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# GROWTH RESPONSE OF HARARGHIE COFFEE ACCESSIONS TO SOIL MOISTURE STRESS AT SEEDLING STAGE AT JIMMA, SOUTH WEST ETHIOPIA

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**ABSTRACT**

Changes in climatic conditions and, thus, frequent occurrence of dry weathers are increasingly affecting coffee cultivation in Ethiopia through high seedling mortality, poor plant growth and development especially in drier coffee growing areas like Hararghie. However, very limited research has been conducted to identify the response of different coffee accession to water deficit in general and that of Hararghie genotypes in particular. This study was, therefore, conducted to determine growth responses of seedlings of fifteen Coffea arabica accessions collected from Hararghie areas. The experiment was conducted under a controlled condition in a rain shelter at Jimma Agricultural Research Center. Eight month old seedlings grown on potted nursery media were subjected to water deficit stress by withholding irrigation for 30 days followed by 21 days of re-watering. It was laid down in a RCBD with three replications. Growth responses were assessed by measuring morphological characteristics and growth rates during the stress period and rate of recovery after re-watering. Beside, the rate of stress development was visually assessed by scoring the extent of wilting early in the morning and at noon hours every other day during the stress period. Analysis of variance for repeated measurements showed that there was a significant difference among genotypes for rate of stress development, rate of recovery, root to shoot ratio and leaf thickness. Among tested accession H-981 and H-857 showed significantly lesser extent of wilting at green house and higher rate of recovery after re-watering despite their lower total dry matter yield and root to shoot ratios, whereas as, lowest rate of recovery from the stress was observed for accession H-915. Therefore, among the evaluated Hararghie coffee genotypes, accession H-981 and H-857 were found to be relatively tolerant to drought at seedling stage.



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## INTRODUCTION

Arabica coffee accounts for more than 62% of the world coffee production (Dias *et al.,* 2007) and 90% of the world coffee market (Worku and Astatkie, 2010). However, in most cases, its production and productivity is adversely affected by drought or moisture deficit. Drought stress is the major climatic limitation due to inadequate amount and erratic distribution of the seasonal rainfall in most coffee growing areas of Ethiopia. This production constraint, which is expected to become more challenging, has a profound adverse effect on the growth, yield and quality of coffee (Da Matta and Ramalho, 2006; Tesfaye *et al*. 2013).

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Water deficit has an immediate effect on plant growth, and metabolic processes ranging from photosynthesis to solute transport and accumulation are seriously affected by water stress (Hale and Orcutt, 1987). It decreases plant growth and productivity by reducing the rate of net photosynthesis (Boyer, 1976; Tesfaye *et al*., 2013) and decreasing cell division and elongation (Pugnaire *et al.,* 1999). Under extreme conditions, permanent water deficit may develop and result in permanent wilting and death of plants by dehydration (Tesfaye, 2005; Tesfaye *et al*., 2013). However, plants have evolved physiological and biochemical mechanisms as well as morphological strategies to cope with water shortages by either stress avoidance or stress tolerance (Kozlowski and Pallardy 1997; Tesfaye, 2005; Tesfaye *et al*., 2013). These responses allow them to survive and even to maintain some growth under very harsh circumstances (Navari-Izzo and Rascio, 1999). The physiology of plant responses to drought stress is complex, showing different modifications following soil drying. The dynamics of soil water depletion, changes in water demand from the atmosphere, as well as plant growth and phonological state in which water deficits develop, are sources of the wide variation in plant responses to drought (Medrano *et al.,* 1998). Moreover, drought tolerant species/varieties generally differ morphologically and/or physiologically, with mechanisms allowing greater production under restricted water supply (DaMatta, 2004). In line with this, some varieties of coffee were found to differ in their growth responses to water deficit in Uganda (Dancer, 1963), Zimbabwe (Anon, 1987), Colombia (Carr, 2001) and Brazil (Carr, 2001). The existence of high genetic diversity in Arabica coffee for yield and yield components, disease resistance, and other traits related to drought tolerance has also been reported in Ethiopia (Tesfaye, 2005). Varietal differences in biomass allocation to the stems and leaves, and leaf area were reported for coffee (Dias *et al.,* 2007). The presence of various strategies for tolerance to drought stress among populations of wild coffee growing in different agro-ecological zones of Ethiopia was also indicated (Burkhardt *et al.,* 2006). Specific leaf area, leaf dry weight and relative leaf water content have been reported to be indirect indicators of drought tolerance in coffee (Yakob *et al.,* 1995). A study on Robusta coffee showed that the root systems were deeper in drought-tolerant clones than in drought-sensitive ones (Pinheiro *et al.,* 2005) and another study associated drought tolerance with a larger root dry mass (Tesfaye *et al.,* 2015). Coffee is more sensitive to moisture stress at seedling stage (until two years old) than at young stage (after the age of two years). Therefore, it appears to be very important to identify coffee genotype with drought tolerance traits especially at the seedling stage as early detection strategy to overcome stress periods. In this study, seedling released and those promising (pipe-line) Harerege coffee genotypes were used evaluated for their performance under moisture deficit condition. The objective of the study was to identify drought tolerant genotypes for further use in the area, where moisture deficit stress is the major challenges of coffee production.

