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Research Article

Evaluation of Coffee Genotype for Drought Tolerance and Water Use Efficiency in Western Ethiopia at West Wollega

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Abstract

The growth and output of coffee are significantly hampered by drought. To lessen the effects of climate change on coffee production, it is crucial to choose genotypes of Arabica coffee that are resistant to drought. The goal of the study was to select genotypes of Wellega coffee that are drought-tolerant at the Haru Agricultural Research Sub-Center in the Oromia National Regional State, Western Ethiopia. The experiment was carried out in a controlled environment from 2017 to 2019 G. C., with three replications laid out in RCBD. For 28 days, two watering regimes—well-watered and water-stressed—were applied to fourteen genotypes of Wellega coffee. The mother trees of genotype were tested at field condition. The experiment's findings showed that the genotypes not differed significantly in terms of total dry matter, relative leaf water content, and leaf retention capacity as well as in terms of the degree of wilting and in all destructive parameters. So, to select the drought tolerance coffee genotypes the stress period should be minimized in to 15-21 days.

Keywords

Arabica, Drought Tolerance, Well Watered, Water Stressed, Coffee, West Wellega

1. Introduction

Ethiopians' socioeconomic and cultural existence is fundamentally influenced by the growing of coffee [16]. It is the main agricultural export crop, contributing 20–25 percent of the country's income in foreign currency [13]. The coffee industry generates between 4% and 5% of the nation's GDP and hundreds of thousands of local job possibilities [14]. Several coffee types have been created through both short-term and long-term initiatives [16]. From 1977 to 1981, the first 26 pure Arabica coffee varietals were created, and their performance varied depending on the environment and administration [16].

Many developing nations grow coffee (Coffea arabica), which makes a substantial contribution to eradicating poverty and advancing national economies [1]. Ethiopia's ability to produce coffee is being progressively hampered by local and global climate changes that have led to irregular seasonal rain distribution and frequent droughts [10]. With an annual production of around 400,000 tons, Ethiopia is the largest producer of coffee in Africa, and the industry employs about 1.2 million smallholder growers. Water deficit or water stress in plants is a result of drought, an environmental issue. Low water potential and a decrease in cell turgidity below the maximal value cause an internal water deficit to start [9]. Since coffee is a perennial crop that remains in the field all year long, it is the primary source of income for many smallholder farmers in

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Ethiopia. However, drought has become a significant threat to coffee output in recent years. The main climatic constraints on coffee production in Ethiopia are drought and adverse temperatures. The main causes of the variations in coffee production are these constraints, which are anticipated to become increasingly challenging obstacles in a number of coffee-growing regions. In the majority of Ethiopia's coffee-growing regions, where there is a population strain for arable land, coffee planting has moved to marginal areas where there is a water deficit and high temperatures that significantly reduce coffee productivity. Additionally, in the majority of situations, there are insufficient water resources for irrigation during extended dry periods, which has an impact on the growth and development of plants in various forms during the phonological phases of the coffee crop [11]. Alternative strategies to combat drought in coffee agriculture include the adoption of resistant genotypes that are adapted to climatic changes, irrigation, high density planting, and agronomic methods including shade and high density planting. As a result, this study was carried out from 2017 to 2019 to screen genotypes of Wellega coffee that are drought tolerant under cover from the rain. Finding coffee cultivars resistant to drought for areas under moisture stress was a benefit of this study.

2. Methodology

2.1. Description of the Study Area

The study was conducted at the Haru Agricultural Research Sub-Center (HARSC) in West Wollega zone, Oromia National Regional State, Western Ethiopia. Haru Agricultural Research Sub-center of the Jimma Agricultural Research Center was established in 1998 mainly to address the potentials and constraints in west Wollega specialty coffee growing areas [6]. The center represents the sub humid tepid to cool mid highlands coffee agro-ecological zone in West Ethiopia. Haru agricultural Research sub center was located geographically between the latitude of 8°54' 30" North and longitude of 35°52' 0" East at an elevation of 1750 m.a.s.l. The area is characterized by unimodal rainfall pattern with an average annual rainfall of 1700 mm. The rainy season starts in March or May and extends up to October. The mean maximum and minimum air temperature is 27.8℃ and 12.4℃, respectively. The soil type of the center is Acrisols and sandy clay loam [12]. And it is found at 28 km from Gimbi town of West Wollega zone and 466 km from Addis Ababa in western Ethiopia.

Soil type of the study area based on 2014 G. C result have ; average PH of 4.84, OM (%) 4.63, N (%) 0.23, Available K (meq k/100 gm) 0.5, CEC (meq/100gm) 16.25, % OC 2.7, and Sandy Clay Loam soil texture.

