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Hibah Shahin Fathimaa H
M. Sc. Scholar, Department of Medicinal and Aromatic Crops, HC & RI, TNAU, Coimbatore, India

Nalina L
Associate Professor, Department of Medicinal and Aromatic Crops, HC & RI, TNAU, Coimbatore, Tamil Nadu, India

Rajamani K
Professor and Head, Department of Medicinal and Aromatic Crops, HC & RI, TNAU, Coimbatore, Tamil Nadu, India

Balachander D
Professor, Department of Agricultural Microbiology, TNAU, Coimbatore, Tamil Nadu, India

Thiribhuvanamala
Associate Professor, Department of Plant Pathology, TNAU, Coimbatore, Tamil Nadu, India

Correspondence
Nalina L
Associate Professor, Department of Medicinal and Aromatic Crops, HC & RI, TNAU, Coimbatore, Tamil Nadu, India

Effect of different media and bioinoculants on growth and yield characters of vetiver (*Chrysopogon zizanioides* (L.) Roberty)

Hibah Shahin Fathimaa H, Nalina L, Rajamani K, Balachander D and Thiribhuvanamala

Abstract
The present study was conducted with the principal aim to identify a suitable medium for sustainable vetiver production. The essential oil of vetiver is globally known for its use in perfumery and cosmetic industry. The roots are the economic part of this crop. Harvesting of vetiver from open field results in detainment of the core roots and reduction in root yield. About 40% of the roots are retained in the soil after harvest. This can be prevented by either maintaining a loose textured soil or by growing the plants in grow bags, which facilitates easy harvesting. In order to study the effect of different medium on growth and biomass of vetiver, the slips were grown in bags containing combinations of media components supplemented with organic manures. The medium was also supplemented with a consortium of bioinoculants (VAM, *Azospirillum* and *Phosphobacteria*). The highest morphological and biomass parameters were obtained in the treatment M_3B_2 (FYM + red earth (1: 4) + biofertilizers) resulting in increased root yield per plant. However, the highest oil content was observed in M_1B_2 (Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium + bioinoculants).

Keywords: Vetiver, medium, biofertilizers, farmyard manure, vermicompost

Introduction
Vetiver, botanically called as *Chrysopogon zizanioides* (L.) Roberty, is a high value aromatic plant widely popular for its essential oil commonly known as 'vetiver oil' or 'khus oil'. The major constituent of the oil distilled from the roots of this grass is 'vetiverol' or 'khusinol'. The complex odour profile of vetiver oil indicates the presence of many compounds, mainly sesquiterpenes and their derivatives, which impart a woody balsamic tonality to the oil. The active compounds have insinuated themselves into the fields of cosmetics and perfumery industries. Therapeutically they are used in the treatment of arthritis, rheumatism, sprain, lumbago *etc* (Maffei, 2002) [6].

The major constraint in vetiver cultivation practised in open field conditions is the detainment of the roots in the soil during harvest, resulting in economic loss to farmers. About 40% of the produce remains in the soil after harvest. This can be prevented by the development of an alternate technique to obtained increased yields in vetiver. The oil content in vetiver is observed to be high in the core roots. Hence, it is necessary to develop an innovative method to not only increase the biomass yield but also the number of roots.

The quantity and quality of the essential oil can also be improved by the supplementation of organic manures. Amendment of soils by the use of organic compost, oil cakes, vermicompost, green manure *etc*, has directed the path for increased soil health and quality. Application of biofertilizers has also proven to have a positive correlation with the utilization of nutrients present in the soils. Microbial symbiosis with plant or their presence as individual colonies of free living microfauna has created an environment which is hugely conducive for the growth of plants. Inoculation of microbes has also been reported to have widened the beneficial effects on plants (Akhazari, 2018) [1].

Hence, in vetiver cultivation it is essential to maintain a loose textured soil benefiting increased efficiency during harvest. The present study was aimed to identify a suitable media which provides increased profitability in vetiver when cultivated in grow bags.