## MATERIALS AND METHODS

***Description of the experimental area:*** The experiment was conducted at Jimma Agricultural research center in south west Ethiopia for the consecutive two years. The Jimma Agricultural research center is located at $7^{0}46'$ N latitude, $36^{0}0'$ E longitude, and at an altitude of 1753m above sea level. The center receives an average annual rainfall of about 1530mm with monthly mean maximum and minimum temperatures of $25.9^{0}$C and $11.3^{0}$C, respectively.

***Experimental materials and procedure:*** Fourteen Hararghie coffee genotypes, which were selected from a large number of collections and advanced to variety verification trial for their yield, quality and disease resistance potential, were used in this study. Seeds of these released and pipe-line genotypes were collected from the verification plot planted in the field at Mechara Agricultural research center and seedling were raised in potted standard nursery seed bed with recommended coffee nursery management practices at Jimma Agricultural research center. Uniformity grown seedlings of each genotype were selected at the age of seven months (a stage of field transplanting), transferred to a rain out shelter and well managed as per the recommendation to ensure maximum rate of establishment for a month. Beside the 14 Harerege coffee genotypes (H-618/98, H-622/98, H-674/98, H-739/98, H-822/98, H-823/98, H-856/98, H-981/98, H-980/98, H-968/98, H-929/98, H-915/98, H-858/98, H-857/98) one released cultivar (74110) which is high yielding, coffee berry disease resistance and widely adaptable, was included as a check in the study. The genotypes along with the check were tested for their responses to water deficit stress in a Randomized Complete Block Design (RCBD) with three replications, where each genotype was subjected to two levels of irrigation (well-watered control and water-stressed by withholding irrigation) making treatment combination. Each experimental plot contained 30 plants. After a month of establishment period, seedlings were subjected to the respective watering treatment for 30 days and then, 10 seedlings from each plot were used to measure destructive parameters, while 20 seedlings in each water-stressed plot were re-watered for three weeks to determine the rate of recovery of each accession from severe water deficit stress.

***Data Collected***

***Stress scoring:*** Sensitivity of coffee genotypes to soil drying was assessed visually at two-day-intervals since the first wilting symptom was observed. The degree of leaf folding or wilting was scored during morning and noon hours at 7:00-8.00 am and 9:00 – 12:00 pm, respectively, using 1 to 5 scales, where 1 represent fully turgid leaves and 5 stands for severely stressed drying leaves. Each plant in a plot was assessed and the plot was given a mean stress score value. Besides, the ability of plants to recover during the night time and maintain leaf turgidity early in the morning on the next day was also considered in the evaluation.

***Rate of Recovery ($R_r$):*** After 30 days of water stressed seedlings in the stressed plots were re-watered, at three days interval for three weeks and, then, number of plants producing new growths (flushes of buds and new leaves) and these fully recovered or died were counted to estimate genotypic differences in rate of recovery from the soil drying or water stress treatment.

***Plant Growth Parameters:*** Non- destructive plant growth parameters such as plant height, number of leaves, total leaves area, stem girth, internodes length, growth rate, number of wilted seedlings and percentage of rolled leaves were recorded for seedlings in the central part of each plot.

Leaf area was calculated using the method developed by Yakob *et al.,* (1993). It was calculated as

$$L_A = L \times B \times K$$

Where, $L_A$ = Estimated leaf area ($cm^2$), L = Leaf length (cm)
B = Maximum leaf breadth (cm) and K = Correction factor = 0.7

Likewise, destructive plant growth parameters such as fresh and dry weights of shoots (stem plus leaves) and roots, root to shoot ratio and total dry matter yield were recorded by uprooting six randomly selected seedlings from the central rows of each plot. Fresh weight of plant parts was measured right after harvesting, while dry matter yield was determined after oven drying plants parts at 70-$80^{0}$C to a constant weight.

***Physiological parameters:*** Leaves immediately detached from the plant were used for the estimation of leaf relative water content (RLWC) and leaf thickness.

