Selection of the most suitable pot height and harvesting stage for higher growth, yield and oil quality of Vettiver (*Vetiveria zizanioides*)

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Abstract

Vetiveria zizanioides (L.) Nash is a valuable medicinal and aromatic plant used in both indigenous medicine and perfumery industry. Economically most important part of the Vettiver is root system. Vettiver roots are directly used for the medicinal purposes and indirectly for extraction of essential oils. Low yield and poor quality roots as well as oil are the problems associated with Vettiver production. Yield and quality of Vettiver roots depend on climatic conditions, growing media, agronomic practices, time of harvesting etc. Objective of the present study was to select the most promising pot height and harvesting stage in order to enhance bio-mass production, oil content and quality of Vettiver. A pot experiment was conducted at Medicinal Plant Garden, Faculty of Agriculture, from March 2008 to April 2009. Three pot heights, namely, 35, 40 and 45 cm with four different harvesting intervals such as 3, 6, 9 and 12 months after planting were used for this experiment. Data on number of tillers, number of leaves, dry weight of roots and shoots were recorded at 3, 6, 9 and 12 months of planting as different harvesting stages. Root oil contents, chemical composition of oils such as Khusimol, β-Vetivenene, β-Vetivone, α-Vetivone, Iso-valencinol and fiber content were also analyzed. Results revealed that, Vettiver planted in 45 cm pot height showed higher biomass production. Oil content of Vettiver increased with the increasing harvesting intervals. Higher oil content (2.15%) was recorded 12 months after planting. Subsequently higher oil percentage (2.13%) was recorded in 9 months after planting. However, there were no significant differences between oil content of 9 and 12 months after planting. It was also observed in the present study that the Vettiver harvested at 9 months of planting had significantly ($P < 0.05$) high Khusimol (14.5%), β-Vetivone (1.4%) and Iso-valencinol (4.9%) contents in root oil. Relatively lower fiber contents (36%) were associated with 9 months after planting compared to 12 months after planting. Therefore, Vettiver planted in 45 cm pot height and roots harvested at 9 months after planting could be used as most promising pot height and harvesting interval in order to enhance bio-mass production, oil content and quality of Vettiver.

Introduction

Vetiveria zizanioides (L.) Nash (Sinhala – Sevendara, Tamil – Vettiver) which belongs to the family Poaceae is one of the most important medicinal and aromatic plants widely used in indigenous medicine and perfumery industry. Vettiver oil is one of the most valuable product of Vettiver roots. Vettiver oil has 442 extensive applications in the soap and cosmetic industries, pharmaceutical companies and as antimicrobial and anti-fungal agent [1]. In Sri Lanka, annual national demand for Vettiver is 41175 Kg (dry basis) and this is valued as 4 million rupees [2]. The root system of Vettiver consists of long fibrous roots and rootlets. These roots grow more than 2 m in depth and about 80% of the roots can be found in the first 30-35 cm [3]. Even after the careful harvesting, 40% of the roots remain in the soil yielding highly damaged roots. One of the main problems in Vettiver production is poorly developed low quality roots. These roots produce lower oil yields as well as low quality oils. Such problems in Vettiver production could be avoided by adopting proper agronomic and crop management practices. Therefore, the present study was carried out to select the most promising pot height and harvesting stage in order to enhance bio-mass production, oil content and quality of Vettiver.

Materials and Methods

A pot experiment was conducted from March 2008 to April 2009 at Medicinal Plant Garden, Faculty of Agriculture, University of Ruhuna. Three pot heights, namely, 35, 40 and 45 cm with four different harvesting intervals such as 3, 6, 9 and 12 months after planting were used for this experiment. Three different heights of black polythene bags were filled using top soil: sand (1:2). Leaves of tillers were cut down by keeping 3 cm from the base. Tillers were planted in pots keeping one tiller per pot. Pots were arranged in a Completely Randomized Design (CRD) with four replicates. Watering was done at

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two day intervals up to four weeks after planting and thereafter plants were subjected to rain fed condition. Hand weeding was practiced at two month intervals.

