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Influence of harvesting age on yield and yield related traits of lemongrass (*Cymbopogon Citratus L.*) varieties at Wondo genet, southern Ethiopia

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The experiment was conducted at Wondo genet agricultural research center, southern Ethiopia from 2014 to 2016 cropping season to determine the optimum harvesting age of lemongrass varieties for maximize essential oil yield. The experimental design was RCBD in factorial arrangement with three replications. The treatments were two lemongrass varieties (Lomisar-UA and Lomisar-Java) and five harvesting age (45, 60, 75, 90 and 105) days after planting. The study showed that variety had a very highly significant (p≤0.001) influence on numbers of tillers/plant, longest leaf length, fresh herbage yield kg/plot, fresh herbage yield kg/ha, dry herbage yield kg/ha and essential oil yield kg/ha and significant (p≤0.05) influence on essential oil content. Harvesting age had a very highly significant (p≤0.001) influence on fresh herbage yield kg/plot, fresh herbage yield kg/ha, dry herbage yield kg/ha and essential oil yield; highly significant (p≤0.01) influence on longest leaf length, numbers of leaves/plant and significant (p≤0.05) influence on number of tillers/plant. Fresh biomass g/plant, fresh herbage yield kg/plot, fresh herbage yield kg/ha, dry herbage yield kg/plat, dry herbage yield kg/ha and essential oil yield kg/ha were a very highly significantly (p≤0.001) influenced by the interactions of variety and harvesting age. The minimum essential oil yield for both lemongrass varieties were recorded from harvesting age of 45 days after planting. Whereas, the maximum essential oil yield (59.03 kg/ha) and (101.13 kg/ha) ware recorded from 105 days after planting for Lomisar-UA and Lomisar-Java varieties respectively.

Key words: Essential oil, Lemongrass, Harvesting age

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INTRODUCTION

Lemongrass (Cymbopogon Citratus L) is an aromatic plant belonging to the Gramineae family (Akhila, 2010). It is a tropical perennial plant which yields aromatic oil. The name lemongrass is derived from the typical lemon-like odour of the essential oil present in the shoot. The herb originated in Asia and Australia. Lemongrass was one of

the herbs to travel along the spice route from Asia to Europe. Lemongrass oil of commerce is popularly known as Cochin oil in the world trade, since 90% of it is shipped from Cochin port. The state of Kerala in India had the monopoly in the production and export of lemongrass oil (Joy *et al*., 2006).

Lemongrass flourishes in sunny, warm, humid conditions of the tropics. It produce highest oil yield per ton of herbage where the rainfall averages 2500-3000mm annually. *C. Citratus* is more drought tolerant (Weiss, 1997). In areas where rainfall is poor, it can be grown with supplemental irrigation. Day temperature of 25-30°C is considered optimum for maximum oil production, with no extremely low night temperature. Lemongrass flourishes in a wide variety of soil ranging from rich loam to poor laterite. In sandy loam and red soils, it requires good manuring. Calcareous and water-logged soils are unsuitable for its cultivation (Farooqi and Sreeramu, 2001).

Lemongrass is one such plant whose essential oil is widely used as a flavoring due to its lemon scent (Maswal *et al*., 2014). The most abundant compound in lemongrass essential oil is citral, which is a natural mixture of geranial (*trans*-citral or citral A) and neral (*cis*-citral or citral B) and its percentage determines essential oil quality. Freshly cut and partially dried leaves are used medicinally and are the source of the essential oil. *Cymbopogon Citratus* possesses various pharmacological activities such as anti-amoebic, anti-bacterial, anti-diarrheal, anti filarial, anti-fungal and anti-inflammatory properties (Karkala *et al*., 2013). The essential oil is also used in perfumery and cosmetic. In East India and Sri Lanka, where it is called "fever tea," lemon grass leaves are combined with other herbs to treat fevers, irregular menstruation and stomachaches. Lemon grass is one of the most popular herbs in Brazil and the Caribbean for nervous and digestive problems. The Chinese use lemon grass in a similar fashion, to treat headaches, stomachaches, colds, and rheumatic pains. The essential oil is used straight in India to treat ringworm or in a paste with buttermilk to rub on ringworm and bruises. Many studies show it does destroy many types of biomaterial and fungi and is a deodorant. *Traditional Uses:* Take as a tea for fevers, coughs, colds, and as a pleasant tonic or beverage. Promotes perspiration and excretion of phlegm, and eases stomach cramps.

