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Effect of Deficit Irrigation on Dry Matter Yield and Water Productivity of Young Harerghe Coffee Genotypes at Jimma, Southwest Ethiopia

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Abstract: Coffee plays an important role in Ethiopia's economy; it is a major source of revenue, accounting for almost 70% of total export earnings. However, the recurrent drought and seasonal moisture deficit impacted the coffee production. Therefore, the experiment was conducted to investigate the performance of Harerghe coffee genotypes under different deficit irrigation levels at Jimma (Malko) in rain shelter. Six Harerghe coffee genotypes seedlings with age of eleven months were subjected to three deficit irrigation levels (40, 80 and 120% of ETc) with randomized complete block design, which replicated three times. It was observed that different deficit levels significantly affected water productivity, dry mater yield production and growth traits for all genotypes. Based on mean values of total dry matter production, genotype H-823, H-957 and H-981 were classified as more productive than H-929 and H-979 under 80%ETc irrigations, while H-929 found to be less productive in terms of dry matter production. The 40%ETc of irrigation significantly improved water productivity, but, 120%ETc considerably reduced the water productivity of most genotypes. As supply of irrigation increased the water productivity was linearly decreased and opposite trend is observed for dry mater yield and plant growth. Regardless of genotypes, almost all genotypes differentially responded to irrigation amounts, the highest and lowest water productivity had produced from H-823 and H-929, respectively, but similar values was observed among H-857 and H-981. The genotype X irrigation interaction significantly impacted all measured plant traits. Among genotypes, H-823 produced highest water productivity under 80%ETc and followed by H-674, H-857 and H-929 under 40%ETc, while the lowest had from H-981 and H-674 with 120%ETc. In contrast, the 40%ETc significantly reduced dry matter production as well as inhibit plant growth. But, under 80%ETc coffee seedlings gave medium water productivity, maximum dry matter and promoted vegetative growth. However, this finding should further proofed with replicated field experiments under different agro-ecological conditions.

Keywords: Dry Matter Yield, Water Productivity, Coffee Genotypes, Deficit Irrigation

1. Introduction

Coffee is important cash crops produced globally as well as in Africa's particularly in the Ethiopian. The overall global coffee production is estimated to be 165 million bags. From this Africa takes a lion share, particularly Ethiopia produced 7.4 million bags, of which nearly 4.1 million was exported and got 906 million USD earns during 2020 years, which is approximately 70% of export revenue. The lives of most people in coffee producing areas including Ethiopia mainly depend on an economy generated from this crop. More people in these developing regions directly or indirectly derived their income from coffee [1].

In specific detail, in Ethiopia about 60% of foreign exchange and 30% government direct revenue are derived from coffee. Despite government's revenues, more than quarter of its population livelihood typically depend on coffee production and marketing. However, its productivity is quite low as compared to other countries. This is because of occurrence of frequent recurrent drought, lack of improved varieties, and diseases [2].

Likewise, sever moisture deficit and polluting environmental value are frightening agricultural sustainability in developing countries including Africa. In general, drought and rise of temperature are the most important climatic limitations for coffee production. Therefore, Coffee is naturally dependant on environment and few rises in temperature can greatly reduce the yield and quality of coffee in coffee growing regions. In view of the climate change, most coffee growing areas expected to be shrinking [3].

A combined method is important to improve plant performance for moisture deficit regions involves the identification and selection of traits that contribute to drought tolerance. A partial list of potentially important traits might include water-extraction efficiency, water productivity, hydraulic conductance, osmotic and elastic adjustments, and modification of leaf area. Most of these traits are complex, and their control and molecular basis are not well understood [4].

Boosting irrigation efficiency would therefore reduce the demand of developing new infrastructure to supply additional water for all sectors by 2025 by roughly one half [5]. For instance, farmers may expect to minimize water use either with cultivation of water efficient crops or adopting water efficient irrigation technologies [6].

