Effect of harvesting stages on herbage and essential oil yield of rosemary (*Rosmarinus officinalis* L.) under northern dry zone of Karnataka

ABSTRACT

Aim: To study the effect of different phenological stages of harvesting on the yield and quality of rosemary
Study design: Fisher's method of ANOVA
Place and duration of study: Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bagalkot, Karnataka during rabi 2023-24.
Methodology: The experiment was laid out in Randomized Complete Block Design with five replications, comprising five different stages of harvesting namely vegetative stage, flower initiation stage, fifty per cent flowering stage, full bloom stage and seed setting stage.
Results: The maximum mean fresh herbage yield (589.79 g plant^{-1}, 14.74 kg plot^{-1} and 13.54 t ha^{-1}) and dry herbage yield (308.40 g plant^{-1}, 7.71 kg plot^{-1} and 7.08 t ha^{-1}) were noticed at the seed setting stage. Whereas the superior essential oil content (1.51 %) was viewed at the vegetative stage. The greater essential oil yield (129.34 kg ha^{-1}) was observed at the full bloom stage, which was on par with the seed setting stage (127.20 kg ha^{-1}) and fifty per cent flowering stage (118.11 kg ha^{-1}).
Conclusion: Fifty per cent flowering stage can be considered as suitable harvesting stage of rosemary under northern dry zone of Karnataka.

Keywords: Harvesting stages, rosemary, yield, quality, essential oil

1. INTRODUCTION

Rosemary (*Rosmarinus officinalis* L.), is an evergreen and highly branched aromatic shrubby herb, belonging to the family Lamiaceae. Mainly cultivated in Mediterranean countries, such as Spain, Morocco, Tunisia, France and Italy. In India it is cultivated in Karnataka, Tamil Nadu, Jammu and Kashmir etc. The leaves and flowering tops on steam-distillation or hydro distillation yield the essential oil.

In England and Germany, rosemary is regarded as "Symbol of remembrance". Greek and Roman scholars used this for improving memory, concentration and rejuvenating spirit. In the year 2000, rosemary was considered as the Herb of the year by International Herb Association [1]. In India it is called as rujamari, and is a component in ayurvedic and unani medicine, which is used to treat flatulent dyspepsia associated with psychogenic tension and migraine headaches.

Rosemary is an evergreen and hardy shrub reaches to a height of one meter, the stem is erect and divided into many long, slender branches. The leaves are sessile, opposite, two to four centimetre in length and are cylindrical, leathery, green on top, white and hairy below. The flowers are hermaphrodite and are located as little clusters towards the end of the branches. Calyx is two lipped, the upper lip with one single broad oval lobe, the lower lip is with two segmented triangular lobes. Corolla is also two lipped with two

violet stamens and a long style projecting from it. It is a cross pollinated and the fruit is called as cremocarp which is oval and four sectioned [2].

There are mainly two types of rosemary namely French rosemary with white flowers and superior oil quality usually grown in southern India and Italian rosemary with purple flowers and inferior oil quality commonly grown in northern India.

The main bioactive molecules in rosemary are monoterpenes (92.3-95.3 %) which include 1,8-cineole (eucalyptol), camphor, α-pinene, borneol, β-pinene, limonene, p-cymene, verbenone. Sesquiterpenes include β-caryophyllene, diterpenes such as carnosic acid, carnosol, rosmarol, epirosmanol, isorosmanol, rosmaridifenol, triterpenes are olenolic acid, ursolic acid, betulin, α-amyrin and β-amyrin, flavonoids include luteolin, apigenin, genkwanin, diosmetin, hispidulin, 5-hydroxy-7-4′-dimetoxy-flavone, crisimaritin and phenolic acids such as caffeic acid, chlorgenic acid and rosmarinic acid [3]. Among them the chief volatile compounds in rosemary include camphor and 1,8-cineole, followed by borneol, verbenone, α-pinene and camphene. There are three different chemotypes of rosemary such as cineoliferum with high percentage of 1,8-cineole, camforiferum with more than 20 per cent of camphor and verbenoniferum with more than 15 per cent of verbenone.

The essential oil of rosemary is prized for its applications in the cosmetic, culinary, medicinal and fragrance industries. Additionally, it is utilised in compounded oil compositions to flavour meat, sauces, condiments and other food items. In cooking, the leaves are used for garnishing the dishes, seasoning the soups and stews.

In cosmetic industries, the hydroalcoholic extraction of rosemary is used in preparation of herbal gel which is used to treat acne vulgaris [4]. The essential oil is used to prepare oleogels which enhance the hair growth [5]. It is also reported that rosemary leaf supplemented diet controls the fasting blood glucose levels in diabetes [6]. The distilled water obtained from the blossoms can be used as a relaxing eye wash.

