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Medicinal & Aromatic Plants

Research Article

Optimizing Essential Oil Yield and Water Use Efficiency of Lemongrass (*Cymbopogon citratus* L.) Under Different Furrow Application Method and Deficit Irrigation Levels

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ABSTRACT

Appropriate agricultural water management and implementation of deficit irrigation methods can reduce water usage in addition to minimizing the adverse effects of irrigation agriculture. The experiment was conducted Wondo Genet, Ethiopia for three consecutive years to optimize the essential oil yield and water use efficiency of Lemongrass. Three levels of deficit irrigation and furrow application method were used. The study revealed that the maximum Lemongrass essential oil yield of 55.12 kg ha^{-1} was obtained from no deficit irrigation with conventional furrow application method while the minimum oil yield 36.03 kg ha^{-1} obtained from 50% ETc (Evapotranspiration of crop) under fixed furrow application method. The optimum lemongrass essential oil yield 100% ETc under alternate furrow application method which is statistically similar to the maximum oil yield. Statistically, the highest water use efficiency was obtained from 50% ETc under alternate furrow application method. Therefore, the optimum Lemongrass essential yield can be produced under alternate furrow application method with 1005 ETc which provides the water use efficiency of 0.041 kg m^{-3}.

Keywords: Optimizing; Lemongrass; Essential oil yield; Water use efficiency

INTRODUCTION

Water is an essential factor in agricultural production all over the world. In regions with low annual rainfall, irrigation becomes a necessity for crop production. Even in areas with sufficient seasonal rainfall, irrigation becomes essential during the dry season as more food needs to be produced for the teeming population [1]. The rainfall distribution in Ethiopia is becoming unreliable and erratic in the pattern. In the semi-arid part of Ethiopia, numerous anthropogenic and natural factors are the major contributors to the accessibility of water resources for economic [2,3].

Since water stress is among the major factors that affect the yield of different crops, it is essential to maximize the yield obtained per amount of irrigation water used in water-limiting areas [4,5]. Appropriate agricultural water management and implementation of deficit irrigation methods can reduce water usage in addition to minimizing the adverse effects of irrigation agriculture [6]. Optimum irrigation scheduling based on water use patterns and crop response to water deficit can potentially improve the water productivity which is the ratio of the crop yield to seasonal water use, while the irrigation water productivity is the ratio of the crop yield for a particular treatment to the applied water for that treatment [7]. The goal of deficit irrigation is to increase crop water use efficiency by reducing the amount of water at irrigation or by reducing the number of irrigation events [8].

Recently, attention has been paid to the possibility of cultivating medicinal and aromatic plants to diversify agricultural production by a new productive trend which would raise farm income and create new job opportunities, especially in virgin lands with low fertility and limited water supply [9]. Lemongrass (*Cymbopogon citratus L.*) is one of the essential oil-bearing perennial grasses belong to Poaceae or Gramineae family which is mainly used for aromatic and medicinal purposes. Among the aromatic purpose it is widely used in different foods and drinks manufacturing additionally, its oil has been used as anti-bacterial and anti-fungal properties to cure various diseases with anti-oxidant activity [10,11]. With this regard the experiment was conducted to optimize Lemongrass essential oil yield and water use efficiency under different deficit levels and furrow application method.

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Received: April 14, 2021, **Accepted:** April 21, 2021, **Published:** April 26, 2021

Citation: Tesfaye H (2021) Optimizing Essential Oil Yield and Water Use Efficiency of Lemongrass (*Cymbopogon citratus* L.) Under Different Furrow Application Method and Deficit Irrigation Levels. Med Aromat Plants (Los Angeles) 10: 382.

