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Sara Fathima Sharif
M.Sc. Scholar, Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, India

Maruthi Prasad BN
Associate Professor and Head, Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, India.

Itigi Prabhakar
Assistant Professor, Department of SAS, College of Horticulture, Bengaluru, India.

Harish BS
Assistant Professor, Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, India.

Mohan Kumar S
Assistant Professor, Department of Bio-technology and Crop Improvement, College of Horticulture, Bengaluru, India.

Dhananjaya BN
Associate Professor, Department of SAC, College of Horticulture, Bengaluru, India.

Corresponding Author:
Sara Fathima Sharif
M.Sc. Scholar, Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, India

Economics of rosemary (*Rosemarinus Officinalis* L.) as influenced by foliar application of different growth regulators and elicitors

Sara Fathima Sharif, Maruthi Prasad BN, Itigi Prabhakar, Harish BS, Mohan Kumar S and Dhananjaya BN

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Abstract
Rosemary (*Rosmarinus officinalis* L.) is a perennial aromatic shrub belongs to the mint family Lamiaceae. It is one of the most important cultivated aromatic crops grown in world for its diverse utility in cosmetics, pharmaceutical, perfumery and culinary purpose. A field experiment was conducted at Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, during the year 2022-23 form July 2022 to August 2023, to evaluate the impact of different growth regulators and elicitors on economics of dry herbage and essential oil yield of rosemary. The experiment was laid out in randomized complete block design with replication. There were thirteen treatments *viz*., Ascorbic acid at 150 ppm, NAA at 200 ppm, GA_3 at 300 ppm, Chlormequat at 3000 ppm, Chlormequat at 4000 ppm, Kinetin at 10 ppm, Chitosan at 5000 ppm, Humic acid at 200 ppm, Brassinosteroid at 3 ppm, Potassium silicate at 200 ppm, Paclobutrazol at 200 ppm, Citric acid at 1000 ppm and Control. The variety was Oooty-1 all the treatment showed notable impact on economics of dried herbage and essential oil yield. In terms of essential oil yield Chlormequat at 4000 ppm recorded highest net returns (Rs. 20,95,068 ha^{-1}) and benefit cost ration (4.58). Whereas, maximum net returns (Rs. 12,76,113 ha^{-1}) and benefit cost ration (3.77) on dry herbage yield was registered in chlormequat at 3000 ppm.

Keywords: Chlormequat, rosemary, essential oil, growth regulators, elicitors

Introduction
Aromatic plants have gained significant attention due to their possession of odorous volatile chemicals, primarily found in various parts such as roots, stems, leaves, and flowers, in the form of essential oils, oleoresins, and other bioactive compounds. These complex chemical components contribute to their distinctive aroma and have a wide range of applications in industries such as cosmetics, pharmaceuticals, perfumery, and even in culinary products (Joy *et al*., 1998; Riaz *et al*., 2021) [8, 10].

Among the various aromatic crops, rosemary (*Rosmarinus officinal*is L.) stands out as a significant member of the Lamiaceae (Labiatae) Family, known for its multitude of traditional uses and a rich historical background. Originating from the Mediterranean region, particularly thriving in areas such as Algeria, France, Italy, and Spain, rosemary has been cultivated for centuries due to its medicinal, culinary, and ornamental purposes (Boelens, 1985) [3]. Historically, rosemary has been associated with love, marriage, and remembrance (Dafni *et al*., 2020) [12]. Renowned for its memory-enhancing properties since ancient times, it was revered as a brain tonic and a symbol of fidelity. The extraction of its essential oil, predominantly containing compounds such as cineole, camphor, and borneol, has been a significant practice dating back to the 14th century (Hernandez *et al*., 2016; Gopal *et al*., 2000) [7, 5].

Apart from its historical significance, rosemary essential oil has found diverse applications in the food, fragrance, and pharmaceutical industries. With proven antimicrobial properties, it is used in the production of soaps, household sprays, and medicinal products. Furthermore, its therapeutic potential extends to being antioxidant, antimicrobial, and even possessing anti-inflammatory and neuroprotective properties (Farooqi and Sreeramu, 2001; Hamidpour *et a*l.,

2017) [4, 6]. While rosemary cultivation holds substantial economic potential, various factors such as growth regulators and elicitors play a pivotal role in influencing the yield, quality, and essential oil content of the plant (Nazarideljou, 2023). [13] These exogenous treatments have shown promise in augmenting the quantity and enhancing the quality of both herbage and essential oil content, contributing to the overall productivity of rosemary in agricultural settings (Asangi and Vasundhara, 2013; Angelova *et al*., 2006) [2, 1].

