Journal of Botanical Research
https://ojs.bilpublishing.com/index.php/jbr

ARTICLE

Evaluation of Germplasm of Pearl Millet (*Penissetum glaucum* L.) for Agronomic, Physiological and Biochemical Traits under Semi-arid Conditions of Hamelmalo

Habteslase Teklu Tesfagiorgis* **Woldeamlak Araia** **N.N. Angiras***

Department of Agronomy, Hamelmalo Agricultural College, Keren, Eritrea

ARTICLE INFO

Article history
Received: 3 June 2021
Accepted: 21 June 2021
Published Online: 6 July 2021

Keywords:
Pearl millet
Germplasm
Agronomic characters
Physiological characters
Biochemical characters

ABSTRACT

A field experiment was conducted at the experimental farm of Hamelmalo Agricultural College during summer 2017, to evaluate the agronomic, physiological, and biochemical performance of the collected Eritrean germplasm of pearl millet. A total of 16 accessions were tested, out of which 2 were improved varieties included as a check. The experiment was laid out in 4 x 4 Simple Lattice Design with Randomized Block using 4 replications with a gross plot size of 3.0 m x 1.2 m, row to row spacing of 75 cm and plant to plant spacing of 30 cm. The data collected were Agronomic parameters (growth, development, yield, and yield contributing characters); Physiological parameters (Relative water content and Water Use Efficiency); and Biochemical parameters (crude fat, crude fiber, protein content, TSS, and ash content). The data were analyzed using GENSTAT software and correlation analysis was worked to see the positive and negative contribution of agronomic, physiological, and biochemical attributes. The results of the study showed that Bariyay908 and Kona being statistically at par with Bariyay 910, Hagaz, Zibedi, Shleti, Delkata, Tokroray, and Kunama produced significantly higher grain yield. However, among these Baryay908 because of its superior agronomic characteristics, lower incidence of downy mildew, relatively higher water use efficiency and higher crude protein content were found to be comparatively superior to the check improved varieties Kona and Hagaz. Grain yield has shown a positive and significant correlation with harvest index, number of seeds per panicle, panicle length, leaf area and water use efficiency. These promising accessions need to be further tested for future breeding programs to develop varieties higher in productivity and resistant to downy mildew under semi-arid conditions of Eritrea.

1. Introduction

Pearl millet (*Pennisetum glaucum* L.) is known by different common names all over the world such as Cattail millet, Bullrush millet, Candle millet, and Penicillaria in English, Bultug in Eritrea and Bajra in India. It is the world's fourth most important cereal crop in the tropics. It is small-seeded hardy grass that grows well in dry zones

**Corresponding Author:*
N.N. Angiras,
Department of Agronomy, Hamelmalo Agricultural College, Keren, Eritrea;
Email: angirasnsk@gmail.com
Habteslase Teklu Tesfagiorgis,
Department of Agronomy, Hamelmalo Agricultural College, Keren, Eritrea;
Email:habtishagro@gmail.com

 DOI: https://doi.org/10.30564/jbr.v3i3.3319

under rain-fed conditions, in areas with marginal soil fertility conditions and moisture [1] which makes it one of the preferred cereal crops in drier areas. Millet is one of the oldest food crops known to humans and possibly the first cereal grain to be used for domestic purposes [2]. It is considered an orphan crop that is widely grown for food and fodder in Africa and India. Among the most important grain crops in the world, Pearl millet is widely grown in the semi-arid regions of Africa and Asia as a staple food crop by the poorest people living in the most difficult production environment [3]. It has multiple uses especially its ability to cope up with harsh climatic conditions and will continue to feed the world's expanding populations. Moreover, it will be the crop of the future due to the changing global climatic trends and the increase in the use of marginal lands for crop production [4].

In Eritrea, pearl millet grains are used for making a variety of foodstuffs commonly known as *Injera, Kicha,* and *Ge'at* while the stalks are used for animal fodder, house construction and fuel. It is widely grown in the lowlands under an arid and semi-arid climate of Eritrea; especially in areas with rainfall shortages where other crops survive the least.

Pearl millet is grown in an area of 36,288 million hectares in the world with average total production of 298,006 tons and average productivity of 821 kg per hectare. In Africa, it is cultivated in an area of 20774 hectares with a total production of 14606 tons and productivity of 703 kg per hectare. In Eritrea, pearl millet production has declined due to land degradation; the use of traditional farm implements and global climate change. Moreover, drought is the major cause of the under-production of the crop. In Eritrea, the total area occupied by Pearl millet during the year 2014 was 85,856 ha (16.3%) with a production of 44,772 (8.8%) tons. But in 2015, the total area occupied decreased to 66,920 ha (15.4%) with a production of 10,348 tons (8.7%) and productivity of 0.3 to 0.5 t/ha ,which is very low [5]. The average productivity of Pearl millet in Eritrea is much less than its productivity in the African continent which is 703 kg ha^{-1} and that of the world with 821 kg ha^{-1}. The major constraints of the low productivity in Eritrea are mono-cropping, poor soil fertility, imbalanced use of fertilizers, low and erratic distribution of rainfall, shortage of quality seeds, infestation by weeds, attack of diseases (downy mildew and smut), and insect pests.

