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Effect of different levels and methods of application of zinc on growth, oil yield and economics of patchouli [*Pogostemon patchouli* (Blanco) Benth.]

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Abstract
A field experiment was conducted to study the effect of zinc on growth, oil yield and economics of patchouli [*Pogostemon patchouli* (Blanco) Benth.] variety Johore at Medicinal and Aromatic Plants Unit, Saidapur Farm, Department of Horticulture, College of Agriculture, University of Agricultural Sciences, Dharwad during 2018-19. The experiment was laid out in Randomized Block Design with three replications. In this study significant differences were found among different doses and methods of zinc application to crop on growth, oil yield and economics. Among all treatments, treatment with application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent recorded higher values in growth parameters, which includes like plant height (93.93 cm), number of primary branches (15.20), number of secondary branches (43.47), number of leaves (528.13), leaf area (48.24 dm^2/plant) and leaf area index (1.79) at the time of harvest. The same treatment also recorded the higher values with the yield parameters like dry herbage yield (2.63 t/ha), oil content (1.53%), oil yield (40.17 kg/ha) and B:C ratio (2.33).

Keywords: Patchouli, zinc, soil application, spray, growth, yield

Introduction

Patchouli [(*Pogostemon patchouli*) (Blanco) Benth.] an industrially important essential oil bearing crop belonging to family *Lamiaceae*. It is a native of Philippines. Patchouli is grown in many states of India like mainly Karnataka, Maharashtra, Goa, Gujarat, Assam and Kerala (Venugopal *et al*., 2008) [18]. The economic part of the crop is herbage which is used for the extraction of essential oil from it after shade drying. Distillation of shade dried herb yields yellow coloured essential oil which is used in high value perfumes, cosmetics, toiletries, breath fresheners, flavouring baked foods, meat, sausages, etc. Patchouli oil blends well with other essential oils like vetiver, sandalwood, geranium, lavender and clove so it has high demand in perfumery industry. It is used for its fixative property as it gives tenacity to other perfumes. The patchouli oil is possess several properties such as antidepressant, antiseptic, antirheumatic, aphrodisiac, astringent, fungicidal, insecticidal, etc (Bunrathep *et al*., 2006) [4]. There is no synthetic chemical to replace the oil of patchouli which further enhances its value thus it has a unique position in the market. Indonesia is the largest producer, has a production exceeding 1500 tonnes of oil (91.7% of the total). Production of patchouli in India is negligible (about 20 tonnes of oil/year). Presently India is importing over 200 tonnes of oils from Indonesia, Malaysia and Singapore. The continuous increase in demand for patchouli oil in both domestic and international market has compelled the country to increase its area under cultivation.

Patchouli is perennial, erect, branched, pubescent herb, 0.5 to 1.0 meter hight and produce aromatic odour when crushed. Leaves ovate to oblong-ovate, simple or doubly crenate-serrate, coarse, on both surfaces more or less densely tomentose, the glands are dotted beneath and sized up to 12 cm by 10 cm. January to February is the time for its flowering in India, Philippines and Malaya (Swamy and Sinniah, 2015) [17]. There is a tremendous demand for patchouli oil in the market; hence there is a good scope for the cultivation of patchouli. For the successful crop production, selection of planting material, spacing, nutrients management, irrigation and other cultural operations are important.

Micronutrients application is very much important in the production of medicinal and aromatic crops including patchouli, as these micronutrients helps in increasing the growth of plants, essential oil yield and quality of the oils. Zinc is one of trace element which helps in healthy growth of the plant and also reproduction of crop plants.

It is a metal component of various enzymes which helps in activation of many enzymes such as carbonic alcohol dehydrogenase and anhydrase. It also has the role in the synthesis of the amino acid tryptophan, which turns into auxin and helps in increasing the growth and development of the plant. In plants which are suffering from zinc deficiency, it was found that, auxin concentration in the shoots and roots are very less. It has a role in the synthesis of nucleic acids and proteins (Amberger, 1974) [3]. It also helps in the photosynthesis, sexual fertilization, cell division and maintaining the membrane structure and function.