**Table 1. Mean morning and noon stress score values (1-5 scale) for Harerege coffee genotypes under water stressed condition on different days until 30days of treatment application**

| Variety | Morning score | | Noon score | | Mean score of water stressed (Ws) |
|---|---|---|---|---|---|
| | Well-watered (Ww ) | Water stressed (Ws ) | Well-watered (Ww ) | Water stressed (Ws) | |
| H-618/98 | 1.00 | 2.86[c-g] | 1.00 | 2.93[b-d] | 2.89 |
| H-622/98 | 1.00 | 3.01[b-f] | 1.00 | 3.67[a] | 3.34 |
| H-674/98 | 1.00 | 3.96[c-f] | 1.00 | 3.01[b-d] | 2.98 |
| H-739/98 | 1.00 | 3.31[a-c] | 1.00 | 3.31[a-c] | 3.31 |
| H-822/98 | 1.00 | 2.81[d-g] | 1.00 | 2.89[cd] | 2.85 |
| H-823/98 | 1.00 | 2.89[c-g] | 1.00 | 2.91[cd] | 2.90 |
| H-856/98 | 1.00 | 2.78[e-g] | 1.00 | 2.88[cd] | 2.83 |
| H-981/98 | 1.00 | 2.67[fg] | 1.00 | 2.78[cd] | 2.72 |
| H-980/98 | 1.00 | 3.25[a-d] | 1.00 | 3.31[a-c] | 3.28 |
| H-968/98 | 1.00 | 3.15[b-f] | 1.00 | 3.24[a-c] | 3.19 |
| H-929/98 | 1.00 | 3.43[ab] | 1.00 | 3.58[ab] | 3.50 |
| H-915/98 | 1.00 | 3.56[a] | 1.00 | 3.67[a] | 3.61 |
| H-858/98 | 1.00 | 2.82[d-g] | 1.00 | 2.95[b-d] | 2.88 |
| H-857/98 | 1.00 | 2.49[g] | 1.00 | 2.65[d] | 2.57 |
| 74110 | 1.00 | 2.79[d-g] | 1.00 | 2.92[b-d] | 2.85 |
| LSD at 0.05 | - | 0.46 | - | 0.66 | |
| CV % | - | 13.84 | - | 18.62 | |

*Figures followed by same letters with in a column are not significantly different at P = 0.05*

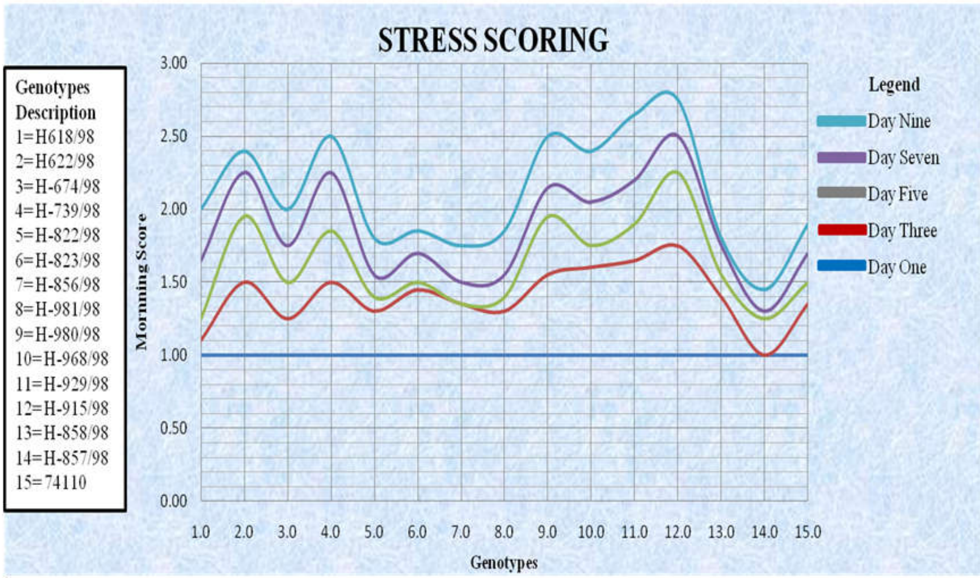


**Figure 1. The First Nine Days of Morning Hours Visual Stress Score Values for Hararghie Coffee Genotypes**

Relative water content of leaves Discs of fresh leaf tissues were weighted to get the fresh weight ($W_f$), soaked in distilled water and kept in an incubator at $5^0$C for 24 hours and reweighed to get turgid weight ($W_t$) and finally oven dried at $70^0$C for 24 hours and weighed to get the dry weight ($W_d$). Relative leaf water content was obtained using the equation given below (Baker, 1984):

$$\text{RLWC} = \frac{\text{Wf}-\text{Wd}}{\text{Wt}-\text{Wd}} \text{ x } 100$$

Leaf thickness ($L_T$) was calculated as leaf dry weight divided by leaf area ($L_T = W_d/L_A$) (Bowyer and Danson 2004)

***Statistical Analysis***

The collected data were statistically analyzed using statistical analysis system (SAS) software version 9.0 using the general linear programming procedure (GLM).

