,000 tonnes in 2011. Between 1965 and 2006, the

Email: dr_ncspc@rediffmail.com

Indian mentha oil market grew from 2 MT to 32,000 MT, registering an incredible production increase. India is the largest producer and consumer (an estimated of 8500MT (2009-10) of Mentha oil, compared to the rest of the world's consumption (about 20,000 MT). India now dominates 75-80% of the world market mint oil production lagging behind Brazil and China. Plant growth regulators have a pivotal role in intensive agriculture and hence are quite valuable in organic production of high value crops. Gibberellins (especially GA_3) are the most important valuable compound for enhancing the productivity of commercial crops. PGRs have been effectively used to enhance the herb and oil yield in mint species. Among them auxin and GA_3 have been evaluated for enhancing the productivity of crops (Keltawi *et al*.,1987). In *Mentha piperita*, GA_3 has been found to induce enhancement of total herb and foliar spray of GA_3 have been found to increase the menthol content in oil. Gibberellins and ethereal are also reported to increase the plant biomass and leaf area in *Mentha spicata* (Singh *et al*., 2001).

Keeping in view the scanty information available with respect to influence of plant growth regulators on mint crop, the present investigation was conducted to improve the vegetative growth, herbage yield and quality of mint by the use of plant growth regulators.

MATERIALS AND METHODS

Present investigation was undertaken during pre-*kharif* (Feb-May) season of 2020 and 2021 for studying the influence of different concentration of GA_3 and IAA on growth, total biomass yield and essential oil quality of mint (*Mentha arvensis* L.) at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The research station is located at 23.5° North altitude and 89^0 East longitudes, with an altitude of 9.75m above the mean sea level. The soil of the experimental field was gangetic alluvial sandy clay loam texture, good water holding capacity well-drained with moderate soil fertility status having P^H 6.90. The experimental field was prepared thoroughly by repeated ploughing to get a fine tilth. Trashes were removed and leveled. After leveling the experimental plots were demarcated into 39 plots of 1.8 m x 1.5 m dimension with 30 cm wide ridges around the plots. Irrigation channels of 50cm wide were also made. Planting materials (mother plants) were collected from Komal Gandhar nursery, Kalyani, Nadia, West Bengal during December 2019. Cuttings were prepared from mother plants grown, planted in pots in the shade house during mid of January taking only terminal cuttings having 2-3 leaves with luxurious growth. Cuttings were treated with blitox @ $2gl^{-1}$ to protect from fungal disease during nursery planting. Regular irrigation was done to get the well establishment of cuttings. Well rotten farm yard manure (10 t ha^{-1}) was applied at the time of field preparation as basal application (10 days before planting) and mixed well with the soil. The recommended dose of nitrogen, phosphorus and potassium were applied @ 150:60:60 kg ha^{-1} (Aswani *et al*., 2020) before trans-planting of mint. The nitrogen, phosphorus and potassium were applied in the form of urea (46%N), single superphosphate (16%P_2O_5) and muriate of potash (60%K_2O) respectively. Pots having rooted cuttings were first hardened by holding the water for about one week before transplanting and exposing them to direct sunlight. Healthy cuttings having good roots were uprooted for transplanting in the main field after one Later month in the mid of February. Healthy rooted cuttings were dipped in different concentrations of plant growth regulators for 30 minutes for pre planting cutting treatments. The treatments consisting of T_1-Control (Planting of cutting without growth regulator), T_2-Pre-planting cutting treatment with GA_3 50 ppm + spraying with GA_3 50 ppm at 30, 60 and 90 DAT, T_3-No pre-planting cutting treatment + spraying with $GA_3$50 ppm at 30, 60 and 90 DAT, T_4-Pre-planting cutting treatment with GA_3 75 ppm + spraying with GA_3 75 ppm at 30, 60 and 90 DAT, T_5-No pre-planting cutting treatment + spraying with GA_3 75 ppm at 30, 60 and 90 DAT, T_6-Pre-planting cutting treatment with GA_3 100 ppm + spraying with $GA_3$100 ppm at 30, 60 and 90 DAT, T_7-No pre-planting cutting treatment + spraying with GA_3 100 ppm at 30, 60 and 90 DAT, T_8-Pre-planting cutting treatment with IAA 75 ppm + spraying with IAA 75 ppm at 30, 60 and 90 DAT, T_9-No pre-planting cutting treatment + spraying with IAA 75 ppm at 30, 60 and 90 DAT, T_{10}-Pre-planting cutting treatment with IAA 100 ppm + spraying with IAA 100 ppm at 30, 60 and 90 DAT, T_{11}-No pre-planting cutting treatment + spraying with IAA 100 ppm at 30, 60 and 90 DAT, T_{12}-Pre-planting cutting treatment with IAA 125 ppm + spraying with IAA 125 ppm at 30, 60 and 90 DAT and T_{13}(No pre-planting cutting treatment + spraying with IAA 125 ppm at 30, 60 and 90 DAT) in RBD with 3 replications. Transplanting was done in the early morning at 45cm apart with 30cm row to row spacing. One week after transplanting, the gap filling was done in order to maintain the required plant population per plot. First irrigation was given immediately after planting. Afterwards twice in a week in the initial stages and thereafter as and when required depending upon the soil moisture and weather condition. The irrigation was withdrawn one week before each harvest. Uniform recommended cultural operation was carried out for all the treatments throughout the experimental period to maintain the plots weed free. Manual weeding operation was carried out as per the