Out of the total cultivated area in Zoba Anseba (60,000 ha) of Eritrea, pearl millet occupies 28080 ha with an average production of 23494.9 tons and average productivity of 960 kg ha^{-1}. Whereas in sub- Zoba Hamelmalo of Zoba Anseba out of the total cultivated area (9252 ha), pearl millet occupies 5210 hectares with a total average production of 5595.8 tons and average productivity of 1070 kg ha^{-1}. Therefore, pearl millet is the first important crop followed by the sorghum in the Anseba region in terms of total area coverage [6]. In Hamelmalo, sorghum mono-cropping has resulted in the infestation of Striga weed in the crop fields hence farmers are shifting to pearl millet which is relatively immune to Striga. Due to this reason, there is a change in total area and production in Hamelmalo area where pearl millet is becoming the most important cereal crop.

Farmers in Eritrea use landraces of pearl millet that have been grown for generations. These landraces have been selected and maintained by the farmers over a longer period of time and have made the necessary adjustments to the environmental conditions and specific requirements of the area. Because of their different morphological, physiological, and biochemical characteristics, they provide an important genetic resources for the development of improved varieties having drought and pest resistance. Some of the varieties released before a longer period of time have deteriorated in their performance because of mechanical mixtures (at planting, harvesting and threshing), out crossing, attack from new races of diseases, etc. Apart from these, genetic erosion has also been caused by land degradation due to loss of soil fertility, drought or moisture stress, weed and disease infestation, and changes in agricultural practices over a period of time.

The National Agricultural Research Institute of the country has collected and preserved the biodiversity of the available germplasm of pearl millet in the gene bank. The pearl millet germplasm collected is expected to be a source of variability of different characters that are useful for crop improvement programs. But their evaluation for agronomical, physiological, and biochemical characteristics for specific environmental conditions has not been attempted to date. Furthermore, it is important to identify pearl millet land races with valuable traits to be used for the future breeding programs and to be screened in future advanced yield trials. Therefore, the present investigation was carried out to evaluate the agronomical, physiological, and biochemical characteristics of some of the pearl millet landraces out of the germplasm conserved in the gene bank for higher productivity under semi- arid conditions of Hamelmalo.

2. Materials and Methods

A field experiment was conducted at the experimental farm of Hamelmalo Agricultural College located at latitude of 15° 52' 18" N, longitude of 38° 27' 55" E and an altitude of 1280 m a.m.s.l. during summer rainy season of 2017.Topography of the area is medium flat and hilly, which is undulated as well as exposed to erosion. The soil type ranges from sandy to sandy loam. The rainfall in the area is low and erratic in distribution. In most of

  DOI: https://doi.org/10.30564/jbr.v3i3.3319

the years rainfall starts around mid-June and ends up by mid-September. The area receives a mean annual rainfall of 430 mm, which is a typical amount of rainfall obtained in semi-arid regions. The total amount of rainfall in 2017 was 549.6 mm with an average maximum and minimum temperature of 33.7 ^{o}C and 13.9 ^{o}C , respectively. There was no variation in evapo-transpiration rate during the main growing period of the crop from July to September ranging from 5.8 to 5.9 mm [7].

A total of 16 pearl millet genotypes were tested out of which 14 accessions are from the Eritrean pearl millet germplasm collection and 2 standard checks (Hagaz and Kona) (Table 2). The germplasm were obtained from the Genetic Resource Division of the National Agricultural Research Institute (NARI). The details of the accessions evaluated in the study were as follows:

Treatment	Acc. No.	Name
T1	EG-1078	Kunama
T2	EG-1094	Gundmay
T3	EG-1200	Bartu
T4	EG-1197	BultugNara
T5	EG-947	Mensura
T6	EG-907	Zibedi
T7	EG-904	Shleti
T8	EG-117	Jengeren
T9	EG-908	Baryay1
T10	EG-203	Anseba
T11	EG-910	Baryay2
T12	EG-205	Delakda
T13	EG-935	Tokriray
T14	EG-148	Ferdeghi
T15	Check (Improved)	Kona
T16	Check (Improved)	Hagaz

Note: T= treatment; EG= Eritrean germplasm

The experiment was laid out in 4 x 4 Simple Lattice Design with Randomized Block using 4 replications with a gross plot size of 3.0 m x 1.2 m , row to row spacing of 75 cm and plant to plant spacing of 30 cm. All other agronomic practices like seed bed preparation, fertilizer application, and weed management were uniform in all the experimental plots.

The following agronomical, physiological, and biochemical characteristics of each of the accessions under study were recorded as per the methodology mentioned against each.

Agronomic parameters

Phenological and growth parameters

Plant count: Number of seedlings emerged in the plot and plants that reached maturity were counted and recorded in percent.