Materials and methods
The investigation was carried out in a completely randomized factorial design with two replications, at Department of Medicinal and Aromatic Crops, HC & RI, TNAU, Coimbatore for the period of September 2018 to March 2019.

The experiment was performed with two factors *viz.*, different medium (M) at eight levels and bioinoculants (B) at two levels. The different levels of medium were M_1 – Coir, M_2 – Sand, M_3 - FYM + red soil (1:4), M_4 - FYM + red soil (1:4) + neem cake + castor cake (250g/ 25 kg of medium), M_5 - Sand + red soil + vermicompost (2:2:1), M_6 - Sand + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium), M_7 - Coir + red soil + vermicompost (2:2:1) and M_8 - Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium). All the above medium were used without biofertilizers (B_1) and with biofertilizers (B_2). The plants were grown in bag size of 55 x 23 cm, filled with the combinations of the above medium. Each bag was planted with a single vetiver slip of variety Khusinolika. The morphological characters like plant height, number tillers per plant, number of leaves per plant, root length, fresh and dry root weight, number of roots, fresh and dry shoot weight were measured after six months of planting. The roots were shade dried and the oil was distilled from the dried roots by modified Clevenger's Apparatus method (Pruthi, 1999) [9] and expressed in percentage.

Results and discussion

Effect of medium and biofertilizers on morphological characters

The highest plant height (108.75 cm) was recorded in the medium M_4 (FYM + red soil (1:4) + neem cake + castor cake (250g/ 25 kg of medium)) and it was statistically on par with M_3 (111.73 cm) and M_8 (108.75 cm). The interactive effect of M_4B_2 (FYM + red soil (1:4) + neem cake + castor cake (250g/ 25 kg of medium) + biofertilizers) exhibited the highest plant height of 122.85 cm while plants treated with biofertilizers (B_2) produced a plant height of 106.04 cm.

The number of leaves per plant and number of tillers per plant were found to be the highest (311.00 and 38.52) in M_3 (FYM + red soil (1:4)) which was on par with M_8 (301.00 and 37.22). The plants treated with biofertilizers (B_2) produced 248.48 leaves per plant and 34.47 tillers per plant. The combination of M_4B_2 (FYM + red soil (1:4) + neem cake + castor cake (250g/ 25 kg of medium) + biofertilizers) exhibited the highest number of leaves per plant (376.4) at 6 months after planting (Table 1).

The ability of farmyard manure to provide appropriate levels of NPK and organic carbon for a prolonged period of time might have influenced the growth attributes. The application of neem cake which contains 2.00 to 5.00% of nitrogen also increased the nitrate levels available to the plants. This might have resulted in increased vegetative growth. Sharma and Bhalla (1995) [11] proclaimed that the nutritive value of organic manures improved the biological, physiological and metabolic activities of the plants resulting in increased photosynthesis. Similar results were observed by Tanu *et al.* (2003) in *Cymbopogon winterianus* when they were grown under the supplementation of various organic amendments. Gajbhiye *et al.*, (2013) [3] proclaimed that application of 10 tons of FYM resulted in enhanced biomass in lemongrass.

Table 1: Effect of different media and biofertilizers on plant height (cm), number of tillers and number of leaves per plant on vetiver var. Khusinolika