## RESULTS AND DISCUSSION

***Stress Scoring:*** The analysis of variance revealed that there was a significance difference among the genotypes morning and noon hours visual scoring. As expected, there was no significance difference between well-watered treatments, since all the plants maintained their leaf turgidity (Table 1). Accession H-857/98 and H-981/98 showed more stress tolerance symptoms, where as H-915/98, H-929/98, H-622/98, H-739/98, H-980/98 and H-968/98 were found to be sensitive to moisture stress. Besides H-857/98 and H-981/98 accessions H-856/98, H-822/98 and 74110 showed moisture stress tolerance symptoms.

However, accessions H-858/98, H-618/98, H-823/98 and H-674/98 showed a moderate level of tolerance (Table 1). The proportion of plants recovering during the night time (stress score value of 1.00 early in the morning), mean days to complete 100% wilting and days (time) taken to shown the first wilting signs after withholding irrigation also varied with accessions specially during the first week of the stress period (Figure 1 and 2). Similar results have also been reported for different genotypes of both Arabica and Robusta coffees (Maestri *et al*., 1995; Tesfaye, 2005 and Tesfaye *et al*., 2013) rice (Lilley and Fukai, 1994) and peanut cultivars (Adam and Barakbah, 1990).

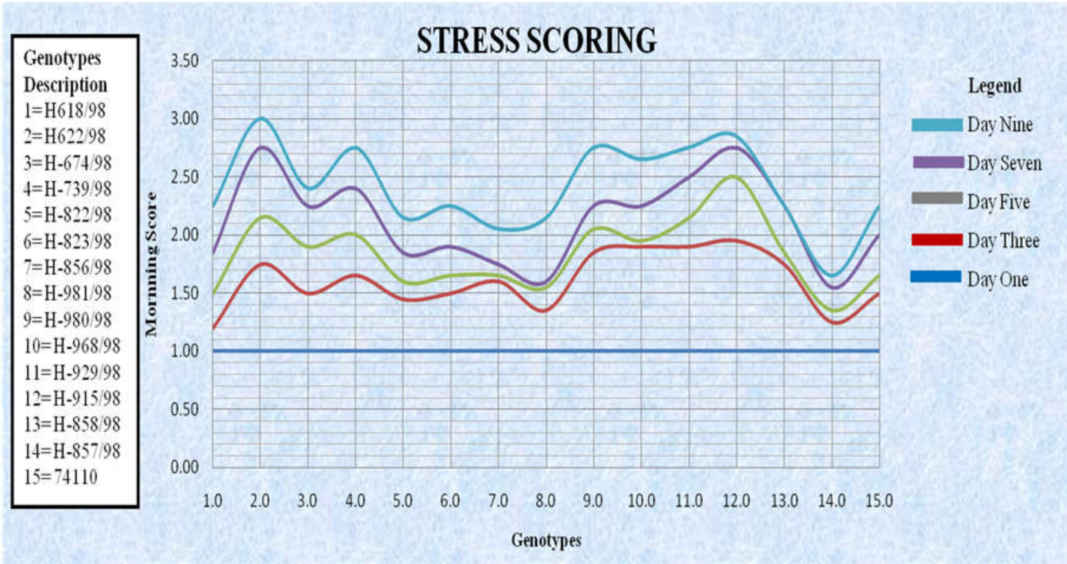


**Figure 2. The First Nine Days of Noon Hours Visual Stress Score Values for Hararghie Coffee Genotypes**

**Table 2. Leaf area and leaf thickness for Harerege coffee genotypes under water stressed condition on different days until 30days of treatment application**