Table 1. *Climate data of the study site.*

month	Tmin (℃)	Tmax (℃)	Humidity (%)	Wind speed (m/s)	RF (mm)
January	9.16	28.53	60.49	2.09	3.15
February	10.66	30.95	53.87	2.16	0.67
March	12.89	32.94	52.94	2.18	6.72
April	13.96	32.97	61.51	2.33	77.91
May	14.07	30.31	75.86	2.07	204.56
June	13.70	25.78	83.95	2.07	271.01
July	13.03	24.28	87.07	2.47	261.91
August	13.11	24.23	87.58	2.44	241.91
September	13.19	24.79	85.50	1.97	258.52
October	10.78	25.49	79.10	1.93	134.47
November	9.09	25.80	72.71	2.08	18.06
December	9.00	26.46	67.09	2.09	7.88
Average	11.89	27.71	72.31	2.15	1486.77

2.2. Experimental Design

The study used 14 promising wollega coffee genotypes (W6/98, W10/98, W13/98, W14/98, W33/98, W66/98, W76/98, W92/98, W105/98, W170/98, W175/98, W265/98, 78/84, and 74110) and two watering regimes (well-watered and water stressed) in RCBD. There were three replications in the study. Each experimental block had 28 plots (14 cultivars x 2 watering regimes); the seedlings were started in pots and irrigated fully every four days for the well water treatments, but not for the stressed plots, where water was withheld until the desired stress was visible for 28 days. Each plot had five seedling pots.

2.3. Experimental Materials and Procedures

The experiment was carried out from 2017 to 2019 G.C. at the Haru Agricultural Research Sub-center. At the start of the trial, young trees of promising and released cultivars, those land races in verification plots Wollega, were assessed at stations for their response to moisture stress during the peak dry spell and rat of recovery at the end of the wet season using a visual scoring method. At 8:00 a.m. and 1:00 p.m. each day, stress levels were visually assessed. Scores for leaves were assigned on a scale of 1 to 5, with 1 being given for all leaves that are green and turgid, 2 for most leaves that are still turgid but younger leaves that show folding, 3 for all leaves that wilt or fold, 4 for all leaves that are turning pale green and exhibiting severe wilting, and 5 for all leaves that are turning brown and dry, mostly drooping. Additionally, data on the degree of leaf folding, rolling, cupping, rate of leaf fall and branch death, recovery rate (producer of new flushes), yield potential, and disease reaction will be gathered. By sowing seeds in larger pots with traditional nursery media, promising genotypes' seedlings will have some physiological and morphological mechanisms related to drought resistance assessed in a controlled environment like a rain shelter. The seedlings of each genotype in this study were given one of two treatments—well-watered (control) or water stressed—after they had grown eight pairs of genuine leaves.

According to accepted practices, the essential data was gathered, and are listed here: The date of all fieldwork, date of germination, measurement of soil moisture while visually evaluating the physical characteristics of the soil and water varied weather each day, Pest and disease frequency, the height of the plant and other pertinent agronomic factors, Yield, as well as other pertinent yield characteristics Stomata conductance, leaf thickness, and other physiological factors, as well as biochemical factors (proline concentration, soluble solutes, etc.).

Relative leaf water content and Leaf thickness (LT) was calculated from leaf dry weight (LDW) and leaf area (LA) was then calculated as follows [15].

$$\text{RLWC (\%)} = \frac{FLW-LDW}{LTW-LDW}*100 \quad (1)$$

Whereas: - FLW= Fresh leaf weight (gram), LDW- leaf dry weight (gram), LTW- leaf turgid weight (gram)

$$\text{LT}= \frac{LDW}{LA} \quad (2)$$

Whereas: - LT=leaf thickness (mm), LDW= leaf dry weight (gram), LA= leaf area (cm^2)

2.4. Data Analysis

The collected soil and plant data were summarized and subjected to ANOVA (analysis of variance) using SAS software (version 9.3). [8], for significantly different treatments, the means were separated using Duncan's Multiple Range Test (DMRT) at p=0.05.

3. Result and Discussion

The mean of three years result was indicated that, no insignificance difference among Wollaga coffee genotypes for all parameters, which was subjected to moisture stress imposed under greenhouse condition. Even though there was no significance in score morning and noon in all cultivars. The tallest plant height was recorded at W-66/98 and the smallest one at 74110 cultivars. Generally from the result, W-76 /98 cultivar was moderately droughts tolerant compared to others since it scores low stress score, medium plant height and high rate of recovery after re-watering (Table 2). As the report of [3], coffee probably evolved as 'water spender' species. Coffee is therefore a highly environmentally-dependent crop and an increase of a few degrees of average temperature and/or short periods of drought in coffee-growing regions can substantially decrease yields of quality coffees. So, the result was similar in this finding, because the long stress period for coffee planting not recommended.