	Plant height (cm)			Number of tillers per plant			Number of leaves per plant		
	B_1	B_2	Mean	B_1	B_2	Mean	B_1	B_2	Mean
M_1	70.80	86.30	78.55	5.15	10.54	7.85	31.00	37.33	34.17
M_2	96.10	104.80	100.45	21.25	29.50	25.38	124.53	173.46	148.99
M_3	110.50	112.95	111.73	33.56	43.47	38.52	245.60	376.40	311.00
M_4	105.80	122.85	114.33	32.45	39.13	35.79	254.40	290.80	272.60
M_5	88.40	93.30	90.85	24.55	34.77	29.66	159.75	187.90	173.83
M_6	95.80	108.00	101.90	28.60	37.77	33.19	218.50	298.33	258.42
M_7	82.40	108.00	95.20	30.27	39.31	34.79	223.40	265.60	244.50
M_8	105.35	112.15	108.75	33.19	41.25	37.22	245.60	356.40	301.00
Mean	94.39	106.04	100.22	26.13	34.47	30.30	187.85	248.28	218.06
	M	B	M*B	M	B	M*B	M	B	M*B
S. Ed.	2.789	1.395	3.944	0.728	0.364	NS	5.195	2.598	7.347
CD (P=0.05)	5.913	2.956	8.362	1.482	0.741	NS	10.582	5.291	14.965

Effect of medium and biofertilizers on root parameters

The number of roots per plant was the highest in the medium M_3 (FYM + red soil (1:4)) with a mean of 385.25 roots per plant and it was statistically on par with M_4B_2 (370.73). It was reported to be the highest in plants treated with biofertilizers (B_2) (328.04) and in the treatment combination M_3B_2 (FYM + red soil (1:4) + biofertilizers) (409.24).

The root length was the highest (80.18 cm) in M_2 (Sand) and it was the lowest (54.60 cm) in M_1 (Coir). Application of biofertilizers (B_2) recorded the highest root length of 70.91 cm when compared to B_1 (no biofertilizers) with a root length of 62.31 cm. The root length was the highest (88.85 cm) in the interaction effect of M_2B_2 (Sand + biofertilizers).

The highest root fresh weight per plant (345.13 g) was reported in M_8 (Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium)), which was statistically on par with M_3 (341.25 g) and M_4 (336.07 g). The presence of biofertilizers (B_2) resulted in a mean value of 282.99 g of root fresh weight per plant while the dual interaction of M_8B_2 (Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium) + biofertilizers) produced a mean of 388.25 g. It was statistically on par with M_3B_2 (367.60 g).

The root dry weight per plant was the highest (83.45 g) in M_6 (Sand + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium)). It was on par with M_3 (78.63 g), M_7 (76.28 g), M_4 (75.83 g) and M_8 (75.67 g). The inoculation of biofertilizers (B_2) resulted in a dry weight of 67.77 g per plant, while plants without biofertilizers (B_1) reported 58.21 g per plant. The highest dry weight per plant (88.45 g) was reported in combination of M_3B_2 (FYM + red soil (1:4) + biofertilizers) (Figure 2).

Root length was observed to be the highest in sand which might be the consequence of superior penetrable nature of sand which facilitates the deep seated perforation of roots in exploration of water. It also creates an unfavourable environment which stimulates increased accumulation of secondary metabolites in their tissues. The increased accessibility towards water restrained by vermicompost and composted coir pith sanction the entry of water into the plant cells and thereby significantly influences the number of roots