*Plant height***:** It was determined from 5 randomly selected plants at 40 DAF (Days after flowering) by measuring the height from ground level to the base of the youngest fully opened leaf. After panicle emergence, height was recorded from the base of the plant to the tip of the panicle at physiological maturity and expressed in a centimeter.

The number of fertile tillers: A number of basal fertile tillers was counted at 40 DAF.

The number of green leaves (NGL) and number of senescence leaves (NSL): It was determined from 5 randomly selected plants. A number of green leaves having more than 50 % green portion were counted. The number of senescence leaves was counted when more than 50% of the leaf area had senesced. The measurements of both parameters were done at the same time.

Green Leaf Area (cm2): Leaf area of 5 tagged plants was recorded at 40DAF by measuring length (L) from the leaf base to the tip and maximum breadth (B) of fully opened leaf lamina. The product of leaf length, breadth, and correction factor (CF) 0.747 [8] were used to express the leaf area in cm^2 per plant as given below by taking an average of five plants:

Leaf area (cm^2) = Lx B x CF

*Leaf area index***:** It was obtained by dividing leaf area per plant by area covered under one plant.

Days to 75% Flowering: The number of days taken to 75% anthesis (flowering) was recorded when 75% of the plants flowered in the two central rows in each plot and expressed in days from sowing up to flowering.

*Days to maturity***:** The date when 90% of the plants reaching maturity were recorded from the central two rows and the number of days taken was counted from sowing up to maturity.

Yield and yield components

Yield components such as Panicle length (cm), Panicle weight (g), Number of grains per panicle, and Thousand -grain weight (g) were recorded immediately after harvest of the crop. Grain yield (kg/ha) was recorded after threshing of the total biomass after recording its dry weight. The harvest index was calculated by dividing the grain yield by the biomass yield of each plot.

Physiological parameters

Relative Water Content: Second or third fully expanded leaf from the top was collected at 30 DAF in polyethylene bags and kept in an ice box after transporting from the field. Immediately, twenty leaf discs were weighted on an electronic balance to determine the fresh weight (FW). The weighted leaf discs were floated overnight in a Petri-dish containing distilled water and subsequently blotted gently and weighted again (TW= turgid weight). After taking turgid weight, the discs were oven-dried at 80^{o}C for

 DOI: https://doi.org/10.30564/jbr.v3i3.3319

28 hours and dry weight (DW) was recorded separately. The RWC was calculated using the following formula and expressed in percent.

Relative water content (%) = (FW-DW) / (TW-DW) * 100

*Water use efficiency (WUE)***:** It was calculated by dividing the grain yield by the amount of rainfall received during the growing season by using the following formulae.

$$\text{WUE (kg/mm)} = \frac{\text{Grain yield (Kg)}}{\text{Amount of rainfall during the season(mm)}}$$

Biochemical parameters

The analysis for biochemical attributes was carried out in Villagio, National Animal and Plant Health Laboratory (NAPHL). A composite sample of each landrace in four replications was taken as a representative sample due to unavoidable reasons. There were a total of 16 samples used. The grain samples were dried and powdered to 1 mm particle size. Total soluble sugar content, Fat contents, Fiber content, Total nitrogen content, and Ash content were analyzed from these processed samples.

Protein content was determined by multiplying the nitrogen content in per cent with the Conversion factor (5.83).

Downy mildew infestation

The number of infected plants plot^{-1} due to downy mildew (DM) was counted and calculated as :

DM incidence%= n/N*100

Where N is the total number of observed plants, n is the total number of diseased plants [9].

Statistical Analysis

GENSTAT software was used to compile and analyze the data. The mean comparison was estimated using LSD at 5%. Correlation analysis among the characters was carried out using GENSTAT software.

3. Results and Discussion

Growth parameters

The growth parameters averaged over the post- flowering periods for all the accessions tests are given in Table 1.

Plant height

Overall, there were significant differences among the pearl millet accessions in plant height when averaged over the post- flowering periods (Table 1). The plant height ranged from 168.3 to 256.4 cm. The accession Jengeren (256.4 cm) being statistically at par with Anseba was significantly taller as compared to all other accessions. Kona (check), Bartu and Bultug Nara being statistically at par were shorter compared to the other accessions. This is in agreement with the findings of [10], [11] and [12] ,who reported that there was a variation in plant height among the varieties of pearl millet. The work done by [13] on pearl millet also showed that Kona was short to medium (160-200 cm) in height depending on the location and the plant height is within the range as reported by other researchers.

Leaf Area

There was a significant difference in leaf area among the pearl millet accessions when averaged over the post-flowering stage (Table 1).A significantly higher leaf area was recorded from Delakda (190.1 cm^2), Ferdeghi (188.9 cm^2), Bariyay908 (188.8 cm^2), Bariyay910 (188.5 cm^2) Tokriray (187.3 cm^2), Zibedi (185.4 cm^2), Gudmay (172.1) and Shelti (165.1) over the remaining accessions. A significantly lower leaf area was recorded from Bartu, Bultug Nara, Anseba, and Jengeren. Pawar [14] reported that there was significant difference in green leaf area among sorghum accessions which is in agreement with the current study.