As non destructive measurements, number of tillers per bush and number of leaves were taken in 3, 6, 9 and 12 months after planting. Roots were harvested manually and roots were air dried in the laboratory for three weeks period to a constant weight. Dry weight of roots and shoots were taken in Vettiver roots harvested at 3, 6, 9 and 12 months after planting as different harvesting stages. Total root oil content, chemical composition of oil (Khusimol, β-Vetivenene, β-Vetivone, α-Vetivone, Iso-valencinol) and fiber content were determined. Vettiver root samples were air dried in the laboratory for three weeks period and roots were cut into 1 cm length of root pieces using a secatier. Then prepared root samples were used for the oil extraction and the residue after the oil extraction was used for the analysis of fiber content of Vettiver roots with the four replicates from each treatment. Samples were subjected to AOAC method for determination of crude fiber [4]. Oil content and chemical compounds in oil were analyzed using Steam Distillation Procedure and Gas Chromatography Internal Normalization method, respectively. Data with percentage values were subjected to angular transformation where necessary and analyzed using ANOVA (analysis of variance) with Statistical Analysis System (SAS version 6.12).

Results

Effect of different pot height and harvesting stages on biomass production of Vettiver

A pot height of 45 cm (T_3) showed higher root (dry) weights 84.5 g, 242 g, 641 g and 777 g respectively at 3, 6, 9 and 12 months after planting. At 9 months after planting it was more than double the root (dry) weight at 6 months after planting (Figure 1).

Higher shoot weights (dry) were recorded in 45 cm pot height (T_3) 192.25 g, 584g, 1572.8 g and 1836.8 g respectively at 3, 6, 9 and 12 months after planting (Figure 2).

Figure 1: Changes in dry root weight of Vetiver as affected by different pot heights (cm) at different harvesting stages (3, 6, 9 and 12 months after planting) (α=0.05). T_1-35 cm, T_2-40 cm T_3-45 cm.

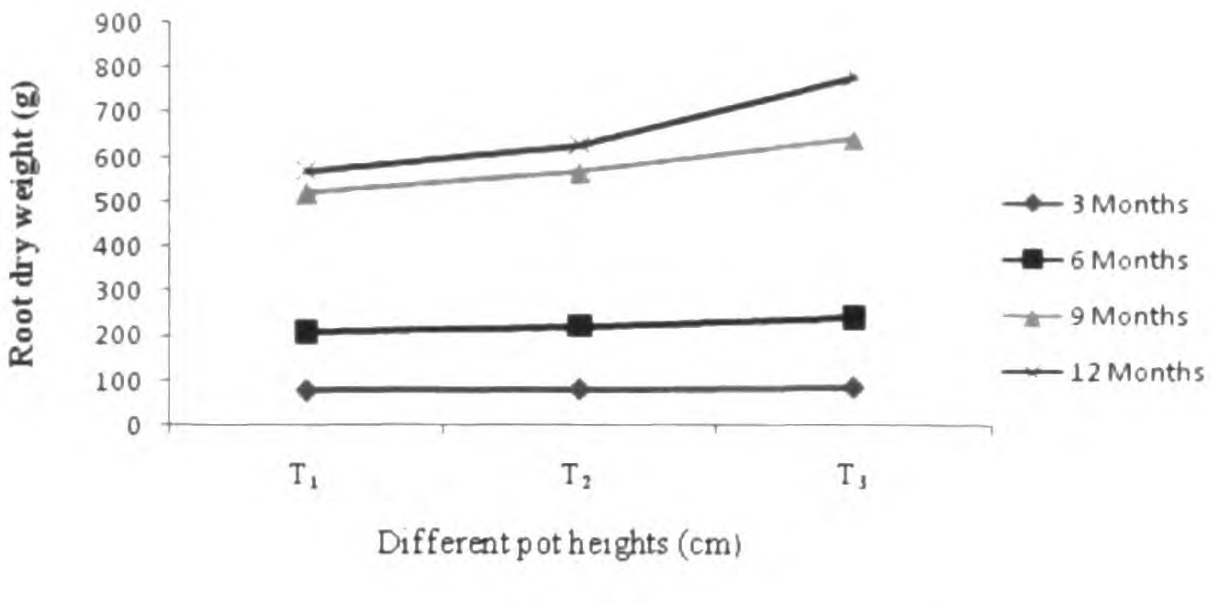


Figure 2: Changes in shoot dry weight of Vetiver as affected by different pot heights (cm) at different harvesting stages (3, 6, 9 and 12 months after planting) (α=0.05). T_1-35 cm, T_2-40 cm T_3-45 cm.