Rosemary has been used as a source of traditional medicine. It is considered as therapeutic agent for antioxidant, anticancer, antidiabetic, antidepressant, neuroprotective, anti-inflammatory and anti-obesity treatment. It is often used in aromatherapy to increase concentration, memory and to relieve stress [7]. Potentiality of rosemary against various diseases and disorders are still under investigation. The economic part in rosemary is herbage and flowering tops. These leaves and flowering tops yield essential oil upon distillation which is used in various industries. The time required to distil one charge is three hours.

The growing demand for drugs and cosmetics derived from rosemary essential oil is attracting interest of researchers on the harvesting. Generally, the rosemary herbage is harvested after 50 per cent of flowering *i.e.,* six months after transplanting at first and further it is harvested at an interval of 3-4 months for oil extraction. For culinary purpose the leaves are harvested just before the blooming stage. Different harvesting stages can affect the quantity and quality of essential oil and other active compounds. Identifying the ideal stage for harvesting can maximize both yield and economic efficiency by maximizing the value of the crop.

Rosemary is an emerging aromatic crop of India, the productivity and yield of the rosemary essential oil generally depends on various factors such as geographical origin [8], plant part harvested, stage of harvest [9], extraction methods used, seasonal variations, other agronomical practices, postharvest drying procedure, drying time and storage conditions. Among all these factors the phenological stage of plant is a major factor which decides the quantity and quality of the yield obtained. The appropriate harvesting stage have yet to be established in Karnataka's northern dry zone, where the cultivation of rosemary is still in nascent state. Considering the significance of above-mentioned elements, the current study was carried out to investigate the influence of different harvesting stages on yield and quality parameters of rosemary.

2. MATERIAL AND METHODS

The present investigation was conducted during rabi 2023-24 at the Department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, University of Horticultural Sciences, Udyanagiri, Bagalkot. The experimental site was located at 16 0C 10' North latitude, 74 0C 42' East longitudes. Altitude of 542.0 m above mean sea level (MSL). Karnataka's northern dry zone consists this domain (Zone- III). The research was set out in Randomized Complete Block Design and replicated five times with five different phenological stages of harvesting namely vegetative stage, flower initiation stage, fifty per cent flowering stage, full bloom stage and seed setting stage.

The rooted rosemary cuttings of two months old were transplanted at 60 cm × 60 cm in the field, all the cultural operations were done by referring the package of practice from University of Horticultural Sciences, Bagalkot. In each plot, five plants were chosen at random, they were tagged and harvested according to the treatments. The observations on yield and quality parameters such as fresh herbage yield, dry herbage yield, essential oil content and essential oil yield were recorded.

Essential oil content (%): The essential oil content was calculated and expressed as percentage using the following formula.

$$\text{Percentage yield of essential oil} = \frac{\text{Weight of oil}}{\text{Weight of sample}} \times 100$$

Essential oil was extracted by hydro-distillation method using the Clevenger apparatus. For the distillation process, shade dried herbage was used which was taken in a flask with water of required quantity and then distilled for three hours. During distillation process care was taken in order to keep the condenser cool by passing the tap water. The temperature for boiling was kept at 70-80 ºC until boiling and after that it was decreased to 65 ºC for two hours of distillation. Extracted essential oil was condensed and then collected in receiver unit. Quantity obtained was noted after the completion of distillation. The essential oil yield was calculated on weight basis.

The data recorded on various yield and quality parameters were subjected to Fisher's method of "Analysis of variance" (ANOVA) as suggested by Panse and Sukathme [10]. The F-test was tested at five per cent level of significance and data was interpreted using critical difference at a probability of 0.05 per cent.

3. RESULTS AND DISCUSSION

Different phenological stages can affect the quantity and quality of essential oil and chemical composition. Identifying the ideal stage for harvesting can maximize both yield and economic efficiency by maximizing the value of the rosemary crop. The harvesting stages caused the substantial variation in the yield parameters such as fresh and dry herbage yield, essential oil yield and also exhibited significant variation in the essential oil content, which is presented here.

3.1 Herbage yield

The harvesting stages had shown the significant difference in the fresh herbage yield in rosemary, which is depicted in the Table 1. The highest fresh herbage yield per plant, fresh herbage yield per plot and fresh herbage yield per hectare was recorded at seed setting stage (589.79 g plant^{-1}, 14.74 kg plot^{-1} and 13.54 t ha^{-1}, respectively) which was followed by full bloom stage (507.47 g plant^{-1}, 12.69 kg plot^{-1} and 11.65 t ha^{-1}, respectively). The lowest fresh herbage yield was viewed at vegetative stage (117.20 g plant^{-1}, 2.93 kg plot^{-1} and 2.69 t ha^{-1}). The fresh herbage yield increased with the increase in crop duration and hence seed setting stage had recorded the maximum fresh herbage yield. Verma et al. (2019) also obtained similar results with respect to fresh herbage yield in rosemary var. CIM Hariyali which was harvested during different growth stages in the subtropical region of north India [11]. These variations may also be due to the various extrinsic factors such as soil and climatic conditions, which considerably affect the yield [11,12,13].