Leaf Area Index

There was a significant difference in Leaf Area Index among the accessions when averaged over the post-flowering periods (Table 1). Delakda, Fedeghi, Bariyay908, Bariyay910, Zibedi, Tokriray, Shelti, Gudmay, and Mansurea being statistically at par resulted in significantly higher Leaf Area Index. But significantly lower LAI was recorded in Bartu, Bultug Nara, Jengera, Anseba, and Kunama accessions which are statistically at par.

Number of Fertile Tillers

There was a significant difference in a number of fertile tillers among the accessions of pearl millet when the values taken during post-flowering period were averaged(Table 1). A significantly highest number of fertile tillers was obtained from Kunama followed by Bultug Nara, and Bartu compared to the other accessions. But significantly lower fertile tillers were produced by Anseba, Bariyay910, Delakda, Tokriray, Ferdeghi, Jengren, and Bariyay910 accessions which were statistically at par. The two improved varieties, Hagaz and Kona produced relatively less effective tillers but the panicle size was large enough which is expected to compensate the grain yield. The accessions with more fertile tillers had relatively smaller panicles which resulted in lower grain yield. The finding on fertile tillering capacity is in agreement with the report of several authors who indicated that there was significant difference in the number of fertile tillers per plant among the pearl millet varieties [15,16].

Number of Green leaves

There was a significant difference in a number of green leaves (NGL) among the accessions of pearl millet when the values were averaged on the different periods of post-flowering (Table 1). The accessions such as Jengeren, Anseba, and Ferdeghi had significantly lower number of

  DOI: https://doi.org/10.30564/jbr.v3i3.3319

green leaves. Kunama (33.36) had significantly highest number of leaves per plant. Bariyay908 (25.14), Bartu (24.26), Bultug Nara and Mensura (23.4), Shelti and Ferdeghi being at par were the next higher in a number of green leaves compared to the other accessions indicating that they stayed green for a longer period during post-flowering stage.

This could be attributed to more number of tillers produced by these accessions resulting in a higher number of green leaves. According to [17] genotypes with a higher number of green leaves stayed green for a longer period of time and retained chlorophyll in their leaves with the ability to carry out photosynthesis for a longer period resulting in higher yield compared to those with the lower number of green leaves.

Number of Senescence Leaves

There was a significant difference in the number of senescence leaves among the pearl millet accessions when the values were averaged on the post-flowering period (Table 1). The number of senescence leaves increased with time but it was significantly lower in Kona Torrey, Bariyay910, and Hagaz (check variety). A significantly higher number of senescent leaves were observed in Anseba and Jengeren accessions these two accessions were very late- maturing types that were affected by drought during the post-flowering period.

Per cent plant count, Crop Phenology and Disease incidence

The results on per cent plant count; crop phenology and downy mildew disease incidence as influenced by accessions were significant and are presented in Table 2.

Per cent plant count

The Plant count for all the accessions was satisfactory except for Ferdeghi (50.25%) which showed the lowest crop stand (Table 2). The reason for the lower crop stand was due to heavy rainfall at that time resulting in water logged conditions. This is in contrary to the report of [18] that did not show any significant difference in Plant count of pearl millet variety in terms of Plant count (in 2010 and 2011 cropping seasons) but were satisfactory in a number of Plant count. The current study is in agreement with the findings of [19] who reported that in cereals, the Plant count for both pearl millet and sorghum is hardly affected significantly by the type of a variety when both environmental and soil conditions are favorable for the crop.

Number of Days to 75%Flowering

Accessions showed significant differences in number of days to flowering. Among the accessions Kona (check), Bartu and Bultug Nara, Kunama, and Hagaz (check) took fewer number of days to flowering ranging from 49 to 55 days. It was further noted that Jengeren and Anseba took a significantly higher number of days to flowering (79 days)

Table 1. Effect of pearl millet accessions on growth parameters at post-flowering stage.

Treatment	Plant height (cm)	Leaf Area (cm^2)	LAI	Number of Fertile tillers	Number of Green leaves	Number of Senescence leaves
Kunama	183.3	138.6	0.061	7.5	33.4	11.5
Gudmay	225.6	172.1	0.076	4.0	17.4	11.5
Bartu	168.8	112.1	0.049	6.4	24.3	13.0
Bultug Nara	168.4	116.0	0.051	6.4	23.4	12.1
Mensura	201.6	163.6	0.074	4.7	23.4	11.0
Zibedi	207.7	185.4	0.083	4.2	19.7	10.9
Shleti	203.4	165.1	0.073	4.3	22.6	11.1
Jengeren	256.4	124.5	0.055	3.4	9.3	22.2
Bariyay908	215.8	188.8	0.084	4.8	25.1	12.2
Anseba	248.9	118.7	0.054	3.9	12.4	23.2
Bariyay910	214.8	188.5	0.084	3.6	16.3	9.2
Delakda	230.1	190.1	0.084	3.9	18.2	12.3
Tokriray	209.4	187.3	0.083	3.3	16.6	8.4
Ferdeghi	206.0	188.9	0.085	3.8	15.7	10.9
Kona	168.3	134.5	0.060	4.2	16.9	6.6
Hagaz	192.4	159.8	0.071	4.6	22.5	10.2
Mean	206.6	158.4	0.070	4.6	19.8	12.3
LSD (5%)	18.78	24.98	0.012	0.76	6.57	4.2
CV(%)	6.4	11.1	12	1.5	23.3	24.1