requirement of the crop. Crop became ready for harvesting after 4 months of planting. Harvesting was done with the help of sharp sickle. Plants were cut 3-4 cm above the ground level from randomly marked plants and rest of the plants for measuring yield per plots during the first harvest. The second harvest was done close to the ground. The harvesting was done in the late morning in the clear sunshine hours. Then it was dried in shade for about one week, then it grinds into powder to extract essential oil from it. Data collected from 5 randomly selected plants (excluding border line) per replication and tagged for assessing the growth parameters like plant height (cm), number of primarybranches, number of secondary branches, plant spread in east-west and north - south (cm) direction, leaf length (cm) and leaf width(cm) of each plot at 30, 60 and 90 DAT(days after transplanting) with the help of scale. For the observation regarding yield attributes like fresh yield per plot (kg2.7m^{-2}), a total of 20 plants were harvested with the help of sickle. Plants were cut just above the ground level and fresh herbage yield were recorded. Afterwards they were undertaken for shade drying for about one week in room temperature after that dry weight per plot (g) were recorded by using digital balance. The projected yield per hectare (q) was calculated on the basis of yield per plot,considering80% area occupied by mint in present experiment. Fresh leaves of mint were collected from the plant having enough foliage (before flowering stage)for essential oil content (ml100g^{-1}dryleaves sample) estimation. Harvested fresh leaves were first sundried for 2 days followed by oven drying for 2 days. Then treatments wise grinding was done in grinding machine, and after completion of grinding it was sieved in sieving equipment. Essential oil from mint leaves was extract edusing the Clevenger apparatus, 100g dry sample (powder) of mint leaves was poured in to a flask mixed with350ml distilled water. Then the water was boiled at 98°C, Steam starts rising up in to a condenser, where it condenses and forms a drop then the condensate falls into the small burette on the right. The oil which is lighter than water gradually returned to the heated flask through the diagonal conduit. After 2:30 hours of extraction, the oil volume collected in the burette can be directly measured. The total cost of production, gross return and net profit were calculated to work outthe economics of mint cultivation in gangetic alluvial soil of West Bengal. The data collected from the experimental field were subjected to statistical analysis, appropriated to RBD (Gomezand Gomez,1984). The significance of different treatment of variation was tested by Fisher and Snedecor's 'F' test at a probability of 0.05 per cent. For the determination of least significant difference at5% level of significance, the statistical tables formulated by Fisher and Yates (1979) were consulted.