Lemongrass leaves accumulates essential oils in specific oil cells that are present in parenchyma tissues (Lewinsohn et al. 1998; Luthra *et al.* 2007). The essential oil isolated from aerial parts (leaves) of lemongrass is yellow to reddish-brown in color and the odor is powerful lemon like.

Essential oil and citral contents were influenced by factors such as temperature, light intensity, soil moisture, fertilizer, and maturity stage (Miyazaki, 1965). During maturity, the plant developed from the vegetative to the reproductive stage (Kays, 1991). Research reports showed that overall essential oil production is associated with the early growth stage in plants such as Cymbopogon flexuosus (Singh *et al.,* 1989), Cymbopogon martini (Sangwan *et al*., 1982) and Mentha (Caskill and Croteau, 1995).

It is clearly indicated that in aromatic crops, the chemical composition of the essential oil is related to the age of the leaves, thus emphasizing the importance of the growth stage at which harvesting takes place (Motsa, 2006). Harvesting stage of plant has an influence on quantity and quality of essential oil in most essential oil bearing plants (Ramezani *et al*., 2009). Essential oil yield and composition vary with developmental stage of the whole plant, plant organs and cells (Sangwan *et al*., 2001; Gora *et al*., 2002). According to Kothari *et al.* (2004) biomass yield was greater in the first harvest and gradually decline in subsequent harvest of *Ocimum tenuiflorem* but the methods of harvesting have no significant effect on biomass yield. Contrary to the decrease in biomass yield the essential oil content is lower in the first harvest increased gradually in the subsequent harvests to reach maximum in the fourth harvest. The oil content and yield of aromatic plants are often altered during harvesting and post harvesting processes (Motsa, 2006).

Despite, harvesting age influence agronomic and chemical characteristics of aromatic plants, there is gaps of information on the effects of harvesting age on agronomic and chemical traits of those lemongrass varieties, in Ethiopia. Thus, the experiment was designed to determine the optimum harvesting age, for maximize essential oil yield of lemongrass varieties.

MATERIALS AND METHODS

Field experiment was conducted at southern nations and nationality people's regional state (SNNPRS) of Ethiopia, in Wondo genet Agricultural research center. Two varieties of lemon grass (V1= Lomisar-UA and V2= Lomisar-Java) and five harvesting ages (HA1= 45 days after planting (DAP); HA2=60 DAP; HA3=75 DAP; HA4=90 DAP; and HA5= 105 DAP) were arranged in a Factorial Randomized Complete Block Design (RCBD) with three replications. To have sufficient biomass for essential oil physico-chemical analysis, each plots had 3.6 m length and width. During planting, a spacing of 60 cm was maintained between plants and rows. A respective spacing of 2 m and 1m was maintained between replication and plots.

Seedlings (slips) of lemongrass taken from Wondo Genet Agricultural Research Center were transplanted to the experimental plots on the commencement of main rainy season. Slips were prepared by cutting tops of

clumps 20-25 cm above the ground. The lower sheath was removed to expose young roots and the old roots were clipped off keeping the slip 25-30 cm long. Three slips were planted into each hole, about 5-8 cm deep.

During planting and after subsequent harvesting, 20 kg N/ha was applied in the form of urea. During experimentation, all field horticultural practices were performed as required. Harvesting was done by cutting the plant 10 cm above the ground level with the help of sickles in the morning as soon as the night dew has evaporated from the plants.