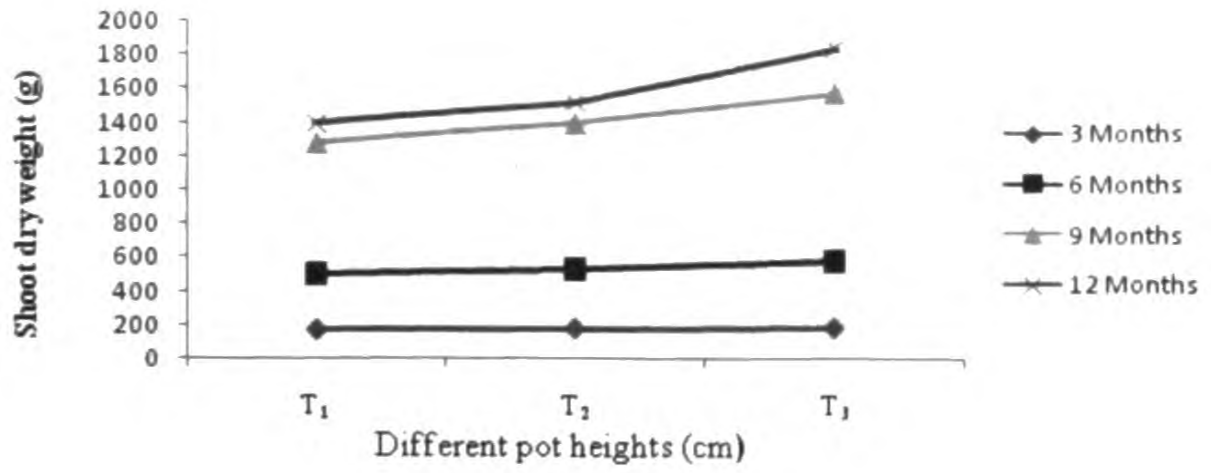


Figure 3: Changes in number of leaves of Vetiver as affected by different pot heights (cm) at different harvesting stages (3, 6, 9 and 12 months after planting) (α=0.05). T_1- 35 cm, T_2- 40 cm T_3- 45 cm.