Hence, just to enhance water productivity requires both improved variety and good agronomic management. The problem is to deal with the crop or improve its genetic makeup [7]. Productivity defined as how the output volume is produced with efficient utilization of input resource without waste [8]. Similarly in crops, due to water scarcity aligned with escalating demand of different sectors, enhancing water productivity and reducing agricultural water usage plays significant role in saving existing water to meet the environmental demand by leaving a sufficient amount of water in the river and lakes and to meet the demand of industries and cities. In general, water productivity is the amount of carbon assimilated (biomass produced) or crop yield per unit of water used [9].

The stomata closure and open primarily controlled by amount of water added to soil and, therefore crop yield and actual evapotranspiration is driven by this physiological process. In given climate and crop cultivar there is well well-known direct association between plant biomass and transpiration [10]. As irrigation amount reduced, the crop yield becomes reduced. However, the quality may be improved by some extents [11]. Plants use available water in the soil optimally. In addition, the mechanism by which plants lessen evapotranspiration is either by closing stomatal or reduction of leaf area, beside in retarding plant growth. In some cases the intentional imposition of moisture stress is required. For example, the water productivity of medicinal and aromatic plants increases under drought conditions [12].

Water productivity greatly varied among crop species which is mainly related to different carboxylation pathways [13]. Even for the same plant species, the water productivity varied between genotypes and which means, the water productivity is controlled by plant genes [14]. Breeders had been able to develop new high yielding cultivar, but require higher water to produce higher yield. There is direct relationship between the amounts of water transpired by plant with that of growth and yield [15].

The concept of water productivity is crucial, while water remains a limited and costly resource. To increase coffee yield under such limiting water, it needs selection of water efficient genotypes and generating efficient irrigation amounts that enable us to boost water productivity and thereby overcome water shortage in water limiting areas, either in amount or accessibility. Developing new varieties that demonstrate better ability to improve water productivity through innovative research approach will help to modernize all crop production [16].

Therefore, this study was aimed at screening of water efficient Harerghe coffee genotypes under varies irrigation levels in rain shelter.

2. Materials and Methods

The experiment was executed from March 25, 2020 to September 4, 2020 in a rain shelter at Melko (JARC), Jimma, Ethiopia. The research center is found at 7°40'05" N latitude, 36°47'09" E longitude, and with altitude of 1746 m above asl. The average rainfall of the center was 1541 mm. The monthly mean temperature reached peak (25.8°C) during March and getting lowest (11.3°C) during July. The mean monthly relative humidity was 67.2%.

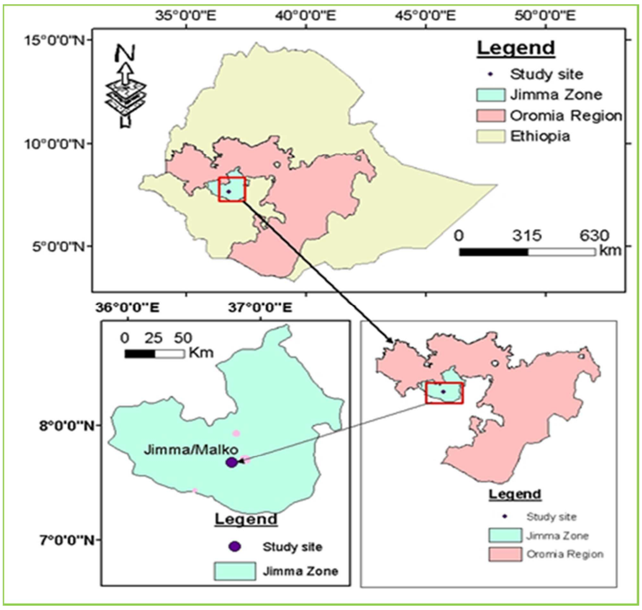

Figure 1. *Study area map.*

2.1. Experimental Design

The experiment was conducted in a factorial RCBD which replicated three times that involved six Harerghe genotypes (H-674/98, H-739/98, H-823/98, H-981/98, and H-929/98 and H-857/98) and three irrigation levels.