For each harvesting ages, data on number of tillers/hill, number of leaves/tiller, longest leaf length, fresh herbage biomass (g)/hill, fresh herbage yield (kg/plot), dry herbage yield (kg/plot), fresh herbage yield(kg/ha), essential oil content(%) and essential oil yield (kg/ha) were recorded critically. EO content was determined on fresh weight basis from 300 g of herbage biomass, which harvested from the middle rows of a plot. The laboratory analysis was performed at Wondo Genet Agricultural Research Center. EO was determined by hydro-distillation as illustrated by Guenther (1972).

To statically analyze the differences in yield and quality characteristics caused by the different harvesting ages, five samples were taken from the central rows of each plot. 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 $P < 0.05$.

RESULT AND DISCUSSION

Variation of agronomic and chemical traits of lemongrass as affected by harvesting age and varieties

Harvesting age exerted highly significant (p≤0.001) influence on fresh biomass g/plot, fresh herbage yield kg/ha, dry herbage yield kg/plot, dry herbage yield kg/ha and essential oil yield kg/ha. It had a significant (p≤0.01) influence on number of leaves/tiller and longest leaf length (Table 1). Harvesting age of lemongrass showed significant (p≤0.05) influence on number of tillers/plant. The interactions of harvesting age and varieties were exerted a highly significantly influence (p≤0.001) on all parameters, except number of tillers/plant, number of leaves/tiller and longest leaf length.

Analysis of variance showed that, varieties had very highly significant (p≤0.001) influence on number of tillers/plant, longest leaf length, fresh biomass/plant, fresh herbage yield kg/plot, fresh herbage yield kg/ha, dry herbage yield kg/plot, Dry herbage yield kg/ha and essential oil yield kg/ha. Varieties also exerted significant (p≤0.05) influence on essential oil content. High value was recorded on java – lomisar for longest leaf length, fresh biomass, fresh herbage yield kg/plot, fresh herbage yield kg/ha, dry biomass kg/plot, dry biomass kg/ha and essential oil yield (Table 2). The maximum values of number of leaves/tiller and essential oil content were recorded under UA – lomisar variety.

Fresh herbage yield g/hill

Varieties, harvesting ages and their interactions had a very highly significant (p≤ 0.001) influence on fresh biomass/hill (Table 1). The average values of fresh biomass/hill were recorded from (325.90g- 541.54g) and (290.67g – 996.50g) for Lomisar-UA and Lomisar-Java respectively. The maximum value of fresh biomass g/hill 541.54 g and 996.50g were obtained from Lomisar-UA and Lomisar-Java respectively at harvesting age of 105 days planting. Whereas, the minimum value was recorded at harvesting age of 45 days after planting for both lemongrass varieties. This was contradict with Kothari *et al.* (2004) who reported that, biomass yield was greater in the first harvest and gradually decline in subsequent harvest of *Ocimum tenuiflorem.*

Fresh herbage yield kg/ha

Fresh herbage yield was a very significantly (p≤0.001) influenced by harvesting age and varieties (table 1). The recorded value of fresh herbage yield/ha was varied from (9055-15043 kg/ha) and (8074-27616kg/ha) for Lomisar-Java and Lomisar-UA respectively (table 3). When harvesting age duration prolonged from 45 to 105 days after planting, the recorded values of fresh herbage yield was increased by 66.13% and 242% for Lomisar-UA and Lomisar-Java respectively (table 3). (Mallavarapu *et al*., 1999) reported similar trained on davana (*Artimisia pallens* W.), in which essential oil content was higher at the full emergence of flower heads than at anthesis and initiation of seed set stages.

Dry herbage yield kg/ha

Dry herbage yield was a very highly significant (p≤0.001) influenced by variety, and harvesting age (table 1). The obtained values of dry herbage yield was ranged from (2567.7-3864.4 kg/ha) to (2521.6-8210.3 kg/ha) for Lomisar-UA and Lomisar-Java, respectively (table 4). The highest value of dry herbage yield was recorded at harvesting age of 105 days after planting; whereas, the minimum value was obtained from harvesting age of 45 days after planting for both varieties. When the harvesting age duration was increased from 45 to 105 days after planting, the value of dry herbage yield

Table 1. Mean square of agronomic and chemical traits of lemongrass as affected by harvesting age and varieties