Material and Methods

The experiment was carried out during 2018-19 at Medicinal and Aromatic Plants Unit, Saidapur Farm, Department of Horticulture, College of Agriculture, University of Agricultural Sciences, Dharwad to study the effect of zinc on growth, oil yield and economics of patchouli.

The experiment was laid out in the randomized block design with nine treatments and three replications. The patchouli crop with variety Johore was taken for the present experiment during *Kharif* 2018.

Treatment details

T_1	RDF
T_2	RDF + $ZnSO_4$ @ 10 kg/ha
T_3	RDF + $ZnSO_4$ @ 15 kg/ha
T_4	RDF + $ZnSO_4$ @ 20 kg/ha
T_5	RDF + $ZnSO_4$ @ 25 kg/ha
T_6	RDF + $ZnSO_4$ @ 10 kg/ha + $ZnSO_4$ @ 0.5% foliar spray (45 and 90 DAT)
T_7	RDF + $ZnSO_4$ @ 15 kg/ha + $ZnSO_4$ @ 0.5% foliar spray (45 and 90 DAT)
T_8	RDF + $ZnSO_4$ @ 20 kg/ha + $ZnSO_4$ @ 0.5% foliar spray (45 and 90 DAT)
T_9	RDF + $ZnSO_4$ @ 25 kg/ha + $ZnSO_4$ @ 0.5% foliar spray (45 and 90 DAT)

Note: RDF = Recommended dose of fertilizer (NPK – 150:50:50 kg/ha + FYM 12 t/ha), Zinc sulphate = $ZnSO_4$, DAT = Days after transplanting

For the experiment healthy, uniformly grown and well rooted cuttings of 40 days old were used for transplanting to the main field. The experimental site was divided into plots of 3.6 × 2.3 m dimensions. Cutting were transplanted in ridges and furrows with spacing of 60 cm × 45 cm. FYM, NPK and zinc to assigned plots were applied before rooted cuttings transplanted to main field. Spraying of zinc at 0.5 per cent was also given at 45 and 90 days after transplanting.

Plants were harvested after they attained satisfactory vegetative growth at five months (150 days) after transplanting. Harvesting of crop was done before the oldest leaves started turning yellow and dropping. Harvesting was done by removing the leaves along with tender shoots and taken for shade drying and oil distillation.

The oil extraction was done by taking hundred grams of shade dried herbage with tender shoots of each treatment were cut into small pieces of two centimeter size and distilled in Clevenger's apparatus. For the distillation, the mixture of dried leaves along with the shoots were taken in the ratio of 60:40 and distilled for four and a half hours.

Result and Discussion

Plant height

Significantly increased plant height was noticed after 150 days after transplanting (at harvest) with the application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (T_9) (93.93 cm) which was followed by treatment with RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (T_8) (92.00 cm) and treatment with RDF + $ZnSO_4$ @ 15 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (T_7) (90.73 cm). Plant height of 82.20 cm at the time of harvest recorded significantly lower results with the control (RDF only).

Zinc has the positive effect on plant height by accelerating the cell division. Zinc helps in the biosynthesis of amino acid like tryptophan which is the precursor of IAA (Indole Acetic Acid). This IAA helps in the cell division and differentiation in the plants which ultimately results in increasing the plant height. Similar results in increasing the plant height with application of zinc were reported by many studies like Hendawy and Khalid (2005) [7] in Salvia officinal is, Abd El-Hady (2007) [1] in barley, Pandey *et al.* (2007) [12] in mint and Said-Al-Ahl and Omer (2009) [15] in coriander.

Number of primary and secondary branches

It was found that, there was significant increase in the number of primary and secondary branches per plant at 150 DAT with the application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5% (T_9) (14.53 and 43.47) and followed by the treatment with application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 0.5% (T_8) (14.40 and 41.53) which was found on par with the treatments like T_7, T_6 and T_5 in number of primary branches per plant at harvest. The different levels and methods of application of zinc showed significant results in the number of primary branches per plant.