RESULTS AND DISCUSSION

Growth Parameters

Plant height

The data of plant height at 30DAT, 60 DAT and 90 DAT were significantly influenced by different treatments of plant growth regulators (Table-1). At 30DAT, the mean highest plant height (21.05cm) was recorded under pre-planting cutting treatment with $GA_3$100 ppm + spraying with $GA_3$100 ppm at 30, 60 and 90 DAT (T_6) followed by that with pre-planting cutting treatment with IAA 125 ppm + spraying with IAA 125 ppm at 30, 60 and 90 DAT (T_{12}20.50cm) and the mean lowest plant height (14.20cm was noticed in the planting of cutting without growth regulator (T_1). At 60 DAT, the mean maximum plant height (35.20cm) was associated with pre-planting cutting treatment with $GA_3$100 ppm + spraying with $GA_3$100 ppm at 30, 60 and 90 DAT(T_6) followed by that under pre-planting cutting treatment with IAA 125 ppm +spraying with IAA 125 ppm at 30, 60 and 90 DAT (T_{12}; 34.00cm) and the mean minimum plant height (29.30cm) was noticed in the planting of cutting without growth regulator (T_1). At 90 DAT, the mean highest plant height was recorded under T_6(47.25cm) followed byT_{12}(45.60cm)and the mean lowest plant height was observed in T_1(38.00cm).

Number of primary branches

The number of primary branches per plant was significantly influenced by different treatments of plant growth regulators (Table-1). At 30 DAT, the mean maximum number of primary branches was recorded under T_6(4.10) closely followed by T_{12}(4.00) and the mean minimum number of primary branches (2.50) was noted in control plots(T_1). Similarly, at 60 DAT the mean highest number of primary branches (6.20) was observed under T_6followed by (6.00) in $T_{12}$and the mean lowest number of primary branches was found in T_1(4.50). At 90 DAT, the mean maximum number of primary branches was recorded under T_6(8.30) followed by T_{12}(8.10) and the mean minimum number of primary branches (5.90) was noticed control plot (T_1).

Number of secondary branches

The number of secondary branches per plant was significantly influenced by different treatments of plant growth regulators (Table-2). At 30 DAT, the mean maximum number of secondary branches was recorded under T_6(10.33) followed by T_{12}(9.35) and the mean minimum number of secondary branches (5.29) was noticed in control plot (T_1). Likewise at 60 DAT, the highest mean number of secondary branches was observed under T_6 (13.50) followed by T_{12}(12.60) and the lowest mean number of secondary branches was

Table 1: Influence of pre and post planting treatments of plant growth regulators on height and no. of primary branches of Mint (Mean of two years)

Treatments	Plant height(cm)			No. of primary branches		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	14.20	29.30	38.00	2.50	4.50	5.90
T_2	18.35	32.50	44.25	4.00	6.00	7.30
T_3	15.00	32.40	40.10	3.33	5.60	7.20
T_4	19.00	33.00	41.55	4.00	6.00	8.00
T_5	16.75	31.90	42.70	3.00	5.50	7.00
T_6	21.05	35.20	47.25	4.10	6.20	8.30
T_7	17.15	31.70	39.35	3.00	5.00	7.00
T_8	18.30	32.40	44.10	3.50	5.80	7.25
T_9	17.90	30.60	40.40	3.00	5.00	6.67
T_{10}	18.50	32.60	44.33	4.00	6.00	7.50
T_{11}	17.50	32.40	43.85	3.50	5.00	6.00
T_{12}	20.50	34.00	45.60	4.00	6.00	8.10
T_{13}	17.90	32.50	40.50	3.00	5.00	6.00
SEm (±)	**0.26**	**0.46**	**0.60**	**0.05**	**0.08**	**0.01**
LSD(0.05)	**0.75**	**1.34**	**1.77**	**0.15**	**0.23**	**0.29**