Each variety was combined with three irrigation amounts (6 genotype X 3 irrigation treatments), then combined treatments were randomly allocated to experimental plots. Each experimental block contained 18 plots, six irrigated with 40%ETc, six irrigated with 80%ETc and six irrigated with 120%ETc, eight plants per plot and totally, 432 plants were evaluated in this experiment. All irrigation treatments were scheduled at four days intervals, based on field capacity determination and daily evaporation, accordingly, individual varieties subjected to three irrigation amounts, namely, 40, 80 and 120%ETc.

2.2. Planting Material

The released pure seeds of six Harerghe coffee genotypes were collected and sown on the nursery, managed according to recommended nursery mgt standards, vigor and healthy seedling of eleven months old had transplanted to the pots of 5 litr volume in rain shelter. One seedling was planted in each pot and watered to FC to facilitate good establishment.

2.3. Parameter Measurements

The first response measurements were made after five days of treatment application and continued till harvesting. A destructive sampling method was used for determination of total-dry matter production. The four representative plants selected from each plot were harvested, then allocated in to leaves, stem and roots, and oven-dried at 70°C to a constant weight to determine total dry matter yield. Plant height was measured using a graduated ruler from base stem to apical bud. Girth was measured with a digital caliper in the stem base region. The roots were immersed and washed in clean water to remove adhering soil. The total leaf area was determined with the leaf area meter. Number of nodes and leaf number were determined by physical counting from destructed seedling. The water productivity of each treatment estimated using the following formula:

$$WP = \frac{TDY}{W} \quad (1)$$

Where, WP was water productivity, TDY was total dry matter yield and W was the volume of consumed water.

2.4. Field Capacity Determination

Sun-dried nursery soil was filled in pots, each with five liters capacity. The pots were weighed and watered to drip point, covered with a polyethylene sheet to prevent evaporation and placed on a wooden frame bed raised above the ground level to allow free drainage for 24 hours. Next the pots were reweighed to determine the field capacity (FC) of the soil. The moisture content on dry weight basis was determined by gravimetric method (drying soil samples in an oven at 105°C to a constant weight); using 150–200 g wet soil samples taken from wetted pots just after 24 hrs and the loss of water on daily base were estimated on v/v of percent. Accordingly, the amount of irrigation water needed per day was calculated from initial minus final pot weight and scheduling was done accordingly.

2.5. Data Analysis

The collected data were subjected to statistically analyses using R-software version 4.0.4 using agricolae package. Finally, the mean separation were done using LSD test. Lastly, the growth parameters were correlated with water productivity.

3. Result and Discussion

3.1. Agronomic Parameter

The plant growth traits like girth and leaf area were significantly differed due to variety and irrigation interaction, but plant height, number of nodes and tap root length were not affected. The tallest plant height was produced by H-823/98 (46.41 cm) under 80%ETc, whereas shortest from H-674 (30.5 cm) under 40%ETc. Furthermore, for most varieties, the shortest plant was produced from 40%ETc and whiles the longest had from 80%ETc. This implies that, the severe soil moisture retards plant growth and moist soil can highly promote plant growth. Plant height was increased with increasing soil moisture at some extent and started to drops at 120%ETc. As [17] discovered that plant height increased rapidly as the amount of water went up in each growing period. Both extreme events, excessive and lower amount of water significantly affected tobacco growth. Under such extreme condition, the cell elongation will be inhibited and cause retarded growth. Moreover, excessive irrigation quantity made a waste of water at the point of considering saving-water and high efficiency.

