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Agronomic Characteristics and Essential Oil Yield of Palmarosa (*Cymbopogon martinii* (Roxb.) Wats) as Affected by Population Density and Harvesting Age at Wondo Genet, Southern Ethiopia

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ABSTRACT

A study was conducted to evaluate the effect of harvesting age and population density on agronomic characteristics and essential oil yield of palmarosa (*Cymbopogon martinii* (Roxb.) Wats). Data on number of tiller/bunch, number of leaf/bunch, fresh weight/bunch, fresh herbage yield/ha, dry weight/bunch, dry herbage yield/ha, essential oil (EO) content and EO yield/ha were collected and analyzed. Population density exerted a very highly significant ($P < 0.001$) influence on fresh herbage yield/ha, dry herbage yield/ha and essential oil yield/ha of palmarosa. A very highly significant ($P < 0.001$) influence of harvesting age was observed on number of leaves/bunch, fresh weight/bunch and fresh herbage yield/ha while a highly significant ($P < 0.01$) effect was observed on EO yield/ha. Dry weight/bunch, dry herbage yield/ha and EO content was affected significantly ($P < 0.05$) by harvesting age. Maximum fresh herbage yield/ha (20.86 t), dry herbage yield/ha (6.85 t) and EO yield/ha (100.65 kg) were obtained at 60 × 60 cm spacing for harvests made at every 3 months after plating and the preceding harvests. Higher and statistically similar EO content were obtained for harvests made at every 3, 4 and 5 months after planting regardless of spacing.

Keywords: essential oil content, Ethiopia, herbage yield, palmarosa grass, vegetative characters

INTRODUCTION

Palmarosa (*Cymbopogon martinii* (Roxb.) Wats) is an aromatic perennial grass belonging to the family Poaceae (Husain *et al*. 1988). It is a tropical plant that grows in warm and humid areas. The plant can grow up to a height of 2-3 m. A well drained loamy soil having irrigation facilities and receiving rain fall of about 1500 mm are ideal conditions for its cultivation (Husain *et al*. 1988). The exact origin of the crop is not clearly known; but it is grown wild in India particularly. The plant is cultivated for its aromatic herbal leaves and production of essential oil (EO) (Beemnet *et al*. 2010).

The EO obtained from the grass is reach in geraniol, which is highly valued as a perfume and as a starting material for a large number of synthetic aroma chemicals like geranyl ester which have a permanent rose-like odour (Joy *et al*. 2001). Palmarosa oil has also been shown to be an effective insect repellent to stored grain and beans (Kumar *et al*. 2007), an anthihelmintic against nematodes (Kumaran *et al*. 2003), and an antifungal and mosquito repellent (Duke and Cellier 1993).

There are many factors that influence agronomic characteristics, biomass and EO yield of aromatic plants (Yasin *et al*. 2003; Khazaie *et al*. 2007; Al-Ramamneh 2009). In addition, influence of harvesting time, plant age and crop density on yield of many aromatic plants was reported by Marotii *et al*. (1994). The influence of harvesting age and spacing was also reported by Beemnet *et al*. (2011) for lemon grass (*Cymbopogon citratus* (DC) Stapf) and peppermint (*Mentha piperiata* L.), Solomon and Beemnet (2011) for spearmint (*Mentha spicata* L.) and Japanese mint (*Mentha arvensis* L.) and Zewdinesh (2010) for artemisia (*Artemisia annua* L.) in Ethiopia.

Despite harvesting age and plant population density have an impact on agronomic and chemical characteristics of different aromatic plants; there is limited information about their effect on yield and yield components of palmarosa in Ethiopia. Hence, this experiment was designed to determining the appropriate plant population density and harvesting age that optimize yield of the crop.

MATERIALS AND METHODS

The experiment was conducted during 2009/2010 at Wondo Genet Agricultural Research Center. Wondo Genet is located at 7° 192 N latitude and 38° 382 E longitude with altitude of 1780 m.a.s.l. The site receives mean annual rainfall of 1128 mm with minimum and maximum temperatures of 11.47 and 26.51°C, respectively. The soil textural class of the experimental area was sandy loam with pH of 7.2 (Abayneh *et al.* 2006).

