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Spearmint (*Mentha spicata* L.) Response to Deficit Irrigation

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Abstract: **An experiment was conducted with the objective to identify the level of deficit irrigation which allows achieving optimal yield and investigate the effect of deficit irrigation practice on spearmint (*Mentha Spicata* L.) yield and yield components. The experiment was conducted at Koka research station of Wondo Genet Agricultural Research Center, Ethiopia latitude 8^{O}26', longitude 39^{O}2' and altitude 1602masl for two years (2011/2012 and 2012/2013 dry season). Nine treatments three level of irrigation water amount percentage based on evapo-transpiration of the crop (ETc) (100%ETc, 75%ETc and 50%ETc) and three types of furrow irrigation water application method (alternate furrow, fixed furrow and conventional furrow) were used in randomized completely block design (RCBD) with three replications. The pooled mean of two year data showed different level of deficit irrigation had a significant effect ($p<0.05$) on fresh biomass yield per hectare and fresh leaf yield per hectare. Moreover, there is a significant ($p<0.01$) variation among treatments due to deficit irrigation on dry biomass yield per hectare, dry leaf yield per hectare, essential oil yield per hectare and water use efficiency. However, different deficit irrigation level had no significant influence on wet harvesting index. The highest fresh biomass, dry biomass, fresh leaf, dry leaf and essential oil yield per harvesting cycle of 12093kg/ha, 3746kg/ha, 8133kg/ha, 2441.1kg/ha and 37.0kg/ha respectively was obtained due to 100%ETc with conventional furrow application method. Moreover, the highest water use efficiency of 16.3x10^{-3}kg/m^{3} was achieved due to deficit irrigation to 50%ETc with alternate furrow irrigation water application method. The study showed that the best treatment is deficit irrigation to 50%ETc with conventional furrow application method which had no significant variation with treatments that showed higher yields of spearmint including water use efficiency.**

Keywords: **Alternate furrow, conventional furrow, deficit irrigation, fixed furrow, spearmint.**

I. INTRODUCTION

In contrary to the water need to irrigate agricultural land for enhancing crop production, there is an increasing demand for limited water resource for municipality, industries and for natural resource rehabilitation. Moreover, agriculture is the highest water consuming sector worldwide (Biswas, 1997). Though irrigated agriculture is the main solution to produce crop to feed and achieve the different needs for an ever increasing world population, water is the main limiting factor for restricting crop production in the world (Umar, 2006). In this regards irrigation only based on crop water requirement is not an option especially in areas where water resource is limited. The increasing demand of irrigated agricultural, domestic consumption and industrial use of limited water resource requires wise use and conservation of the resource.

In many part of Ethiopia, agricultural production is limited by water rather than land availability due to high variability of rainfall (Woldeamlak, 2009). Moreover, in areas where water is lifted for the irrigated land from lakes, underground water wells and rivers by using pumps, the increasing cost of fuel exacerbates the problem. Therefore, innovations are needed to increase the efficiency of water use for productivity of agricultural land in a limited water resource and by decreasing fuel cost in areas where water is lifted by pump as well.

Spearmint (*Mentha spicata* L.) is an aromatic plant cultivated mainly for its aromatic oil. The essential oil is used for flavoring of different foods, alcoholic and non alcoholic drinks, gum and dental hygiene products, perfumes, hygiene products, pesticides, and pharmaceutical products as medicinal purpose. Moreover, the herbage yield can be used as tea.

Spearmint leaves has a synergistic action of antioxidant phytochemicals, arotenoids and flavonoids. Consuming spearmint leaves used to combating oxidative stress that causes chronic disease like diabetes (Rajeshwari *et al*., 2012).

Many studies have shown that deficit irrigation practices to some extent can lead to increase water productivity without significantly affecting the yield of the crops under production (FAO, 2002; Fereres and Soriano, 2006). Different studies have shown that deficit irrigation practice can be used for the production of spearmint in areas where water scarcity is high with acceptable biomass and essential oil yield reduction. Spearmint is a suitable crop for sustained deficit irrigation management strategy (Romulus *et al*., 2009).