Similar to plant height, the stem girth was considerably affected due to variety and irrigation. Accordingly, the thickest plants were produced from H-739/98 (0.79 cm) under 80%ETc and while the thin from H-674 (0.52 cm) under 40%ETc irrigation level. In general, the plants treated within 40%ETc produced thinnest plants relatively, which was about 37% thinner than 80%ETc and 120%ET. Even though, plants treated with 80% and 120%ETc produced thickest stem girth, but they were not statically differed from each other. H-823 (12.5) produced lot of nodes than other varieties and the fewer had from H-929 (11.67), but there were no significance difference among H-857/98 and H- 739 genotypes. The 40%ETc surprisingly reduced number of nodes by about 16.7% and 13.9% over 120%ETc and 80%ETc respectively.

The leaf area was significantly ($p<0.05$) affected both by irrigation and variety. Regardless of varieties, the widest leaf areas were produced from H-823 and H-674, while the narrow got from H-981 and H-929. Irrespective to irrigation, 40%ETc reduced the leaf area of the coffee seedlings by about 14.5% and 4.4% over 120% and 80%ETc, respectively. The H-857 (20.88 cm^2) and H-674 (18.31 cm^2) had produced the narrow leaf area under 40%ETc and while wider leaf area had from H-981 under 80%ETc and followed by H-674 and H-929 under 120% irrigation level. This indicated that severe moisture stress (40%ETc) had significantly reduced the leaf area of the coffee seedling, but some genotypes adjusting themselves with maintaining lower leaf area in order to reduce the evaporating surface, thereby conserve existing moisture and retarding growth in leaves. As soil moisture increases the leaf area increases and vice versa. This could related to [18], the plant has mechanism of adjusting itself to reduced soil moisture either by reducing its leaf area to reduce evaporating surface or retard shoot growth, rather invest growth into root parts as drought become progressed. The Author [19] reported that plants in well-watered plots exhibited significantly higher shoot growth, expressed as plant height, girth at the base, number of nodes, internodes length, number of branches, total branch length, number of leaves and total leaf area. According to [20] pointed out that water stress decreased photosynthesis due to stomata closure. Reduction in photosynthesis decreased and growth regulators, which resulted in reduced turgid pressure, reduced leaf area and decreased growth.

Table 1. *Effects of genotypes and different irrigation regimes on plant height, girth, number of nodes, number of leaves, and leaf area.*

Treatment	plant height (cm)	girth (cm)	node number	leaf number	leaf area (cm^2)
variety	***	***	***	**	***
H823	46.41a	0.785ab	12.5a	25.31a	20.5a
H857	37.27bc	0.73bc	11.36bc	21.44ab	46.8b
H674	30.52d	0.52d	11.94ab	13.99c	55.8a
H739	44.63a	0.79a	11.47bc	23.78ab	23.44c
H929	36.95c	0.69c	10.69d	19.76b	51.9ab
H981	40.78b	0.78ab	10.96dc	19.69b	47.5b
LSD @0.05	3.76	0.06	4.82	4.82	6.3
Irrigation	***	***	***	***	*
33% FC	30.04b	0.53b	10.24b	12.85b	38.25b
66% FC	44.19a	0.81a	11.93a	25.27a	40.02b
100% FC	44.05a	0.82a	12.30a	23.87a	44.75a
LSD @0.05	2.65	0.05	0.46	3.41	4.5
variety*Irrigation	ns	*	ns	ns	*
CV (%)	9.80	9.36	5.85	24.01	16.0

*Significant at p<0.05, **significant at p<0.01 and *** significant at p<0.001

3.2. Plant Dry Matter Yield

The both variety and irrigation significantly affected all characters measured in terms of leaf, stem and root dry weight as well as total dry matter yield. On another hand, the Genotype X irrigation interactions were significant (p<0.001) for LDW, SDW, RDW and TDY. The dry biomass production of leaves stems and roots over period of experiment had highly increased with increasing irrigation water to some extent and dropped as irrigation water decreased. Thus, 40%ETc irrigation amount had significantly reduced the plant dry biomass (stem, leave, root, total dry biomass yield), while 80%ETc and 100%ETc irrigations levels did not differed. Regarding genotypes, H-823 had produced the heaviest stem dry, leaf dry, root dry and total dry matter yield while H-739 had produced maximum root dry matter at expense of leaf and steam dry weight.