The experiment was conducted by using randomized complete block design in a factorial arrangement with three replications. Three population densities (27,778; 18,518 and 12,346) and five harvesting ages (3, 4, 5, 6 and 7 months after planting) treatments were used for the experiment. Plot size was 3.6 × 3.6 m with area of 12.96 m^2. The distances between plots and blocks were 1 and 1.5 m, respectively. Proper hoeing, weeding and irrigation of the experimental field were carried out uniformly whenever required. Throughout the experimental periods, incidence of disease, insect damage, frost and storm did not occur. The experiment was completed on August, 2010 after 14 months.

To determine the yield and agronomic characteristics of palmarosa under different population density and harvesting ages, data on number of tiller/hill, number of leaves/hill, fresh herbage weight/hill, dry herbage weight/hill, fresh herbage yield/hectare, dry herbage yield/ha EO content and EO yield/ha were collected. Throughout the experimental periods, each parameter was collected four times for harvestings made at three months after planting (H1), three times for harvestings made at four months after planting (H2) and two times for harvestings made at five months after planting (H3), six months after planting (H4) and seven

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Short Communication

Table 1 Mean squares from analysis of variance for eight traits of palmarosa under varying harvesting age and plant population density.

Source of variation	Df	THI	LHI	FWHI	FBYH	DWHI	DBYH	EOC	EOY
Replication (RP)	2	549.03	541.34	0.01	3.54	0.005	3.31	0.02	468.19
			86413.59**						
Harvesting age (HG)	4	406.38ns	*	0.33***	140.4***	0.02*	9.12*	0.08*	2408.65**
Population density (PD)	2	258.74ns	7093.65ns	0.02ns	489.51***	0.002ns	58.29***	0.03ns	11949.01***
HG × PD	8	597.35ns	8274.70ns	0.03ns	23.39ns	0.006ns	4.575	0.01ns	528.45ns
Error	28	620.29	5527.12	0.03	11.94	0.005	2.79	0.03	540.62
CV%		23.72	19.84	21.33	22.85	29.30	34.38	10.56	32.19

*** = Significant at $P < 0.001$ and ** = Significant at $P < 0.01$ ** = Significant at $P < 0.05$ and ns = Non significant at $P < 0.05$; THI = number of tillers/hill; LHI = number of leaves/hill; FWHI = fresh herbage yield/hill; DWHI = dry herbage yield/hill; FBYH = fresh herbage yield/ha; DBYH = dry herbage yield/ha; EOC = essential oil content ; EOY = essential oil yield

Table 2 Mean comparison for different traits of palmarosa under varying harvesting age and population density.

Treatments	THI	LHI	FWHI	FBYH	DWHI	DBYH	EOC	EOY
Harvesting age in months								
3	100.13	210.57 c	1.07 a	21.20 a	0.31 a	6.06 a	1.63 a	94.77 a
4	102.27	415.70 ab	0.78 b	15.30 b	0.25 a	4.93 ab	1.54 ab	75.64 ab
5	112.89	402.48 ab	0.79 b	15.05 b	0.24 ab	4.50 ab	1.62 a	69.03 bc
6	111.37	469.64 a	0.70 bc	13.80 b	0.26 a	5.41 a	1.44 b	72.70 ab
7	98.17	374.69 b	0.54 c	10.26 c	0.18 b	3.39 b	1.43 b	48.99 c
$LSD_{0.05}$	ns	71.789	0.16	3.3371	0.07	1.6132	0.1562	22.452
Plant population density (plants/ha)								
27,778	100.41	350.01	0.75	20.86 a	0.25	6.85 a	1.48	100.65 a
18,518	108.54	391.26	0.81	15.08 b	0.26	4.81 b	1.57	71.81 b
12,346	105.95	382.58	0.76	9.43 c	0.24	2.91 c	1.55	44.21 c
$LSD_{0.05}$	ns	ns	ns	2.5849	ns	1.2496	ns	17.391
CV %	23.72	19.84	21.33	22.85	29.30	34.38	10.56	32.19

Means followed by the same letter are statistically non significant at $P < 0.05$ according to least significant difference (LSD) test; THI = number of tillers/hill; LHI = number of leaves/hill; FWHI = fresh herbage yield/hill; DWHI = dry herbage yield/hill; FBYH = fresh herbage yield/ha; DBYH = dry herbage yield/ha; EOC = essential oil content ; EOY = essential oil yield

months after planting (H5). The average value over the 14 months were taken for number of tiller/hill, number of leaves/hill and EO content. For the rest parameters total yield over the 14 months was taken.