Table 2: Influence of pre and post planting treatments of plant growth regulators onno. of secondary branches and plant spread in north – south direction of Mint (Mean of two years)

Treatments	No. of secondary branches			Plant spread in N - S direction (cm)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	5.29	8.40	15.40	20.00	28.00	37.50
T_2	8.20	11.50	19.45	25.00	34.00	42.00
T_3	5.60	9.80	17.20	22.00	32.00	41.20
T_4	8.33	12.00	20.85	28.00	33.00	41.00
T_5	6.33	9.50	17.45	24.00	31.00	40.25
T_6	10.33	13.50	21.55	33.00	41.00	50.30
T_7	6.50	8.60	16.75	22.00	27.00	35.50
T_8	7.90	10.00	18.85	24.50	33.50	41.25
T_9	6.75	9.33	16.80	22.00	29.00	38.50
T_{10}	8.25	11.60	20.20	26.00	36.00	44.00
T_{11}	7.00	9.90	18.20	24.00	32.00	40.00
T_{12}	9.35	12.60	21.00	30.00	39.00	48.25
T_{13}	7.90	10.00	18.85	24.00	32.00	40.50
SEm (±)	**0.11**	**0.15**	**0.27**	**0.35**	**0.46**	**0.58**
LSD(0.05)	**0.31**	**0.44**	**0.78**	**1.03**	**1.35**	**1.70**

Notes : (T_1-Control (Planting of cutting without growth regulator), T_2-Pre-planting cutting treatment with GA_3 50 ppm + spraying with GA_3 50 ppm at 30, 60 and 90 DAT, T_3-No pre-planting cutting treatment + spraying with $GA_3$50 ppm at 30, 60 and 90 DAT, T_4-Pre-planting cutting treatment with GA_3 75 ppm + spraying with GA_3 75 ppm at 30, 60 and 90 DAT, T_5-No pre-planting cutting treatment + spraying with GA_3 75 ppm at 30, 60 and 90 DAT, T_6-Pre-planting cutting treatment with GA_3 100 ppm + spraying with $GA_3$100 ppm at 30, 60 and 90 DAT, T_7-No pre-planting cutting treatment + spraying with GA_3 100 ppm at 30, 60 and 90 DAT, T_8-Pre-planting cutting treatment with IAA 75 ppm + spraying with IAA 75 ppm at 30, 60 and 90 DAT, T_9-No pre-planting cutting treatment + spraying with IAA 75 ppm at 30, 60 and 90 DAT, T_{10}-Pre-planting cutting treatment with IAA 100 ppm + spraying with IAA 100 ppm at 30, 60 and 90 DAT, T_{11}-No pre-planting cutting treatment + spraying with IAA 100 ppm at 30, 60 and 90 DAT, T_{12}-Pre-planting cutting treatment with IAA 125 ppm + spraying with IAA 125 ppm at 30, 60 and 90 DAT and T_{13}-No pre-planting cutting treatment + spraying with IAA 125 ppm at 30, 60 and 90 DAT)

Table 3: Influence of pre and post planting treatments of plant growth regulators on plant spread in east-west direction and leaf length of Mint (Mean of two years)