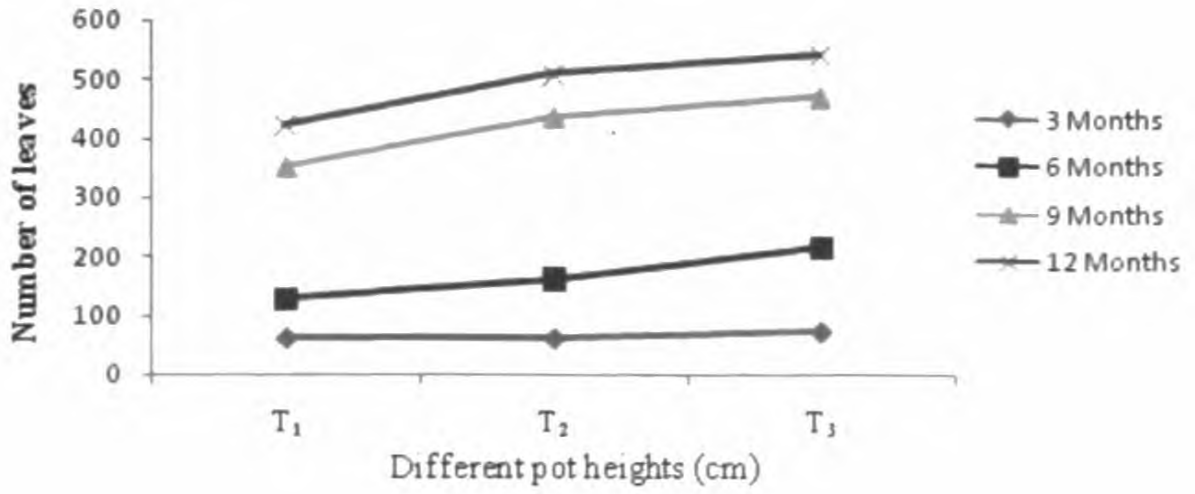
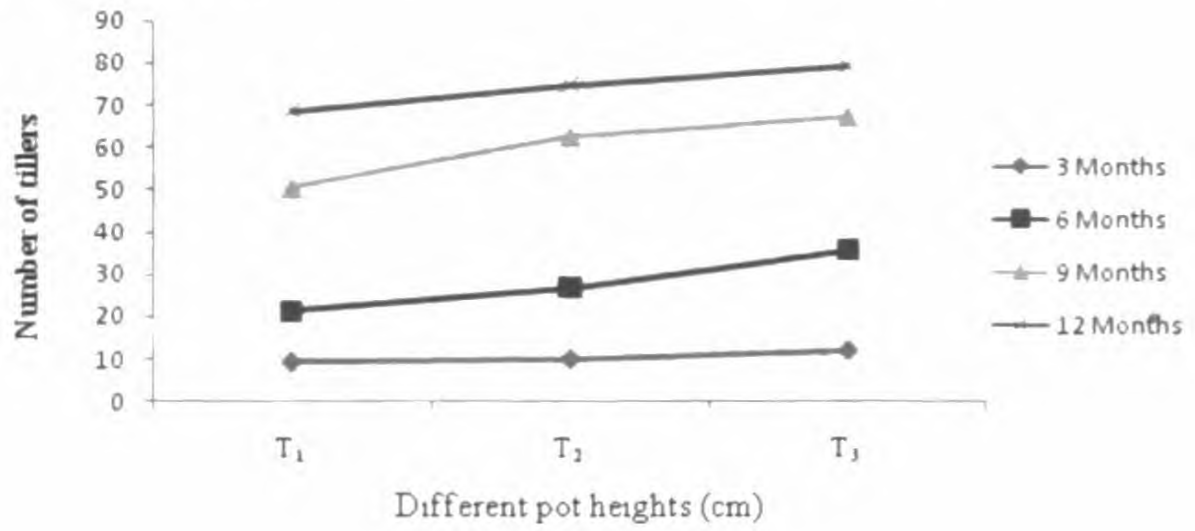


Figure 4: Changes in number of tillers of Vetiver as affected by different pot heights (cm) at different harvesting stages (3, 6, 9 and 12 months after planting) (α=0.05). T_1- 35 cm, T_2- 40 cm T_3- 45 cm.



Pot height had not shown significant differences (P> 0.05) in number of leaves up to 3 months after planting. However, numbers of leaves were significantly (P<0.05) affected by pot height after 6 months of planting. Significantly higher (P<0.05) number of leaves of 215, 471 and 543 were recorded in 45 cm pot height (T_3) at 6, 9 and 12 months after planting respectively (Figure 3).

Similarly, pot height had not shown significant differences (P>0.05) in number of tillers up to 3 months of planting. However, it was significantly affected by pot height after 6 months of planting. A significantly higher (P? 0.05) number of tillers of 36, 67 and 79 was recorded in 45 cm pot height (T_3) at 6, 9 and 12 months after planting respectively (Figure 4).

All the growth and yield parameters (root dry weight, shoot dry weight, number of leaves and number of tillers) of Vettiver were higher in 45 cm pot height (T_3) compared to other treatments (pot height of 35 and 40 cm).

Effect of different harvesting stages on oil content and quality of Vettiver

Oil content of Vettiver increased with the increasing harvesting intervals. Highest oil content (2.15%) was observed 12 months after planting (T_4). Subsequently higher oil percentage (2.13%) was recorded in 9 months after planting (T_3) (Figure 5).

Results of chemical compound analysis revealed that a significantly highest (P<0.05) Khusimol content (14.5%) was recorded in Vettiver harvested 9 months after planting (T_3). It varied as 10.5%, 7.7 % and 13.5 % respectively at the 3, 6 and 12 months after planting. Khusimol content was higher in 3 months old plants (10.5%) than in the 6 months old plants (7.7%). Production of Khusimol showed a twofold increase 9 months after planting (14.5%) compared to the 6 months after planting (7.7%) (Figure 6).