Therefore, this study aims to investigate the influence of different growth regulators and elicitors on economics of rosemary under the Eastern Dry Zone of Karnataka. The objective of this investigation to explore the impact of various growth regulators and elicitors on economic aspects of rosemary cultivation in this specific region in terms of dry herbage and essential oil yield. This research endeavour is aimed at providing valuable insights into optimizing rosemary cultivation methods and enhancing its overall productivity, thereby contributing to the development and potential commercialization of this aromatic crop.

Materials and Methods

The experiment was carried out in randomized complete block design with 13 treatments and 2 replications for rosemary at Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, University of Horticultural Sciences campus, Gandhi Krishi Vignana Kendra, Bengaluru during July 2022 to August 2023. The well rooted rosemary cuttings of variety Ooty-1 were procured from NGO named HOPE, Tamil Nadu. The cuttings were transplanted on 21st July. The spacing followed was 45cm between rows and 45cm between plants. The plots were watered immediately after transplanting and irrigation was given twice a week through hose pipe throughout the cropping period. The fertilizers are applied based on recommendation of the recommendation of the book cultivation of medicinal and aromatic crop (Farooqi and Sreeramu, 2001) [4].

Various growth regulators and elicitors treatment was done thrice, first and second at 30 and 90 days after transplanting, third at 30 days after first harvest through foliar spray. The various treatments include T_1: Ascorbic acid at 150 ppm, T_2: NAA at 200 ppm, T_3: GA_3 at 200 ppm, T_4: Chlormequat at 3000 ppm, T_5: Chlormequat at 4000 ppm, T_6: Kinetin at 10 ppm, T_7: Chitosan at 5000 ppm, T_8: Humic acid at 200 ppm, T_9: Brassinosteroid at 3 ppm, T_{10}: Potassium silicate at 200 ppm, T_{11}: Paclobutrazol at 200 ppm, T_{12}: Citric acid at 1000 ppm and T_{13}: Control. The Ascorbic acid (0.15 g) was dissolved in 2ml distilled water and the required volume of one litre of ascorbic acid solution was made by adding water. NAA (0.20g) was dissolved in 2 ml of 1N NaOH and then the required volume of one litre of NAA solution was made by adding water. Gibberellic acid (0.30g) was dissolved in 1 ml of ethanol and then the required volume of odne litre of gibberellic acid solution was made by adding water. Chlormequat (6ml and 8ml) was mixed in 2 ml and 3 ml of distilled water respectively and then required volume of one litre chlormequat solution was made by adding water. Kinetin (0.01g) was dissolved in 1ml of 1N NaOH and then the required volume of one litre kinetin solution was made by adding water. Chitosan (5g) was dispensed in the solution of 1 per cent glacial acetic acid. The solution was agitated constantly for 6 hours using electric stirrer and then the required volume of one litre chitosan solution was made by adding water. Humic acid (0.204 g) was dissolved in 2ml distilled water and the required volume of one litre humic acid solution was made by adding water. Brassinosteroid (7.5 μL) was mixed in 1ml of distilled water and then required volume of one litre brassinosteroid solution was made by adding one litre water. Potassium silicate (0.66 g) was mixed in 2ml of distilled water and then required volume of one litre potassium silicate solution was made by adding water. Paclobutrazol (0.20 g) was dissolved in 2ml of ethanol and then the required volume of one litre paclobutrazol solution was made by adding one litre water. Citric acid (1.0 g) was dissolved in 2ml distilled water and the required volume of one litre citric acid solution by adding water. The first harvesting was done 8 months after transplanting and second was carried out 60 days after first harvest. For dried herbage the fresh rosemary leaves were shade dried for 10 days. Rosemary essential oil was extracted using Clevenger's apparatus at 60º C for three hours.

Cost of cultivation

The cost incurred towards inputs and farm labours charges that were prevailed during the study period in Bengaluru region are considered while computed per hectare cultivation cost and presented in Table 1. The quantity of growth regulators and elicitors used and their respective cost are presented in Table 2. While, the total cost of cultivation (in rupees) incurred towards cultivation of rosemary for dry herbage yield and essential oil yield is presented in Table 3 and Table 4.

Gross returns and net returns

The gross income was worked out based on the prevailing market price of rosemary essential oil (Rs.6,500 per kg according to FAFAI, price list 2022) and dried rosemary leaves (Rs. 200 per kg according to CIMAP price list 2023).

Net income

Net income per hectare was obtained by subtracting the total cost of cultivation from gross income per hectare.