Similarly, each genotype significantly responded to different irrigation amounts with respect of producing greater dry biomass (stem, leave and roots). Therefore, most genotypes responded highly to 80%ETc and they produce higher stem dry, leaf dry and root dry weight relatively. I contrast; under 40%ETc level plant dry biomass production was significantly inhibited. For example, this phenomena is justified by H-823 which produced heaviest leave (15.3 g), stem (13.46 g), root and total dry matter (37.35 g) under 80%ETc irrigation level, but lower dry biomass was produced under 40%ETc and medium under 120%ETc levels. This indicated that the best irrigation strategy for most genotypes and especially for H-823 was found to be 80%ETc. Similarly, [21] demonstrated that a significant reduction of dry matter in all different parts of drought-treated trees including leaves, main branches, lateral branches and roots. Similarly, the study of [19] on coffee seedling investigated that leaf dry weight; shoot dry matter yield and total dry matter production were considerably higher for the well watered than deficit irrigation. Moreover [22] reported that the root growth of loblolly and Scotch pine seedlings is significantly reduced in drying soil than normally irrigated plant. Therefore, the decrease in total dry matter yield of coffee seedlings in deficit irrigation could be attributed to the reduced total leaf area, which might have reduced the photosynthetic capacity of plants.

3.3. Water Productivity

The interaction effect of variety and irrigation were significantly (P<0.0001) differed in water use efficiencies due to variety and irrigations. The water productivity was significantly increased with decreased irrigation water. Accordingly 40%ETc of irrigations produced maximum water productivity and followed by 80%ETc, while the least had from 120%ETc with the corresponding values of 4.2, 3.7 and 2.45 g/liter, respectively. Irrespective of genotypes, almost all genotypes differentially responded to irrigation amounts, consequently, the highest and lowest water productivity had produced from H-823 and H-929, respectively, but similar values was observed among H-857 and H-981 genotypes under varies irrigation levels. Moreover, H-823 had produced highest water productivity under 80%ETc and followed by H-674, H-857 and H-929 under 40%ETc. In contrast, the lowest water productivity had from H-981 and H-674 under 120%ETc irrigation level. Despite 50% and 66.7% reduction in volume of water applied, 40%ETc increased water productivity by more than 47.6% and 11.9% over 120%ETc and 80%ETc treatments. This indicated that as the volume of water decreased the water productivity significantly increased. However, some coffee genotypes produced maximum water productivity under 80%ETc this was especially true for H-823. In general, most genotypes gave maximum water productivity under 40%ETc irrigation levels. In contrast, under 40%ETc, coffee seedling exhibited lower dry matter production and retarded plant growth. But under 80%ETc irrigation level, coffee seedlings gave medium water use efficiency, maximum dry matter and promoted vegetative growth. Therefore, the best irrigation strategy for coffee seedlings was found to be 80% of ETc under nursery conditions. This result closely agree with [19] finding that water productivity of coffee seedlings substantially improved with the deficit irrigation.