MATERIALS AND METHODS

Description of the experimental site

This experiment was carried out at Wondo Genet Agricultural Research Center, Ethiopia, 7°05' N latitude, 38°37' E longitude and mean altitude of 1785 m.a.s.l. for three dries based on an objective to optimize the essential yield and water use efficiency of lemongrass (*Cymbopogon citratus L.).* The soil at the experimental site was sandy clay loam in textures with moisture content at field capacity and permanent wilting point of 30.8 and 19.0%, respectively. The pH of the soil was found to be 6.9. The bulk density was found to be 1.1 g/cm^3 and the total volumetric available water in the root zone was 130 mm/m. The climate of the area is characterized as semi-humid with a total annual rainfall of 1121.8 mm among which 72.3% of the rain falls from April to September which is the main cropping season for the area. The mean maximum temperature varies from 23.3 to 28.4°C; while the mean minimum temperature varies from 9.3 to 12.5°C (Table 1).

Experimental design and procedure

The field experiment was carried out using a randomized complete block design with three replications [12] during 2015/16-2017/18 dry season between November to March. Each experimental unit had 3 m in length and 3 m in width with spacing of 1.50 m between each unit and 3.00 m between blocks. The experiment consists of three-levels of deficit irrigation (100%, 75%, and 50% ETc), and three furrow irrigation water application techniques (alternate, fixed, and conventional furrow) were used in combination. Alternate furrow technique used by watering selective half furrow from the entire plot alternatively during each irrigation event. Fixed furrow techniques are used by watering half of the entire furrows during all irrigation events and conventional furrows irrigating the whole furrows in every irrigation event.

After the experimental land was prepared well for better performance of the lemongrass (*Cymbopogon citratus L.*) bulbous stems were collected from year old mature plant from well-grown clumps. The tops of clumps were cut off 25 cm from the root and the lower brown sheath was removed to expose young roots. Three tiller splits were planted at an interval of 60 cm both between plant (hill) and row of the plant in the ridge of furrow prepared in 60 cm spacing. Regular agricultural management like weeding and hoeing in the study area were followed during the experimental period for all plots uniformly.

Irrigation water was applied based on the treatment variation after it is calculated using CROPWAT 8.0 software using necessary input data. The calculated gross irrigation depth was applied using 2-inch Parshall flume. Soil sample before and after irrigation was taken to monitor the moisture dynamics in the control treatment until the moisture content depleted by 60% from field capacity. The rest treatments obtained irrigation water on the same date as the control treatment and the irrigation depth was given based on the percentage of treatment.

Data collection and analysis

Lemongrass yield, five samples were harvested 30 cm above the ground at the edge of the leaf manually 120 days after planting for the first harvest and 60 days after the first cut for the proceeding harvest. The collected sample was then submitted to Wondo Genet Agricultural Research Center, Natural Product Laboratory for extraction of essential oil using hydro distillation method and determination of moisture content using oven-dry at 105°C for 3 hours. Essential oil yield was calculated based on the results of oil content from the laboratory.

Moreover, based on essential oil yield and amount of irrigation used for each treatment, water use efficiency was calculated using the following formula.

$$WUE=EOY/TW$$

Where: WUE is water use efficiency (kg m^{-3});

EOY: is the essential oil yield (kg ha^{-1});

TW: is the seasonal total water use (m^3 ha^{-1})

The collected data were analyzed using Statistical Analysis System (SAS) version 9.3 procedure of general linear model for the variance analysis. Mean comparisons were carried out to estimate the differences between treatments using Fisher's Least Significant Difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Essential oil yield

The study revealed that essential oil yield has significantly ($p<0.05$) affected by different deficit level and furrow application method on 2015/16 and it was also highly significantly ($p<0.001$) affected during 2017/18. However different levels of deficit and furrow irrigation application methods were no a significant effect on the essential oil yield of lemongrass. The pooled mean analysis indicated that the statistically superior oil was recorded from 100 ETc and conventional furrow application method treated one. Whereas it is statistically similar with 75% ETc conventional and 100% ETc alternate furrow application method (Table 2).