As there is an increase in the height of the plant it may also leads to increase in the number of branches (Singh *et al.*, 2004) [16]. As like increase in plant height with zinc application, it also helps in increasing in the number of branches per plant by accelerating the cell division and by controlling the auxin metabolism in the plant which is responsible for the cell division and differentiation in the plants (Amberger, 1974) [3].

Number of leaves

The application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent recorded that, number of leaves significantly increased (528.13) at the time of harvest, and was followed by treatment with application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (507.53), RDF + $ZnSO_4$ @ 15 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (489.40) and RDF + $ZnSO_4$ @ 25 kg ha^{-1} (474.87). Control (with application of RDF) recorded significantly lesser number of leaves per plant (439.47).

It is obvious that increase in the plant height and increase in the primary and secondary branches tends to increase in the number of leaves in the plants (Singh *et al.*, 2004) [16].

Leaf area

At the time of harvest, application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent recorded significant increase in leaf area (48.24 dm^2 $plant^{-1}$) which was followed by treatment with application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (46.58 dm^2 $plant^{-1}$). The control with RDF alone recorded significantly lower leaf area (40.21 dm^2 $plant^{-1}$).

Increase in the biosynthesis of auxin and the process of cell division in the plants are much influenced by the application of zinc. Its application helped in increasing the auxin level and cell division that lead to increase in the leaf area of the plant.

Leaf area index

Treatment T_9 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5%) showed significantly increased in the leaf area index (1.79). Application with RDF only recorded significantly lower leaf area index (1.49). Leaf area index was increased throughout the crop growth and was found maximum at harvesting time. Increase in doses of zinc increased the leaf area index.

This is because of the increased number of leaves, as there was increase in the vegetative growth of the crop like in plant height, leaf area, number of leaves and branches.

Dry herbage yield per hectare

Dry herbage yield per hectare increased significantly with the application RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (2.63 t/ha) which was on par with the treatment by application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (2.50 t/ha) and RDF + $ZnSO_4$ @ 15 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (2.38 t/ha).

It might be due to the influence of zinc in increasing the vegetative growth of the crop like plant height, number of primary and secondary branches, number of leaves, leaf area and leaf area index. Similar findings were also quoted by Zehtab-Salmasi (2008) [19].

Oil yield (kg/ha)

Treatment with RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent application recorded significantly higher oil yield (40.17 kg/ha) which was on par with T_8 (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 0.5%) with 37.53 kg ha^{-1} and T_7 (RDF + $ZnSO_4$ @ 15 kg ha^{-1} + $ZnSO_4$ @ 0.5%) with 35.05 kg ha^{-1}. The lowest essential oil yield was recorded by the treatment control with 25.15 kg ha^{-1}.

The higher oil yield recorded is due to increased growth parameters like number of leaves, plant height, number of branches and leaf area. There was increase in the oil content which ultimately lead to increase in the oil yield per hectare. It also might be due to the fact that, zinc has indirect effect on biosynthesis of terpenoids by increasing of photosynthesis. As the photosynthesis needs more of carbon dioxide for its process it indirectly supplies carbon dioxide required for the biosynthesis of terpenoids and helps in increasing essential oil yield of the crop. Moreover, enhanced biosynthesis of auxin, and cell division with zinc application can cause an increase of leaf area and plant photosynthesis which helps in enhancing the oil yield of the crop (Derakhshani *et al*., 2011) [5]. These results are similar with Mishra and Sharma (1991) [10] in Japanese mint, El-Sawi and Mohamed (2002) in cumin (*Cumin cyminum*), Akhtar *et al.* (2009) [2] in peppermint (*Mentha piperita*), Said-Al-Ahl and Mohmoud, (2010) in sweet basil (*Ocimum basilicum*) and Nasiri *et al.* (2010) [11] in chamomile (*Matricaria chamomilla*).