Therefore there should be a means to maximize the productivity of water without significantly affecting the economic yield of a crop and increasing the irrigated land with the available water resource. So the field experiments were conducted for two off-season of 2011/2012 and 2012/2013 at Koka Central Rift Valley Ethiopia and evaluated the response of spearmint crop to deficit irrigation level to enhance water use efficiency without significantly affecting the economic yield of the crop. The practicality of deficit irrigation for spearmint was assessed based on the yield of spearmint fresh biomass, dry biomass, fresh leaf yield, dry leaf yield, essential oil yield, water use efficiency and wet harvesting index.

II. MATERIALS AND METHODS

Description of the Experimental Area

Field experiments were carried out at Koka Research Station of Wondo Genete Agricultural Research Center Ethiopia 8°26' N latitude, 39°2' E longitude and 1602masl altitude during 2011/12 and 2012/13 dry season to study the response of spearmint (*Mentha spicata L.)* to deficit irrigation. Climate in this area is semiarid with total annual precipitation of 830.9mm and 131.8mm of rainfall expected in the dry season from October to March (Table 1).

TABLE 1. Long-term monthly climatic data of the experimental area

Month	T_{max} (^{O}C)	T_{min} (^{O}C)	RH (kpa)	U (m/s)	N (%)	RF (mm)
January	27.4	11.3	1.34	4.04	75	13.5
February	28.3	12.6	1.39	4.08	76	26.1
March	30.0	14.4	1.50	4.64	74	51.5
April	30.3	15.2	1.64	3.80	71	58.5
May	30.9	15.1	1.63	3.98	68	48.5
June	30.0	15.5	1.70	4.91	65	72.7
July	26.7	15.0	1.74	4.30	54	212.7
August	26.3	15.1	1.75	3.15	53	202.4
September	27.8	14.9	1.79	2.30	57	104.3
October	28.3	12.7	1.48	3.50	73	21.1
November	27.4	11.3	1.30	4.09	83	9.9
December	26.1	11.0	1.26	4.19	76	9.9

Source: FAO. 2005. New-LocClim, Local Climate Estimator.

The soil type of the experimental area was clay in texture and the available water holding capacity per unit meter of the soil profile in the root zone is 170 mm. Some physical characteristics of soil, such as field capacity, wilting point and total available water holding capacity of the experimental site are presented in Table 2.

TABLE 2. Physical characteristics of soil at the experimental site

Soil texture	Bulk density (g/cm^3)	Field capacity (%)	Wilting Point (%)	Available water holding capacity (mm/m)
Clay	1.17	34.5	17.5	170

Treatment and Experimental Design

Randomized complete block design with three replications were used following the procedure of Gomez and Gomez (1984). The plot size used was 3.00m X 3.00 m. Nine treatments of different deficit irrigation level were randomized in plots as follows: 1) 100%ETc in alternate furrow, 2) 75%ETc in alternate furrow, 3) 50%ETc in alternate furrow, 4) 100%ETc in fixed furrow 5) 75%ETc in fixed furrow, 6) 50%ETc in fixed furrow, 7) 100%ETc in conventional furrow (control), 8) 75%ETc in conventional furrow and 9) 50%ETc in conventional furrow irrigation application system.

Experimental Procedure and Management Practice

Stolen of spearmint (*Mentha spicata* L.) was planted on the first weeks of January 2012 for the first year and on the last weeks December 2012 for the second year trial in 50 cm apart furrows with continuous planting. The row length was 3 m and each plot consisted of six ridges and six furrows. The regular tillage and agricultural operations were followed. All other agronomic practices were kept normal and uniform for all the treatments. Crop water requirement (CWR) for the 100%ETc with conventional furrow irrigation application method was calculated using CropWat version 8.0 for windows irrigation software. Based on the calculated CWR Irrigation water was applied according to the treatment percentage and the method of furrow irrigation. Fixed furrow and alternate furrow treatments received half of the water calculated since only half of the furrows in the plot irrigated. The irrigation water applied was measured using two inch Parshall flume. Soil sample before and after irrigation for both harvesting cycle was taken from control treatment plots to check the moisture content before and after irrigation not to go above field capacity and below allowable moisture depletion level.