| Variety | Leaf area($mm^2$) | | Leaf thickness ($g/mm^2$) | |
|---|---|---|---|---|
| | Well watered | Water stress | Well watered | Water stress |
| H-618/98 | $21.38^{a-c}$ | $15.83^{op}$ | $0.097^{j-m}$ | $0.088^{m}$ |
| H-622/98 | $19.37^{e-i}$ | $17.37^{l-n}$ | $0.145^{c-e}$ | $0.107^{i-m}$ |
| H-674/98 | $19.55^{d-i}$ | $17.41^{l-n}$ | $0.118^{g-j}$ | $0.089^{m}$ |
| H-739/98 | $21.00^{a-d}$ | $14.95^{p}$ | $0.120^{f-j}$ | $0.116^{g-k}$ |
| H-822/98 | $21.57^{ab}$ | $19.10^{e-j}$ | $0.137^{d-h}$ | $0.093^{lm}$ |
| H-823/98 | $19.05^{f-k}$ | $18.97^{f-k}$ | $0.135^{e-i}$ | $0.038^{n}$ |
| H-856/98 | $17.53^{k-n}$ | $12.95^{q}$ | $0.195^{ab}$ | $0.168^{b}$ |
| H-981/98 | $19.03^{f-k}$ | $18.07^{j-n}$ | $0.165^{bc}$ | $0.114^{h-l}$ |
| H-980/98 | $22.46^{a}$ | $20.39^{b-f}$ | $0.157^{b-d}$ | $0.113^{h-l}$ |
| H-968/98 | $20.60^{b-e}$ | $16.65^{no}$ | $0.120^{f-j}$ | $0.093^{lm}$ |
| H-929/98 | $19.66^{d-h}$ | $17.59^{j-n}$ | $0.212^{a}$ | $0.095^{k-m}$ |
| H-915/98 | $18.83^{g-l}$ | $14.99^{p}$ | $0.119^{f-j}$ | $0.052^{n}$ |
| H-858/98 | $18.39^{i-m}$ | $12.16^{q}$ | $0.165^{bc}$ | $0.127^{e-i}$ |
| H-857/98 | $22.56^{a}$ | $12.11^{q}$ | $0.227^{a}$ | $0.171^{bc}$ |
| 74110 | $18.39^{h-l}$ | $14.72^{p}$ | $0.122^{f-i}$ | $0.119^{f-j}$ |
| LSD (0.05) | 1.53 | | 0.022 | |
| CV % | 5.14 | | 10.88 | |

*Figures followed by same letters with in a column are not significantly different at P = 0.05*

### *Vegetative Growth*

***Total leaf area:*** Coffee genotypes did significantly differed in total leaf area both under well-watered and stressed conditions (Table 2). Under well watered condition accession H-857/98, H-980/98 and H-822/98 produce maximum total leaf area, while accession H-856/98 produced lesser total leaf area (Table 2). Similarly, accession H-980/98 and H-822/98 produced relatively comparable total leaf area with well-watered ones whereas, accession H-857/98, H-858/98 and H-856/98 had lesser total leaf area under moisture stressed condition (Table 2). Maintainace of such a smaller total leaf area is one of the desirable morphological traits to reduce the rate of transpiration and maintain plant water status at an optimum level at times of soil moisture stress (Tesfaye, 1995, 2005) and thus, would be used as criteria for screening crop genotypes for drought tolerance (Tesfaye, 2005).

***Leaf thickness:*** Coffee genotypes showed considerable variability in leaf thickness under both well watered and water stressed conditions (Table 2).

Higher value leaf thickness were for accession H-857/98, H-929/98 and H-856/98, while values of lower for accession H-618/98, H-674/98, H-915/98 and H-739/98 under well watered condition (Table 2). Similarly, H-857/98 followed by H-856/98, had more leaf thickness and H-823/98 and H-915/98 had lower value under water stressed condition (Table 2). In general, leaf thickness decreased with water deficit stress in all coffee genotypes. However, some accessions such as H-857/98 and H-856/98 minimum reduction in leaf thickness due to the water stress. In some case, it was observed that lower total leaf area is associated with relatively higher leaf thickness as the case with H-857/98 and H-856/98, which may be an important drought avoidance mechanism.

### *Dry Matter Yield and Partitioning*

***Shoot dry matter yield:*** There was a significance interaction effect for shoot dry matter yield due to watering and coffee genotypes factor. Accordingly, the highest shoot dry weight was observed for accession H-857/98, followed by H-929/98 whereas, the minimum was observed from accession H-674/98 followed by H-858/98 for well watered.

**Table 3. Root, shoot and total dry matter yield and root to shoot ratio for Harerege coffee genotypes under water stressed condition on different days until 30days of treatment application**

