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Identification of drought tolerant finger millet (*Eleusine coracana*) lines based on morpho-physiological characteristics and grain yield

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Drought stress contributes significantly to economic yield losses in finger millet (*Eleusine coracana*) production. This study evaluated morpho-physiological and agronomic traits among 25 finger millet genotypes for drought tolerance under field conditions. Out of the 25 genotypes, 24 were advanced lines preselected for drought tolerance from ICRISAT, KALRO and Egerton University seed units and one check cultivar P-224. The study was conducted at two drought endemic locations (Koibatek, Baringo County and Soin, Kericho County) in Kenya during 2020 cropping season using 5 × 5 triple Lattice design with three replicates. Results revealed that genotype was significant (*P*<0.001) for seedling vigour, peduncle length, plant height, number of productive tillers number of fingers and harvest index (*P*<0.01) and finger length (*P*<0.05). Location was significant (*P*<0.001) for plant stand, number of fingers, finger length and days to 50% flowering and peduncle length. The interaction effect between genotype and location was significant (*P*<0.001) for number of fingers, yield and harvest index. There were significant and positive correlation between ET and HI (*r = 0.537**), ET and grain yield (*r = 0.611****), root relative water content (RRWC) and HI (*r=0.442****). Lines ICFX 1420314-2-1-1-1 (7), KNE 814 X Ex Alupe (P) P8-1-1-1-1 (24) and ICFX 1420415-3-1-1-2 (14) were identified as the most suitable genotypes for drought tolerance based on their superior morpho-physiological traits to withstand soil water deficit with higher grain yield. These identified genotypes can be recommended to farmers and incorporated in breeding programs to improve production in the semi-arid areas.**

Key words: Finger millet, drought tolerant, genotypes, morpho-physiological traits, agronomic traits.

INTRODUCTION

Finger millet is one of the most nutritious food crops extensively grown in Asia and Africa (Rodríguez et al., 2020). The crop covers 12% of millets that are in the world and is ranked fourth after sorghum, pearl millet and foxtail millet (Vetriventhan et al., 2016). In arid and semi-arid regions, soil moisture stress is the major abiotic constraint that adversely affects crop productivity (Choudhary and Padaria, 2015). Finger millet has been

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Table 1. Climatic conditions of ATC Koibatek, Baringo County and ATC Soin, Kericho County.

Location	Agro-ecological zone	Altitude (masl)	Rainfall (mm per annum)	Temperature (^{0}C)		Soil type
				Min.	Max.	
Agricultural Training Centre, Koibatek	Upper midland zone 4 (UM 4)	1890	500-800mm	10.9-18.2	24.3-28.8	Vitricandosols
Agricultural Training Centre, Soin	Lower midland zone 3 (LM 3)	2002	700-1400	12-15	21-28	Volcanicrocks

Source: Jaetzold et al. (2012). Note: masl: metres above sea level

reported to be drought resilient as compared to other cereals such as maize (*Zea mays*) (Gupta et al., 2017).

Studies carried out on finger millet genotypes showed that there exists genotypic variation in the degree of drought tolerance among different varieties (Bartwal et al., 2016; Bartwal and Arora 2017). Finger millet is well adapted to temperature ranges of 11 to 28 ºC. However, it can thrive well under hot conditions where temperatures are as high as 35ºC. Although finger millet is drought tolerant, its growth is adversely affected by both intermittent and terminal droughts. The crop is largely grown by subsistence farmers who rely on rain fed agriculture, hence prone to the risk of economic yield loss due to drought.

Feeding the fast-growing human population with balanced nutritional diet under unpredictable severe weather events is a challenging task globally. The climate change crisis is expected to cause shifts in food production and yield loss, causing a severe threat to food security (Dhankher and Foyer, 2018). A key strategy to adapt to a changing climate is to develop and promote elite germplasms with stable yields that can survive under changing weather conditions (Bhat et al., 2018). There exist great potential in underutilized crops such as finger millet that are well adapted to extreme weather conditions and can act as an alternative food resource towards ensuring food and nutritional security (Mabhaudhi et al., 2019). Despite the many advantages offered by the cultivation of finger millet in Africa including, Kenya, there is limited research on tolerance to drought in finger millet. The production of finger millet is restricted to low yielding and poorly adapted genotypes (Mgonja et al., 2013). However, there is great potential to increase production through screening and selection of well adapted genotypes to low soil moisture with better grain yield.

Numerous morpho-physiological and biochemical traits such as shoot length, root length, shoot to root ratio, relative water content and stomatal conductance among others are considered important under drought stress conditions (Murtaza et al., 2016). In a related study, Mude et al. (2020) reported that water use efficiency, harvest index and biomass are important for resilience to drought in cereal crops. In contrast, decrease in root growth, relative water content and lipid peroxidation was found to show a considerable level of tolerance to drought stress (Mukami et al., 2020). Finger millet improvement in Kenya in the past has laid emphasis on selecting for high yielding lines with little regard on drought tolerance traits (Mukami et al., 2020). Drought tolerant finger millet lines have not yet been developed in Kenya where arid and semi-arid land covers 80%. Therefore, the present investigation was conducted to identify finger millet lines with enhanced tolerance to drought based on morpho-physiological traits with the intention to be used in future breeding programmes to develop improved drought tolerant cultivars.

MATERIALS AND METHODS

Description of the experimental sites

The study was conducted in the field at two locations; Agricultural Training Centre (ATC) Koibatek in Baringo County and ATC Soin in Kericho County in 2020. ATC Koibatek is located at 1°35'S, 36°66'E and elevated at an altitude of 1890 meters above sea level and falls in the Upper Midland zone 4 (UM4) agro-ecological zone (AEZ). ATC Soin is located between latitude 0^o 23'S and longitude 35º 02'E with an altitude of about 2002 m above the sea level and falls in the Lower Midland zone 3 (LM3) AEZ. The climatic conditions of the respective study sites are represented in Table 1.

Finger millet genotypes

The planting material used in this study consisted of 25 genotypes (24 advanced finger millet lines and one commercial check cultivar, P224). These genotypes were obtained from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Kenya Agricultural and Livestock Research Organization (KALRO) and Egerton University Seed Units (Table 2).

Experimental design and agronomic practices

The field experiment was conducted under rain-fed conditions during the long rainy season (June to November 2020). Land preparations were done according to ICRISAT recommendations

Table 2. List of finger millet genotypes used in the study.

Entry no.	Genotype	Source of germplasm
1	EX Alupe(G) X KNE 814 P1-1-2-3-1	ICRISAT
2	EX Alupe (G) X KNE 814 P4-2-1-4-1	ICRISAT
3	ICFX 1420311-3-6-1-2	ICRISAT
4	ICFX 1420312-3-2-1-1	ICRISAT
5	ICFX 1420313-1-2-3-1	ICRISAT
6	ICFX 1420313-3-2-1-1	ICRISAT
7	ICFX 1420314-2-1-1-1	ICRISAT
8	ICFX 1420314-6-2-1-1	ICRISAT
9	ICFX 1420315-2-2-1-2	ICRISAT
10	ICFX 1420342-3-1-2-2	ICRISAT
11	ICFX 1420396-5-5-1-1	ICRISAT
12	ICFX 1420414-7-12-1-1	ICRISAT
13	ICFX 1420414-7-4-1-1	ICRISAT
14	ICFX 1420415-3-1-1-2	ICRISAT
15	ICFX 1420419-3-2-1-1	ICRISAT
16	ICFX 1420420-9-6-3-1	ICRISAT
17	ICFX 1420424-2-1-1-1	ICRISAT
18	ICFX 1420431-1-3-1-2	ICRISAT
19	ICFX 1420431-2-5-1-1	ICRISAT
20	ICFX 142036-3-3-1-1	ICRISAT
21	ICFX 1420437-1-4-1-1	ICRISAT
22	ICFX 1420448-1-1-1-1	ICRISAT
23	KNE 814 X Ex Alupe (P) P7-9-3-2-2	EGERTON UNIVERSITY SEED UNIT
24	KNE 814 X Ex Alupe (P) P8-1-1-1-1	EGERTON UNIVERSITY SEED UNIT
25	P224- check	KALRO

(ICRISAT, 1992). The seeds were planted on June 13, 2020 and June 14, 2020 in Soin and Koibatek locations, respectively. Lattice design with five blocks consisting of five plots per block with three replications was used to carry out the experiment. The plot size was 4 m^2 with four rows, 2-m length. The seeds were drilled by hand at a depth of 2 cm in rows, 15 cm apart, with seed rate of 3.2 kg ha^{-1}. At planting, Di-ammonium phosphate (DAP) fertilizer was applied at 20 kg ha^{-1} to each experimental plot to supply a basal fertilizer dose of 10 kg P ha^{-1}. Two weeks after emergence, the plants were thinned to one plant per hill. Topdressing was done using Calcium ammonium nitrate (CAN) at the rate of 30 kg ha^{-1} to supply 8 kg N ha^{-1}, applied in three split doses, (50% two weeks after emergence, 25% at five leaf and 25% at the time of flowering). Weeding was done twice by hand, two weeks after emergence and two weeks after the first weeding. Insect pest and disease control was carried out as required.