Data Collection

Representative five samples in 50cm length within the middle raw were harvested 120 days after planting for the first harvest and 60 days after the first harvest for the second harvest for both seasons. After harvesting done data on fresh biomass yield and leaf fresh yield were taken. Data of dry biomass yield and dry leaf yield also collected after the sample is dried under oven at $105^{O}C$ for 2 hour. The essential oil yield also collected after the sample extracted at Wondo Genet Agricultural Research Center, Natural Product Laboratory using hydro distillation method. Based on the obtained yields and amount of irrigation used, water use efficiency and wet harvest index were calculated.

Calculation of water use efficiency and wet harvest index

Water use efficiency (WUE) indicates the seasonal increase in oil yield from a unit increase in consumed water (kg oil per m^3 water used). It is calculated as follow:-

$$WUE = \frac{EOY}{TW}$$

Where: WUE is water use efficiency (kg/m^3)

EOY is the essential oil yield (kg/ha)

TW is the seasonal total water use (m^3/ha)

Wet Harvest Index (WHI) is the ratio of the marketable oil yield to the harvested spearmint fresh biomass (wet mass basis). It is an indication of the oil concentration in the harvested green mint hay. It is calculated as follows:-

$$WHI = \frac{EOY}{FBM}$$

Where: WHI is the wet harvest index (decimal)

EOY is the essential oil yield (kg/ha)

FBM is the fresh biomass yield (kg/ha)

Data Analysis

Data collected were statistically analyzed using statistical analysis system (SAS) software version 9.0 using the general linear programming procedure (GLM). Mean separation using least significant difference (LSD) at 5% probability level was employed to compare the differences among the treatments mean.

III. RESULTS AND DISCUSSION

Fresh biomass

The pooled mean of two year analysis of fresh biomass yield influenced significantly ($p<0.05$) due to deficit irrigation practice. Maximum fresh herbage yield of 12093kg/ha was obtained due to 100%ETc with conventional furrow application method followed by 50%ETc with conventional furrow of 9335kg/ha and the least yield of 5892kg/ha was obtained when irrigation water is deficit to 50%ETc with fixed furrow irrigation water application method per harvesting cycle (Table 3). Application of deficit irrigation to 50%ETc with fixed furrow method reduce yield of fresh biomass by 51.3% from the control whereas, deficit irrigation to 50%ETc with conventional furrow method reduce the fresh biomass yield by 22.8%. This may be due to creeping nature of the crop; localized moisture stress on non irrigated furrows and sides will reduce plant population per area. The study indicated the fresh biomass yield decrease with increase in deficit level. This indicated that the water applied based on crop water requirement has a direct influence on fresh biomass production. This is in agreement with former findings of Romulus *et al*. (2009) on spearmint, Bahreininejad *et al*. (2013) on *Thymus daenensis* and Said-Al Ahl and Hussein (2010) on organo plant and Sharmin *et al*. (2009) on Japanese mint.

Dry biomass

Different deficit level and furrow application method has a significant influence ($p<0.01$) on dry herbage biomass production. The mean dry biomass at different deficit level showed decreasing trend due to decreasing of irrigation water applied. Generally the maximum dry biomass yield of 3746kg/ha per harvesting cycle was obtained due to 100%ETc with conventional furrow application method. Whereas, the least dry biomass yield of 1828kg/ha per harvesting cycle was obtained due to deficit irrigation to 50%ETc level with fixed furrow application method. This shows a decreasing of 51.2% from the control treatment. Next to the control, 75%ETc with conventional furrow application treatment scored higher dry biomass yield of 2611kg/ha per harvesting cycle (Table 3). The trend of dry biomass production fairly decreasing as the amount of water applied decreases. This is due to higher biomass production for well irrigated plots since irrigation was applied based on crop water requirement and moisture stress is reduced.