 DOI: https://doi.org/10.30564/jbr.v3i3.3319

compared to all the accessions. In the current study, there was a variation in the number of days to flowering among the accessions with a difference of 30 days between the earliest and the latest which is very big (Table 2).This is in contradiction with [15,20,11] who reported that the pearl millet varieties they tested did not show a significant difference in days to flowering. The same result was reported by [21]. On the other hand, [22] tested eight varieties of sorghum and confirmed that there was a significant difference in days to flowering among the varieties. [23] also stated that the two new improved varieties of Pearl millet in Eritrea showed earliness in flowering compared to the local accessions.

Days to maturity

There was a significant difference in days to maturity among the accessions of pearl millet. The days to maturity ranged from 78 to 113 days. Among these Kunama, Bartu, Kona and Bultug Nara being at par were significantly earliest (78 days) in maturity. Significantly late-maturing accessions were Jengereen and Anseba which took 113 and 108 days, respectively (Table 2).

The two late-maturing accessions (Jengerren and Anseba) taller took more time for vegetative growth resulting in delayed maturity. This is in conformity with [23] who found a significant difference in days to maturity in sorghum varieties. Studies have shown that Kona is earlier in days to maturity compared to the other local landraces (Tokroray) [24].

Downy mildew infestation

In general, the infestation of downy mildew was higher in all the accessions except Bariyay908 compared to recommended varieties (check) Kona and Hagaz. Significantly higher downy mildew incidence was noted in Gudmay (66.6%), Jengeren (61%), Mensura (49%), and Ferdeghi compare (48%) accessions. The improved variety Kona (check) was free from downy mildew incidence. This finding in this study agrees with that of [25] who indicated that there was a significant difference in downy mildew among the pearl millet varieties and similarly with the finding of Downy mildew survey Research in Eritrea [26] who reported its wide distribution in Eritrea with 30-50% infection rate in Zoba Anseba and Gash Barka during the survey period.

Yield components

All the yield components viz. panicle weight, panicle length, thousand grain weight, number of seeds per panicle, and number of fertile tillers were significantly affected by different accessions under study (Table 3).

Panicle weight

Pearl millet accessions Delakda (23.45 g), Bariyay908 (22.35 g), Tokriray (22.25 g), and Anseba (22 g) resulted in significantly higher panicle weight as compared to oth-

Table 2. Effect of pearl millet accessions on per cent plant count, days to 75% flowering, days to maturity and downy mildew disease.

Treatment	Plant count (%)	Days to 75%flowering	Days to maturity	Downy Mildew %
Kunama	100	53	78	55.5
Gudmay	100	58	89	66.6
Bartu	94	52	78	37.8
Bultug Nara	99	52.	78	46.3
Mensura	100	55	81	49.0
Zibedi	94	57	85	21.9
Shleti	99	55	82	26.1
Jengeren	100	79	113	61.0
Bariyay908	82	56	85	19.7
Anseba	100	79	108	35.8
Bariyay910	100	56	85	33.7
Delakda	100	57	86	34.6
Tokriray	100	56	85	30.7
Ferdeghi	50	57	88	48.0
Kona	93	49	78	0.0
Hagaz	100	55	88	16.1
Mean	94	58	87	36.4
LSD (5%)	11	2	1	19.15
CV(%)	8	2.8	1	36.9

DOI: https://doi.org/10.30564/jbr.v3i3.3319

er accessions under study. On the other hand Bartu (15.35 g), Bultug Nara (15.45 g), and Kunama (16.9 g) were the accessions with significantly lower panicle weight. The accessions also had different forms of panicle having compact and loose panicles. This is in agreement with [27] who found out that pearl millet variety with variations on panicle weight for grain yield and yield components.

Panicle Length

Accessions Hagaz (37.5 cm), Tokriray (34.5 cm), Bariyay908 (34.25 cm), Bariyay910 (33.5 cm), Zibedi (33.25), Kona (32 cm), Gundmay (30.75 cm), Delkado (30.75 cm) and Shleti (29.25 cm) being at par produced significantly longer panicles than other accessions under study. On the other hand accessions Jengeren (5.75 cm) and Bultug Nara (13.25 cm) had the lower panicle length. Jengeren recorded lowest panicle length and it was late in flowering and maturity which is an indication that the panicle length was affected by moisture stress (Table 3). [28] and [11] also described on the variation in panicle length among the pearl millet accessions which goes in line with this study.