Data collection

Three plants were randomly selected and tagged from the two middle rows in each experimental plot and data collected on morphological, physiological, yield and yield parameters. For the morphological parameters, seedling vigour, plant height, total number of tillers and productive tillers, finger number and finger size were recorded following the International Board for Plant Genetic Resources (IBPGR, 2011) for finger millet. Root to shoot ratio, total biomass (measured as sum mass of the weight of above ground parts of the plant and root), and harvest index (measured as ratio of grain yield to the total biomass) were taken at harvesting where the plants were uprooted and the biomass was divided into shoot and root. The shoot was oven dried; whereas the root was washed using tap water and dried in the oven at 70 ºC for 24 h. The biomass dry weight was taken using an electronic balance.

Physiological traits included leaf area index (LAI), leaf chlorophyll content (LCC), photosynthetic rate, net leaf exchange rates (CER), stomatal conductance, transpiration rate and relative water content (RWC). Leaf area index (LAI) was measured from the selected plants in each experimental plot using an AccuPAR LP-80 Ceptometer [Simultaneous incident (above canopy) and transmitted (below canopy) photosynthetically active radiation (PAR) measurements were recorded] as follows: LAI was then calculated using the formula: $\frac{1}{k} - \ln t/i$ (Francone et al., 2014).

Where *k* the finger millet extinction coefficient = 0.5, *t* is the transmitted light and *i* is the incident light. Light intensity (LI) was also calculated using the formula:

$$\frac{Incident\ light - transmitted\ light}{Incident\ light}$$

Leaf chlorophyll content was taken using the chlorophyll fluorescence meter at the vegetative stage, flowering stage and grain filling stage. Photosynthetic rate was recorded as µmole CO_2 m^{-2} s^{-1} using an Infrared Gas Analyser. Stomatal conductance and instantaneous transpiration on the uppermost fully expanded leaves were measured at booting stage using the Infrared Gas Analyser (IRGA). Net leaf CO_2 exchange rates were measured on selected leaves using a portable Infrared Gas Analyser, fitted with Parkinson Leaf chamber. The parameters measured by Infrared Gas Analyser (IRGA) and their units are Photosynthetic rate (P, µmol CO_2 $m^{-2}s^{-1}$), Stomatal Conductance (GS, mol H_2O $m^{-2}s^{-1}$) and Transpiration rate (E, mmol H_2O $m^{-2}s^{-1}$). Relative water content (RWC) was calculated using formulas described by Barrs (1968) in (Mude et al., 2020) as follows:

$$RWC = \frac{(Fw - Dw)}{Fw} \times 100$$

Where RWC = relative water content, Fw = fresh weight and Dw = dry weight.

Statistical analyses

The computer program Statistical Analysis Software (SAS) version 9.4 was used for statistical analysis. The data were analysed using the standard procedure of analysing lattice design as described by Gomez and Gomez (1984) using the following statistical model.

$$Y_{ijkl} = \mu + B_i + \tau_j + \gamma_k + \varepsilon_{ijkl}$$

Where Y_{ijkl} denotes the value of the observed trait in the i^{th} block for j^{th} treatments within k^{th} replicate (superblock), μ = general mean, B_i = effect of i^{th} incomplete block, τ_j = effect of j^{th} treatment in the i^{th} incomplete block within the k^{th} replicate, γ_k = effect of k^{th} replicate, ε_{ijkl} = experimental error.

The means of treatments and interactions were separated using Tukey's Honestly Significant Difference at 5% probability level (*P*<0.05).

$$W = q\,[\alpha, P, fe] \times \sqrt{\frac{MSE}{r}}$$ (Gomez and Gomez, 1984)

Where; W= Critical difference, P= number of treatment means, fe=error degrees of freedom, α= level of significance, MSE =mean square error and **r**= number of replicates.

RESULTS

Mean squares and mean performance of the genotypes for agronomic traits

Significant (*P*<0.001) main effects were observed due to genotype for seedling vigour, peduncle length, plant height and number of productive tillers. Genotype effect was also significant for the number of fingers and harvest index at *P*<0.01 and for finger length at *P*<0.05 (Table 2). Effect due to location was significant for plant stand count, number of fingers, finger length and days to 50% flowering at *P*<0.001. Location was also significant for the peduncle length and yield at *P*<0.05 level. Genotype x location interaction had significant effects on number of fingers, grain yield and harvest index at *P*<0.001 (Table 2).

Figure 1 illustrates the variation for yield performance of the lines across the two study locations. Most of the genotypes were scattered closed to the origin indicating low adaptability to drought stress in the two locations. However, genotype KNE 814 X Ex Alupe (P) P8-1-1-1-1 was the most adapted to Soin while genotypes ICFX 1420314-2-1-1-1 and ICFX 1420437-1-4-1-1 were the most adapted in Koibatek. Line KNE 814 X Ex Alupe (P) P8-1-1-1-1 had the shortest days to 50% flowering with lowest plant height in Soin (Table 5). Line ICFX 1420424-2-1-1-1 had the shortest days to 50% flowering in Koibatek. The difference between the earliest flowering 88 days (ICFX 1420342-3-1-2-2), and latest 95 days (ICFX 1420419-3-2-1-1) was 6 days in Koibatek and early flowering 71 days (ICFX 1420431-2-5-1-1) and late flowering 77 days (ICFX 1420414-7-12-1-1 and ICFX 1420314-2-1-1-1) in Soin was 6 days.

Generally, Koibatek had better grain yield performance compared to Soin among the evaluated finger millet lines. In Koibatek the highest grain yield was observed in line ICFX 1420437-1-4-1-1 (358.50 Kg ha^{-1}) and lowest in line EX Alupe (G) X KNE 814 P4-2-1-4-1 (256.50 Kg ha^{-1}) compared to the check P224 (309.58 Kg ha^{-1}) (Table 3). In Soin line KNE 814 X Ex Alupe (P) P8-1-1-1-1 had the highest grain yield (333.30 Kg ha^{-1}) and lowest in line ICFX 1420424-2-1-1-1 (166.00 Kg ha^{-1}) compared to the check P224 (246.40 Kg ha^{-1}) (Table 4). Location was not significant for plant height however; Soin had the highest mean plant height of 75.38 cm compared to Koibatek which had 74.40 cm. In Soin line EX Alupe(G) X KNE 814 P1-1-2-3-1 had the lowest plant height of 50.17 cm whereas line KNE 814 X Ex Alupe (P) P8-1-1-1-1 had the highest plant height of 87.33cm (Table 4). In Koibatek, lowest plant height was observed in line EX Alupe(G) X KNE 814 P1-1-2-3-1 (51.33 cm) and highest in line ICFX 1420396-5-5-1-1 (84.00 cm) (Table 3). For the number of productive tillers, lines EX Alupe (G) X KNE 814 P1-1-2-3-1, ICFX 1420314-2-1-1-1, ICFX 1420315-2-2-1-2 and ICFX 1420437-1-4-1-1 had the highest with an average of 7 tillers both in Koibatek and Soin (Tables 3 and 4).

Morpho-physiological traits

Genotype effect was significant for leaf area index (*P*<0.05), evapotranspiration rate, leaf RWC, root RWC, stomatal conductance, chlorophyll content, CO_2 assimilation and photosynthetic rate at (*P*<0.001). However, genotype effect was not significant for light intensity (Table 5). The effect of location was significant for leaf area index, light intensity and evapotranspiration rate at (*P*<0.05). Interaction effect due to genotypes and location were significant for leaf area index, light intensity, evapotranspiration rate, root RWC, stomatal conductance, chlorophyll content and photosynthetic rate at (P<0.001) and shoot biomass at (P<0.05). Generally, root biomass was highest in Soin (44.10) compared to Koibatek