Figure 5: Oil content (%) of Vetiver at different harvesting periods. Means with the same letter are not significantly different at α=0.05. T_1-3 MAP, T_2-6 MAP, T_3-9 MAP, T_4-12 MAP.

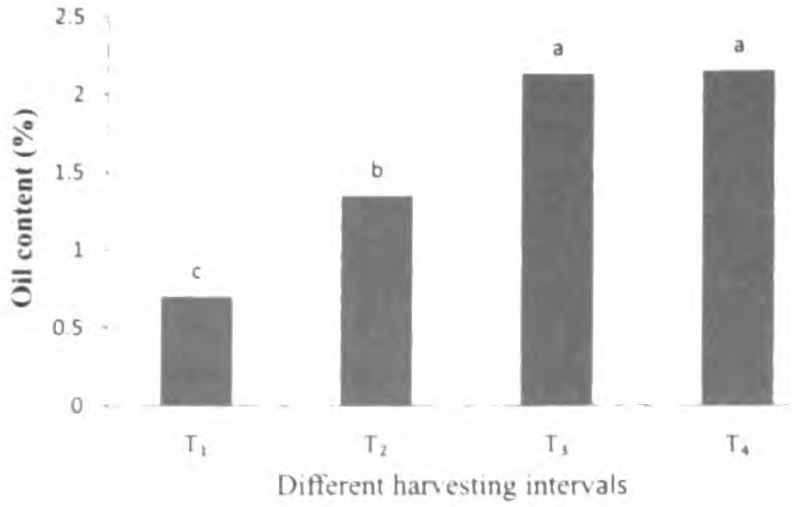


Figure 6: Khusimol content (%) of Vetiver oil at different harvesting periods. Means with the same letter are not significantly different at α=0.05. T_1-3 MAP, T_2-6 MAP, T_3-9 MAP, T_4-12 MAP.

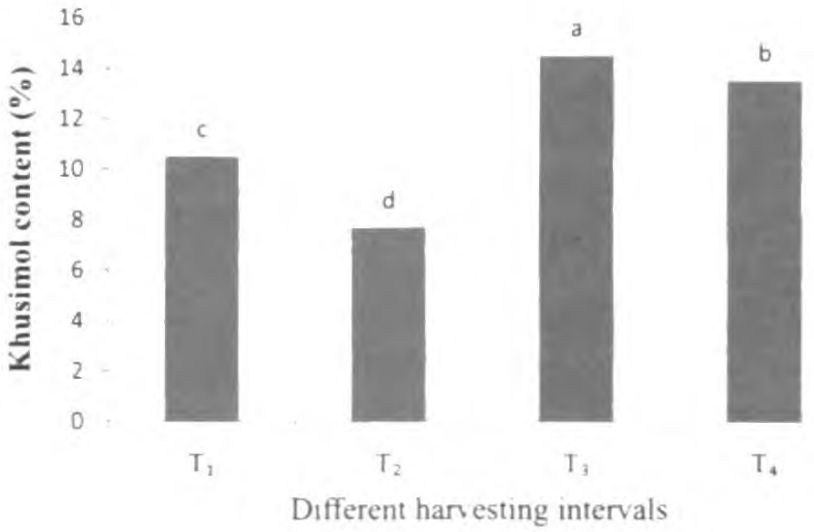
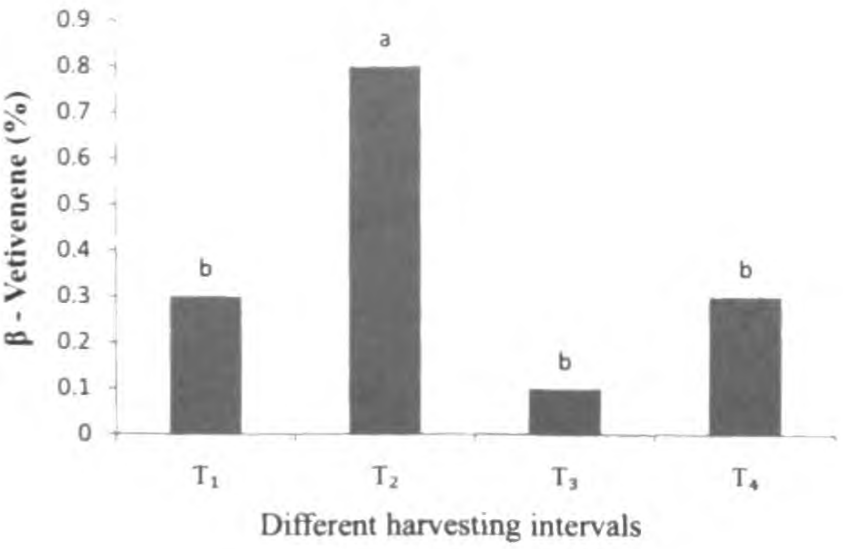