| Variety | Root dry weight (g/plant) | | Shoot dry matter yield (g/plant) | | Total dry matter yield (gm/plant) | | Root to shoot ratio | |
|---|---|---|---|---|---|---|---|---|
| | Well water | Water stress | Well water | Water stress | Well water | Water stress | Well water | Water stress |
| H-618/98 | $3.51^{f-h}$ | $1.36^{m-p}$ | $5.99^{g-i}$ | $3.71^{lm}$ | $9.50^{fg}$ | $5.07^{n}$ | $0.584^{e-g}$ | $0.366^{l-n}$ |
| H-622/98 | $2.98^{h-j}$ | $1.70^{k-n}$ | $6.11^{g-i}$ | $3.53^{m}$ | $9.09^{gh}$ | $5.23^{mn}$ | $0.492^{g-j}$ | $0.487^{g-j}$ |
| H-674/98 | $3.82^{d-f}$ | $1.41^{l-p}$ | $4.52^{j}$ | $2.72^{n}$ | $8.33^{hi}$ | $4.12^{op}$ | $0.848^{a}$ | $0.518^{f-i}$ |
| H-739/98 | $4.57^{bc}$ | $1.67^{k-n}$ | $6.84^{d-f}$ | $4.67^{j}$ | $11.42^{b}$ | $6.34^{kl}$ | $0.670^{c-e}$ | $0.358^{l-n}$ |
| H-822/98 | $4.35^{cd}$ | $1.94^{kl}$ | $5.72^{h-i}$ | $4.11^{j-l}$ | $10.07^{d-f}$ | $6.04^{lm}$ | $0.760^{a-c}$ | $0.472^{h-k}$ |
| H-823/98 | $4.21^{c-e}$ | $1.09^{pq}$ | $7.07^{d}$ | $3.82^{k-m}$ | $11.23^{bc}$ | $4.91^{no}$ | $0.605^{d-f}$ | $0.286^{n-p}$ |
| H-856/98 | $4.05^{c-e}$ | $2.67^{j}$ | $7.71^{bc}$ | $6.41^{e-g}$ | $11.76^{b}$ | $9.08^{gh}$ | $0.525^{f-h}$ | $0.416^{j-n}$ |
| H-981/98 | $2.75^{ij}$ | $1.64^{k-o}$ | $7.37^{cd}$ | $4.32^{jk}$ | $10.12^{d-f}$ | $5.97^{lm}$ | $0.382^{k-m}$ | $0.375^{k-n}$ |
| H-980/98 | $3.63^{fg}$ | $1.89^{k-m}$ | $6.93^{de}$ | $4.42^{j}$ | $10.56^{cd}$ | $6.31^{l}$ | $0.526^{f-h}$ | $0.429^{h-m}$ |
| H-968/98 | $3.77^{e-g}$ | $1.06^{pq}$ | $5.88^{g-i}$ | $3.53^{m}$ | $9.65^{e-g}$ | $4.58^{n-p}$ | $0.641^{de}$ | $0.301^{no}$ |
| H-929/98 | $6.23^{a}$ | $2.07^{k}$ | $8.09^{b}$ | $4.20^{j-l}$ | $14.32^{a}$ | $6.28^{l}$ | $0.769^{ab}$ | $0.495^{g-j}$ |
| H-915/98 | $4.99^{b}$ | $1.10^{o-q}$ | $6.09^{g-i}$ | $2.66^{n}$ | $11.08^{bc}$ | $3.76^{pq}$ | $0.821^{a}$ | $0.423^{i-m}$ |
| H-858/98 | $2.95^{ij}$ | $0.59^{q}$ | $4.22^{jk}$ | $2.67^{n}$ | $7.17^{jk}$ | $3.26^{q}$ | $0.697^{b-d}$ | $0.220^{op}$ |
| H-857/98 | $2.98^{ij}$ | $2.06^{k}$ | $8.68^{a}$ | $6.27^{f-h}$ | $11.60^{b}$ | $9.50^{fg}$ | $0.837^{a}$ | $0.696^{b-d}$ |
| 74110 | $3.22^{g-i}$ | $1.85^{k-m}$ | $7.20^{cd}$ | $5.55^{i}$ | $10.42^{c-e}$ | $7.40^{j}$ | $0.448^{h-l}$ | $0.334^{mn}$ |
| LSD (0.05) | 0.55 | | 0.58 | | 0.86 | | 0.097 | |
| CV % | 12.48 | | 6.57 | | 6.51 | | 7.09 | |

On the other hand, under water-stressed condition, higher root dry matter yield was recorded for H-856/98, H-857/98 and 74110, medium for H-739/98, H-980/98, H-981/98, H-929/98 and H -822/98 and lowest for H- 858/98 and H-915/98 (Table 3). Comparison of stressed and well-watered plots showed that the maximum shoot dry weight loss due to the stress was measured for H-915/98 (56.32%), H-929/98 (48.08%), H-823/98 (45.97%), H-622/98 (42.23%) and H-981 (41.38%), while the minimum reduction was observed for H-856/98 (16.86%), 74110 (22.92%), H-857/98 (27.76%) and H-822/98 (28.15%) (Table 3). Such reduction in shoot growth under moisture stress conditions has also reported for cotton (Fernández *et al.,* 1996) and Sorghum (Muhammad *et al*., 2009**,** Al-Hussaini *et al*., 2013).