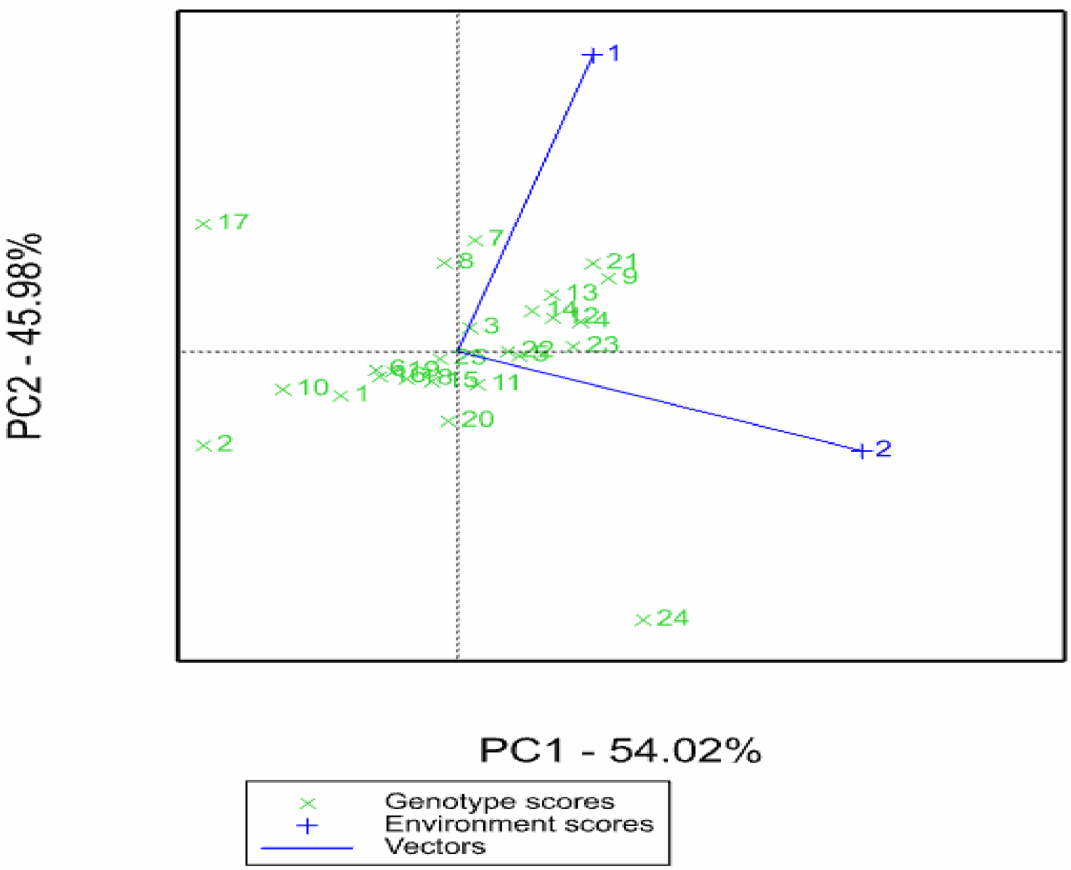

Figure 1. Scatter plot of seed yield for 25 genotypes evaluated for one season at two drought prone locations, ATC Koibatek (1) and ATC Soin (2). Genotypes are presented in green while the locations are blue.

(38.62). In the two locations line ICFX 1420314-2-1-1-1 was consistent with highest root biomass in Koibatek (52.81) and Soin (59.81). Lines ICFX 1420415-3-1-1-2, ICFX 1420424-2-1-1-1 and KNE 814 X Ex Alupe (P) P8-1-1-1-1 had high photosynthetic rate across the two locations with an average rate above 5 µmol 〖CO〗 _2 m^(-2) s^(-1). Stomatal conductance was highest in line ICFX 1420415-3-1-1-2 with an average above 7 mol H〗 _2Om^(-2) s^(-1)) and lowest in line ICFX 1420314-6-2-1-1 with an average of 0.14 mol 〖H〗 _2Om^(-2) s^(-1)) both in Koibatek and Soin. However, there were no significant difference for CO2 assimilation and chlorophyll content across the two locations, the finger millet lines varied significantly. CO_2 assimilation was highest in line KNE 814 X Ex Alupe (P) P7-9-3-2-2 in Koibatek (532.33) and Soin (509.67) lowest in line ICFX 1420420-9-6-3-1 with an average of 307.33 both in Koibatek and Soin. Chlorophyll content was highest in line ICFX 1420314-2-1-1-1, ICFX 1420415-3-1-1-2 and KNE 814 X Ex Alupe (P) P8-1-1-1-1 with an average above 13.00 both in Koibatek and Soin (Tables 6 and 7).

Correlation analysis

There were significant (r = 0.537***, r = 0.650*** and r = 0.611***) positive correlations between evapotranspiration rate and harvest index, 1000 seed weight and grain yield, respectively. However, significant negative correlations were registered between evapotranspiration and leaf area index (r = -0.544***) and evapotranspiration and light intensity (r= -0.505***). Root relative water content had a significant and positive correlations for harvest index (r = 0.442***) and grain yield (r = 0.191*). There were significant negative correlations between root relative water content and number of fingers (r = -0.243**), finger length (r = -0.242***) and root biomass (r = -0.603***). Leaf area index had significant and positive correlation for shoot biomass, root biomass, total biomass and grain yield (*P<0.01*). Light intensity was also significant and positively correlated to shoot biomass, root biomass, total biomass and grain yield (*P<0.01*) (Table 8). Table 9 show the Pearson's correlation coefficients for selected agronomic and morpho-

Table 3. Mean squares for agronomic traits for 25 finger millet genotypes evaluated in Koibatek and Soin.

Source of variation	Df	SV (#)	NF (#)	FL (cm)	PL (cm)	PH (cm)	NPT (#)	Days to 50% FL	Yield (kg ha^{-1})	1000 gw (g)	HI
Replication	2	0.14	1.62	1.06	0.03	31.96	0.07	2.66	3592.09	0.07	0.18
Genotype G)	24	0.11***	2.33**	3.99*	3.93***	207.73***	5.48***	4.98	2464.27	0.03	1.48***
Location (L)	1	0	3116.76***	2167.52***	2.23*	36.02	0.52	11284.01***	152049.37*	21.69**	73.18**
G x L	24	0.02	1.05***	1.87	0.67	18.74	0.19	5.87	2323.55***	0.04	0.25***
Block	26	0.02	0.37	1.3	1.46	83.01	0.15	9.68	403.6	0.05	0.08

*, **, *** significance at *P*< 0.05, *P*<0.01 and *P*<0.001, respectively, Df- degree of freedom, SV- seedling vigour, NF- number of fingers, FL- finger length, PL- Peduncle length, PH- Plant height, NPT- number of productive tillers, Days to 50% FL- Days to 50% flowering, 1000gw- 1000 grain weight and HI- Harvest index.

physiological traits of the finger millet genotypes.

DISCUSSION

In this study environmental and genotypic effects were significant for the agronomic, morphological and physiological traits among the evaluated finger millet genotypes. Plant responses to drought stress have been shown to vary depending on drought level, plant species and plant growth stage (Mukami et al., 2019). Therefore, for drought tolerance agronomic, morphological and physiological traits can provide important information to improve crop production in arid and semi-arid area. Drought adapted crop genotypes may be considered to have various mechanisms such as avoidance, escape or tolerance. However, genotypes that possess these adaptive mechanisms hardly express desirable agronomic characteristics, such as grain yield (Dhami et al., 2018). Evaluation of crops for traits related to drought adaptation has been shown to be limited (Nadeem et al., 2020). The reason being that most of the approaches used for screening drought tolerance are below ground, which are tedious and may involve destructive sampling (Gebreyohannes et al., 2021).

The results from this study revealed a significant variation among the finger millet genotypes for the morphological and physiological traits, with greater implication on the differences under drought stress conditions. These results can be useful in the selection of parental stock for breeding in drought improvement programmes and possible release for commercial production of promising lines. In similar studies, drought tolerance have been reported to vary among finger millet genotypes evaluated in Uganda and Ethiopia (Owere et al., 2016). The variation in the agronomic traits observed across the two study locations for the number of productive tillers, number of fingers, finger length and yield could be attributed to genotypic and environmental differences (Dramadri, 2018). High grain yields observed in Koibatek can be directly associated with high number of fingers, finger length, number of productive tillers and early flowering. In a similar study, improved performance for agronomic traits under drought stress was positively correlated with grain yield (Shanker and Shanker, 2016). According to Bennani et al. (2016) reduced number of days to flowering and heading was considered as one of vulnerabilities of plants to drought stress. Drought stress severity, plant species and crop growth stage as well have been attributed to influence grain yield (Demirevska et al. 2009).

Seedling vigour is considered as one of the reliable phenotypic traits towards selection of drought tolerance at the seedling stage. Among the evaluated finger millet lines, there was a significant variation for the seedling vigour, signalling potential tolerance to soil moisture deficit at the seedling stage. In a related study by Struik et al. (2007), seedling vigour was included in the evaluation of wheat genotypes for drought tolerance at the early growth stage. Vigorous and fast growing plant seedlings can compete against weeds at an early stage, which is critical for better grain yield (Zhang et al., 2015). Ahmad et al. (2015) evaluated 50 wheat genotypes for different seedling traits including seedling vigour, and successfully identified eight potentially drought-tolerant genotypes.