Statistical analysis of experimental data was performed by analysis of variance (ANOVA) using SAS PROC GLM (2002) at $P < 0.05$. Differences between means were assessed using the least significance difference (LSD) test at $P < 0.05$.

RESULTS AND DISCUSSION

Variation in agronomic and chemical characters of palmarosa

Analysis of variance showed the existence of a very highly significant ($P < 0.001$) variation in fresh herbage yield/ha, dry herbage yield/ha and EO yield/ ha of palmarosa due to different population density used. But population density did not exerted significant ($P > 0.05$) influence on number of leaves/hill, number of tiller/hill, fresh herbage yield/hill, dry herbage yield/ hill and EO content (**Table 1**). A very highly significant ($P < 0.001$) influence of harvesting age was observed on number of leaves/hill, fresh herbage yield/ hill and fresh herbage yield/ha; while a highly significant ($P < 0.01$) effect was observed on EO yield/ha. Dry herbage yield/hill, dry herbage yield/ha and EO content was affected significantly ($P < 0.05$) by harvesting age, while harvesting age did not affected number of tiller/hill significantly ($P > 0.05$). Interaction effect of harvesting age and population density was non-significant ($P > 0.05$) on all of the measured parameters.

Performance of agronomic and chemical characters of palmarosa as affected by plant population density

Fresh herbage yield, dry herbage yield and EO yield/ha of palmarosa were increased with increasing plant density and reached at the maximum value with the highest plant density (**Table 2**). The values ranged from 9.43 to 20.85 t/ha, 2.91 to 6.85 t/ha and 44.21 to 100.65 kg/ha for fresh herbage yield, dry herbage yield and EO yield, respectively. Increasing plant density from 12,346 plants/ha to 27,778 plants/ha, increased fresh herbage yield, dry herbage yield and EO yield by 121.1, 135.4 and 127.7%, respectively. In agreement with this finding, Diemer and Griffee (2005) and Charles *et al*. (1990) reported higher dry leaf yield/ha at higher planting density in *A. annua*. Similar findings were also reported by Yasin *et al*. (2003) and Saeed *et al*. (1996) for Mott Elephantgrass (*Pennisetum purpureum* Schum), and Solomon and Beemnet (2011) for Japanese mint. An increase in fresh and dry yield under narrow spacing was also reported by Aflatuni (2005) for pepper mint. Higher biological yield with increasing plant population density was also reported by Nekonam and Razmjoo (2007) and Najafi and Moghadam (2002) for *Plantago ovata*. In addition, Badi *et al*. (2003) and Al-Ramamneh (2009) reported maximum dry leaf yield/ha at higher density than lower density for *Thymus vulgaris*. In accordance with the present study, an increase in EO yield with decreasing plant spacing was also reported by Linares *et al*. (2005) in lemon grass (*Cymbopogon citratus*), Beemnet *et al*. (2011) in pepper mint and Solomon and Beemnet (2011) in Japanese mint. Similar results was also reported by Simon *et al*. (1990) and Zewdinesh (2010) in *A. annua*, Khorshidi *et al*. (2009) in *Foeniculum vulgare* and Badi *et al*. (2003) in *Thymus vulgaris*. The higher biomass and EO yields/ha at lower spacing (higher density) is due to the occurrence of more plants per unit area.