Table 2. *Destructive data.*

Genotypes	Plant height (cm)	Girth (mm)	No of Node	No of Leaf/Plant	Tap Root Length (cm)	Root volume (ml)	Leaf Fresh Weight (gm)	Stem Fresh Weight (gm)	Root Fresh Weight (gm)	Leaf Dry Weight (gm)	Stem Dry Weight (gm)	Root Dry Weight (gm)
W6/98	37.63	3.68	5.83	18.56	19.17	6.83	2.95	4.05	5.97	3.13	3.33	1.77
W10/98	43.92	3.12	6.48	21.89	20.72	5.75	3.63	3.73	3.77	2.65	3.05	1.37

Genotypes	Plant height (cm)	Girth (mm)	No of Node	No of Leaf/Plant	Tap Root Length (cm)	Root volume (ml)	Leaf Fresh Weight (gm)	Stem Fresh Weight (gm)	Root Fresh Weight (gm)	Leaf Dry Weight (gm)	Stem Dry Weight (gm)	Root Dry Weight (gm)
W13/98	43.51	3.69	6.15	24.79	22.01	7.02	4.40	4.48	5.92	3.68	3.97	1.85
W14/98	42.33	3.49	6.32	25.99	20.81	6.05	4.13	4.82	4.23	3.53	4.10	1.50
W33/98	37.80	3.35	6.00	25.77	16.67	5.22	4.07	3.70	4.73	2.62	3.07	1.33
W66/98	46.62	3.71	6.85	29.11	19.76	6.68	4.97	4.87	5.80	4.23	4.35	1.90
W76/98	43.72	3.65	6.48	21.90	22.21	8.23	3.55	5.45	7.17	2.70	3.80	2.02
W92/98	45.73	3.76	6.82	28.22	19.13	6.38	5.05	4.97	4.13	4.20	4.17	1.80
W105/98	41.94	3.62	6.00	25.43	18.48	4.92	5.23	4.57	3.40	4.07	3.82	1.40
W170/98	40.40	3.24	6.48	27.21	21.69	7.18	4.00	3.88	5.10	3.20	3.35	1.68
W175/98	42.47	3.63	6.68	27.57	21.23	7.83	4.27	4.55	4.62	3.48	3.72	1.78
W265/98	41.43	3.08	6.50	23.44	20.97	7.38	4.82	3.93	7.43	3.98	3.37	1.98
78/84	43.13	3.89	6.82	27.90	19.93	6.45	3.80	4.20	4.13	3.08	3.62	1.48
74110	36.67	3.85	7.02	37.67	20.19	5.95	4.53	5.00	4.12	3.98	4.27	2.10
LSD @0.05	Ns	Ns	ns	Ns	ns	ns	Ns	ns	ns	ns	ns	ns
CV (%)	7.05	7.31	5.60	16.99	7.49	14.41	15.21	12.15	24.74	16.75	11.61	14.89

Table 3. *Relative leaf water content, plant height elongation, and score level of leaf two times a day in a two days interval for a month.*

Genotypes	Plant height elongation (cm)	Score level		Leaf				RLWC (%)
		Morn-ing	Noon	Fresh weight (gm)	Turgid weight (gm)	Dry weight (gm)	Area (cm^2)	
W6/98	34.5	2.5	2.8	0.4	1.2	0.3	47.35	18.1
W10/98	40.0	3.0	2.8	0.3	1.0	0.2	43.96	14.6
W13/98	42.2	3.1	2.9	0.3	0.8	0.2	44.78	12.0
W14/98	45.5	3.3	3.1	0.4	1.1	0.2	53.96	14.4
W33/98	39.4	3.1	3.0	0.2	0.7	0.1	37.29	12.4
W66/98	44.6	3.6	3.2	0.3	1.0	0.2	49.64	19.1
W76/98	40.4	2.9	3.0	0.3	1.0	0.2	51.81	16.3
W92/98	42.5	3.2	3.1	0.4	1.3	0.2	65.33	12.7
W105/98	39.3	3.1	3.0	0.4	1.2	0.3	57.29	11.9
W170/98	37.8	3.0	3.0	0.3	1.0	0.2	50.69	12.6
W175/98	41.9	3.2	3.1	0.4	1.1	0.2	59.64	16.2
W265/98	41.8	2.8	3.0	0.4	1.1	0.2	50.08	16.1
78/84	37.7	2.8	2.8	0.4	1.2	0.2	52.3	13.3
74110	38.5	2.8	2.9	0.3	0.9	0.2	38.37	14.1
LSD @0.05	Ns	Ns	ns	ns	Ns	ns	ns	
CV (%)	7.2	8.9	3.7	17.3	15.2	19.0	15.37	