Plant height is one of the morphological traits which can be used for selecting drought tolerance among crop genotypes. In previous studies, plant

Table 4. Mean performance of 25 genotypes evaluated for agronomic traits in Koibatek.

Genotype	SV	NF	FL	PL	PH	NPT	Days to 50% FL	Yield	1000 gw (g)	HI
EX Alupe(G) X KNE 814 P1-1-2-3-1	1.000^{c}	4.943^{d-g}	6.000^{def}	12.267^{a-d}	51.333^{e}	7.000^{a}	94.333^{a-d}	287.107^{f}	2.763^{c}	4.310^{fgh}
ICFX 1420342-3-1-2-2	1.000^{c}	4.997^{d-g}	5.733^{ef}	11.933^{bcd}	65.667^{cd}	4.000^{gh}	88.667^{f}	284.213^{fg}	3.143^{abc}	4.570^{efg}
ICFX 1420396-5-5-1-1	1.000^{c}	4.487^{fg}	7.267^{a-e}	12.667^{a-d}	84.000^{a}	4.333^{fgh}	91.333^{b-f}	303.643^{ef}	3.330^{a}	5.180^{bcd}
ICFX 1420414-7-12-1-1	1.133^{c}	6.043^{abc}	7.933^{abc}	12.400^{a-d}	82.000^{a}	7.333^{a}	92.667^{a-f}	334.910^{a-d}	3.227^{ab}	4.577^{efg}
ICFX 1420414-7-4-1-1	1.000^{c}	5.680^{a-d}	7.333^{a-e}	11.533^{cd}	77.667^{abc}	7.333^{a}	93.000^{a-e}	343.350^{abc}	2.997^{abc}	4.337^{fgh}
ICFX 1420415-3-1-1-2	1.450^{ab}	6.267^{a}	6.733^{b-e}	12.667^{a-d}	76.333^{abc}	4.333^{fgh}	91.333^{b-f}	335.563^{a-d}	2.980^{abc}	5.207^{bcd}
ICFX 1420419-3-2-1-1	1.093^{c}	5.763^{a-d}	7.733^{abc}	11.600^{cd}	74.000^{abc}	5.667^{cd}	95.000^{ab}	300.577^{ef}	3.070^{abc}	4.940^{b-e}
ICFX 1420420-9-6-3-1	1.240^{bc}	5.113^{def}	6.000^{def}	14.000^{a}	77.667^{abc}	5.667^{cd}	94.667^{abc}	297.637^{ef}	2.933^{abc}	4.747^{def}
ICFX 1420424-2-1-1-1	1.000^{c}	5.113^{def}	6.867^{b-e}	13.267^{abc}	78.000^{ab}	6.667^{ab}	92.333^{a-f}	337.830^{a-d}	2.903^{abc}	5.443^{b}
ICFX 1420431-1-3-1-2	1.000^{c}	4.557^{fg}	6.733^{b-e}	11.933^{bcd}	73.333^{abc}	6.000^{bc}	94.667^{abc}	299.217^{ef}	2.810^{bc}	4.470^{efg}
ICFX 1420431-2-5-1-1	1.227^{bc}	5.237^{b-f}	7.200^{a-e}	11.733^{cd}	74.333^{abc}	3.667^{h}	92.333^{a-f}	300.850^{ef}	3.077^{abc}	4.877^{cde}
EX Alupe (G) X KNE 814 P4-2-1-4-1	1.647^{a}	5.593^{a-e}	4.533^{f}	12.667^{a-d}	55.333^{de}	7.000^{a}	93.667^{a-e}	256.500^{gh}	2.913^{abc}	3.643^{ij}
ICFX 142036-3-3-1-1	1.000^{c}	5.200^{c-f}	6.000^{def}	12.800^{a-d}	78.000^{ab}	5.000^{def}	90.000^{ef}	287.487^{f}	3.323^{a}	4.300^{fgh}
ICFX 1420437-1-4-1-1	1.000^{c}	5.443^{a-e}	7.600^{a-d}	12.067^{a-d}	72.667^{abc}	4.333^{fgh}	91.000^{b-f}	358.503^{a}	3.113^{abc}	4.650^{ef}
ICFX 1420448-1-1-1-1	1.240^{bc}	5.990^{abc}	7.333^{a-e}	12.133^{a-d}	66.667^{bcd}	4.667^{efg}	91.333^{b-f}	318.520^{cde}	3.030^{abc}	4.123^{ghi}
KNE 814 X Ex Alupe (P) P7-9-3-2-2	1.000^{c}	5.703^{a-d}	6.400^{cde}	13.733^{ab}	73.333^{abc}	4.000^{gh}	91.333^{b-f}	326.137^{b-e}	3.107^{abc}	4.573^{efg}
KNE 814 X Ex Alupe (P) P8-1-1-1-1	1.000^{c}	4.230^{g}	7.267^{a-e}	12.333^{a-d}	84.667^{a}	3.667^{h}	92.000^{a-f}	232.003^{h}	3.043^{abc}	2.880^{k}
P224- check	1.000^{c}	5.777^{a-d}	8.200^{ab}	12.800^{a-d}	75.667^{abc}	5.333^{cde}	92.000^{a-f}	309.583^{def}	2.880^{abc}	3.553^{j}
ICFX 1420311-3-6-1-2	1.093^{c}	5.657^{a-e}	7.133^{a-e}	12.000^{bcd}	80.667^{a}	4.667^{efg}	96.000^{a}	323.787^{cde}	3.123^{abc}	3.850^{hij}
ICFX 1420312-3-2-1-1	1.133^{c}	5.777^{a-d}	7.000^{a-e}	13.000^{abc}	78.333^{ab}	5.333^{cde}	93.333^{a-e}	335.863^{a-d}	3.067^{abc}	4.460^{efg}
ICFX 1420313-1-2-3-1	1.000^{c}	4.443^{fg}	6.733^{b-e}	11.933^{bcd}	72.667^{abc}	4.333^{fgh}	91.333^{b-f}	317.923^{cde}	2.893^{abc}	4.873^{cde}
ICFX 1420313-3-2-1-1	1.000^{c}	4.810^{efg}	7.467^{a-d}	12.400^{a-d}	73.667^{abc}	4.667^{efg}	92.000^{a-f}	299.803^{ef}	3.120^{abc}	5.267^{bc}
ICFX 1420314-2-1-1-1	1.000^{c}	6.057^{ab}	7.933^{abc}	10.933^{d}	81.000^{a}	5.667^{cd}	90.667^{c-f}	356.377^{a}	3.110^{abc}	5.333^{bc}
ICFX 1420314-6-2-1-1	1.240^{bc}	5.093^{def}	8.533^{a}	11.800^{bcd}	80.333^{a}	4.333^{fgh}	90.333^{def}	345.320^{abc}	3.310^{a}	4.437^{efg}
ICFX 1420315-2-2-1-2	1.000^{c}	5.110^{def}	6.733^{b-e}	12.667^{a-d}	72.667^{abc}	4.000^{gh}	91.000^{b-f}	354.467^{ab}	2.970^{abc}	6.257^{a}
CV (%)	14.90	6.15	11.96	11.53	10.50	7.67	2.44	5.81	9.41	6.99
LSD $_{0.05}$	0.29	0.85	1.61	1.93	12.18	0.79	4.06	29.99	0.46	0.52

Means in a column followed by the same letter are not significantly different using Fisher's Least Significant Difference test at $P<0.05$, CV- Coefficient of Variation, SV- seedling vigour, NF- number of fingers, FL- finger length, PL- Peduncle length, PH- Plant height, NPT- number of productive tillers, Days to 50% FL- Days to 50% flowering, 1000gw- 1000 grain weight and HI- Harvest index.

Table 5. Mean performance of 25 genotypes evaluated for agronomic traits in Soin.