Treatments	Plant spread in E-W direction (cm)			Leaf length (cm)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	16.50	24.60	33.00	0.85	2.05	3.25
T_2	21.50	32.00	40.50	1.65	2.50	3.95
T_3	17.50	24.50	36.00	1.10	2.13	3.35
T_4	23.50	32.50	43.10	1.70	2.55	4.00
T_5	19.30	29.50	38.50	1.06	2.29	3.70
T_6	26.00	34.10	44.10	2.10	2.70	4.30
T_7	17.00	27.00	35.50	0.90	2.22	3.40
T_8	21.00	26.00	40.00	1.50	2.40	3.80
T_9	17.50	27.50	33.00	0.95	2.10	3.30
T_{10}	22.00	31.20	37.00	1.69	2.54	4.00
T_{11}	19.00	29.00	39.00	1.00	2.25	3.50
T_{12}	25.15	34.00	43.50	1.83	2.55	4.20
T_{13}	19.40	24.00	39.00	1.02	2.40	3.55
SEm (±)	**0.29**	**0.42**	**0.54**	**0.02**	**0.03**	**0.05**
LSD(0.05)	**0.84**	**1.22**	**1.60**	**0.06**	**0.09**	**0.15**

Table 4: Influence of pre and post planting treatments of plant growth regulators on leaf width, fresh herbage yield, dry weight, projected fresh herbage yield and essential oil yield of Mint (Mean of two years)

Treatments	Leaf width (cm)			Fresh herbage yield (kg plot^{-1})	Dry yield plot^{-1} (g 2.7m^{-2})	Projected fresh herbage yield (q ha^{-1})	Essential oil yield (ml100g^{-1} dry leaves Sample)
	30 DAT	60 DAT	90 DAT				
T_1	0.73	1.93	2.25	1.53	450.67	56.69	1.40
T_2	1.03	2.33	3.01	1.89	695.67	70.18	1.44
T_3	0.83	2.11	2.82	2.00	645.53	74.14	1.63
T_4	1.08	2.38	3.10	1.99	707.03	73.70	1.73
T_5	0.98	2.23	2.95	2.05	678.37	75.97	1.57
T_6	1.19	2.53	3.30	2.14	730.57	79.24	1.77
T_7	0.85	2.03	2.75	1.93	635.10	71.63	1.50
T_8	1.01	2.23	2.99	2.04	685.57	75.67	1.57
T_9	0.80	2.08	2.77	1.82	640.63	67.41	1.67
T_{10}	1.05	2.33	3.10	1.92	705.33	71.13	1.90
T_{11}	0.98	2.21	2.82	1.78	675.13	65.98	1.83
T_{12}	1.15	2.48	3.20	2.05	725.00	76.07	1.95
T_{13}	1.01	2.23	2.97	1.89	680.53	69.89	1.98
SEm (±)	**0.01**	**0.03**	**0.04**	**0.03**	**9.47**	**0.99**	**0.03**
LSD(0.05)	**0.04**	**0.09**	**0.12**	**0.09**	**27.81**	**2.89**	**0.07**

noticed in T_1(8.40). Similar trend was also noted at 90 DAT. The mean number of secondary branches was recorded highest under T_6(21.55) followed by T_{12}(21.00) and the mean minimum number ofsecondarybranches (15.40) was found in T_1.

Plants pread in north-south direction

The spread of plant was significantly influenced by different treatments of plant growth regulators at30 DAT, 60 DAT and 90 DAT. It is evident from the data presented in Table 2, that at 30 DAT, the mean maximum plant spread (N-S) was noted under T_6 (33.00cm) followed by T_{12} (30.00cm) and the mean minimum plant spread (20.00cm) was observed in control plot (T_1). Similarly, after 60 DAT, the highest mean plants pread was associated under T_6 (41.00 cm) followed by T_{12} (39.00cm) and mean lowest in T_1 (28.00cm). According to the data taken after 90 DAT, the mean maximum plant

Table 5: Influence of pre and post-planting treatments of plant growth regulators on economics (per hectare basis) of Mint