Source of variation	Df	NTPP	NLPT	LLL	FBPP	FHYPP	FHYPH	DBPP	DBPH	EOC	EOY
Rep	2	330.24*	0.053^{ns}	18.39^{ns}	20536.87^{ns}	26.85^{ns}	15752520.6^{ns}	1.62^{ns}	962812.61^{ns}	0.00003^{ns}	121.27^{ns}
Var	1	3625.38***	0.033^{ns}	26816.23***	237208.1***	308.47***	182703984.3***	45.23***	26926829.7***	0.004*	1227.89***
Hg	4	172.97*	0.38**	129.9**	186408.4***	241.74***	143244421.8***	20.62***	12279440.53***	0.002^{ns}	1995.39***
Var*Hg	4	42.65^{ns}	0.13^{ns}	45.05^{ns}	52403.47***	67.84***	40018353.5***	7.92***	4716476.44***	0.0005^{ns}	498.45***
Error		57.44	0.077	22.80	6501.87	8.43	4990096	0.89	529616.4	0.0009	67.23
Cv		12.56	6.02	5.35	15.71	15.71	15.67	17.72	17.72	8.08	15.53

*** = Significant at $P < 0.001$; ** = Significant at $P < 0.01$; * = Significant at $P < 0.05$; ns = Non significant at $P < 0.05$, NTPP = Number of tiller/hill, NLPT=number of leaves/tiller, LLL=longest leaf length, FBPH = fresh biomass/hill, FHYPP=fresh herbage yield/plot, FHYPH= fresh herbage yield/ha, DHYPH=dry herbage yield/ha, EOC=essential oil content and EOY**=** essential oil yield.

Table 2. The performance of agronomic and chemical traits as affected by harvesting age and varieties

	NTPP	NLPT	LLL	FBPP	FHYPP	FHYPH	DBPP	DBPH	EOC	EOY
Varieties										
V1	71.33^{a}	4.65	59.38^{a}	424.77^{a}	15.28^{a}	11791.9^{a}	4.10^{a}	3160^{a}	0.39^{a}	46.41^{a}
V2	49.35^{b}	4.58	119.17^{b}	602.65^{b}	21.70^{b}	16727.5^{b}	6.55^{b}	5054.8^{b}	0.36^{b}	59.21^{b}
LSD@ 0.05	5.81	ns	3.66	61.86	2.23	1713.7	0.72	558.29	0.02	6.29
Harvesting age										
HA1	51.47^{b}	4.47^{bc}	83.38^{c}	308.28^{d}	11.10^{d}	8563^{d}	3.30^{d}	2544.6^{d}	0.37^{b}	32.64^{d}
HA2	63.27^{ba}	4.25^{c}	88.11^{bc}	438.12^{c}	15.77^{c}	12170^{c}	4.32^{cd}	3330.7^{cd}	0.35^{b}	43.08^{c}
HA3	59.02^{ab}	4.73^{ab}	87.83^{bc}	452.95^{c}	16.28^{c}	12563^{c}	4.53^{c}	3496.2^{c}	0.38^{ab}	47.74^{c}
HA4	64.05^{a}	4.86^{a}	91.11^{ab}	600.20^{b}	21.61^{b}	16672^{b}	6.65^{b}	5128^{b}	0.40^{a}	60.50^{b}
HA5	63.89^{a}	4.76^{ab}	95.94^{a}	769.02^{a}	27.69^{a}	21330^{a}	7.82^{a}	6037.3^{a}	0.38^{ab}	80.08^{a}
LSD@0.05	9.19	0.34	5.80	97.81	3.52	2709.6	1.14	882.73	0.04	9.95

Means followed by the same letter with in a column are statistically non-significant at p.0.05 probability level; V1= Lomisar-UA; V2= Lomisar-Java CV=Coefficient of Variance;HA1=45 days after planting; HA2=60 days after planting; HA3=75 days after planting; HA4=90 days after planting; HA5= 105 days after planting; LSD= Least Significant Difference

recorded was increased by 50.5% and 225.5% for Lomisar-UA and Lomisar-Java, respectively (table 4). This might be due to dry herbage yield positively correlated with fresh biomass.