Genotype	SV	NF	FL	PL	PH	NPT	FFLW	Yield	1000 gw (g)	HI
EX Alupe(G) X KNE 814 P1-1-2-3-1	1.000^{c}	12.333^{g}	13.367^{cde}	11.500^{bcd}	50.167^{d}	6.670^{b}	75.333^{abc}	224.167^{ij}	2.313^{ab}	2.900^{h-k}
ICFX 1420342-3-1-2-2	1.000^{c}	15.667^{ab}	13.900^{b-e}	12.333^{a-d}	68.000^{c}	4.000^{lm}	75.333^{abc}	207.830^{jk}	2.137^{b}	2.600^{k}
ICFX 1420396-5-5-1-1	1.000^{c}	14.333^{cde}	14.033^{b-e}	12.333^{a-d}	84.333^{ab}	5.027^{ghi}	75.333^{abc}	259.680^{b-g}	2.327^{ab}	3.533^{cd}
ICFX 1420414-7-12-1-1	1.333^{b}	14.667^{bcd}	15.067^{a-d}	10.833^{bcd}	80.333^{abc}	7.417^{a}	76.000^{ab}	271.763^{bcd}	2.280^{ab}	2.760^{ijk}
ICFX 1420414-7-4-1-1	1.000^{c}	14.667^{bcd}	13.900^{b-e}	11.500^{bcd}	74.833^{abc}	6.463^{bcd}	76.667^{a}	268.630^{bcd}	2.367^{ab}	2.873^{h-k}
ICFX 1420415-3-1-1-2	1.663^{a}	15.333^{abc}	15.900^{ab}	13.000^{a-d}	77.167^{abc}	4.267^{lm}	72.667^{cd}	265.300^{b-f}	2.143^{b}	3.540^{cd}
ICFX 1420419-3-2-1-1	1.333^{b}	14.667^{bcd}	14.700^{bcd}	10.667^{cd}	72.833^{bc}	6.030^{de}	73.333^{bcd}	247.050^{d-i}	2.233^{ab}	2.953^{g-j}
ICFX 1420420-9-6-3-1	1.133^{bc}	13.333^{efg}	15.267^{abc}	14.167^{a}	80.667^{abc}	6.090^{d}	76.000^{ab}	232.373^{hij}	2.193^{ab}	3.487^{cde}
ICFX 1420424-2-1-1-1	1.000^{c}	13.333^{efg}	14.367^{bcd}	14.167^{a}	78.500^{abc}	6.563^{bc}	76.000^{ab}	166.000^{l}	2.297^{ab}	3.633^{bc}
ICFX 1420431-1-3-1-2	1.000^{c}	13.333^{efg}	14.667^{bcd}	11.667^{a-d}	73.667^{abc}	6.157^{cd}	76.000^{ab}	239.900^{f-i}	2.313^{ab}	2.987^{f-i}
ICFX 1420431-2-5-1-1	1.133^{bc}	15.333^{abc}	14.133^{bcd}	11.833^{a-d}	73.667^{abc}	3.893^{m}	70.667^{d}	235.367^{ghi}	2.290^{ab}	3.627^{bc}
EX Alupe (G) X KNE 814 P4-2-1-4-1	1.227^{b}	14.333^{cde}	12.700^{de}	12.500^{a-d}	69.833^{c}	6.887^{b}	73.333^{bcd}	193.353^{k}	2.197^{ab}	2.230^{l}
ICFX 142036-3-3-1-1	1.000^{c}	13.667^{def}	11.600^{e}	12.667^{a-d}	77.333^{abc}	5.583^{ef}	76.000^{ab}	256.267^{b-h}	2.377^{ab}	3.117^{fgh}
ICFX 1420437-1-4-1-1	1.000^{c}	15.667^{ab}	13.833b-^{e}	11.500^{bcd}	71.333^{bc}	4.437^{jkl}	74.667^{abc}	275.867^{bc}	2.307^{ab}	3.477^{cde}
ICFX 1420448-1-1-1-1	1.240^{b}	15.667^{ab}	17.400^{a}	12.167^{a-d}	73.833^{abc}	4.740^{ijk}	75.333^{abc}	263.783^{b-f}	2.370^{ab}	3.017^{f-i}
KNE 814 X Ex Alupe (P) P7-9-3-2-2	1.000^{c}	14.333^{cde}	15.533^{abc}	13.167^{abc}	69.000^{c}	4.330^{klm}	76.000^{ab}	280.700^{b}	2.260^{ab}	3.260^{d-g}
KNE 814 X Ex Alupe (P) P8-1-1-1-1	1.000^{c}	13.000^{fg}	14.800^{bcd}	12.833^{a-d}	87.333^{a}	4.223^{lm}	72.667^{cd}	333.333^{a}	2.277^{ab}	3.173^{e-h}
P224- check	1.000^{c}	14.000^{def}	13.933^{b-e}	10.833^{bcd}	79.167^{abc}	5.530^{f}	76.000^{ab}	246.437^{d-i}	2.357^{ab}	2.613^{jk}
ICFX 1420311-3-6-1-2	1.000^{c}	14.667^{bcd}	14.467^{bcd}	11.667^{a-d}	80.000^{abc}	4.440^{jkl}	75.333^{abc}	250.640^{c-i}	2.500^{a}	2.973^{ghi}
ICFX 1420312-3-2-1-1	1.333^{b}	13.000^{fg}	13.567^{b-e}	13.333^{ab}	80.167^{abc}	5.293^{fgh}	75.333^{abc}	279.777^{b}	2.370^{ab}	3.337^{c-f}
ICFX 1420313-1-2-3-1	1.000^{c}	14.667^{bcd}	16.000^{ab}	11.167^{bcd}	74.500^{abc}	4.343^{klm}	75.333^{abc}	267.377^{b-e}	2.233^{ab}	3.510^{cde}
ICFX 1420313-3-2-1-1	1.000^{c}	14.667^{bcd}	15.600^{abc}	12.000^{a-d}	74.667^{abc}	4.860^{hij}	74.667^{abc}	230.617^{hij}	2.207^{ab}	2.997^{f-i}
ICFX 1420314-2-1-1-1	1.000^{c}	15.667^{ab}	14.900^{bcd}	10.500^{d}	82.167^{abc}	5.343^{fg}	76.667^{a}	241.277^{e-i}	2.363^{ab}	3.917^{b}
ICFX 1420314-6-2-1-1	1.227^{b}	14.333^{cde}	15.167^{a-d}	12.000^{a-d}	76.667^{abc}	5.187^{f-i}	75.333^{abc}	235.863^{ghi}	2.177^{b}	2.577^{kl}
ICFX 1420315-2-2-1-2	1.000^{c}	16.333^{a}	15.667^{abc}	12.833^{a-d}	74.333^{abc}	4.170^{lm}	72.667^{cd}	281.917^{b}	2.337^{ab}	4.843^{a}
CV (%)	14.90	6.15	11.96	11.53	10.50	7.67	2.44	5.81	9.41	6.99
LSD $_{0.05}$	0.22	1.21	2.49	2.62	14.46	0.46	3.32	26.82	0.32	0.35

Means in a column followed by the same letter are not significantly different using Fisher's Least Significant Difference test at $P<0.05$, CV- Coefficient of Variation, SV- seedling vigour, NF-number of fingers, FL- finger length, PL- Peduncle length, PH- Plant height, NPT- number of productive tillers, Days to 50% FL- Days to 50% flowering, 1000gw- 1000 grain weight and HI-Harvest index.

height was directly linked to grain yield, where short plants had higher grain yield compared to taller plants (Mohammadi et al., 2012; Koocheki et al., 2014). Short plants were found to reduce moisture demand and prevent plant moisture loss due to transpiration (Zhang et al., 2018). In wheat (*Triticum aestivum*), reduced plant height was reported to reduce photosynthesis and nutrient translocation, especially during the stem

Table 6. Analysis of variance for 25 finger millet genotypes based on morpho - physiological traits evaluated in Koibatek and Soin.

Source of variation	df	LAI	LI	ET	LRWC	SC	CC	RRWC	SBIO	TBIO	RBIO	COA	PR
Replication	2	0.01***	0.06***	71.79***	252.23***	0.018	5.46***	44.34***	157.14***	1800.00***	168.58***	3819.34*	7.64
Genotype (G)	24	0.001*	0.009	67.61***	27.68***	10.77***	30.19***	109.37***	62.79***	235.69***	236.13***	9571.79***	285.38***
Location (L)	1	0.19*	1.49*	4429.36*	524.35	0.352	0.396	227.43	839.65	3750	1122.79	52.81	33.77
G x L	24	0.0005***	0.008***	6.94***	0.28	1.67***	3.41***	0.39	7.48*	0	7.31	1051.62	119.70***
Block	26	0.0002	0.003	2.39	18.54	0.17	0.90	0.88	7.94*	161.2	5.5	897.38	21.04

*, **, *** significance at *P*< 0.05, *P*<0.01 and *P*<0.001, respectively, df- degree of freedom, LAI - Leaf area index, LI- light intensity, ET- Evapotranspiration rate, LRWC-Leaf relative water content, SC- Stomatal conductance (mol $H_2O m^{-2} s^{-1}$), CC- Chlorophyll content, RRWC- Root relative water content, SBIO-Shoot biomass (g), TBIO-Total biomass, RBIO-Root biomass (g), COA- CO_2 assimilation (mol$m^{-2} s^{-1}$) and PR-Photosynthetic rate (µmolCO_2 $m^{-2} s^{-1}$).

elongation stage due to low moisture content (Sarto et al., 2017). Reduced plant height has also been associated with increased partitioning of assimilates to the ear (Grover et al., 2018). Short plants may also result in higher HI and lodging resistance (Divashuk et al., 2013).