Thousand grain weight

A significantly higher thousand-grain weight was recorded in checks varieties, Kona (2.25 g) and Hagaz(2.08 g) but were at par with Zibedi (1.68 g), Anseba (1.62 g), and Ferdeghi (1.60 g). The accessions Bariyay910 (0.40 g) and Mensura (0.82 g) showed the lowest thousand- grain weight (Table 3). [11] reported that there was a significant difference among varieties of pearl millet in thousand-grain weight which agrees with the findings of the current study.

Number of grains panicle^{-1}

A significantly higher number of seeds per panicle were recorded from accession Gudmay but were at par with Bariyay908, Zibedi, Shleti, Bariyay910, Delakda, Tokriray, and Hagaz due to their large panicle size but small seed size. The accessions Jengeren produced significantly the lowest number of grains per panicle but accessions Anseba, Bultug Nara, Bartu, and Kunama were also low in grain number but were superior to it (Table 3). The accessions Anseba and Jengeren were late maturing types with small number of seeds per panicle. [29] reported a significant difference in the number of grains per panicle among accessions in sorghum and the same was observed in the number of grain per panicle with significant difference among the tested genotypes of pearl millet.

It can be inferred that among accessions under study, all the yield components of accessions Bariyay908, Delakda, Tokriray, Zibedi, Shleti, and Gundmay were almost at par with recommended variety Hagaz.

Grain Yield, Biomass yield and Harvest Index

Grain yield, biomass yield and harvest index were significantly influenced by different accessions under study

Table 3. Effect of pearl millet accessions on yield components

Treatment	Panicle weight (g)	Panicle length (cm)	1000 grain weight (g)	Number of grains/panicle
Kunama	16.90	17.25	1.32	9061
Gundmay	20.60	30.75	1.25	16299
Bartu	15.35	16.50	1.27	8914
Bultug Nara	15.45	13.25	1.27	7817
Mensura	21.20	26.00	0.82	10731
Zibedi	20.55	33.25	1.68	13783
Shleti	21.35	29.25	1.57	13220
Jengeren	20.75	5.75	1.57	2375
Bariyay908	22.35	34.25	1.57	15128
Anseba	22.00	16.75	1.62	7384
Bariyay910	20.15	33.50	0.40	13651
Delakda	23.45	30.75	1.45	13678
Tokriray	22.25	34.50	1.57	14277
Ferdeghi	21.25	25.75	1.60	10728
Kona	18.35	32.00	2.25	10240
Hagaz	20.65	37.50	2.08	13032
Mean	20.16	26.06	1.46	11270
LSD(5%)	1.687	9.605	1.46	4205.0
CV(%)	5.9	25.9	22.8	26.2

 DOI: https://doi.org/10.30564/jbr.v3i3.3319

(Table 4).

Grain Yield

Accessions Bariyay908 (2.9 t ha^{-1}) and Kona (2.8 t ha^{-1}) being statistically at par with Bariyay 910 (2.6 t ha^{-1}), Hagaz (2.5 t ha^{-1}) , Zibedi (2.5 t ha^{-1}), Shleti (2.4 t ha^{-1}), Delkata (2.4 t ha^{-1}) ,Tokroray (2.4 t ha^{-1}) and Kunama (2.1 t ha^{-1}) produced a significantly higher grain yield (Table 4) because of their higher growth in terms of leaf area, LAI, green leaves etc. (Table 1), higher plant population, early development and lower attack of downy mildew (Table 2) higher yield components (Table 3). Jengeren and Anseba were significantly lowest yielding accessions because both had lower leaf area, LAI, number of green leaves (Table 1), late in maturity and were affected by drought during post-flowering period (Table 2), high incidence of downy mildew (Table 2) and poor in yield components (Table 3). Accessions like Bultug Nara, Bartu, and Kunama had smaller panicle lengths resulting in lower yields. According to [22] and [30] pearl millet varieties showed a significant difference in grain yield which agrees with the current study.

Biomass yield

The higher biomass yield was produced in Anseba (20.3 t/ha), Jengeren (19.3 t/ha), and Bariyay908 (18.6 t/ha). The accessions Anseba and Jengeren gave maximum biomass yield but not higher grain yield. These two accessions were tall in plant height compared to the other accessions and varieties resulting in much higher biomass. On the other hand, Kona (improved variety), Bultug Nara, Bartu, and Kunama gave the lowest biomass yield (Table 4) but higher grain yield because of more translocation of the photosynthates to well-developed sink. This is in agreement with [12] and [30] who reported that there was a highly significant difference among pearl millet varieties in biomass yield and also agrees with [22] who indicated that sorghum varieties differed significantly in biomass yield.