The highest RLWC (%) was obtained at genotype of W66/98 (19.1) and the smallest one at W105/98 (11.9) (Table 3). The result of 2018 revealed that, there was insignificance difference among Wollaga coffee genotypes for all parameters except plant height, which was subjected to moisture stress imposed under greenhouse condition. Even though there was no significance in score morning and noon in all cultivars, low value of noon score and morning were obtained at W-76/98, but high value observed at w-175/98. The tallest plant height was recorded at W-10/98 and 78/78 cultivars. Generally from the result, W-76 /98 cultivar was moderately droughts tolerant compared to others since it scores low stress score, medium plant height and high rate of recovery after re-watering (Tables 2 and 3). As the report of [3], coffee probably evolved as 'water spender' species. Coffee is therefore a highly environmentally-dependent crop and an increase of a few degrees of average temperature and/or short periods of drought in coffee-growing regions can substantially decrease yields of quality coffees. So, the result was similar in this finding, because the long stress period for coffee planting not recommended. This activity was also designed to identify drought tolerant coffee genotypes for moisture stress area in the third time in 2019. The analyzed result of drought tolerant coffee genotype data in this year (2019 G.C) are presented in the table below. As the result indicated that, all destructive parameters in a well-watered condition have not shown significance difference. Relative leaf water content, plant height elongation weekly, and score level of leaf at morning and noon also has shown non-significance difference in all genotypes. And above destructive data of the water stressed condition not shown significance difference in all destructive parameters. Among the treatments mean in relatively genotype W¬-76/98 have best drought tolerance potential. Different scholars reported that, coffee displays a diversity of acclimation mechanisms to avoid and endure drought and heat stresses (as well as the oxidative stress usually promoted by them), developed within the genetic bounds of the plant/species [4, 18]. When working with potted plants, [17] found out that plant water stress develops more slowly in the drought-tolerant than in the drought-sensitive clones. Morphological traits such as leaf area and root mass to leaf area ratio were not associated with that response. Instead, the much deeper root system of the tolerant clones enabled them to gain greater access to water towards the bottom of the pots and, therefore, to maintain a more favorable internal water status longer than in drought-sensitive clones. Root characteristics and growth play a crucial role in maintaining the water supply to the plant, and drought adapted plants are often characterized by deep and vigorous root systems. However, [2] observed coffee plants with extensive root system but vulnerable to drought due to their hydraulic system and stomata behavior. Physiological evaluations of some of the coffee clones perceived to be drought tolerant suggested that keeping an adequate water status, maintenance of leaf area [5, 17] and steep leaf inclinations are of utmost importance. Drought-tolerant coffee genotypes are able to maintain higher tissue water potential and water use efficiency than drought-sensitive ones under water-deficit conditions [7]. Such differences are even more evident in the field, where the development of the root system is much less restricted.

4. Conclusion

The best option for reducing the effects of climate change on Ethiopia's coffee-growing regions is to create coffee genotypes that are resistant to drought. The findings discovered that W6/98, W10/98, W13/98, W14/98, W33/98, W66/98, W76/98, W92/98, W105/98, W170/98, W175/98, W265/98, 78/84, and 74110 have not performed well in terms of extent of wilting scored value, leaf retention capacity, relative leaf water content, dry matter partitioning and root to shoot ratio. This study provides important information into selection of varieties for drought tolerance for use in the coffee sector. And in this stress period genotype W-76/98 was relatively drought tolerant among the varieties. Generally, in the three consecutive years the most growth parameter data are not statistically significance and plants are not recover after stress period because of long stress period and the environment dose not fully controlled, because of oldest greenhouse. For best justification, the time will be min=15 and max=21 days for stress as the score, relative leaf water content, and plant height elongation data indicates, because, above this day the plant fits permanent wilting point. However, a holistic approach to variety selection that incorporates drought, disease, pest, and frost tolerance may provide a stronger basis.

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Author Contribution

The author confirms sole responsibility for the following: The first author, made that; data collection, analysis, interpretation of results, and manuscript preparation, second author; made data collection, analysis and editing the manuscript, the third author and fourth author; made editing the manuscript.

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Data Availability Statement

All data are measured and taken from experimental field by authors own. And different related scholars were reviewed for supporting the study.

Highlight

The drought tolerance coffee was determined by using destructive data.

The relative leaf water content of each genotype was determined and interpreted.

Conflict of Interest

The authors declare no conflict of interests.

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