Increased number of productive tillers could be a desirable trait to higher grain yield. However, under drought stress, this trait can be detrimental due increased competition for assimilate partitioning (Geleta et al., 2019). In this study, the number of productive tillers was negatively correlated with harvest index. Similar findings were reported by Lule et al. (2012), where grain yield low was registered in finger millet genotypes, which had high number of productive tillers under low soil moisture.

Positive correlations were registered between days to flowering and grain yield. Similar results were reported by Ganapathy et al. (2011) and Chandra et al. (2013), who found that late maturity was associated with grain yield and yield components. In this study, 1,000-grain weight, finger number, finger length, days to maturity and harvest index were positively correlated with grain yield; this was in accordance with the results of Bezaweletaw et al. (2006), who reported a positive association of 1,000-grain weight with finger number, finger length, days to maturity, harvest index and grain yield per plant. Moreover, Wolie et al. (2013) and Kumar et al. (2016) found grain yield to be positively correlated with biomass and harvest index in finger millet.

Harvest index (HI) can influence yield, as it is the proportion of the whole plant mass that is partitioned to the seed (Pachepsky et al., 2011). Harvest index is the partitioning of dry matter into the reproductive parts; hence, it can be used as an important indicator for drought tolerance. In this study, results showed a significant positive relationship between HI and grain yield. Similar results have been also reported by Jyothsna et al. (2016) and Reddy (2020), where harvest index was positively correlated with number of tillers per plant, finger length and grain yield. Grain yield is considered a complex trait that is highly influenced by genotypic and environmental factors. Therefore, high variation observed for yield among the finger millets can be attributed to genotypic and environmental difference across the two locations. However, lines ICFX 1420314-2-1-1-1 (7), KNE 814 X Ex Alupe (P) P8-1-1-1-1 (24) and ICFX 1420415-3-1-1-2 (14) displayed consistency with relatively high grain yield both in Koibatek and Soin. Similar findings reported that high variation in grain yield was attributed to both genetic and environmental factors (Malambane and Jaisil, 2015; Mukami et al., 2019).

Physiological traits were noted to vary across the finger millet genotypes and location. Similarly, a change in physiological traits has been demonstrated to be triggered by both genetic and environmental conditions (Anjum et al., 2011; Mukami et al., 2019). Reduced photosynthetic rate and chlorophyll content have been widely associated with soil moisture deficits. Drought influences nutrient uptake such as nitrogen, which affects chlorophyll content that regulates photosynthetic activities (Fathi and Tari, 2016). The reduction in chlorophyll content is a mechanism that responds to drought in order to reduce the light absorbed by chloroplasts (Gu et al., 2017).

Root and shoot biomass accumulation has been used as an indicator of drought tolerance. Genotypes allocate biomass differently between roots and shoots (Weiner, 2004); and there are indications that drought tolerance can be improved

Table 7. Mean performance of 25 genotypes evaluated for morpho - physiological in Koibatek.

Genotype	LAI	LI	ET	LRWC	SC	CC	RRWC	SBIO	RBIO	TBIO	COA	PR
EX Alupe(G) X KNE 814 P1-1-2-3-1	0.077^{c-g}	0.415^{ab}	24.867^{ef}	62.823^{a-d}	4.537^{d}	6.337^{m}	30.087^{def}	33.990^{cd}	67.923^{abc}	33.900^{ij}	357.667^{cd}	30.033^{c-g}
ICFX 1420342-3-1-2-2	0.097^{bc}	0.408^{bc}	24.500^{ef}	56.713^{ef}	2.600^{jk}	11.670^{cd}	25.843^{jk}	27.840^{hij}	68.473^{abc}	36.927^{ghi}	337.667^{de}	59.633^{a}
ICFX 1420396-5-5-1-1	0.082^{b-f}	0.318^{d-i}	20.920^{h}	63.683^{ab}	2.770^{ijk}	11.337^{cde}	29.887^{efg}	25.837^{j}	66.000^{abc}	36.250^{hij}	363.000^{cd}	24.967^{e-i}
ICFX 1420414-7-12-1-1	0.089^{b-e}	0.317^{d-i}	23.923^{efg}	57.880^{b-f}	0.203^{m}	7.553^{i-m}	39.357^{b}	38.287^{a}	78.463^{ab}	40.273^{efg}	363.667^{cd}	31.480^{c-f}
ICFX 1420414-7-4-1-1	0.075^{c-g}	0.311^{d-i}	26.353^{b-e}	55.630^{f}	2.690^{jk}	12.993^{bc}	26.853^{ij}	28.480^{ghi}	76.840^{ab}	50.930^{a}	372.333^{cd}	24.463^{f-i}
ICFX 1420415-3-1-1-2	0.087^{b-e}	0.337^{b-h}	28.467^{bc}	58.023^{b-f}	7.623^{a}	10.693^{def}	23.343^{lm}	25.777^{j}	66.277^{abc}	41.950^{de}	379.333^{cd}	21.283^{hi}
ICFX 1420419-3-2-1-1	0.074^{c-g}	0.297^{d-i}	23.707^{e-h}	62.807^{a-d}	3.103^{ghi}	8.590^{h-k}	27.547^{hij}	29.790^{fgh}	74.733^{abc}	44.940^{cd}	351.000^{cd}	25.870^{d-h}
ICFX 1420420-9-6-3-1	0.067^{efg}	0.281^{f-i}	24.163^{efg}	62.557^{a-e}	0.117^{m}	8.510^{h-l}	28.627^{f-i}	29.823^{fgh}	62.837^{abc}	33.010^{jk}	307.333^{e}	20.433^{hi}
ICFX 1420424-2-1-1-1	0.077^{c-g}	0.282^{f-i}	23.383^{fgh}	67.257^{a}	5.190^{c}	8.290^{h-l}	34.887^{c}	28.513^{f-i}	64.410^{abc}	33.547^{ij}	368.000^{cd}	24.767^{e-i}
ICFX 1420431-1-3-1-2	0.072^{c-g}	0.286^{e-i}	23.587^{e-h}	58.113^{b-f}	1.908^{l}	8.457^{h-l}	24.667^{kl}	33.323^{cd}	69.680^{abc}	38.993^{e-h}	337.333^{de}	34.207^{bc}
ICFX 1420431-2-5-1-1	0.078^{c-g}	0.246^{i}	25.033^{ef}	61.473^{a-f}	3.483^{ef}	8.820^{g-j}	31.773^{d}	29.077^{fgh}	59.053^{bc}	32.993^{jk}	350.333^{cd}	31.467^{c-f}
EX Alupe (G) X KNE 814 P4-2-1-4-1	0.054^{g}	0.258^{hi}	24.883^{ef}	62.537^{a-e}	4.280^{d}	7.593^{i-m}	28.623^{f-i}	32.467^{de}	72.250^{abc}	40.780^{ef}	374.333^{cd}	17.930^{i}
ICFX 142036-3-3-1-1	0.068^{efg}	0.289^{e-i}	25.377^{def}	63.003^{a-d}	2.913^{hij}	15.883^{a}	31.660^{de}	36.947^{ab}	69.780^{abc}	32.790^{jk}	355.000^{cd}	27.513^{c-h}
ICFX 1420437-1-4-1-1	0.068^{efg}	0.278^{f-i}	26.040^{c-f}	60.417^{b-f}	1.960^{l}	7.167^{j-m}	28.137^{ghi}	27.673^{hij}	69.380^{abc}	42.113^{de}	356.667^{cd}	26.267^{d-h}
ICFX 1420448-1-1-1-1	0.080^{c-f}	0.323^{c-i}	25.423^{def}	57.117^{def}	5.797^{b}	12.050^{bcd}	21.850^{m}	28.440^{ghi}	78.180^{ab}	49.363^{ab}	368.333^{cd}	39.113^{b}
KNE 814 X Ex Alupe (P) P7-9-3-2-2	0.075^{c-g}	0.328^{b-i}	25.987^{c-f}	57.710^{c-f}	3.470^{efg}	11.860^{cd}	24.360^{kl}	35.277^{bc}	69.690^{abc}	41.987^{de}	454.667^{b}	31.893^{cde}
KNE 814 X Ex Alupe (P) P8-1-1-1-1	0.139^{a}	0.499^{a}	41.920^{a}	61.477^{a-f}	4.494^{d}	9.620^{e-h}	28.487^{f-i}	30.660^{ef}	68.900^{abc}	38.643^{e-h}	369.333^{cd}	25.367^{d-h}
P224- check	0.095^{bc}	0.367^{b-f}	24.587^{ef}	56.027^{f}	3.697^{e}	7.960^{h-m}	29.050^{fgh}	29.420^{fgh}	82.360^{a}	46.573^{bc}	360.667^{cd}	20.467^{hi}
ICFX 1420311-3-6-1-2	0.082^{b-f}	0.336^{b-h}	26.040^{c-f}	60.607^{b-f}	2.670^{jk}	13.657^{b}	26.907^{ij}	30.347^{efg}	79.023^{ab}	52.810^{a}	352.000^{cd}	24.067^{ghi}
ICFX 1420312-3-2-1-1	0.093^{bcd}	0.349^{b-g}	28.100^{bcd}	61.257^{b-f}	2.867^{hij}	10.497^{d-g}	27.260^{hij}	37.210^{ab}	73.387^{abc}	36.780^{ghi}	345.667^{cde}	29.133^{c-g}
ICFX 1420313-1-2-3-1	0.068^{d-g}	0.300^{d-i}	23.633^{e-h}	59.210^{b-f}	2.450^{k}	15.593^{a}	38.320^{b}	37.830^{a}	68.340^{abc}	29.700^{k}	351.333^{cd}	25.333^{d-h}
ICFX 1420313-3-2-1-1	0.094^{bc}	0.375^{b-e}	23.503^{fgh}	63.180^{abc}	2.807^{ijk}	6.800^{lm}	28.930^{fgh}	29.160^{fgh}	67.827^{abc}	38.203^{fgh}	532.333^{a}	26.800^{d-h}
ICFX 1420314-2-1-1-1	0.106^{b}	0.378^{bcd}	21.650^{gh}	62.060^{a-e}	3.210^{fgh}	11.910^{cd}	30.173^{def}	26.770^{ij}	65.953^{abc}	38.820^{e-h}	380.667^{c}	32.313^{bcd}
ICFX 1420314-6-2-1-1	0.083^{b-f}	0.356^{b-g}	24.280^{efg}	57.533^{c-f}	0.140^{m}	6.980^{klm}	24.967^{kl}	36.570^{ab}	70.030^{abc}	34.357^{ij}	364.333^{cd}	25.050^{e-i}
ICFX 1420315-2-2-1-2	0.061^{fg}	0.276^{ghi}	28.940^{b}	61.387^{a-f}	3.437^{efg}	9.260^{f-i}	41.947^{a}	33.137^{cd}	52.080^{c}	18.953^{l}	360.000^{cd}	66.730^{a}
CV (%)	11.39	12.26	8.01	6.73	9.59	9.09	4.39	6.16	19.92	5.18	7.84	13.07
$LSD_{0.05}$	0.03	0.09	2.79	5.93	0.38	1.72	1.86	2.16	22.74	3.74	42.18	7.19