The study shows that during the production year of 2015/16 the maximum essential oil yield of 62.48 kg ha^{-1} was obtained from 75 ETc and conventional furrow application method however, this was statistically similar with 50, 100 ETc conventional furrow, 100,75% ETc with fixed furrow application method and 100% ETc with alternate furrow application method. The maximum essential oil yield of 40.09 kg ha^{-1} was recorded from 100% ETc conventional furrow application method during 2017/18 production. Still, it is statistically similar with 100, 75% ETc with alternate furrow application method and 50 &75% ETc conventional methods (Table 2). This might be water deficit in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration that may cause changes in the yield and composition of essential oil in aromatic plants [13]. The minimum essential oil yield was obtained from 50% ETc with fixed furrow application method which is 44.93 and 20.09 kg ha^{-1} during 2015/16 and 2017/18 production year, respectively. According to the report of Mirsa and Strivastava [14], water stress resulted in a significant reduction of fresh and dry matter, nutrient content, and essential oil yield of Japanese mint plants.

Generally, the essential oil yield decreased as the lemongrass gets older from the first year to the third year of production. As the deficit level increased from 100 to 50% ETc the essential oil become reduced. Moreover, essential oil yield gets reduced as the

Table 1: Long-term climatic data of the study area (1986 – 2015).

Month	T min (°C)	T max (°C)	RH (%)	Wind speed (m/s)	Sunshine hours (%)	RF (mm)
January	9.7	28	51	1.26	75	29.4
February	11.2	28.2	50	1.27	71	55.5
March	12	28.4	55	1.5	66	91
April	12.5	27	62	1.31	60	121.8
May	12.5	26.2	70	1.3	60	135.7
June	12.4	24.8	72	1.54	54	107.5
July	12.8	23.3	53	1.12	38	158.4
August	12.9	23.8	71	1.11	42	152
September	12.2	24.7	73	0.92	46	135.6
October	11.2	26	65	0.91	78	80.4
November	9.3	27.3	54	1.06	77	38.6
December	9.8	26.9	69	1.21	62	15.9

NB: - T_{min}: Minimum temperature, T_{max}: Maximum temperature. RH: Relative Humidity. RF: Rainfall

Table 2: Effect deficit irrigation and furrow application method on essential oil yield of Lemongrass.

Treatment	EOY (kg ha^{-1})			
	2015/16*	2016/17	2017/18**	Mean**
100% ETc AF	58.69^{ab}	53.68	34.84^{abc}	49.08^{abc}
100% ETc CF	60.51^{ab}	64.77	40.09^{a}	55.12^{a}
100% ETc FF	60.71^{ab}	50.47	27.89^{cd}	46.36^{bcd}
75% ETc AF	45.68^{c}	54.06	29.89^{abcd}	43.19^{cde}
75% ETc CF	62.48^{a}	54.11	39.19^{ab}	51.90^{ab}
75% ETc FF	53.40^{abc}	53.43	28.68^{bcd}	45.16^{bcd}
50% ETc AF	50.14^{bc}	45.47	25.13^{cd}	40.25^{de}
50% ETc CF	55.56^{abc}	55.06	30.20^{abcd}	46.96^{bcd}
50% ETc FF	44.93^{c}	43.14	20.09^{d}	36.03^{e}
CV	12.04	13.489	20.5	9.12
LSD	11.39	ns	10.88	7.26

NB: -ETc: Evapotranspiration of Crop; AF: Alternate Furrow; CF: Conventional Furrow; FF: Fixed Furrow; EOY: Essential Oil Yield. Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at ***: Very highly significant at $p<0.001$ level of probability, **: Highly significant at $p<0.01$ level of probability.

furrow application method changed from conventional application to fixed and alternate furrow application method, this is due to both application methods has reduced the water application by 50%. The study shows that with a certain moisture deficit level the essential oil can be optimized this finding in line with, the report of Singh et al. [15] that optimum irrigation level leads to higher essential oil production for lemongrass.