Performance of agronomic and chemical characters of palmarosa

During the first harvest, minimum amount of leaf/hill (210.57) was recorded. With increase in harvesting age, number of leaves/hill was increased and reached a maximum (469.64) at 6 months after planting (MAP). After 6 MAP it started to decline (**Table 2**). Maximum fresh herbage weight/hill (1.1 kg) and fresh herbage yield/ha (21.2 t) was obtained at first harvest, then declined with increasing age and reached at a minimum values of 0.54 kg and 10.26 t, respectively at 7 MAP (**Table 2**). The decrease in fresh herbage weight/hill and fresh herbage yield/ha with increasing age were 49.5 and 51.6%, respectively. For dry herbage

weight/hill and dry herbage yield/ha, highest and comparable values were recorded for harvests made from 3 to 6 MAP; the values were decreased for plants harvested at 7 MAP (**Table 2**). In accordance with this finding Zewdinesh (2010) reported a decreasing trend of dry leaf yield with increasing age in *Artemisia annua*.

EO content and yield varied from 1.43-1.63% and 48.99-94.77 kg/ha, respectively. The highest values were obtained for harvests made at every three months, while the lower values were recorded when harvesting was made at every 7 months for both EO content and yield. In agreement to this finding, higher EO content and yield at bud formation than flowering was reported by Zheljazkov and Creven (2009) in peppermint. Contrary to this finding, an increase in EO content with increasing harvesting age was reported by Verma *et al*. (2010) for menthol mint and peppermint, Beemnet *et al*. (2011) for peppermint. An increase in EO yield of Japanese mint with increasing harvesting age was also reported by Solomon and Beemnet (2011). In this study, the higher EO yield was obtained for harvests made at earlier age. This is due to the reason that harvests made at 3 months interval is repeated four times throughout the year, but with prolonging harvesting ages, harvest frequency decreased and the obtained yield was also decreased.

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REFERENCES

Abayneh E, Demeke T, Ashenafi A (2006) *Soils of Wondo Genet Agricultural Research Center*, National soil Research Center, Addis Ababa, Ethiopia, 67 pp

Aflatuni A (2005) The yield and essential oil content of mint (*Mentha* spp.) in Northern Ostrobothnia. PhD thesis, Faculty of Science, University of Oulu, 52 pp

Al-Ramamneh EA (2009) Plant growth strategies of *Thymus vulgaris* L. in response to population density. *Industrial Crops and Products* **30**, 389-394

Badi HN, Yazdani D, Ali SM, Nazari F (2003) Effect of spacing and harvesting time on herbage yield and quality/quantity of oil in thyme (*Thymus vulgaris* L.). *Industrial Crops and Products* **19**, 231-236

Beemnet MK, Omarsherif M, Tsion T, Solomon AM (2010) *Production, Processing and Utilization of Aromatic Plants*, Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia, 31 pp

Beemnet MK, Solomon AM, Zinash T, Haylesilase G, Beniyam Y, Gizachew A, Bekri M, Wossen KM, Teixeira da Silva JA (2011) Performance of lemongrass (*Cymbopogon citratus* L. (DC) Stapf) for agronomic and chemical traits in different agro ecologies of Ethiopia. *Medicinal and Aromatic Plant Science and Biotechnology* **5 (2)**, 133-138

Beemnet MK, Teixeira da Silva JA, Solomon AM (2011) Agronomic characters, leaf and essential oil yield of peppermint (*Mentha piperiata* L.) as influenced by harvesting age and row spacing. *Medicinal and Aromatic Plant Science and Biotechnology* **5 (1)**, 49-53

Charles DJ, Simon JE, Wood KV, Heinstein P (1990) Germplasm variation in artemisinin content of *Artemisia annua* L. using an alternative method of artemisinin analysis from crude extracts. *Journal of Natural Products* **53**, 157-160

Diemer P, Griffee P (2005) *Artemisia annua: The Plant, Production and Processing and Medicinal Applications*, FAO, Rome, Italy, 392 pp

Duke JA, Cellierand J (1993) *CRC Handbook of Alternative Cash Crops*, Boca Raton, CRC Press, 214 pp

Joy PP, Thomas J, Mathew S, Jose G, Joseph J (2001) Aromatic plants. In: Bose TK, Kabir J, Das P, Joy PP (Eds) *Tropical Horticulture* (Vol II), Naya Prokash, Calcutta, pp 633-733