Means in a column followed by the same letter are not significantly different using Fisher's Least Significant Difference test at $P<0.05$, CV- Coefficient of Variation, LAI - Leaf area index, LI-light intensity, ET- Evapotranspiration rate, LRWC-Leaf relative water content, SC- Stomatal conductance (mol $H_2O m^{-2} s^{-1}$), CC- Chlorophyll content, RRWC- Root relative water content, SBIO-Shoot biomass (g), TBIO-Total biomass, RBIO-Root biomass (g), COA- CO_2 assimilation (mol$m^{-2} s^{-1}$) and PR-Photosynthetic rate (µmolCO_2 $m^{-2} s^{-1}$).

via traits, such as root length, shoot and root biomass accumulation (Paustian et al., 2016; Griffiths and Paul, 2017). Drought-tolerant genotypes have been reported to have higher root dry matter per unit of leaf area, signalling that they would invest more in deeper rooting for water absorption. Increased root biomass has also been linked to drought avoidance in which plants accumulate more root biomass compared to

Table 8. Mean performance of 25 genotypes evaluated for morpho – physiological traits in Soin.

Genotype	LAI	LI	ET	LRWC	ST	CC	RRWC	SBIO	RBIO	TBIO	COA	PR
EX Alupe(G) X KNE 814 P1-1-2-3-1	0.142^{fgh}	0.521^{b-g}	12.273^{g-j}	59.463^{a-d}	3.823^{efg}	6.427^{m}	27.190^{efg}	38.687^{b-e}	39.233^{lm}	77.923^{abc}	357.667^{cde}	30.033^{c-h}
ICFX 1420342-3-1-2-2	0.120^{i}	0.448^{ghi}	14.263^{e-i}	52.903^{e-h}	2.487^{h}	12.547^{c}	23.027^{kl}	32.840^{hij}	43.510^{ijk}	78.473^{abc}	323.333^{de}	37.567^{b}
ICFX 1420396-5-5-1-1	0.182^{ab}	0.543^{a-f}	10.857^{j}	59.937^{ab}	2.217^{h}	12.033^{c}	27.127^{e-h}	35.620^{e-i}	41.250^{klm}	76.000^{abc}	348.667^{cde}	28.633^{d-i}
ICFX 1420414-7-12-1-1	0.144^{fgh}	0.512^{c-g}	13.603^{e-i}	54.607^{b-h}	0.153^{i}	11.907^{cd}	36.530^{b}	43.287^{a}	47.760^{efg}	88.463^{ab}	363.667^{cd}	32.013^{b-e}
ICFX 1420414-7-4-1-1	0.123^{i}	0.428^{hi}	13.203^{f-j}	51.683^{h}	3.737^{efg}	14.323^{b}	26.043^{f-j}	33.480^{g-j}	52.990^{cd}	86.840^{ab}	372.333^{cd}	34.380^{bc}
ICFX 1420415-3-1-1-2	0.163^{cde}	0.585^{abc}	16.983^{cd}	53.647^{c-h}	7.060^{a}	10.693^{de}	21.047^{lm}	30.777^{j}	46.950^{e-h}	76.277^{abc}	463.333^{ab}	21.000^{jkl}
ICFX 1420419-3-2-1-1	0.159^{c-f}	0.609^{a}	15.827^{cde}	58.933^{a-e}	2.683^{h}	8.623^{ghi}	25.190^{hij}	34.800^{e-j}	49.940^{de}	84.733^{abc}	347.000^{cde}	30.480^{c-h}
ICFX 1420420-9-6-3-1	0.160^{c-f}	0.587^{abc}	16.093^{cde}	58.647^{a-f}	3.847^{d-g}	8.510^{ghi}	26.543^{f-i}	34.820^{e-j}	38.010^{mn}	72.837^{abc}	307.333^{e}	19.433^{l}
ICFX 1420424-2-1-1-1	0.151^{efg}	0.588^{abc}	12.413^{f-j}	63.677^{a}	5.077^{b}	9.977^{ef}	33.083^{c}	33.513^{g-j}	38.547^{lm}	74.410^{abc}	368.000^{cd}	24.767^{h-l}
ICFX 1420431-1-3-1-2	0.144^{fgh}	0.497^{d-h}	11.807^{ij}	54.550^{b-h}	2.703^{h}	8.400^{hij}	22.080^{l}	38.323^{c-f}	43.633^{h-k}	79.680^{abc}	337.333^{cde}	34.183^{bcd}
ICFX 1420431-2-5-1-1	0.153^{def}	0.532^{a-g}	14.193^{e-i}	57.453^{b-h}	3.587^{efg}	7.980^{ijk}	28.610^{de}	34.077^{f-j}	33.290^{o}	69.053^{bc}	350.333^{cde}	28.667^{c-i}
EX Alupe (G) X KNE 814 P4-2-1-4-1	0.134^{ghi}	0.425^{hi}	8.280^{k}	59.013^{a-d}	4.443^{cd}	7.717^{i-l}	25.993^{f-j}	37.467^{d-g}	45.780^{f-i}	82.250^{abc}	374.333^{c}	23.900^{i-l}
ICFX 142036-3-3-1-1	0.146^{e-h}	0.515^{c-g}	14.397^{e-h}	59.883^{ab}	3.470^{fg}	15.883^{a}	29.270^{d}	42.643^{abc}	43.730^{h-k}	79.780^{abc}	340.000^{cde}	27.513^{e-i}
ICFX 1420437-1-4-1-1	0.147^{e-h}	0.568^{a-e}	13.693^{e-i}	56.243^{b-h}	3.997^{def}	7.163^{j-m}	25.410^{g-j}	32.673^{hij}	43.773^{h-k}	79.380^{abc}	372.333^{cd}	25.000^{g-l}
ICFX 1420448-1-1-1-1	0.118^{i}	0.398^{i}	12.070^{hij}	52.803^{fgh}	4.913^{bc}	11.790^{cd}	19.793^{m}	33.433^{g-j}	54.330^{bc}	88.180^{ab}	335.000^{cde}	54.480^{a}
KNE 814 X Ex Alupe (P) P7-9-3-2-2	0.150^{efg}	0.496^{d-h}	16.040^{cde}	53.507^{d-h}	3.470^{fg}	11.757^{cd}	22.387^{l}	34.807^{e-j}	48.987^{ef}	79.690^{abc}	447.667^{b}	31.583^{c-f}
KNE 814 X Ex Alupe (P) P8-1-1-1-1	0.175^{abc}	0.496^{e-h}	30.643^{a}	57.727^{a-h}	3.470^{fg}	9.620^{e-h}	25.877^{f-j}	37.660^{d-g}	44.803^{g-j}	78.900^{abc}	369.333^{cd}	25.480^{g-k}
P224- check	0.190^{a}	0.605^{ab}	14.657^{d-g}	52.327^{gh}	3.583^{efg}	7.153^{klm}	26.610^{f-i}	36.717^{e-h}	56.820^{ab}	92.360^{a}	360.667^{cd}	25.717^{g-k}
ICFX 1420311-3-6-1-2	0.151^{efg}	0.514^{c-g}	14.827^{def}	56.720^{b-h}	4.154^{de}	14.020^{b}	24.497^{jk}	34.890^{e-j}	59.810^{a}	89.023^{ab}	352.000^{cde}	20.413^{kl}
ICFX 1420312-3-2-1-1	0.162^{cde}	0.534^{a-f}	17.003^{cd}	57.867^{a-g}	3.360^{g}	11.573^{cd}	24.840^{ijk}	34.387^{e-j}	41.780^{jkl}	83.387^{abc}	345.667^{cde}	29.133^{c-i}
ICFX 1420313-1-2-3-1	0.150^{efg}	0.521^{b-g}	19.883^{b}	55.993^{b-h}	2.407^{h}	9.740^{efg}	35.530^{b}	43.163^{ab}	34.700^{no}	78.340^{abc}	342.000^{cde}	26.113^{f-k}
ICFX 1420313-3-2-1-1	0.171^{bcd}	0.580^{a-d}	13.130^{f-j}	59.683^{abc}	2.357^{h}	7.077^{klm}	26.463^{f-j}	34.160^{e-j}	41.213^{klm}	77.827^{abc}	509.667^{a}	26.800^{e-i}
ICFX 1420314-2-1-1-1	0.188^{ab}	0.614^{a}	12.037^{hij}	57.837^{a-g}	0.193^{i}	11.910^{cd}	27.447^{def}	31.770^{ij}	44.030^{h-k}	75.953^{abc}	351.000^{cde}	28.733^{c-i}
ICFX 1420314-6-2-1-1	0.183^{ab}	0.591^{abc}	11.900^{hij}	54.137^{b-h}	0.143^{i}	6.567^{lm}	22.260^{l}	41.523^{a-d}	39.350^{lm}	80.030^{abc}	364.333^{cd}	26.297^{e-j}
ICFX 1420315-2-2-1-2	0.132^{hi}	0.478^{f-i}	17.487^{bc}	57.757^{a-g}	3.503^{fg}	9.260^{fgh}	39.127^{a}	35.423^{e-i}	28.163^{p}	62.080^{c}	439.667^{b}	30.533^{c-g}
CV (%)	11.39	12.26	8.01	6.73	9.59	9.09	4.39	6.16	19.92	5.18	7.84	13.07
LSD $_{0.05}$	0.02	0.08	2.55	6.05	0.61	1.24	1.99	4.59	22.74	3.33	50.89	5.72