Water use efficiency

The water use efficiency of lemongrass was very highly significantly affected by the deficit irrigation and furrow application method during 2015/16 and 2016/17 years of production. Whereas it was highly significantly affected during the production year of 2017/18. During the 2015/16 and 2016/17 production year the maximum water use efficiency of 0.08 and 0.066 kg m^{-3} was recorded at 50% ETc with alternate furrow application method, respectively however, it is statistically similar with 50% ETc fixed furrow application method. Moreover, during the 2017/18 production year the maximum water use efficiency of 0.052 kg m^{-3} has obtained from 50% ETc with alternate furrow application method still it is statistically similar with 50 and 75% ETc fixed and alternate furrow application methods, respectively. While the minimum water use efficiency of 0.024, 0.024, and 0.021 kg m^{-3} was recorded from 100% ETc with conventional furrow application method during 2015/16, 2016/17, and 2017/18 production year, respectively (Table 3).

The pooled mean result also indicated that the maximum water use efficiency of 0.066 kg m^{-3} was recorded from 50% ETc with alternate furrow application method however it is statistically similar with 50% ETc with fixed furrow application method. Generally, the water use efficiency trends leaner relationship with the deficit irrigation level and furrow application method which is as the deficit level increase the water use efficiency also gets increased and the vice. The water use efficiency can be improved by 56% where 50% ETc and alternate furrow application methods are used rather than using 100% ETc conventional furrow application

Table 3: Effect deficit irrigation and furrow application method on water use efficiency of Lemongrass.

Treatment	WUE (kg m^{-3})			
	2015/16***	2016/17***	2017/18**	Mean***
100% ETc AF	0.047^{b}	0.039^{c}	0.036^{bc}	0.041^{cd}
100% ETc CF	0.024^{d}	0.024^{e}	0.021^{d}	0.023^{e}
100% ETc FF	0.048^{b}	0.037^{cd}	0.029^{bcd}	0.038^{d}
75% ETc AF	0.048^{b}	0.053^{b}	0.041^{ab}	0.047^{bc}
75% ETc CF	0.033^{cd}	0.026^{de}	0.027^{cd}	0.029^{e}
75% ETc FF	0.05^{6b}	0.052^{b}	0.040^{abc}	0.049^{b}
50% ETc AF	0.080^{a}	0.066^{a}	0.052^{a}	0.066^{a}
50% ETc CF	0.044^{bc}	0.040^{c}	0.031^{bcd}	0.039^{d}
50% ETc FF	0.071^{a}	0.063^{ab}	0.042^{ab}	0.059^{a}
CV	15.52	15.22	21.68	11.37
LSD	0.014	0.012	0.013	0.009

NB: -ETc: Evapotranspiration of Crop; AF: Alternate Furrow; CF: Conventional Furrow; FF: Fixed Furrow; WUE: Water Use Efficiency. Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at ***: Very highly significant at $p<0.001$ level of probability, **: Highly significant at $p<0.01$ level of probability.

method (Table 3). This improvement directly associated with the amount of applied water reduction when using alternate furrow application methods and deficit irrigation. The current study is in with the study reported by El-Halim [16] on the corn crop. Different studies reported that the water use efficiency improvement is allied to the reduction in applied water using water stress options [17-19]. According to Fan et al. [20], Water use efficiency increases under deficit irrigation, relative to its value under full irrigation, as shown experimentally. Infield crops, a well-designed DI regime can optimize water productivities over an area when full irrigation is not possible [21].

CONCLUSION

The study indicated that the maximum Lemongrass essential oil yield obtained from 100% ETc with conventional furrow method however it is statistically equivalent with 100% ETc under alternate furrow application method. Lemongrass can be produced with optimal essential oil yield at 100% ETc under alternate furrow application method with significant water reduction. For maximum water use efficiency achieved at 50% ETc under fixed furrow application method. This can be enhancing the water use efficiency by 56% as compared to no deficit irrigation under conventional furrow application method.

ACKNOWLEDGEMENT

The authors are grateful to the Natural Resource Management Research Directorate, Ethiopian Institute of Agricultural Research, for providing funds for the experiment. They are also thankful to Abreham yakob, and Misikir Eshetu for their support and technical assistance during field experimentations and laboratory staff work during essential oil extraction.

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