Treatments	Fresh herbage yield (q ha^{-1})	Gross return from fresh herbage yield (Rs. ha^{-1})	Cost of Production (Rs. ha^{-1})	Net Profit (Rs.ha^{-1})	Benefit-Cost: ratio
T_1	56.69	141725.00	49448.00	92277.00	1.86:1
T_2	70.18	175450.00	51759.00	123691.00	2.39: 1
T_3	74.14	185363.00	56988.00	125375.00	2.20: 1
T_4	73.70	184250.00	59698.00	127552.00	2.13: 1
T_5	75.97	189925.00	55648.00	133227.00	2.39: 1
T_6	79.24	198100.00	56698.00	142452.00	2.51: 1
T_7	71.63	179075.00	55448.00	123627.00	2.23: 1
T_8	75.67	189175.00	58573.00	130602.00	2.23: 1
T_9	67.41	168525.00	51698.00	116827.00	2.26: 1
T_{10}	71.13	177825.00	54698.00	126127.00	2.30: 1
T_{11}	65.98	164950.00	50448.00	114502.00	2.27: 1
T_{12}	76.07	190198.00	54498.00	135700.00	2.49: 1
T_{13}	69.89	174725.00	51698.00	123027.00	2.38:1

Notes : (Rates of inputs like FY M @Rs4.00kg $^{-1}$, GA_3 @ Rs. 150g^{-1} , NAA @Rs. 90g^{-1} , nitrogen (urea) @ Rs.8.50 kg^{-1}, phosphorus (SSP) @ Rs.14kg^{-1} , potassium(MOP)@ Rs.20kg^{-1} , planting materials @ Rs5cuttings^{-1}, labor wages@ Rs 328m.u^{-1} and output (fresh mint leaves) @Rs.25kg^{-1} were considered)

spread was recorded under T_6(50.30cm) followed by T_{12} (48.25 cm) and the mean minimum plant spread was noted in T_1(37.50cm).

Plant spread in east-west direction

The spread of plant in the east-west direction was significantly influenced by different treatments of plant growth regulators at 30 DAT, 60 DAT and 90 DAT. Data presented inTable-3 revealed that at 30 DAT, the mean maximum plant spread was noted under T_6 (26.00 cm) followed by T_{12}(25.15cm), and mean minimum of 16.50 cm was observed in control plot (T_1). Similar trend was also noted at 60 DAT. The mean highest plant spread was associated with T_6(34.10cm) closely followed by (34.00cm) with $T_{12}$and the mean lowest plant spread was noticed inT_1(24.60cm). According to the data taken after 90 DAT, the mean maximum plant spread was observed under T_6 (44.10cm) followed by T_{12}(43.50 cm) and the mean minimum plants pread was recorded in T_1 (33.00 cm).

Leaf length

The data revealed that different treatments of plant growth regulators significantly increased the leaf length at 30, 60 and 90 DAT (Table-3). At 30 DAT, the mean maximum leaf length was observed under T_6(2.10cm) followed by T_{12}(1.83cm) and the mean minimum leaf length (0.85cm) was recorded under control plot (T_1). Like wise at 60 DAT, the mean highest leaf length was associated in T_6 (2.70cm) followed by T_{12} (2.55cm) and the mean lowest leaf length was observed under T_1 (2.05 cm). Similar trend was also noted at 90 DAT. The mean maximum leaf length was observed under T_6(4.30cm) followed by T_{12}(4.20cm). However, the mean minimum leaf length was found underT_1(3.25cm).

Leaf width

The data revealed that different treatments of plant growth regulators significantly increased the leaf width at 30, 60 and 90 DAT (Table-4). At 30 DAT, the mean maximum leaf width was associated under T_6(1.19cm) closely followed by T_{12}(1.15cm), while the mean minimum leaf width (0.73cm) was observed under control plot (T_1). Similarly, at 60 DAT the mean highest leaf width was noted in T_6(2.53cm) closely followed by T_{12} (2.48cm) and the mean lowest leaf width was observed under T_1 (1.93cm). According to the data taken after 90 DAT, the mean maximum leaf width was noticed under T_6(3.30cm) followed by under treatment of T_{12}(3.20cm) and the mean minimum leaf width was observed under T_1 (2.25cm).