Fresh leaf yield

Leaf is the part of spearmint plant used for extraction of essential oil. The pooled mean of two year data showed that deficit irrigation had influenced fresh leaf yield production significantly ($p<0.05$). The fresh leaf yield production demonstrated decreasing trend due to increasing deficit level. The highest fresh leaf yield of 8133kg/ha per harvesting season was obtained in control treatment followed by 50%ETc with conventional furrow application method treatment yielding 6520kg/ha per harvesting cycle which is statistically the same with both control and 75%ETc with conventional furrow treatments (Table 3). As the amount of water applied decrease to 50%ETc with conventional furrow application method, fresh leaf yield was reducing only by 19.8% from the control. While the minimum fresh leaf yield of 4214kg/ha per harvesting cycle obtained when irrigation water is deficit to 50%ETc and applied in fixed furrow method which indicates that the yield of fresh leaf yield reduced by 48.2% from the control treatment. This may be due to fixed furrow irrigation method restricts the expansion of the creeping spearmint plant by constantly creating localized water stress with un-irrigated furrows.

TABLE 3. Two year average yield of spearmint due to deficit irrigation per harvesting cycle 2011/12 and 2012/13

Treatments	Fresh biomass yield (kg/ha)*	Fresh leaf yield (kg/ha)**	Dry biomass yield (kg/ha)*	Dry leaf yield (kg/ha)**
AF 100%ETc	8519^{b}	2441^{b}	5862^{bc}	1580.9^{bc}
AF 75%ETc	8429^{bc}	2433^{b}	5951^{b}	1699.3^{b}
AF 50%ETc	7181^{bc}	2080^{bc}	5139^{bc}	1390.1^{bc}
FF 100%ETc	8510^{b}	2043^{bc}	5754^{bc}	1254.2^{c}

FF 75ETc%	8627[b]	2558[b]	6152[b]	1742.5[b]
FF 50%ETc	5892[c]	1828[c]	4214[c]	1206.8[c]
CF 100%ETc	12093[a]	3746[a]	8133[a]	2441.1[a]
CF 75%ETC	9073[b]	2611[b]	6315[b]	1767.5[b]
CF 50%ETc	9335[b]	2396[bc]	6520[ab]	1553.7[bc]
CV (%)	17.3	13.9	16.3	15.4
$LSD_{0.05}$	2586.5	590.7	1692.7	432.08

Means with the same column followed by the same letters are not significantly different. *significant (p<0.05), **significant (p<0.01), ***significant (p<0.001), [ns] not significant (p<0.05).

Dry leaf yield

The pooled mean of two year data showed that different level of deficit irrigation significantly (p<0.01) influenced the dry leaf yield. Maximum dry leaf yield of 2441.1kg/ha per harvesting season was obtained when spearmint irrigated with 100%ETc with conventional furrow application method which fairly decrease with increased level of deficit level, reaching minimum dry leaf yield of 1206.8kg/ha per harvesting season when the crop is irrigated with 50%ETc with fixed furrow application method (Table 3). This leads to a decrease of 50.6% than the maximum yield obtained by the control treatment.

TABLE 4. Two year average yield of spearmint due to deficit irrigation per harvesting cycle 2011/12 and 2012/13

Treatments	Essential oil yield (kg/ha)**	Wet harvest index (decimal X10^3)	Water Use Efficiency (kg/ha X10^3)**
AF 100%ETc	29.4bc	3.62	11.1cde
AF 75%ETc	27.2bcd	3.41	12.8bcd
AF 50%ETc	22.5d	3.33	16.3a
FF 100%ETc	25.4cd	3.23	9.4e
FF 75ETc%	28.9bc	3.56	13.9abc
FF 50%ETc	22.2d	3.88	15.9ab
CF 100%ETc	37.0a	3.16	9.9de
CF 75%ETC	29.8bc	3.40	10.4de
CF 50%ETc	31.5ab	3.55	15.9ab
CV (%)	12.2	9.9	15.0
$LSD_{0.05}$	5.96	ns	3.35

Means with the same column followed by the same letters are not significantly different. *significant (p<0.05), **significant (p<0.01), ***significant (p<0.001), [ns] not significant (p<0.05).