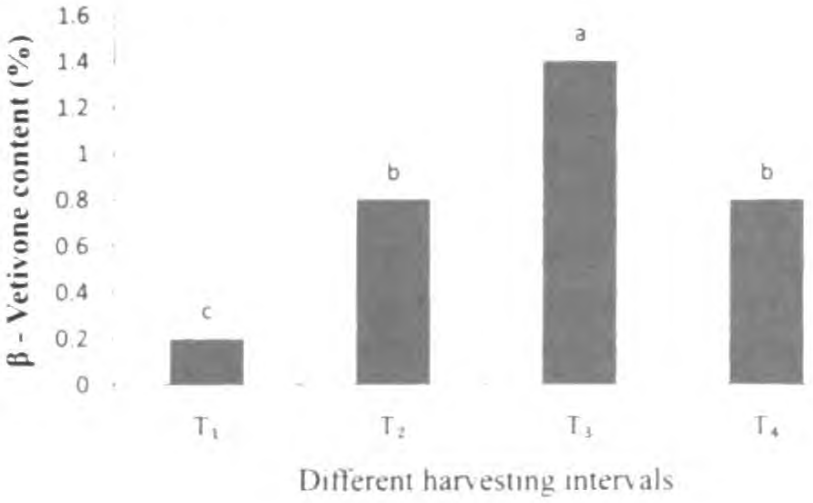
Figure 7: β-Vetivenene content (%) of Vetiver oil at different harvesting periods. Means with the same letter are not significantly different at α=0.05. T_1-3 MAP, T_2-6 MAP, T_3-9 MAP, T_4- 2 MAP.



A significantly (P<0.05) higher β-Vetivenene (0.8%) content was recorded 6 months old plants (T_2) compared to 3, 9 and 12 months old plants (Figure 7).

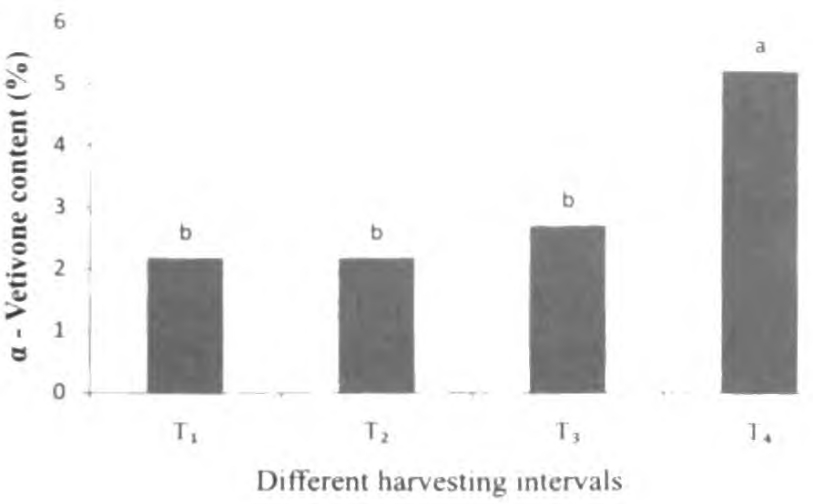
A significantly higher (P<0.05) β-Vetivone content (1.4%) was recorded at the 9 months after planting (T_3) compared to the other harvesting intervals. Production of β-Vetivone increased during the first nine months and after that it decreased to 0.8%, when it reached to 12 months after planting (Figure 8).

Figure 8: β-Vetivone content (%) of Vetiver oil at different harvesting periods. Means with the same letter are not significantly different at α=0.05. T_1-3 MAP, T_2-6 MAP, T_3-9 MAP, T_4-12 MAP.