Yield parameters

Fresh herbage yield

Perusal of data presented in Table-4 clearly demonstrated that among different treatments of plant growth regulators had significant influence on fresh herbage yield per plot (kg2.7m^{-2}). The mean maximum fresh herbage yield per plot was recorded underT_6(2.14kg) followed by T_{12} (2.05kg), while the mean minimum fresh herbage yield (1.53kg) was observed under control plot (T_1).

Dryweight

Table-4 clearly illustrated that dry weight per plot (g2.7 $m^{-2)}$ has significantly varied among different treatment combination. The highest mean dry weight perplot was recorded under combination of T_6(730.57g) followed by T_{12}(725.00g). However, the mean lowest dry weight per plot was observed under T_1(450.67g).

Projected fresh herbage yield

Like yield per plot the same pattern of influence of different treatments of plant growth regulators was noticed in respect to projected yield per hectare (Table-4). The mean maximum yield per hectare was noted underT_6(79.24 q) followed by T_{12}(76.07q),while the mean minimum (56.69q) was observed under control plot (T_1).

Essential oil yield

It was evident from the data (Table-4) that essential oil yield was significantly affected by different treatments of plant growth regulators. Among different treatments of plant growth regulators, the mean maximum oil yield was observed under T_{13}(1.98ml) closely followed by T_{12}(1.95ml) and the mean minimum oil yield was recorded underT_1(1.40ml).

Economics

The data presented in Table-5 revealed the economics per hectare basis as in fluenced by application of different treatments of plant growth regulators. Among all the treatments it was observed that mean maximum net profit (Rs. 142452.00 ha^{-1}) was found under the treatment of pre-planting cutting treatment with $GA_3$100 ppm + spraying with $GA_3$100 ppm (T_6) and mean minimum was observed under control plot (Rs. 92277.00 ha^{-1}). The mean maximumbenefit cost ratio of 2.51: 1 was gain from pre-planting cutting treatment with $GA_3$100 ppm + spraying with $GA_3$100 ppm (T_6) whereas, the mean minimum benefit cost ratio of 1.86:1 was obtained from control plot (T_1).

All the treatments have significant influence over control with respect to growth and yield.The responses of plant growth regulators on different growth parameters like plant height, number of primary branches, number of secondary branches, plant spread in direction (north-south and east-west), leaf length,leaf width differ in a significant way in different treatments. Among different treatments maximum mean plant height (47.25cm), mean number of primary branches (8.30), mean number of secondary branches (21.55), mean leaf length (4.30cm), mean leaf width (3.30 cm) and mean plant spread in north-south (50.30 cm) and east-west (44.10 cm) direction were evident under pre-planting cutting treatment with $GA_3$100 ppm + spraying with $GA_3$100 ppm at 30, 60 and 90 DAT (T_6). In case of yield parameters mean maximum fresh herbage yield $plot^{-1}$ (2.14kg), mean dry yield $plot^{-1}$ (730.57g), mean projected yield perhectare (79.24 q ha^{-1}) under pre-planting cutting with $GA_3$100 ppm + spraying with $GA_3$100 ppmat 30, 60 and 90 DAT (T_6). However, the mean maximum essential oil yield (1.98 m l100 g^{-1} dry leaves sample) was obtained from no pre-planting cutting treatment + spraying with IAA125 ppm at 30, 60 and 90 DAT (T_{13}).