Essential oil yield

Essential oil yield is the most economic yield of spearmint which is a composition of 21different components. The major constituents are carvone, d-limonene and dihydrocarvone (Jasim *et al*., 2007). The pooled mean of two year data showed that deficit irrigation significantly (p<0.01) influenced the essential oil yield produced (Table 4). The yield vary from 37.0kg/ha per harvesting cycle in control treatment to 22.2kg/ha per harvesting cycle in 50%ETc with fixed furrow application method treatment. The result showed that deficit irrigation to 50%ETc with fixed furrow application method and 50%ETc with alternate furrow application method reduce the essential oil production by 40% and 39.2% respectively. However, deficit irrigation in conventional furrow application to 50%ETc reduces the oil yield by only 14.9% which is statistically the same with the oil yield obtained by the control treatment. Generally, essential oil yield shows decreasing trend as the amount of irrigation water reduced. The result indicated that there is positive relation with water content of the soil and the essential oil yield. This is in line with former reports of Bahreininejad *et al.* (2013) on *Thymus daenensis*, Said-Al Ahl and Hussein (2010) on oregano and Sharmin *et al*. (2009) on Japanese mint.

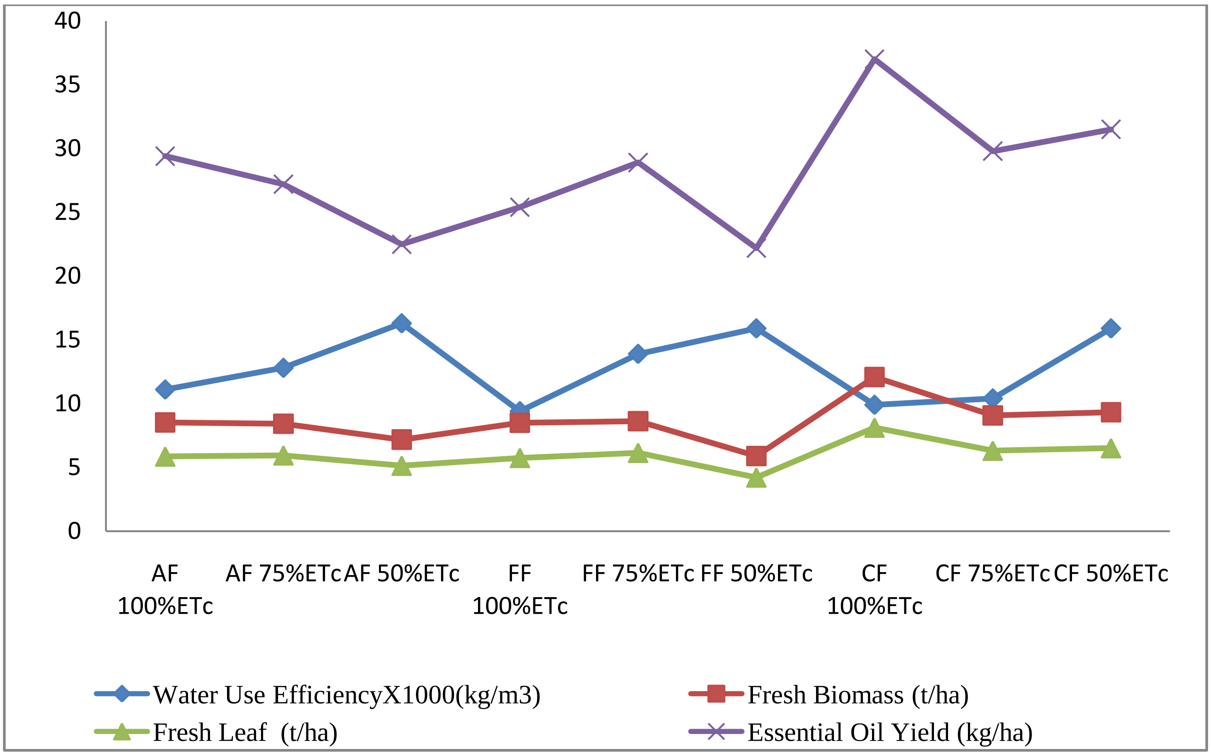

Fig. 1 Fresh biomass, fresh leaf yield, essential oil yield and water use efficiency as influenced by different level of deficit irrigation

Remark: AF (alternate furrow) FF (fixed furrow) CF (conventional furrow)

Wet harvesting index

The pooled mean of two year data showed that the influence of different level of deficit irrigation was not significantly affect the wet harvesting index of spearmint (Table 4). However, higher average value of $3.88x10^{-3}$ due to deficit irrigation to 50%ETc with fixed furrow application method and minimum average wet harvesting index of $3.16x10^{-3}$ in control treatment. Wet harvesting index was not significantly influenced both years in both harvesting cycle.

Water use efficiency

In moisture stressed area, the water use efficiency is among the main parameters to decide the level of irrigation water amount applied as far as agricultural water management is concerned. It is an increase in the economical part of the crop yield due to a unit increase of irrigation water amount applied. Our finding showed fairly an increasing trend as the deficit level increase