Economics

Benefit cost ratio was recorded lowest with the treatment control (1:1.79). RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent (T_9) recorded the highest benefit cost ratio (1:2.33) which was followed by treatment with application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent with 1:2.23.

The higher gross returns per hectare (₹ 92,050) and net returns (₹ 52,638) were recorded with application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 0.5 per cent as this treatment recorded highest dry herbage yield, while lower gross returns (₹ 67,550) and net returns (₹ 29,944) were recorded with control. These recorded results are in agreement with Lal *et al*. (2014) [9] in coriander, Kumar *et al.* (2010) [8] in menthol mint, Rao and Rajput (2011) in palmrosa and Singh (2014) [16] in turmeric.

Table 1: Effect of different levels and methods of application of zinc on growth, yield and oil content of patchouli (*Pogostemon patchouli*)

Treatments	Plant height (cm)	No. of primary branches	No. of secondary branches	No of leaves	Leaf area (dm^2 $plant^{-1}$)	Leaf area index	Dry herbage yield (t/ha)	Oil yield (kg/ha)
T_1: RDF	82.20	11.00	34.00	439.47	40.21	1.49	1.93	25.15
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	83.60	11.27	35.47	447.93	41.17	1.52	1.99	26.82
T_3: RDF + $ZnSO_4$ @ 15 kg ha^{-1}	84.60	11.67	35.67	456.87	41.83	1.55	2.04	27.45
T_4: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	86.47	12.33	37.80	461.47	42.12	1.56	2.10	29.49
T_5: RDF + $ZnSO_4$ @ 25 kg ha^{-1}	89.07	13.27	40.60	474.87	44.18	1.64	2.30	33.29
T_6: RDF + $ZnSO_4$ @ 10 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	88.40	13.13	39.80	467.73	43.36	1.61	2.21	32.09
T_7: RDF + $ZnSO_4$ @ 15 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	90.73	13.73	41.27	489.40	45.53	1.69	2.38	35.05
T_8: RDF + $ZnSO_4$ @ 20 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	92.00	14.40	41.53	507.53	46.58	1.73	2.50	37.53
T_9: RDF + $ZnSO_4$ @ 25 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	93.93	15.20	43.47	528.13	48.24	1.79	2.63	40.17
Mean	87.89	12.89	38.84	474.82	43.69	1.62	2.23	31.89
S.Em. ±	2.47	0.73	2.01	14.51	1.46	0.05	0.09	1.66
CD at 5%	7.41	2.19	6.02	43.51	4.37	0.16	0.27	4.99

Table 2: Effect of different levels and methods of application of zinc on economics of patchouli (*Pogostemon patchouli*)

Treatments	Gross returns per hectare (Rs. 35/kg dry herbage)	Net returns	B:C Ratio
T_1: RDF	67,550	29,944	1.79
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	69,650	31,494	1.82
T_3: RDF + $ZnSO_4$ @ 15 kg ha^{-1}	71,400	32,969	1.85
T_4: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	73,500	34,794	1.89
T_5: RDF + $ZnSO_4$ @ 25 kg ha^{-1}	80,500	41,519	2.06
T_6: RDF + $ZnSO_4$ @ 10 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	77,350	38,763	2.00
T_7: RDF + $ZnSO_4$ @ 15 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	83,300	44,438	2.14
T_8: RDF + $ZnSO_4$ @ 20 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	87,500	48,363	2.23
T_9: RDF + $ZnSO_4$ @ 25 kg ha^{-1}+ $ZnSO_4$ @ 0.5%	92,050	52,638	2.33

Conclusion

From the present study, it can be concluded that, growth parameters, yield parameters and oil yield per hectare were recorded maximum values by the application of RDF + ZnSO4 @ 25 kg ha-1 + ZnSO4 @ 0.5 per cent which was followed by the RDF + ZnSO4 @ 20 kg ha-1 + ZnSO4 @ 0.5 per cent. Also the same treatment has recorded the highest B:C ratio so this treatment can be recommended for commercial cultivation.

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