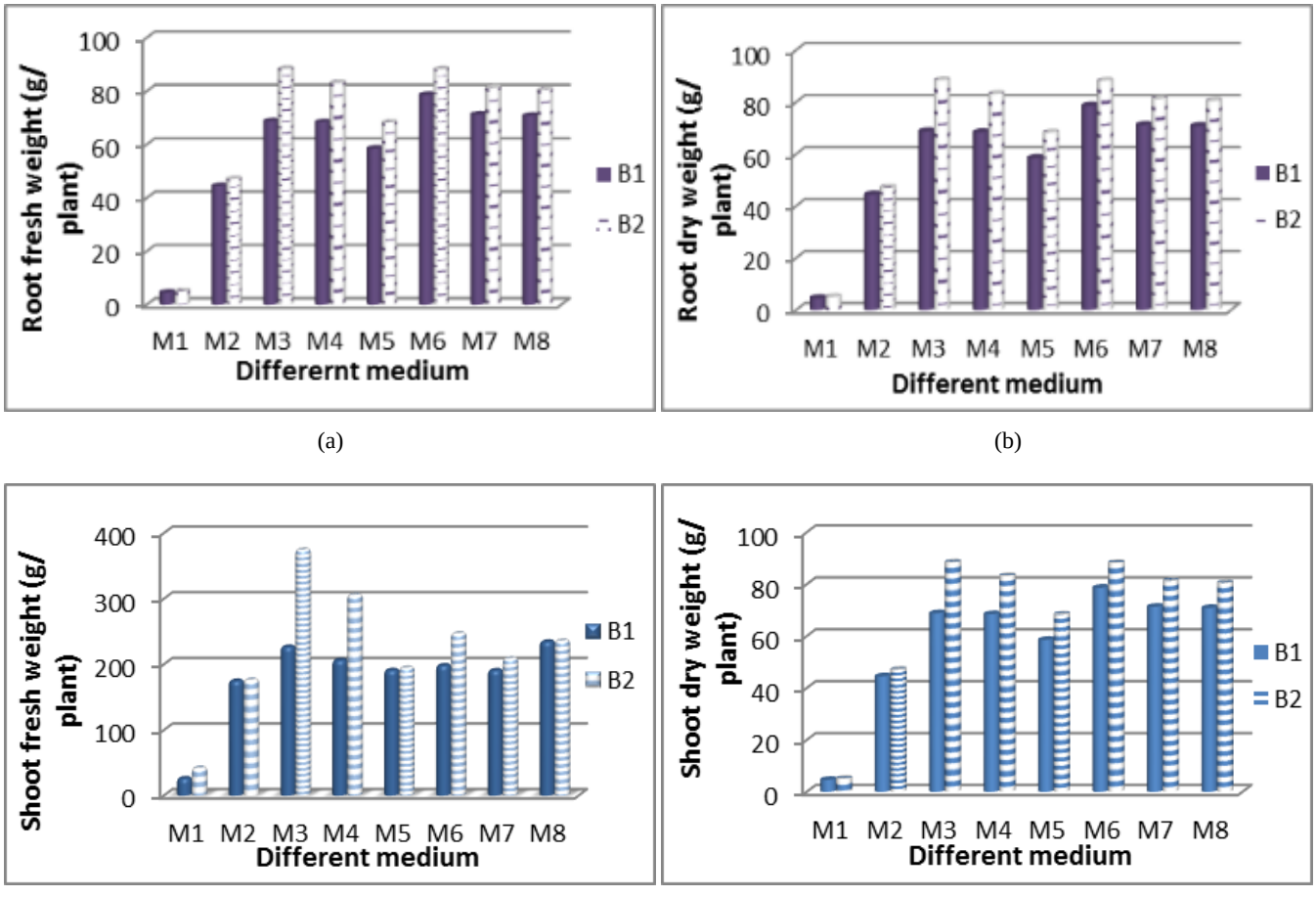
and their fresh weight. Akhzari *et al.*, (2018) [1] reported the increase in root characters by the infection of vetiver with mycorrhiza while inoculation of *Glomus fasciculatum* promoted the biomass of vetiver. *Catharanthus roseus* exhibited increased root and shoot length and yield when treated with a consortium of PGPR (Lenin and Jayanthi, 2012) [5].

Table 2: Effect of growing media and biofertilizers on total number of roots and root length (cm) on vetiver var. Khusinolika

	Total number of roots			Root length (cm)		
	B_1	**B_2**	**Mean**	**B_1**	**B_1**	**Mean**
M_1	4.60	5.10	4.85	52.50	52.50	16.00
M_2	44.50	47.10	45.80	188.00	188.00	197.30
M_3	68.80	88.45	78.63	361.25	361.25	341.25
M_4	68.45	83.20	75.83	338.20	338.20	336.07
M_5	58.55	68.30	63.43	266.00	266.00	273.43
M_6	78.65	88.25	83.45	288.50	288.50	330.25
M_7	71.3	81.25	76.28	320.90	320.90	266.83
M_8	70.85	80.50	75.67	331.50	331.50	345.13
Mean	58.21	67.77	62.99	244.44	244.44	263.28
	M	B	M*B	M	M	M*B
S. Ed.	4.503	2.251	6.368	8.495	8.495	11.674
CD (P=0.05)	9.546	4.773	13.499	18.010	18.010	24.748