due to reduction of applied irrigation water amount especially within the same irrigation methods. The pooled mean of two year study showed that different level of deficit irrigation significantly ($p<0.01$) influenced water use efficiency. Better water use efficiency of $16.3x10^{-3}kg/m^3$, $15.9x10^{-3}kg/m^3$ and $15.9x10^{-3}kg/m^3$ was recorded by 50%ETc with alternate furrow, 50%ETc with fixed furrow and 50%ETc with conventional furrow treatments respectively (Table 4). In contrary to this, lower water use efficiency of $9.4x10^{-3}kg/m^3$, $9.9x10^{-3}kg/m^3$, $10.9x10^{-3}kg/m^3$ and $11.1x10^{-3}kg/mm$ was achieved when spearmint was irrigated by 100%ETc with fixed furrow, 100%ETc with conventional furrow, 75%ETc with conventional furrow and 100%ETc with alternate furrow treatments respectively. Water use efficiency was increased by 68.4%, 65.4% and 63.3% from the control treatment due to deficit irrigation to 50%ETc with alternate furrow method, 50%ETc with fixed furrow method and 50%ETc with conventional furrow method. Water use efficiency increased as amount of water applied reduced due to deficit irrigation except in 50%ETc with conventional furrow treatment, which is more efficient than the lower irrigation water receiving treatments of 75%ETc fixed furrow and 75%ETc alternate furrow treatments. The result indicated that deficit irrigation practice to enhance water use efficiency in spearmint production. This is in agreement with former report FAO (2002) on wheat, cotton and other crops, Ismail (2010) on bird pepper (*Capsicum annuum* L.) production, Romulus *et al.*, (2009) on spearmint and R. Huang (2006) on maize production.

IV. CONCLUSION AND RECOMMENDATION

Deficit irrigation is an important practice to wisely use the scarce water resource, avoid the risk of water table increase in irrigated agricultural land and to minimize competition and conflict between different water users with limited water resource. The amount of water saved by deficit irrigation will help to irrigate additional crop land in water resource scarce areas which now a day is common problems due to climate change and other related natural resource degradation with acceptable crop yield reduction per a given area. Moreover the method may lead to economical in irrigated agriculture especially in areas where the irrigation water is pumped from the source to farm like practiced in the experimental area by reducing fuel cost associated with pumping.