Net income = Gross income - Total costs

Benefit cost ratio

The benefit cost ratio was worked out by using the following formulae.

$$\text{Benefit: cost ratio (B : C ratio)} = \frac{\text{Net income (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Results and Discussion

Table 1: Fixed cost (Rs. Hectare)

Particulars	Quantity	Unit cost	Total cost (Rupees)
Land prepration (Tractor)	8 hours	Rs. 600 hour^{-1}	4,800
FYM	20 t ha^{-1}	Rs.2,000 t^{-1}	40,000
Planting material	49,000	Rs. 5^{-1} cuttings	2,45,000
Fertilizers (100:40:40 kg NPK ha^{-1}) Urea SSP MOP	217.39 kg 250.00 kg 66.66 kg	Rs. 6.40 kg^{-1} Rs. 14.00 kg^{-1} Rs. 34.00 kg^{-1}	1,391.29 3,500.00 2,266.44
Transplanting	10 labours	Rs.450 labour^{-1}	4,500
Weeding	30 labours	Rs. 450 labour^{-1}	13,500
Plant protection chemicals: Chlorfenapyr SAAF Kavach	1liter 0.5 kg 0.5 kg	Rs. 490 liter^{-1} Rs. 598 kg^{-1} Rs. 1,775 kg^{-1}	490 299 887.5
Application of plant protection chemical	2 labours	Rs. 450 labour^{-1}	900
Application of growth regulators and elicitors	2 labours	Rs. 450 labour^{-1}	900
Harvesting and postharvest handling	30 labours	Rs. 450 labour^{-1}	13,500
Essential oil extraction	T_1 - 27.45 t/ha T_2 - 28.76 t/ha T_3 - 38.38 t/ha T_4 - 43.02 t/ha T_5 - 24.78 t/ha T_6 - 36.63 t/ha T_7 - 22.91 t/ha T_8 - 26.95 t/ha T_9 - 20.08 t/ha T_{10} - 17.48 t/ha T_{11} - 39.33 t/ha T_{12} - 21.35 t/ha T_{13} - 21.31 t/ha	Rs. 3,000 t^{-1}	Rs. 82,350.00 Rs. 86,280.00 Rs. 1,15,140.00 Rs. 1,29,060.00 Rs. 74,340.00 Rs. 1,09,890.00 Rs. 68,730.00 Rs. 80,850.00 Rs. 60,240.00 Rs. 52,440.00 Rs. 1,17,990.00 Rs. 64,050.00 Rs. 63,930.00
Miscellaneous	Transportation and others	2,500	2,500
Total			14,39,724.23

Table 2: Quantity required and cost of growth regulators and elicitors used per hectare

Particulars	Quantity required (g or ml)	Rate (Rs. / g or ml)	Total cost (Rs.)
Ascorbic acid 150 ppm	102.75 g	8.16 Rs. /g	838.442
NAA 200 ppm	137 g	5.76 Rs. /g	789.12
GA_3 300 ppm	205.5 g	180 Rs. /g	36,990.00
Chlormequat 3000 ppm	4,110 ml	0.84 Rs. /ml	3,452.40
Chlormequat 4000 ppm	5,480 ml	0.84 Rs. /ml	4,603.20
Kinetin 10 ppm	6.85 g	566.6 Rs. /g	3,881.21
Chitosan 5000 ppm	3,425 g	28 Rs. /g	95,900
Humic acid 200 ppm	139.74 g	0.2 Rs. /g	27.94
Brassinosteroid 3 ppm	5.13 ml	1.58 Rs. /ml	8.10
Potassium silicate 200 ppm	452.1 ml	0.35 Rs. /l	158.23
Paclobutrazol 200 ppm	137 g	419.5 Rs. /g	57,471.5
Citric acid 1000 ppm	685	0.73 Rs. /g	500.05

Table 3: Cost of cultivation as influenced by foliar application of growth regulators and elicitors on dry leaves yield of rosemary