Khazaie HR, Nadjafi F, Bannayan M (2007) Effect of irrigation frequency and planting density on herbage biomass and oil production of thyme (*Thymus vulgaris*) and hyssop (*Hyssopus officinalis*). *Industrial Crops and Products* **27**, 315-321

Khorshidi J, Tabatabaei M F, Omidbaigi R, Sefidkon F (2009) Effect of densities of planting on yield and essential oil components of fennel (*Foeniculum vulgare* Mill Var. Soroksary). *Journal of Agricultural Science* **1 (1)**, 152-157

Kumar R, Srivastava M, Dubey NK (2007) Evaluation of *Cymbopogon martinii* oil extract for control of postharvest insect deterioration in cereals and legumes. *Journal of Food Protection* **70 (1)**, 172-178

Kumaran AM, D'Souza P, Agarwal A, Bokkolla RM, Balasubramaniam M (2003) Geraniol, the putative anthelmintic principle of *Cymbopogon martinii*. *Phytotherapy Research* **17 (8)**, 957

Linares S, González N, Gómez E, Usubillaga A, Darghan E (2005) Effect of fertilization, plant density and time of cutting on yield and quality of the essential oil of *Cymbopogon citratus* Stapf. *Revista de la Facultad de Agronomia (Universidad del Zulia)* **22**, 247-260

Marotti M, Piccaglia R, Giovanelli E, Deans SG, Eaglesham E (1994) Effects of planting time and mineral fertilization on peppermint (*Mentha piperita* L.) essential oil composition and its biological activity. *Flavour and Fragrance Journal* **9**, 125-129

Najafi F, Moghadam PR (2002) Effect of irrigation regimes and plant density on yield and agronomic characteristics of blond psyllium (*Plantago ovata*). *Journal of Agricultural Science and Technology* **16**, 59-65

Nokonam MS, Razamjoo KH (2007) Effect of plant density on yield, yield components and effective medicinal ingredients of blond psyllium (*Plantago ovata* F.). *Journal of Agriculture and Biology* **9 (4)**, 607-609

Saeed M, Siddiqui NA, Maqsood M, Mahmood T (1996) Effect of nitrogen and plant spacing on growth, green fodder yield and quality of Mott elephantgrass (*Pennisetum purpureum* Schum). *Journal of Science* **39**, 54-59

SAS (Statistical Analysis System) (2002) SAS/STAT. Guide Version 9. SAS, Institute Inc. Raleigh, North Carolina, USA

Simon JE, Charles D, Cebert E, Grant L, Janick J, Whipkey A (1990) *Artemisia annua* L: A promising aromatic and medicinal. In: Janick J, Simon JE (Eds) *Advances in New Crops*, Timber Press, Portland, Oregon, USA, pp 522-526

Solomon AM, Beemnet MK (2011) Effect of inter row spacing and harvesting time on growth and essential oil yield of spearmint (*Mentha spicata* L.). *International Journal of Sustainable Agriculture* **3 (2)**, 39-43

Solomon AM, Beemnet MK (2011) Row spacing and harvesting age affect agronomic characteristics and essential oil yield of Japanese mint (*Mentha arvensis* L.). *Medicinal and Aromatic Plant Science and Biotechnology* **5 (1)**, 74-76

Verma RS, Rahman L, Verma RK, Chauhan A, Yadav AK, Singh A (2010) Essential oil composition of menthol mint (*Mentha arvensis*) and peppermint (*Mentha piperiata*) cultivars at different stages of plant growth from Kumanon region of West Himalaya. *Open Access Journal of Medicinal and Aromatic Plants* **1**, 13-18

Yasin M, Malik MA, Nazir MS (2003) Plant spacing cum nitrogen management effect on forage yield of mott elephantgrass. *Journal of Agronomy* **2 (1)**, 13-19

Zewdineash DZ (2010) *Cultivation of Artemisia (Artemisia annua L.) in Ethiopia: Cultural Practice and Chemistry*, VDM Publishing House Ltd., Germany, 89 pp

Zheljazkov VD, Cerven C (2009) Effect of nitrogen, location, and harvesting stage on peppermint productivity, oil content, and oil composition. *Horticultural Science* **44 (5)**, 1267-1270