The important part of this study was to find the higher water use efficiency without significantly reducing the economical yield of spearmint crop in irrigated agriculture. Based on the objective, among the nine treatments used in this experiment, deficit irrigation to 50%ETc with conventional furrow application method is the best to be selected. However, well irrigated treatment to 100%ETc with conventional furrow irrigation water application method (control treatment) demonstrated higher average yield per hectare values except in water use efficiency which is least. Besides to this, alternate and fixed furrow method also showed higher water use efficiency but the yield obtained was less. So spearmint crop is suitable to deficit irrigation to some level in areas similar agro-ecology with Koka. Thus it can be concluded that whenever spearmint (*Mentha spicata* L.) is cultivated with irrigation agriculture where water resource is minimum, it can be irrigated to 50%ETc with conventional furrow irrigation water application method.

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Annex 1: Response of Spearmint (*Mentha spicata* L.) Yield and Yield Component to Deficit Irrigation during the First Harvesting Cycle 2011/2012season at Koka

Treatments	Fresh biomass yield (kg/ha)	Fresh leaf yield (kg/ha)	Dry biomass yield (kg/ha)*	Dry leaf yield (kg/ha)	Essential oil yield (kg/ha)*	Wet harvest index (decimal X10^3)	Water Use Efficiency (kg/ha X10^3)*
AF 100%ETc	12233	8457	2602c	1702.9	28.6ab	3.00	8.2cd
AF 75%ETc	12977	9153	3142abc	2369.5	34.5a	2.77	12.5ab
AF 50%ETc	9715	6911	2862bc	2007.2	18.6c	2.55	9.3bcd
FF 100%ETc	12342	8584	2758c	1830.2	27.3ab	2.39	7.8d
FF 75ETc%	12807	9095	3148abc	2075.7	29.0ab	2.33	10.5bcd
FF 50%ETc	7570	5657	2051c	1501.3	22.5bc	2.27	11.3abc
CF 100%ETc	15475	10243	4227a	2861.3	35.0a	2.26	10.0bcd
CF 75%ETC	13163	9153	4124ab	3235.6	33.9a	2.24	12.3ab
CF 50%ETc	13041	9226	2740c	1900.7	28.5ab	1.97	14.3a
CV (%)	22.0	20.6	24.5	32.7	16.6	18.6	18.0
$LSD_{0.05}$	ns	ns	1304.9	ns	8.2	ns	3.3

Means with the same column followed by the same letters are not significantly different. *significant ($p<0.05$), **significant ($p<0.01$), ***significant ($p<0.001$), ^{ns} not significant ($p<0.05$).

Annex 2: Response of Spearmint (*Mentha spicata* L.) Yield and Yield Component to Deficit Irrigation during the Second Harvesting Cycle 2011/2012season at Koka

Treatments	Fresh biomass yield (kg/ha)	Fresh leaf yield (kg/ha)	Dry biomass yield (kg/ha)**	Dry leaf yield (kg/ha)*	Essential oil yield (kg/ha)	Wet harvest index (decimal X10^3)	Water Use Efficiency (kg/ha X10^3)*
AF 100%ETc	7558	5355	2542bc	1779b	29.5	3.95	12.6b
AF 75%ETc	6888	5068	2043bc	1542b	23.1	3.46	13.2b
AF 50%ETc	7664	5553	1751bc	1148b	26.7	3.53	22.8a
FF 100%ETc	8888	6287	1530c	954b	29.8	3.45	12.7b
FF 75ETc%	8950	6520	2866b	2076ab	33.8	3.73	19.2ab
FF 50%ETc	4892	3555	1570bc	1039b	21.0	4.38	17.9ab
CF 100%ETc	12123	8510	4502a	3141a	36.8	3.07	13.6b
CF 75%ETC	7584	5614	1648bc	1055b	26.6	3.56	13.1b
CF 50%ETc	8490	6213	2180bc	1504b	30.4	3.58	22.5a
CV (%)	29.9	27.6	33.2	41.5	26.1	12.7	25.4
$LSD_{0.05}$	ns	ns	1318	1136	ns	ns	7.23

Means with the same column followed by the same letters are not significantly different. *significant ($p<0.05$), **significant ($p<0.01$), ***significant ($p<0.001$), ^{ns} not significant ($p<0.05$).