Means in a column followed by the same letter are not significantly different using Fisher's Least Significant Difference test at *P*<0.05. CV- Coefficient of Variation, LAI - Leaf area index, LI- light intensity, ET- Evapotranspiration rate, LRWC-Leaf relative water content, SC- Stomatal conductance (mol $H_2Om^{-2}s^{-1}$), CC- Chlorophyll content, RRWC- Root relative water content, SBIO-Shoot biomass (g), TBIO-Total biomass, RBIO-Root biomass (g), COA- CO_2 assimilation (mol$m^{-2}s^{-1}$) and PR-Photosynthetic rate (μmolCO_2 $m^{-2}s^{-1}$).

above ground biomass (Zhou et al., 2018). Root biomass is directly associated with the root length and number of root hairs, which are important for increased water uptake. Therefore, increased root biomass displayed among the selected finger millet genotypes in this study can be attributed to an increase in one, or combinations of, these root system components.

These results agree with those of Chen et al.

Table 9. Pearson's correlation coefficients for selected agronomic and morpho- physiological traits of the finger millet genotypes.

Traits	RRWC	NF	FL	NPT	FFLW	HI	TSW	LAI	LI	SBIO	RBIO	TBIO	Yield
ET	0.191*	-0.794***	-0.713***	-0.253***	0.736***	0.537***	0.650***	-0.544***	-0.505***	-0.31	-0.27	-0.223	0.611***
RRWC		-0.243**	-0.242**	0.131	0.218**	0.442***	0.224	-0.271	-0.257	0.094	-0.603***	-0.269	0.191*
NF			0.934***	0.024	-0.945***	-0.699***	0.841***	0.803***	0.753***	0.429***	0.359***	0.315***	0.635***
FL				-0.011	-0.903***	-0.652***	0.809***	0.815***	0.761***	0.406***	0.344***	0.312***	0.553***
NPT					0.030	-0.174*	-0.092	-0.027	-0.008	0.174	0.168	0.175	0.161
FFLW							0.676***	0.818***	-0.814***	0.776	0.437***	0.274***	0.269***
HI							0.651***	-0.650***	-0.606***	0.483***	0.581***	0.493***	0.687***
TSW								-0.729***	-0.717***	0.426***	0.426**	0.316***	0.316***
LAI									-0.932***	0.425***	0.349***	0.341***	0.544***
LI										0.422***	0.308***	0.333***	0.565***
SBIO											0.059	0.383***	0.262**
RBIO												0.566***	0.164*
TBIO													0.200*

***P<0.001, ** P<0.01, ET– evapotranspiration rate, RRWC– root relative water content, NF – number of fingers, NPT– number of productive tillers, FL–finger length, FFLW– days to 50% flowering, HI – harvest index, TSW – thousand seed weight, LAI – leaf area index, LI – light intensity, SBIO – shoot biomass, RBIO – root biomass, TBIO – total biomass.

(2020), who established that biomass allocation pattern influences drought tolerance in wheat. Plants that invest significantly in root biomass increase their potential for water and nutrient absorption, which directly influences their growth potential (Wasaya et al., 2018). Large root biomass is important in dryland farming conditions where crops have to explore large volumes of soil to extract enough moisture for growth (Ehdaie et al., 2012).

Changes in stomata conductance cause changes in leaf water potential by changing the transpiration rate. High photosynthesis and stomatal conductance among the evaluated finger millet genotypes indicated that photosynthetic CO_2 fixation in the genotypes was not affected by a water stress condition across the two locations. Furthermore, the high photosynthesis and stomatal conductance exhibited by these genotypes can be an indicator for improved water use efficiency. In a related study by Chen and Hao (2015), transpiration rate, stomatal conductance and water use efficiency (WUE) were found to have no correlation with grain yield in wheat. In contrast, Sharma et al. (2015) observed a positive correlation between water use efficiency and grain yield in pearl millet. Photosynthetic and transpiration rates, which depend on stomatal conductance, have been widely proven to be regulated by soil moisture levels (Frih et al., 2021).

The leaf area index showed a significant positive relationship with shoot biomass as well as grain yield. Reduced leaf area resulted in a lower shoot biomass and grain yield in all the genotypes. Low light intensity reduces the leaf expansion rates and delays the complete expansion of a leaf; thus, leaf area per plant is decreased under shade conditions (Fan et al., 2018). In the present study, the leaf area was reduced under low light intensities, which might be due to higher allocation of biomass towards stem elongation than to leaf expansion (Wu et al., 2017). Furthermore, low light intensity reduces the photosynthesis rate, slowing down other physiological processes in plants (Anjum et al., 2020).

Conclusion

Morphological and physiological traits have been widely used in the screening and selection for drought among the cultivated crops. Morphological traits (such as the number of root hairs, lateral roots, root volume, root length, root density and root surface area) have been directly linked to higher water uptake from water-deficient soils. Deep and proliferate root systems avoid drought stress due to their ability to acquire more water from deeper soil horizons.

Improved water uptake is considered a key strategy towards drought tolerance in crops. Therefore, the development and distribution of root systems can be regarded as key factors for more efficient water uptake; and thereby is a means for managing the performance of finger millet under drought stress. Physiological traits as well have been widely exploited for drought tolerance. Results of this study revealed the genotypic and environmental differences for the physiological traits assessed. The wide variability that existed among the finger millet genotypes and in locational differences could be used to generate important information towards selection for drought tolerance among the evaluated finger millet genotypes. Finger millet lines ICFX 1420314-2-1-1-1 (7), KNE 814 X Ex Alupe (P) P8-1-1-1-1 (24) and ICFX 1420415-3-1-1-2 (14) proved to be consistent for better morpho-physiological traits across the two locations. Therefore, the named finger millet lines can be considered for further evaluations and breeding programs towards drought tolerance.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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