### *Root dry matter yield*

There was a significant interaction variation among the coffee genotypes for root dry biomass under well watered and water stress conditions. Accordingly, the highest root dry weight was observed for accession H-929/98, followed by H-915/98 whereas, the minimum was observed from accession H-981/98 followed by H-858/98 for well watered. On the other hand, under water-stressed condition, higher root dry matter yield was recorded for H-856/98 and H-929/98, medium for H-622/98, H-739/98 and H-980/98 and lowest for H- 858/98, H-823/98 and H-968/98 (Table 3). Comparison of stressed and well-watered plots showed that the maximum root dry weight loss due to the stress was measured for H-858/98 (80.00%), H-9915/98 (77.96%), H-823/98 (74.11%), H-968/98 (71.88%) and H-929/98 (66.77%), while the minimum reduction was observed for H-857/98 (29.69%), H-856/98 (34.07%), H-981/98 (40.36%), and H-622/98 (42.95%) (Table 3). This implies that the low reduction in root dry weight due to water stress may be associated with differences in genetic potential of the accessions to partition more dry matter to roots than to the shoot system under any circumstances (Tesfaye, 2005; Tesfaye *et al.,* 2008, 2013) as the case with accession H-857/98, which maintained its root development to extract water from deeper soil layers regardless of the adverse soil moisture condition but the result was contradict with the finding of Dias *et al.,* (2007), showing that coffee plants may not shift biomass allocation to roots as response for drought stress.

***Total dry matter yield:*** As shown in Table 3, there were significant differences among coffee genotypes in total dry biomass yield of watered and water stressed treatments. Under well watered treatment accession H-929/98 (14.32g), H-856/98 (11.76g), H-857/98 (11.60g), H-739/98 (11.42g) and H-823/98 (11.23g) produced maximum total dry biomass and the minimum was obtained from H-858/98 (7.17g) and H-674 (8.33 g). Among the water stressed treatment accession H-857/98(9.50g), H-856/98 (9.08g) produced comparable or more closer to the value exhibited by well water plots, while lower values were recorded for H-858/98 (3.26g), H-915/98 (3.76g) and H-674/98 (4.12g). The difference between well water and water stress plots was much lower for accession H-857/98 (18.10%) and H-856/98 (22.79%) (Table 3). This implies that total dry biomass yield of these accessions was not much affected by water deficit stress as compared to well watered treatments. Such relatively less difference between well watered and water stressed plots of a genotypes could be attributed to the inherent potential of the genotype to produce and accumulate more assimilates and, thus, total dry matter yield even with limited water supply and stomatal conductance and lower photosynthetic rate under soil moisture deficit condition. And this can be regarded as one of the adaptive or tolerance mechanisms to water deficit stress (Tesfaye, 2005; Tesfaye *et al*., 2013 and Abel *et al*., 2014).

***Root to shoot ratio:*** The root to shoot ratio was significantly varied among the coffee genotypes under both stressed and non-stressed conditions. Accordingly, the highest root to shoot ratio was recorded for H-674/98 (0.848), H-857/98 (0.837) and H-915/98 (0.821) under well water condition and also, H-857/98 (0.696) and H-674/98 (0.518) under water stressed condition (Table 3). While H-981/98 (0.382) and H-622/98 (0.492) under well water condition exhibited lower root to shoot ratio (Table 3). In addition, the minimum root to shoot ratio was recorded for H-858/98 (0.220) and H-823/98 (0.286) under water stressed condition (Table 3). Partitioning of more dry matter to roots and, thus, higher root to shoot ratio especially under soil moisture stress condition has been reported for different crops including coffee (Tesfaye, 2005), sorghum (Bibi *et al.,* 2012) and cotton (Pace *et al.,* 1999). On the present study, some of the coffee genotypes, such as H-857/98 and H-674/98 had relatively higher root to shoot ratio under well-watered and water stressed condition (Table 3).

**Table 4. Relative leaf water content and rate of recovery for Harerege coffee genotypes under water stressed condition on different days until 30days of treatment application**

| Variety | Relative leaf water content (g/g) | | Rate of recovery (%) | |
|---|---|---|---|---|
| | Well watered | Water Stress | Well watered | Water Stress |
| H-618/98 | 84.30$^{f}$ | 74.10$^{j}$ | 100 | 82.83$^{d}$ |
| H-622/98 | 91.60$^{a}$ | 81.20$^{g}$ | 100 | 98.50$^{a}$ |
| H-674/98 | 86.43$^{de}$ | 76.30$^{i}$ | 100 | 88.23$^{b}$ |
| H-739/98 | 84.93$^{ef}$ | 73.10$^{jk}$ | 100 | 86.02$^{b-d}$ |
| H-822/98 | 83.87$^{f}$ | 70.10$^{lm}$ | 100 | 84.42$^{cd}$ |
| H-823/98 | 86.60$^{de}$ | 73.20$^{jk}$ | 100 | 96.83$^{a}$ |
| H-856/98 | 85.07$^{ef}$ | 71.80$^{kl}$ | 100 | 88.83$^{b}$ |
| H-981/98 | 76.90$^{i}$ | 65.40$^{o}$ | 100 | 75.22$^{f}$ |
| H-980/98 | 85.63$^{ef}$ | 67.10$^{no}$ | 100 | 72.25$^{f}$ |
| H-968/98 | 89.97$^{a-c}$ | 79.10$^{h}$ | 100 | 86.10$^{bc}$ |
| H-929/98 | 91.60$^{a}$ | 84.30$^{f}$ | 100 | 87.52$^{bc}$ |
| H-915/98 | 88.10$^{cd}$ | 67.4$^{n}$ | 100 | 84.50$^{cd}$ |
| H-858/98 | 90.30$^{ab}$ | 69.70$^{m}$ | 100 | 79.58$^{e}$ |
| H-857/98 | 89.80$^{a-c}$ | 84.30$^{f}$ | 100 | 100.00$^{a}$ |
| 74110 | 89.23$^{bc}$ | 70.20$^{lm}$ | 100 | 100.00$^{a}$ |
| LSD (0.05) | 1.96 | | - | 3.17 |
| CV | 4.5 | | - | 8.18 |