Harvest index

The highest harvest index of 41% was obtained from the Kona variety. A higher harvest index means higher grain yield due to better translocation of photosynthates from the leaves to the good development of sinks even with relatively lower biomass yield (Table 4). In food crops, accessions or varieties with higher harvest index are selected but for their use as forage crop lower harvest index is needed. The other accessions such as Bartu, Kunama, Hagaz (check), Mensura and Bariyay 910 gave harvest index between 20% and 22%. The accessions Anseba and Jengeren gave the lowest harvest index which means that the proportion of grain yield compared to biomass yield is very low due to the effect of drought stress. [31] reported that pearl millet varieties have shown a significant difference in harvest index which is similar to the current study. Furthermore [32] also mentioned that drought stress contributes towards lower harvest index.

Table 4. Effect of pearl millet accessions on biomass yield, grain Yield and harvest index.

Treatment	Grain yield (t ha^{-1})	Biomass yield (t ha^{-1})	Harvest index (%)
Kunama	2.083	9.444	22.06
Gundmay	1.944	11.389	17.07
Bartu	1.528	7.222	21.16
Bultug Nara	1.250	6.944	18.00
Mensura	1.944	8.889	21.87
Zibedi	2.500	13.611	18.37
Shleti	2.361	12.361	19.10
Jengeren	0.278	20.278	1.37
Bariyay908	2.917	18.611	15.67
Anseba	1.111	19.306	5.75
Bariyay910	2.639	13.056	20.21
Delakda	2.361	13.889	17.00
Tokriray	2.361	11.250	20.99
Ferdeghi	1.250	9.583	13.04
Kona	2.778	6.944	40.01
Hagaz	2.500	11.389	21.95
Mean	1.988	12.135	18.35
LSD (5%)	0.968	3.729	0.068
CV (%)	34.2	21.6	25.6

Physiological Parameters

The effect of pearl millet concessions on Relative Water Content and Water Use Efficiency is shown in Table 5.

Relative Water Content

There was no significant difference in Relative Water Content among the accessions. Numerically, Ferdeghi (59.78%), Shleti (55.98), Hagaz (53.93%), and Gudmay (53%) accessions had a higher relative water content. This is an indication that the accessions stayed green and maintained better water status in the plant system. The next best accessions were Tokriray (52.58%), Delakda (51.45%), Anseba (51.15%), Bartu (51.35%), and Mensura (51.33%). This could be attributed to the maintenance of better water status. There were accessions that showed lower Relative Water Content such as Jengeren (45.48%), Bariyay910 (46.18%), Kunama (47.7%) and Kona (48.95%) which was relatively lower compared to the other accessions (Table 5). The difference in Relative Water Content between accessions even though is not significant among the accessions signifies the resistance to terminal drought and adaptation of the materials to the local conditions.

Water Use efficiency

There was a significant difference in water use efficiency among the accession. Accession Bariyay908 (8.03 kg/mm of

DOI: https://doi.org/10.30564/jbr.v3i3.3319

water) being statistically at par with Kona (7.65 kg/mm of water), Bariyay910 (7.25 kg/mm of water) , Zibedi (6.90 kg/mm of water), Hagaz (6.85 kg/mm of water), Tokriray (6.50 kg/mm of water), Shleti and Delakda (both 6.48 kg/mm of water), Kunama(5.73 kg/mm of water) and Mensura (5.46 kg/mm of water) because of their higher grain yields gave a significantly higher water use efficiency. Because of lower grain yield accessions Jengeren (0.78 kg/mm of water), Anseba (3.03 kg/mm of water), Ferdeghi (3.43 kg/mm of water) and Bultug Nara (3.48 kg/mm of water) resulted in significantly lower water use efficiency. Water Use Efficiency gives a clue on the amount of water used to produce a kg of seed and the accessions that produced the highest kg of seed per mm of water is the most efficient in terms of water use.

Table 5. Effect of pearl millet accessions on physiological parameters.

Treatment	Relative Water Content (%)	Water Use Efficiency (kg grain/mm of water)
Kunama	47.70	5.73
Gundmay	53.93	5.35
Bartu	51.33	4.23
Bultug Nara	50.40	3.43
Mensura	51.33	5.46
Zibedi	50.03	6.90
Shleti	55.98	6.48
Jengeren	45.48	0.78
Bariyay908	49.33	8.03
Anseba	51.15	3.05
Bariyay910	46.18	7.25
Delakda	51.45	6.48
Tokriray	52.58	6.50
Ferdeghi	59.78	3.43
Kona	48.95	7.65
Hagaz	53.00	6.85
Mean	51.16	5.47
LSD (5%)	NS	2.65
CV (%)	10.2	34

According to [28], sorghum accessions showed a significant difference in water use efficiency which is in agreement with the current study on pearl millet.

Biochemical attributes

The results of biochemical attributes like ash, crude protein, total soluble sugar, nitrogen, crude fiber, and crude fat are shown in Table 6.

Ash

The ash content ranged from 1.62% to 2.48%. It was numerically higher for Bartu (2.48%), Anseba (2.46%) Bariyay908 (2.43%), Jengeren (2.27%), Shleti 2.21%), Gudmay (2.13%), Delakda (2.07%), and Bariyay910 (2.05%) while the minimum values of ash content were obtained from Ferdeghi (1.62%) and the improved varieties Kona (1.71%) and Hagaz (1.79%).