Effect of medium and biofertilizers on shoot biomass

The highest shoot fresh and dry weight per plant was reported in M_3 (FYM + red soil (1:4)) at 300.43 g and 136.68 g respectively. The application of biofertilizers enhanced the shoot biomass resulting in 232.87 g fresh weight and 111.64 g of dry weight. Interaction effects resulted in M_3B_2 (FYM + red soil + biofertilizers) being the best treatment with high fresh (374.45g) and dry weight (147.80 g) (Figure 1). The increased nitrogen content in M_3 might have resulted in increased vegetative growth resulting in increased fresh and dry weights. These findings were supported by results given by Cavender *et al*. (2003) [2]; Pashanasi *et al.* (1996) [8] and Roy *et al*. (2010) [10].



(a) (b)

(c) (d)

Fig 1: Effect of different medium and biofertilizers on root fresh weight (a), root dry weight (b), shoot fresh weight (c) and shoot dry weight (d) in vetiver var. Khusinolika

Table 3: Effect of growing media and bioinoculants on oil content (%) on vetiver var. Khusinolika

	Oil content (%)		
	B1	**B2**	**Mean**
M_1	0.10	0.33	0.17
M_2	0.67	0.82	0.75
M_3	0.55	0.67	0.61
M_4	0.58	0.68	0.63
M_5	0.60	0.70	0.65
M_6	0.63	0.73	0.68
M_7	0.59	0.70	0.64
M_8	0.63	0.88	0.76
Mean	0.53	0.69	0.61
	M	B	M x B
S. Ed.	0.022	0.011	0.032
CD (P=0.05)	0.047	0.024	0.067

Effect of medium and biofertilizers on oil content

Application of Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium) (M_8) recorded the highest oil percent of 0.76, which was statistically on par with M_2 (0.75%), while plants inoculated with biofertilizers produced an oil content of 0.69%. Significant results were obtained on the effect of medium and biofertilizers on oil content. The highest percent of oil (0.88%) was observed in the interaction of M_8B_2 (Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium) + biofertilizers) and it was found to be statistically on par with M_2B_2 (0.82%) (Table 3). The nutrient supplementation by the organic amendments increased the CO_2 evolution in soils resulting in enhanced enzymatic activity (Padmadevi *et al.*, 2016) [7], which might have been the reason for increased secondary metabolite production, leading to higher yield of oil. Similar results was observed in experiments conducted on vetiver by Akhzari *et al.* (2018) [1], black musli by Joy *et al.* (2005) [4] and coleus by Padmadevi *et al.* (2016) [7].

Conclusion

A study was conducted to standardize the growing medium for sustainable vetiver production. The results revealed that application of FYM + red soil (1:4) + neem cake + castor cake (250g/ 25 kg of medium) + biofertilizers (M_4B_2) produced the highest plant height and number of leaves per plant. The number of roots per plant was highest in M_3 (FYM + red soil (1:4)) which might have been influenced by the increased availability of P and Ca from farm yard manure. Although the yield contributing characters like fresh and dry root and shoot weight were highest in M_3B_2 (FYM + red soil + biofertilizers), high oil content was obtained in M_8B_2 (Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium) + biofertilizers) and M_2B_2 (Sand + biofertilizers). Hence, the treatments M_3B_2 (FYM + red soil + biofertilizers) and M_8B_2 (Coir + red soil + vermicompost (2:2:1) + neem cake (175g/ 25 kg of medium) + biofertilizers) are suitable medium for growing vetiver to obtain high yield and economic returns.

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