Treatments	FYM	Land Preparation	Cuttings	Transplanting	Fertilizers	Growth regulators and elicitors	Spraying of growth regulators and elicitors	Weeding	Plant Protection	Application of plant protection chemicals	Harvesting and processing	Miscellaneous	Total Cost	Gross returns
T_1	40,000	4,800	2,45,000	4,500	7,157.73	838.44	900	13,500	1,676.5	900	13,500	2,500	3,35,273	10,86,000
T_2	40,000	4,800	2,45,000	4,500	7,157.73	789.12	900	13,500	1,676.5	900	13,500	2,500	3,35,223	11,54,000
T_3	40,000	4,800	2,45,000	4,500	7,157.73	36,990.00	900	13,500	1,676.5	900	13,500	2,500	3,71,424	14,28,000
T_4	40,000	4,800	2,45,000	4,500	7,157.73	3,452.40	900	13,500	1,676.5	900	13,500	2,500	3,37,887	16,14,000
T_5	40,000	4,800	2,45,000	4,500	7,157.73	4,603.20	900	13,500	1,676.5	900	13,500	2,500	3,39,037	15,70,000
T_6	40,000	4,800	2,45,000	4,500	7,157.73	3,881.21	900	13,500	1,676.5	900	13,500	2,500	3,38,315	9,58,000
T_7	40,000	4,800	2,45,000	4,500	7,157.73	95,900.00	900	13,500	1,676.5	900	13,500	2,500	4,30,334	12,96,000
T_8	40,000	4,800	2,45,000	4,500	7,157.73	27.94	900	13,500	1,676.5	900	13,500	2,500	3,34,462	10,48,000
T_9	40,000	4,800	2,45,000	4,500	7,157.73	8.10	900	13,500	1,676.5	900	13,500	2,500	3,34,442	10,68,000
T_{10}	40,000	4,800	2,45,000	4,500	7,157.73	158.23	900	13,500	1,676.5	900	13,500	2,500	3,34,592	7,26,000
T_{11}	40,000	4,800	2,45,000	4,500	7,157.73	57,471.5	900	13,500	1,676.5	900	13,500	2,500	3,91,906	5,40,000
T_{12}	40,000	4,800	2,45,000	4,500	7,157.73	500.05	900	13,500	1,676.5	900	13,500	2,500	3,34,934	7,94,000
T_{13}	40,000	4,800	2,45,000	4,500	7,157.73	0.0	900	13,500	1,676.5	900	13,500	2,500	3,34,434	7,86,000

Table 4: Cost of cultivation as influenced by foliar application of growth regulators and elicitors on essential oil yield of rosemary

Treatments	FYM	Land Preparation	Cuttings	Transplanting	Fertilizers	Growth regulators and elicitors	Spraying of growth regulators and elicitors	Weeding	Plant Protection	Application of plant protection chemical	Harvesting and processing	Essential oil extraction	Miscellaneous	Total Cost	Gross returns
T_1	40,000	4,800	2,45,000	4,500	7,157.73	838.44	900	13,500	1,676.5	900	13,500	82,350	2,500	4,17,623	13,95,485
T_2	40,000	4,800	2,45,000	4,500	7,157.73	789.12	900	13,500	1,676.5	900	13,500	86,280	2,500	4,21,503	16,77,910
T_3	40,000	4,800	2,45,000	4,500	7,157.73	36,990.00	900	13,500	1,676.5	900	13,500	1,15,140	2,500	4,86,564	18,62,185
T_4	40,000	4,800	2,45,000	4,500	7,157.73	3,452.40	900	13,500	1,676.5	900	13,500	1,29,060	2,500	4,66,947	25,36,300
T_5	40,000	4,800	2,45,000	4,500	7,157.73	4,603.20	900	13,500	1,676.5	900	13,500	1,17,990	2,500	4,57,027	25,52,095
T_6	40,000	4,800	2,45,000	4,500	7,157.73	3,881.21	900	13,500	1,676.5	900	13,500	74,340	2,500	4,12,655	15,38,290
T_7	40,000	4,800	2,45,000	4,500	7,157.73	95,900.00	900	13,500	1,676.5	900	13,500	1.09,890	2,500	4,30,334	17,91,465
T_8	40,000	4,800	2,45,000	4,500	7,157.73	27.94	900	13,500	1,676.5	900	13,500	68,730	2,500	4,03,192	13,15,015
T_9	40,000	4,800	2,45,000	4,500	7,157.73	8.10	900	13,500	1,676.5	900	13,500	80,850	2,500	4,15,292	15,58,180
T_{10}	40,000	4,800	2,45,000	4,500	7,157.73	158.23	900	13,500	1,676.5	900	13,500	60,240	2,500	3,94,832	11,89,955
T_{11}	40,000	4,800	2,45,000	4,500	7,157.73	57,471.5	900	13,500	1,676.5	900	13,500	52,440	2,500	4,44,346	10,53,975
T_{12}	40,000	4,800	2,45,000	4,500	7,157.73	500.05	900	13,500	1,676.5	900	13,500	64,050	2,500	3,98,984	11,46,665
T_{13}	40,000	4,800	2,45,000	4,500	7,157.73	0.0	0.0	13,500	1,676.5	900	13,500	63,930	2,500	3,97,464	9,86,115