Discussion

These results were in good agreement with findings of (Khan *et al*., 2015). They reported that plant growth was improved by GA_3 significantly and the increase was maximum at 100 ppm concentration in plant height, leaf area, tiller number and herbage yield. Chlorophyll content, protein content, NR activity and oil content increased in the plants due to GA_3treatment compared to untreated plants and the increase was maximumat100 ppm concentration. Mahmoud *et al*. (1995) reported that GA_3application stimulates the growth characters like plant height, number of leaves, leaf area, fresh and dry weight etc. whereas , IAA and kinetinre markably decreased basil growth and produce relatively little yield from herb weight. GA_3treatments act in revise to decrease oil content whereas, IAA and Kinetin promoted it. In the present investigation plants treated with no pre-planting cutting treatment + spraying with IAA@ 125 ppm at 30, 60 and 90 DAT(T_{13}) also resulted maximum essential oil yield (1.98 ml $100g^{-1}$ dry leaves sample). Tufail *et al*. (2020) opined that GA_3 @ 50 mm olL^{-1} was more effective as compared to IAA for the enhancement of biomass production, yield and biochemical attributes of fenugreek under Pakistan condition. It was also determined that IAA and GA_3can be used to enhance the foliage biomass production and yield but $GA_3$is superior over IAA in fenugreek. Similar results were also recorded in the present experiment. Sevik *et al*. (2013) analyzed the potential of producing *Melissa officinalis* L. (Lemon Balm) using stem cuttings. Four different hormones (IAA,IBA, NAA, and GA_3) were applied to the cuttings, with and without buds, in two doses (1000 mgL^{-1} and 5000 mgL^{-1}). The results of the study showed that the cuttings with at least one bud must be used in order to produce *M. officinalis* using stem cuttings. However, the auxin group hormones (IAA, IBA and NAA) do not have an apparent effect on rooting percentage. These hormones were positively affect the morphological characteristics (root generation) of the newly generated plants. GA_3application has a considerable effect on plant height. This finding is good agreement with the present experiment.

CONCLUSION

Depending upon the above results it may be concluded that pre-planting cutting treatment with GA_3 100 ppm + spraying with GA_3 100 ppm at 30, 60 and 90 DAT (T_6) may be recommended. However, the experiment should be carried out for at least 2-3years to confirm the results.

REFERENCES

Aswani, J. S., Pushpa, T., Srikantprasad, D., Gangaraddi, V., Patil, C.P. and Biradar, I. B. 2020. Assessment of yield and economics of menthol mint (*Mentha arvensis* L.) with different bio fertilizers and organics. *Int. J. Chem. Stud.,* **8 :**1747-1750.

Fisher, R. A. and Yates, F. 1979. Statistical Tables for Biological Agricultural and Medical Research. 6thEdn., Longman Group, United Kingdom.

George, C.K. 1994. Export of mint oils from India and world trade. *Indian Perfumer*, **38**:76-76.

Gomez. K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research (2ndedition). *A wil. Int.Sci. pub. New*

Kapoor, L.D., Handa, K.L., Chandra, I. and Abrol, B.K. 1955. Cultivation of *Mentha arvensis* in Jammu and Kashmir. *J. Sci. Ind. Res*. A., **14:**374-378.

Keltawi, El. N. E.and Croteau, R. 1987. Influence of foliar applied cytokininon growth and essential oil content of several members of the Lamiaceae. *Phytochem.*, **26**: 891-895.

Khan, A. F., Mujeeb, F.A., Aha, F.A. and Farooqui, A.L. 2015. Effect of plant growth regulators on growth and essential oil content in palmarosa (*Cymbopogon martinii*). *Asian J. Pharm Clin Res*., **8**: 373-376.

Sevik, H. and Guney, K. 2013. Effects of IAA, IBA, NAA, and GA_3 on rooting and morphological features of *Melissa officinalis* L. stem cuttings. *Scientific World Journal*.

Singh, P., Misra, A. and Srivastava, N. K. 2001. Influence of Mn deficiency on growth,chlorophyll content, physiology, and essential monoterpene oil (s) in genotypes of spearmint (*Mentha spicata* L.). *Photosynthetica*, **39**:473-476.

Tufail, M., Hussain, K., Iqbal, I., Nawaz, K., Arshad, N., Jafar, S. and Arif, U. 2020. Efficacyof IAA,GA. *Legume Research-An International Journal*, **43** : 780-787.