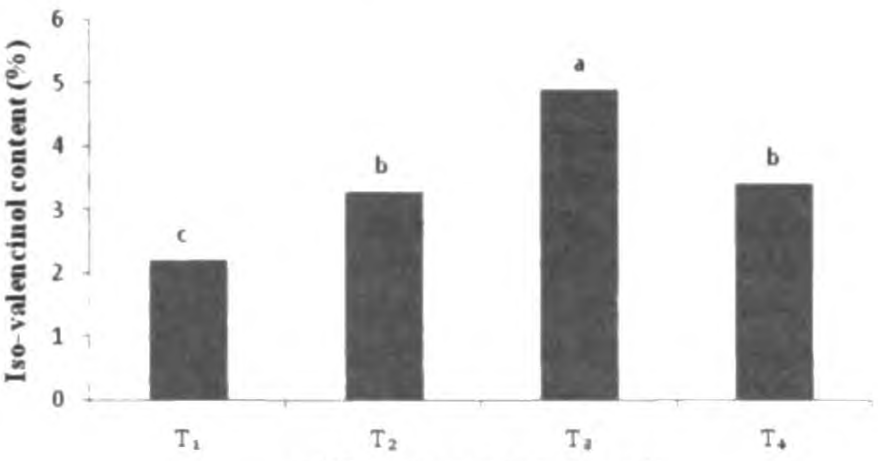
There was an increasing trend in α-Vetivone content (%) with increasing intervals of harvesting. Significantly high (P<0.05) α-Vetivone content (5.2%) was recorded 12 months after planting (T_4) (Figure 9).

Figure 9: β-Vetivone content (%) of Vetiver oil at different harvesting periods. Means with the same letter are not significantly different at α=0.05. T_1-3 MAP, T_2-6 MAP, T_3-9 MAP, T_4-12 MAP.



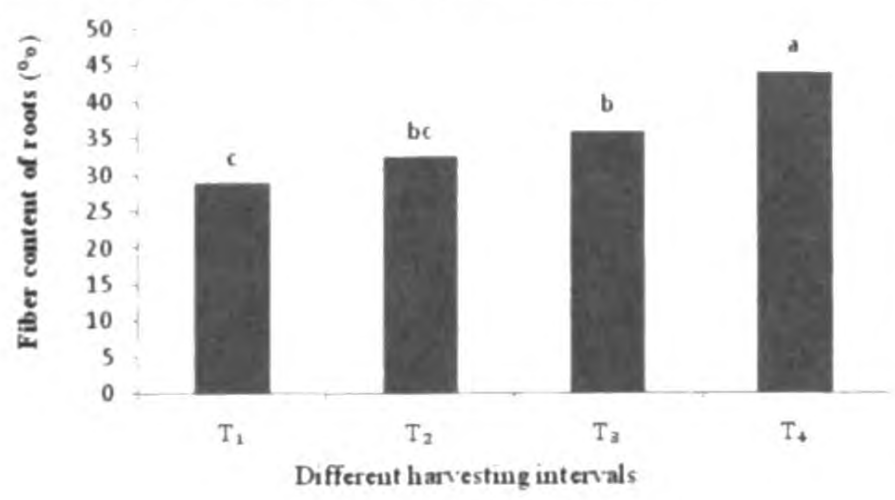
A significantly higher (P<0.05) Iso-valencinol content (4.9%) was recorded at 9 months after planting (T3) compared to other harvesting intervals (Figure 10).

Figure 10: Iso-valencinol content (%) of Vetiver oil at different harvesting periods. Means with the same letter are not significantly different at α=0.05. T_1-3 MAP, T_2-6 MAP, T_3-9 MAP, T_4-12 MAP.



Different harvesting intervals showed significant differences (P<0.05) in fiber content of roots. Fiber content of roots increased with the increasing harvesting intervals. A significantly high (P<0.05) root fiber content (44.1%) was recorded in Vettiver harvested 12 months after planting (T_4) (Figure 11).

Figure 11: Changes in root fiber content of Vetiver as affected by different harvesting intervals. Means with the same letter are not significantly different at α=0.05. T_1-3 MAP, T_2-6 MAP, T_3-9 MAP, T_4-12 MAP.