Table 5: Influence of growth regulators and elicitors on economics of dried rosemary leaves

Treatment	Cost of cultivation (Rs. ha^{-1}	Gross returns (Rs.)	Net returns (Rs.)	B:C ratio
T_1	3,35,273	10,86,000	7,50,7272	2.23
T_2	3,35,223	11,54,000	8,18,777	2.44
T_3	3,71,424	14,28,000	10,56,576	2.84
T_4	3,37,887	16,14,000	12,76,113	3.77
T_5	3,39,037	15,70,000	12,30,963	3.63
T_6	3,38,315	9,58,000	6,19,685	1.83
T_7	4,30,334	12,96,000	8,65,666	2.01
T_8	3,34,462	10,48,000	7,13,538	2.13
T_9	3,34,442	10,68,000	7,33,558	2.19
T_{10}	3,34,592	7,26,000	3,91,408	1.16
T_{11}	3,91,906	5,40,000	1,48,094	0.37
T_{12}	3,34,934	7,94,000	4,59,066	1.37
T_{13}	3,34,434	7,86,000	4,51,566	1.35

Economic of essential oil yield is enumerated in Table 6. The cost incurred was maximum (Rs. 4,86,564) towards GA_3 at 300 ppm treatment followed by chlormequat at 3000 ppm (Rs. 4,66,947). While, the least expenditure was incurred in potassium silicate at 200 ppm (Rs. 3,94,832) followed by control (Rs. 3,97,464). Whereas, Maximum gross returns of rupees 25,52,095 was obtained from plots applied with chlormequat at 4000 ppm followed by chlormequat at 3000 ppm (Rs. 25,36,300) while least (Rs. 9,86,115gross returns were recorded in control. The net returns were also more from chlormequat at 4000 ppm (Rs. 20,95,353) treated plots followed by chlormequat at 3000 ppm (Rs. 20,69,353) while least was registered in control (5,88,651). Similarly, B: C ratio was also maximum in chlormequat at 4000 ppm (4.58) treated plots followed by chlormequat at 4000 ppm (4.43). Whereas the least B: C ratio was recorded in paclobutrazol at 200 ppm (1.37) followed by control (1.48).

This revealed that foliar application of paclobutrazol is not profitable. Because this treatment had higher treatment cost due to the costlier paclobutrazol (419.5 Rs. g^{-1}) and poor plant growth and herbage yield making it unprofitable for cultivation. While chlormequat treatment at 3000 and 4000 ppm recorded highest dry herbage and oil yield respectively.

Table 6. Influence of growth regulators and elicitors on economics of essential oil yield

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs.)	Net returns (Rs.)	B:C ratio
T_1	4,17,623	13,95,485	9,77,862	2.34
T_2	4,21,503	16,77,910	12,56,407	2.98
T_3	4,86,564	18,62,185	13,75,621	2.82
T_4	4,66,947	25,36,300	20,69,353	4.43
T_5	4,57,027	25,52,095	20,95,068	4.58
T_6	4,12,655	15,38,290	11,25,635	2.72
T_7	4,30,334	17,91,465	13,61,131	3.16
T_8	4,03,192	13,15,015	9,11,823	2.26
T_9	4,15,292	15,58,180	11,42,888	2.75
T_{10}	3,94,832	11,89,955	7,95,123	2.01
T_{11}	4,44,346	10,53,975	6,09,629	1.37
T_{12}	3,98,984	11,46,665	7,47,681	1.87
T_{13}	3,97,464	9,86,115	5,88,651	1.48

The results are clearly aligned Vaghasia and Polara (2016) where net return obtained from chrysanthemum cultivation was less towards the paclobutrazol spray due to less flower yield coupled with higher cost of production in PBZ treatment was mainly due to more price of paclobutrazol than that of chlormequat. De *et al*. (2023) reported that treatment comprising the paclobutrazol spray recorded the least net returns and benefit cost ratio compare to control which is mainly due to the more cost incurred on paclobutrazol.

Conclusion
Economically, the treatment featuring chlormequat at 4000 ppm and 3000 ppm demonstrated the most promising outcomes, showcasing the highest gross and net returns, and a favourable benefit-cost ratio in terms of essential oil and herbage yield, respectively. These findings hold great significance for enhancing rosemary cultivation in the specific region, contributing to improved productivity and economic sustainability.

Future Scope
To enhance the economics of rosemary, it is necessary to consider an escalation in the frequency of foliar applications of growth regulators and elicitors, as the duration of first harvest is between 7 to 8 months.

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Conflict of interest
None.

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