*Figures followed by same letters with in a column are not significantly different at P = 0.05*

Therefore, this result may probably show that, in addition to other morphological, physiological and biochemical mechanisms, root to shoot ratio can also be used as a selection criteria during screening genotypes for drought tolerance (Cook 1985; Pace *et al*., 1999; Worku and Astatkie 2010).

### *Relative Leaf Water Content*

The present study revealed that there is a significant difference among genotypes for relative leaf water contents. From the result, all the coffee genotypes showed an average relative water content ranging from 65.4% (H-981/98) – 84.3% (H-857/98) under water stress conditions and from 76.9 (H-981/98) – 91.60% (H-622/98) under well watered conditions (Table 4). Comparison of stressed and well-watered plots showed that the maximum relative leaf water content loss due to the stress was measured for H-915/98 (20.7%), H-858/98 (20.6%), 74110 (19.03) and H-980/98 (18.53%) while, the minimum reduction was observed from H-857/98 (5.5%) followed by H-929/98 (7.3%) (Table 4). In the present study, lower rate of stress development coupled with higher plant water status (as the case with accession H-857/98 and H-929/98) or lower value for both parameters (such as in accession in accession H-981/98) could be attributed to some drought tolerance mechanisms such as osmotic adjustment, which maintain turgidity of leaves, despite the water stress (Tesfaye, 2005). On the other hand, maintainace of plant water status at higher level with relatively sever leaf folding and wilting symptoms could also be regarded as one of the drought avoidance strategies in crop plant (Wiersma and Christie, 1987; Davies *et al*., 2000, Tesfaye 2005; Tesfaye and Ismail, 2008).

### *Rate of Recovery*

It was observed that there is a significant difference between the coffee accessions for rate of recovery after re-watering. Generally, all the accessions recovered well except H-980/98, H-981/98 and H-858/98 after resuming irrigation however, of the accessions seriously affected by moisture stress, only H857/98 and 74110 recovered quickly from the effect of moisture stress, while the rate of recovery H-980/98 recovered more slowly (Table 4). In line with this Moore (1987) has reported that plant recovery ability after drought is more important than drought tolerance. Therefore, this may implies that some accessions such as H-622/98, H-929/98 and H-915/98 regarded as drought sensitive based on their higher mean stress score (> 3.2) but showed the high rate of may be considered as potential genotypes for further study. This observation is also in agreement with the finding of Sundara (1987), who reported that recovery can be rapid, with normal growth resumed, if moisture stress has not adversely affected plant biomass and root growth.

### *Summery and conclusion*

In Ethiopia, there exists a wide genetic diversity among Arabica coffee cultivars for yield potential, quality and resistance to diseases. However, in spite of periodic and frequent occurrence of drought, little attention has been paid to study the response of coffee cultivars to moisture deficit stress. In view of this, fifteen Arabica coffee accessions were evaluated for their response to soil moisture stress at seedling stage of growth. There was a significant difference among the genotypes for sensitivity to water stress imposed under rain shelter at Jimma Agricultural Research Center. Accession H-915/98 and H-929/98 exhibited significantly higher mean stress score value whereas, H-857/98 and H-981/98 showed lower value. Total dry matter yield and root to shoot ratio were higher for accession H-857/98. Similarly, relative leaf water content and leaf thickness of accession H-857/98 was significantly higher while rate of recovery were higher for accession H-857/98 and 74110. In general, among the Harerege coffees tested in this experiment, accession H-857/98 and H-856/98 showed least stress score, higher total dry matter yield, higher relative leaf water content, better root to shoot ratio and higher rate of recovery after re-watering.

Therefore, it was concluded that accession H-857/98 and H-856/98 are the most promising genotypes for production especially drier coffee growing region of Ethiopia, such as Harerege areas.

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