Discussion

There was a positive correlation between biomass productions of Vettiver and pot height. Increase in pot heights facilitates the downward movement of roots providing more space. This may be the reason for higher growth and yield observed in 45 cm than other treatments. It is not practically feasible to handle pot heights above 45 cm. Yoon (1993) found that, larger bag sizes of 6" × 13", 7" × 15" and 8" × 12" are considered too large for practical use and there was a decrease in the number of tillers and top dry weights production from the largest bag to the smallest bag, which is in agreement to results in this study [5]. Chomchalow (2001) reported that digging of soil for root harvesting may be environmentally undesirable, an alternative means of growing Vettiver could be in poly-bags and other containers [6]. He further pointed out that, this would not only mitigate soil erosion concerns but also increase cost benefit ratio of Vettiver cultivation for its roots and root oil, as well as optimum utilization of degraded lands as poly-bag platforms.

It was reported in the present study that oil content (1.24%) doubled 6 months after planting when compared to the oil content (0.63%) at 3 months after planting. Similarly, when considering the oil content between 6 and 9 months after planting it was nearly double at 9 months after planting. But there was no such increment between 9 and 12 months after planting. The most promising harvesting time with respect to the root yield was 9 months after planting. Therefore, it is not economically viable to keep extra 3 months in the field as it increases the cost of production.

Maffi (2002) pointed out that the Vettiver roots give a yield of about 0.3 to 2 % essential oil depending upon the biotype, cultural practices, age of roots and mode and duration of distillation [7]. However, in the present study, the oil yields were 2.13% and 2.15% respectively, 9 and 12 months after planting on a dry weight basis and there were no significant differences oil contents between 9 and 12 months. Therefore, harvesting interval of 9 months after planting could be recommended to obtain an economically viable root and oil yields.

It was also observed in the present study that the Vettiver harvested at 9 months of planting (T3) had significantly (P<0.05) high Khusimol, β-Vetivone and Iso-valencinol contents in root oil. However, during the period of 9 to 12 months of planting α-Vetivone content (5.2%) of Vettiver increased while Khusimol, β-Vetivone and Iso-valencinol contents in Vettiver oil decreased.

There were no remarkable changes in temperature, monthly average rainfall and number of rainy days up to nine months of planting. However, there were remarkable reductions in monthly average rainfall and number of rainy days during the period between harvesting intervals of 9 and 12 months. Present study was conducted under the rain fed conditions (watering was done at two day intervals up to four weeks after planting).

Water stress conditions are highly associated with the secondary metabolites production of Vettiver. These may be the reasons for such changes in active ingredients. Maffei (2002) reported that in North India, there is no definite period for harvesting and the roots are harvested both for the manufacture of articles and for oil distillation when plants are 10-12 months old. Chadha (1995) pointed out that tremendous diversity of oil composition exists

with respect to pattern of growth, orientation and thickness of roots, as well as for occurrence of secondary roots and harvesting time [8]. Aggarwal et al. (1998) demonstrated that the age, quality and stage of root harvest, and processing for distillation are vital components for essential oil distillation [9].

High fiber content reduces the yield and quality of roots as well as oil. Therefore, it is necessary to select best possible harvesting interval with lower fiber content for yield and quality improvement of the Vettiver oil. Anon (1976) reported that Vettiver has a high content of hemicelluloses and its cellulose content is 45.8% (Dry Weight basis) [10]. He also revealed that Vettiver containing short fiber and pulp has to be used in admixture with 30-40% of a long-fibered pulp. Though the high fiber content of Vettiver is important for the paper industry it is not a good feature in oil distillation as it creates practical difficulties in processing, oil extraction as well as loses the essential ingredients in oil.

Conclusion

Pot height of 45 cm and Vettiver harvested at 9 months of planting could be used as most appropriate pot height and harvesting interval in order to enhance bio-mass production, oil content and quality of Vettiver. Period of harvesting highly depends on the soil and climatic conditions, agronomic practices adopted and purpose of harvesting.

Therefore, further research has to be carried out to select proper harvesting time in relation to the soil types and climatic condition of the different regions to obtain maximum yield in good quality.

Acknowledgement

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