The dry herbage yield per plant varied significantly among the different phenological stages of rosemary as shown in Table 1. The highest dry herbage yield per plant, dry herbage yield per plot and dry herbage yield per hectare was recorded at seed setting stage (308.40 g plant^{-1}, 7.71 kg plot^{-1} and 7.08 t ha^{-1} respectively) which was followed by full bloom stage (271.23 g plant^{-1}, 6.78 kg plot^{-1}and 6.23 t ha^{-1} respectively). The lowest fresh herbage yield was viewed at vegetative stage (66.34 g plant^{-1}, 1.66 kg plot^{-1} and 1.52 t ha^{-1}). The increase in duration of crop led to the increase in dry herbage yield which is due to decrease in number of leaves and increase in the woody stem and hence seed setting stage recorded the maximum dry herbage yield. These were similar to the results obtained by Zigene et al. (2012) in the rosemary crop [13] and by Salehi et al. (2014) in *Thymus vulgaris* [14].

Table 1. Effect of harvesting stages on yield parameters of rosemary

Treatment	Harvesting stage	Fresh herbage yield			Dry herbage yield		
		g plant^{-1}	kg plot^{-1}	t ha^{-1}	g plant^{-1}	kg plot^{-1}	t ha^{-1}
T_1	**Vegetative stage**	117.20	2.93	2.69	66.34	1.66	1.52
T_2	**Flower initiation stage**	310.28	7.76	7.12	150.39	3.76	3.45
T_3	**Fifty per cent flowering stage**	464.52	11.61	10.66	250.06	6.25	5.74
T_4	**Full bloom stage**	507.47	12.69	11.65	271.23	6.78	6.23
T_5	**Seed setting stage**	589.79	14.74	13.54	308.40	7.71	7.08
	S. Em. ±	9.44	0.24	0.22	5.85	0.15	0.13
	CD (5 %)	28.30	0.71	0.65	17.54	0.44	0.40

3.2 Essential oil yield

The data on the essential oil content is presented in the Table 2. The highest per cent of essential oil content was found at vegetative stage (1.51 %) and least per cent of essential oil content at seed setting stage (0.94 %), which may be due to the more active development of leaves and stem at vegetative stage [12], where most of the essential oil is stored and as the plant matures and moves towards seed setting stage, there may be slight reduction in density and quality of leaves. Older leaves may have lower concentrations of essential oil compared to the fresh and rapidly growing leaves found during the vegetative stage. The essential oil content of other stages excluding the vegetative stage showed statistically similar values i.e., fifty per cent flowering stage (1.11 %), full bloom stage (1.11 %), flower initiation stage (0.97 %) and seed setting stage (0.94 %) which was similar to the results obtained by Verma et al. (2019), Hassanzadeh et al. (2017) and Zigene et al. (2012) in rosemary, Salehi et al. (2014) in *Thymus vulgaris* [11, 15, 13, 14]

The different harvesting stages caused the significant variation in the essential oil yield per hectare, which is shown in Table 2. The maximum essential oil yield per hectare was obtained at the full bloom stage (129.34 kg ha^{-1}) which was statistically same with the seed setting stage (127.20 kg ha^{-1}) and fifty per cent flowering stage (118.11 kg ha^{-1}). However, the least essential oil yield per hectare was noticed in vegetative stage (40.38 kg ha^{-1}). The essential oil yield increased with the increase in the fresh and dry herbage yield as the growth of the crop progress and hence full bloom stage had shown the higher essential oil yield per hectare, but at the seed setting stage the essential oil content got reduced, which may be due to the more hardy portion and less number of leaves as reported by Singh and Guleria (2013) in the rosemary crop harvested at different phenological stages [12] and similar results regarding the essential oil yield were obtained in *Thymus vulgaris* which is reported by Salehi et al. (2014) [14].

Table 2. Effect of harvesting stages on quality parameters of rosemary

Treatment	Harvesting stage	Essential oil content (%)	Essential oil yield (kg ha^{-1})
T_1	**Vegetative stage**	1.51	40.38
T_2	**Flower initiation stage**	0.97	68.61
T_3	**Fifty per cent flowering stage**	1.11	118.11
T_4	**Full bloom stage**	1.11	129.34
T_5	**Seed setting stage**	0.94	127.20
	S. Em. ±	0.09	4.52
	CD (5 %)	0.26	13.34

4. CONCLUSION

The highest essential oil content was observed during the vegetative stage, but the maximum essential oil yield was obtained at full bloom stage, despite the highest herbage yield occurring at the seed setting stage, Fifty per cent flowering stage recorded the essential oil content (1.11 %), essential oil yield of 118.11 kg ha-1, which was on par with the full bloom stage and hence, the Fifty per cent flowering stage can be considered as suitable harvesting stage of rosemary under northern dry zone of Karnataka.

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