Essential oil yield kg/ha

The analysis of variance table showed that variety and harvesting age had a very highly significant (p≤0.001) influence on essential oil yield/ha (table 1). The highest essential oil yield of 59.03 kg/ha and 101.13kg/ha were maintained at harvesting age of 105 days after planting for Lomisar-UA and Lomisar-Java, respectively (table 4). Whereas, the minimum value of 35.9 kg/ha and 30.09kg/ha

Table 3. Fresh biomass g/hill and Fresh herbage yield kg/ha as harvesting age and varieties

	Fresh herbage yield g/hill		Fresh herbage yield kg/ha	
	V1 (Upper awash)	V2 (Java lomisar)	V1 (Upper awash)	V2 (Java lomisar)
	Harvesting age			
HA1	325.90^{e}	290.67^{e}	9055^{e}	8074^{e}
HA2	391.43d^{e}	484.80^{cd}	10873de	13467^{cd}
HA3	394.58^{de}	511.31^{cd}	10924de	14203^{cd}
HA4	470.42^{cd}	729.99^{b}	13067^{cd}	20277^{b}
HA5	541.54^{c}	996.50^{a}	15043^{c}	27616^{a}
	LSD@0.05	138.32	3831.9	

Table 4. Dry herbage yield kg/plot, Dry herbage yield kg/ha and Essential Oil yield as affected by harvesting age and varieties interaction.

	Dry herbage yield kg/plot		Dry herbage yield kg/ha		Essential Oil yield kg/ha	
Harvesting age	**V1**	**V2**	**V1**	**V2**	**V1**	**V2**
HA1	3.33^{e}	3.27^{e}	2567.7^{e}	2521.6^{e}	35.9^{ef}	30.09^{f}
HA2	3.84^{cde}	4.80^{cde}	2962^{cde}	3699.4^{cde}	41.39^{def}	44.76^{de}
HA3	3.61^{de}	5.46^{c}	2782.80^{de}	4209.5^{c}	44.55^{de}	50.93^{cd}
HA4	4.70^{cde}	8.60^{b}	3623.30^{cde}	6633.4^{b}	51.88^{cd}	69.12^{b}
HA5	5.01^{cd}	10.64^{a}	3864.4^{cd}	8210.3^{a}	59.03^{bc}	101.13^{a}
	LSD@0.05	1.62	1248.4		14.07	

were recorded at harvesting age of 45 days after planting, for Lomisar-UA and Lomisar-Java respectively (table 4).

The higher essential oil yield kg/ha was obtained at prolonged harvesting age is probably due to the maximum above ground biomass at this stage. When harvesting age duration prolonged from 45 to 105 days after planting, the recorded value of essential oil yield was increased by 64.4% and 236% for Lomisar-UA and Lomisar-Java respectively. This might be due to the maximum biomass was obtained at prolonged harvesting age. These findings are in line with those of Solomon and Beemnet (2011a) in spearmint and Solomon and Beemnet (2011b) in Japanese mint, who reported essential oil yield/ha increased with harvesting age. Contradicted ideas was reported by (Baydar and Erbas, 2005) who found that, in lavender (*Lavandula angustifolia*) essential oil contents were decreased from first harvest to the last harvest.

CONCLUSION

The analysis of variance showed that the interaction of harvesting age and variety were a very highly significant ($p \leq 0.001$) influences on fresh biomass g/plant, fresh herbage yield kg/plot, fresh herbage yield kg/ha, dry herbage yield kg/plat, dry herbage yield kg/ha and essential oil yield kg/ha. The minimum essential oil yield for both lemongrass varieties were recorded from harvesting age of 45 days after planting. Whereas, the maximum essential oil yield (59.03 kg/ha) and (101.13 kg/ha) ware recorded from 105 days after planting for Lomisar-UA and Lomisar-Java respectively. As the harvesting age duration prolonged from 45 to 105 days after planting the essential oil yield was increased. Therefore further research needs to identify the optimum harvesting age above 105 days after planting.

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