Annex 3: Response of Spearmint (*Mentha spicata* L.) Yield and Yield Component to Deficit Irrigation during the First Harvesting Cycle 2012/2013season at Koka

Treatments	Fresh biomass yield (kg/ha)*	Fresh leaf yield (kg/ha)*	Dry biomass yield (kg/ha)	Dry leaf yield (kg/ha)	Essential oil yield (kg/ha)*	Wet harvest index (decimal X10^3)	Water Use Efficiency (kg/ha X10^3)*
AF 100%ETc	6008.0bc	3968.0bc	2061.5	1230.4	21.9bcd	3.63	5.2abcd
AF 75%ETc	6664.0bc	4344.0bc	2250.1	1339.3	21.5bcd	3.31	6.0ab
AF 50%ETc	5234.7c	3616.0bc	1993.3	1191.7	17.1cd	3.33	5.9abc
FF 100%ETc	5474.7bc	3874.7bc	1859.3	1168.3	19.2bcd	3.52	4.5bcd
FF 75ETc%	6517.3bc	4434.7bc	2376.7	1508.8	24.1abc	3.70	6.7a
FF 50%ETc	5213.3c	3392.0c	1897.9	1113.2	15.9d	3.13	5.4abc
CF 100%ETc	8680.0a	5928.0a	3118.6	1976.9	29.4a	3.44	4.3cd
CF 75%ETC	7029.3ab	4573.3b	2281.9	1226.5	20.9bcd	2.99	3.8d
CF 50%ETc	6602.7bc	4320.0bc	2095.5	1228.6	24.9ab	3.69	5.9abc
CV (%)	15.7	15.3	24.3	27.0	19.2	19.0	17.8
$LSD_{0.05}$	1738.6	1129.5	ns	ns	7.2	ns	1.64

Means with the same column followed by the same letters are not significantly different. *significant (p<0.05), **significant (p<0.01), ***significant (p<0.001), ^{ns} not significant (p<0.05).

Annex 4: Response of Spearmint (*Mentha spicata* L.) Yield and Yield Component to Deficit Irrigation during the Second Harvesting Cycle 2012/2013season at Koka

Treatments	Fresh biomass yield (kg/ha)**	Fresh leaf yield (kg/ha)*	Dry biomass yield (kg/ha)**	Dry leaf yield (kg/ha)	Essential oil yield (kg/ha)*	Wet harvest index (decimal X10^3)	Water Use Efficiency (kg/ha X10^3)**
AF 100%ETc	8277bc	5669bc	2559ab	1611	37.6ab	4.50	18.6cde
AF 75%ETc	7187bc	5237bc	2297bcd	1546	29.7bc	4.09	19.6cd
AF 50%ETc	6112c	4475bc	1713d	1214	27.5bc	4.48	27.2ab
FF 100%ETc	7333bc	4269c	2025bcd	1065	25.6c	3.72	12.6de
FF 75ETc%	6232c	4557bc	1841cd	1309	28.8bc	4.55	19.0cd
FF 50%ETc	5891c	4251c	1793cd	1174	29.5bc	5.02	29.1a
CF 100%ETc	12093a	7851a	3134a	1785	46.9a	3.88	11.6e
CF 75%ETC	8515bc	5920bc	2389bc	1553	38.0ab	4.49	12.5de
CF 50%ETc	9205b	6323ab	2567ab	1581	42.1a	4.58	20.8bc
CV (%)	19.7	20.5	17	21.7	20.4	12.5	22.1
$LSD_{0.05}$	2678.9	1914.9	664.5	Ns	12	ns	7.3

Means with the same column followed by the same letters are not significantly different. *significant (p<0.05), **significant (p<0.01), ***significant (p<0.001), ^{ns} not significant (p<0.05).