Figure 2. *Response coffee genotypes to deficit.*

Table 2. *Effect of genotypes and deficit irrigation on SDW, LDW, TDMand WUE.*

Treatment	SFW (gm/plant)	SDW (gm/plant)	LFW (gm/pant)	LDW (gm/plant)	RFW (gm/plant)	RDW (gm/plant)	TDY (gm/plant)	WP (gm/liter)
Variety	***	***	***	***	***	**	***	***
H823	15.84^{b}	10.27^{a}	23.57^{a}	11.03^{a}	19.77^{b}	7.35^{a}	28.65^{a}	3.86^{a}
H857	12.16^{b}	7.93^{d}	20.98^{bc}	9.92^{bc}	17.26^{c}	7.03^{ab}	24.87^{c}	3.42^{bc}
H674	10.52^{e}	6.78^{e}	17.85^{d}	9.03^{d}	12.08^{e}	6.47^{bc}	22.28^{d}	3.13^{d}
H739	17.07^{a}	8.83^{b}	22.13^{b}	10.30^{b}	21.31^{a}	7.48^{a}	26.62^{b}	3.52^{b}
H929	14.14^{c}	8.43^{c}	20.38^{c}	9.75^{c}	15.31^{d}	6.11^{c}	24.28^{c}	3.36^{c}
H981	15.82^{b}	8.39^{c}	24.92^{a}	9.83^{bc}	19.59^{b}	6.84^{ab}	25.07^{c}	3.41^{bc}
CV (%)	4.7	3.95	6.46	5.5	5.80	9.68	3.23	4.65
LSD @0.05	0.65	0.32	1.35	0.54	0.99	0.65	0.79	0.15
Irrigation	***	***	***	***	***	***	***	***
33% FC	6.65^{c}	6.01^{b}	5.17^{c}	5.39^{b}	7.28^{c}	5.43^{b}	16.82^{b}	4.20^{a}
66% FC	19.18^{a}	9.585^{a}	30.56^{a}	12.40^{a}	24.51^{a}	7.61^{a}	29.60^{a}	3.70^{b}
100% FC	16.94^{b}	9.73^{a}	29.19^{b}	12.14^{a}	20.86^{b}	7.60^{a}	29.46^{a}	2.45^{c}
LSD @ 0.05	0.46	0.23	0.96	0.38	0.70	0.45	0.56	0.11
VarietyX Irrigation	***	***	***	***	***	**	***	***

*, **, ***, which is significant at $p<0.05$, at $p<0.01$ and at $p<0.001$, respectively, SDW=stem dry weight, LDW= leaf dry weight, RDW= root dry weight, TDY= total dry matter yield, WP= water productivity.

Table 3. *Interaction effects of deficit irrigation and coffee genotypes on dry biomass yield and water productivity.*

Variety level	Irrigation level	SDW (gm/plant)	LDW (gm/plant)	RDW (gm/plant)	TDM (gm/plant)	WP (g/liter)	Leaf area (cm^2)
H823	40%ETc	6.25fg	5.83gh	5.187f	17.26fg	4.31b	19.74f
H823	80%ETc	13.46a	15.30a	8.59a	37.36a	4.67a	53.18ab
H823	120%ETc	11.10b	11.95c-e	8.28ab	31.33b	2.61f-h	52.63ab
H857	40%ETc	6.60f	5.47h	5.19f	17.25fg	4.31b	20.89f
H857	80%ETc	8.48d	11.43e	8.60a	28.51c	3.57d	42.82bcd
H857	120%ETc	8.70d	12.86bc	7.3bcd	28.86c	2.41ih	40.27cd
H674	40%ETc	5.34h	6.59g	5.66ef	17.59f	4.40ab	18.32f
H674	80%ETc	6.62f	8.69f	6.21d-f	21.52e	2.69f	35.29de
H674	120%ETc	8.39d	11.8de	7.54a-c	27.73cd	2.31i	58.91a
H739	40%ETc	5.75gh	4.04hi	5.67ef	15.46g	3.87c	24.72ef
H739	80%ETc	10.48c	13.37b	8.39ab	32.23b	4.03c	53.22ab
H739	120%ETc	10.27c	13.51b	8.41ab	32.19b	2.68fg	49.65abc
H929	40%ETc	6.59f	5.470h	5.51ef	17.57f	4.39b	23.49ef
H929	80%ETc	7.33e	12.69b-d	6.26def	26.28de	3.29e	52.08abc
H929	120%ETc	11.37b	11.09e	6.55cde	29.01c	2.42g-i	55.89a
H981	40%ETc	5.50h	4.95hi	5.363ef	15.81fg	3.95c	24.71ef
H981	80%ETc	11.15b	12.95bc	7.64a-c	31.74b	3.97c	59.65a
H981	120%ETc	8.54d	11.59e	7.54a-c	27.66cd	2.31i	52.68ab
LSD @ 0.05		0.56	1.01	1.28	1.9	0.33	11.7

Means followed by the same letters in column are not statistically different at 5% level for Least Significant Difference Test. *Significant at $p<0.05$, **significant at $p<0.01$ and *** significant at $p<0.001$

3.4. Correlations Between Water Use Efficiency and Growth Traits

Highly significant correlation of water productivity with most plant traits were noted in 80%ETc than other water amounts, due to optimum moisture supply. The plants treated with optimum moisture enhanced photosynthetic assimilation thereby finally improve both dry biomass accumulation and water productivity. However, this relationship becomes diminished under stress greatly as well as under surplus moisture supply condition at lesser extent. Furthermore, the water productivity did not correlate with all plant traits in 40%ETc due to retardation of plant growth as affected by moisture stress. Therefore, as supply of irrigation water increased to some extent plant height, girth and number of leaves were significantly increased, but as moisture supply approaches to 120%ETc, the plant growths become affected. Furthermore, the positive correlation of water productivity with plant growth may due to the fact that the ticker plant and tallest plant produce higher dry mater which improves the water productivity.

Table 4. *Relationship of water productivity with plant traits.*

Traits	WP		
	40%ETc	80%ETc	120%ETc
Plant Height	0.10ns	0.87**	0.59*
Stem Girth	0.12^{ns}	0.73^{**}	0.47^{*}
Number of Nodes	0.10^{ns}	0.14^{ns}	0.18^{ns}
Number of Leaves	0.26^{ns}	0.70^{**}	0.38^{ns}
Leaf Area	-0.26^{ns}	0.59^{*}	0.09^{ns}

*, **, *** Significant at p<0.05, p<0.01 and p<0.0001 levels, respectively. ns, Non-significant, WP- water use productivity.

4. Conclusion

From this experiment we concluded that the water use efficiency was significantly increased with decreased irrigation water. Irrigating coffee seedlings with 40% of ETc produced maximum water use efficiency and followed by 80%ETc but least had from 120% of ETc. Almost all genotypes differentially responded to irrigation amounts, the highest and lowest water use efficiency had produced from H-823 and H-929, respectively, but similar values was observed among H-857 and H-981 genotypes with all irrigations. In contrast, irrigating coffee seedlings with 40% of ETc can greatly inhibit plant growth and development. But irrigating coffee seedling with 80% of ETc optimized water use efficiency as well as enhances vegetative growth. Therefore, irrigating coffee seedling with 80% of ETc can produce higher dry matter production and greater water productivity, it can save considerable amount of water when compared to 120% of ETc irrigation level. This finding, however, needs to be verified in replicated field trials under various agro-ecological circumstances.

Conflict of Interest

The authors declare that they have no competing interests.

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References

[1] ICO. 2021. International Coffee Organization. Annual Review. http://www.ico.org/

[2] Tesfaye, S. G, Ismail, M. R., and Mahmood, M., 2008. Effects of deficit irrigation and partial rootzone drying on growth, dry matter partitioning and water use efficiency in young coffee (Coffea arabica L.) plants. Journal of Food, Agriculture & Environment Vol. 6 (3 & 4): 312-317. 2008.

[3] DaMatta, F. M. and Ramalho, J. D. C., 2006. Impacts of drought and temperature stress on coffee physiology and production: a review. Brazilian journal of plant physiology, 18 (1), pp. 55-81.

[4] DaMatta, F. M., 2004. Exploring drought tolerance in coffee: a physiological approach with some insights for plant breeding. Brazilian journal of plant physiology, 16 (1), pp. 1-6.

[5] Seckler D, Young, RA. 1985. The choices of irrigation technologies in California. American Journal of Agricultural Economics 67: 2.

[6] USDA. 1997. Agricultural resources and environmental indicators, 1996–97. Agricultural Handbook No. 712. Economic Research Service, United States Department of Agriculture. (Available from http://www.ers.usda.gov/publications/ah-agriculturalhandbook/ah712.aspx#.Ucwf_fnI2So) (Accessed on 27 June 2013).

[7] Sharma, B., David, M. and Simon C. n.d. Water use efficiency in agriculture: Measurement, current situation and trends. International Water Management Institute (IWMI), New Delhi, India, b.sharma@cgiar.org pp 51-52.

[8] Jensen, M. E. 2007. Beyond irrigation efficiency, Irrig. Sci., 25, 233–245, doi: 10.1007/s00271-007-0060-5.

[9] Viets, F. G. 1962. Fertiliser and efficient use of water. Advances in Agronomy 14: 223- 264.

[10] Steduto, P., Hsaio, T. C., Fereres, E. 2007. On the conservative behavior ofbiomass water productivity. Irrigation Science 25: 189-207.

[11] Li, Y. S. 1982. Evaluation of field soil moisture condition and the ways to improve crop water use efficiency in Weibei region. Journal of Agronomy in Shaanxi Province, 2, 1–8.

[12] Farahani, H. A., Valadabadi, S. A., Daneshian, J., Shiranirad, A. H. and Khalvati, M. A. 2013. Review on Medicinal and aromatic plants farming under drought conditions. African Journal of Plant Breeding Vol. 1 (5), pp. 083-088.

[13] Ludlow, M. M. and R. C. Muchow. 1990. A critical evaluation of traits for improving crop yields in water-limited environments. Adv. Agron. 43: 107–153.

[14] Yoo, C. Y., H. E. Pence, P. M. Hasegawa, and M. V. Mickelbart. 2009. Regulation of transpiration to improve crop water use. Crit. Rev. Plant Sci. 28: 410.

[15] Bassil, E. S. and Kaffka, S. R. 2002. Response of safflower (Carthamustinctorius L.) to saline soils and irrigation: I. Consumptive water use. Agr. Water Mgt. 54: 67–80.

[16] Morison, J. I.., Baker, N.., Mullineaux, P.., & Davies, W.. (2008). Improving water use in crop production. Philosophical Transactions of the Royal Society B: Biological Sciences, 363 (1491), 639–658. doi: 10.1098/rstb.2007.2175.

[17] You-, B. Y, Dan-yan. C, Xiao, H., Yu-Hua L, Fuzhang, D. and Chantal K. 2012. Effects of different irrigation quantities on plant growth and photosynthesis characters of flue-cured tobacco. Journal of Food, Agriculture & Environment Vol. 10 (2): pp 1160-1163.

[18] Taye, K. 2012. Biomass production and distribution in seedlings of Coffea arabica genotypes under contrasting nursery environments in southwestern Ethiopia. Agricultural Sciences, 3 (06), p. 835.

[19] Tesfaye, S. G., 2008. Effects of deficit irrigation and partial rootzone drying on growth, dry matter partitioning and water use efficiency in young coffee (Coffea arabica L.) plants.

[20] Kramer, P. J. 1969. Plant and water relationship. Mc Graw-Hill book company, New York, pp: 347-390.

[21] Rad, A. H. S. and Abbasian, A., 2011. Evaluation of drought tolerance in winter rapeseed cultivars based on tolerance and sensitivity indices. Žemdirbystė (Agriculture), 98 (1), pp. 41-48.

[22] Kaufmann MR (1968) Evaluation of the pressure chamber method. Proc Am Soc Hortic Sci 93: 186.