Crude protein

The crude protein ranged from 11.09% to 13.53%. The protein content was numerically higher in Bariyay908(13.53%) and Kunama (13.12%) accessions as compared to the other materials tested. The level of crude protein in descending order was noted for Ferdeghi (12.73%), Zibedi, and Mensura both with the value of 12.29%, Bartu (12.22%), Gudmay (12.19%), and Hagaz (12.01%). The crude protein was the lowest in Tokriray (11.09%) (Table 6).

Total soluble sugar

Table 6. Effect of pearl millet accessions on biochemical parameters.

Treatment	Ash (%)	Crude protein(%)	Total sol.sugar (%)	Nitrogen (%)	Crude fiber (%)	Crude fat (%)
Kunama	1.94	13.12	77.95	2.25	1.15	5.84
Gundmay	2.13	12.19	79.58	2.09	1.08	5.01
Bartu	2.48	12.22	78.33	2.10	1.05	5.93
Bultug.N NnnnNara	1.99	11.34	81.13	1.95	0.98	4.56
Mensura	1.91	12.29	80.01	2.11	1.15	4.64
Zibedi	1.99	12.29	80.16	2.11	1.22	4.34
Shleti	2.21	11.67	79.58	2.00	1.11	5.43
Jengeren	2.27	11.84	80.73	2.03	1.03	5.13
Bariyay908	2.43	13.53	78.13	2.32	0.95	4.96
Anseba	2.46	11.99	80.28	2.06	1.15	4.12
Bariyay910	2.05	11.46	81.41	1.97	0.75	4.33
Delakda	2.07	11.68	80.32	2.00	1.09	4.84
Tokriray	1.95	11.09	80.19	1.90	1.35	5.42
Ferdeghi	1.62	12.73	78.72	2.18	1.58	5.35
Kona	1.71	11.93	79.01	2.05	1.04	6.33
Hagaz	1.79	12.01	80.15	2.06	1.17	4.88

Total soluble sugar ranged from 78.13% to 81.41% with numerically higher values of 81.41% and 81.13% in Bariyay910 and Bultug Nara, respectively. The lowest total soluble sugar was recorded in Kunama (77.95). In the present study, the highest yielding types such as Kona, Hagaz and Baryay 908 did not show a high level of total soluble sugar (Table 6). In contrary, [34] mentioned that the development of leaf water deficit in pearl millet leaves resulted in an increased amount of glucose, sucrose and fructose. Furthermore, [14] noted that genotypes with higher accumulated total sugars resulted in higher grain yields compared to other types, thus soluble sugar content proved to be a better marker for selecting improvement of drought tolerance in different crops. However, it was not reflected in the present study.

Nitrogen content

The nitrogen content ranged from 1.90 to 2.32 per cent. It followed a similar trend as that of protein content as protein content is calculated from the nitrogen content. Like protein content accessions Bariyay908 (2.32%) and Kunama (2.25%) gave the higher nitrogen content among the accessions. The nitrogen content was numerically lower in Jengeren (2.03%) and the improved variety Kona (2.05%).

Crude fiber

The crude fiber ranged from 0.75% to 1.58% with Ferdeghi (1.58%) giving the highest crude fiber and Bariyay 910 with the lowest (0.75%) crude fiber. The other accessions with relatively better crude fiber were Tokriray (1.35%), Zibedi (1.22%) Hagaz (1.17%), Anseba (1.15%), Kunama (1.15%), and Mensura (1.15%).

Crude fat

The crude fat ranged from 4.12% to 6.33% with Kona (improved variety) giving the highest (6.33%) and Anseba the lowest (4.12%) crude fat.

These results reveal that biochemical parameters can be taken as one of the parameters for the selection of qualitatively nutritious accessions for further breeding programs.

Correlation studies

The correlation between biomass yield, grain yield and harvest index with agronomic characters is presented in Table 7 while the relationship between biomass yield, grain yield, and harvest index with physiological and biochemical attributes is shown in Table 8.

Table 7. Correlation analysis between agronomic parameters, biomass, and grain yield and harvest index

Agronomic parameters	Biomass	Grain yield	Harvest Index
Plant count	0.090 (NS)	0.540 (NS)	0.094 (NS)
Days to Flowering	0.806 (**)	-0.630 (**)	-0.823 (**)
Days to maturity	0.811 (**)	-0.605 (*)	-0.795 (**)
Downy Mildew	0.059 (NS)	-0.781(**)	-0.570 (*)
Panicle weight	0.631 (**)	0.182 (NS)	-0.341 (NS)
Panicle length	-0.107 (NS)	0.789 (**)	0.508 (*)
Thousand Grain Weight	0.057 (NS)	0.132 (NS)	0.185 (NS)
Plant height	0.878 (**)	-0.367 (NS)	-0.766 (**)
Number of Fertile Tillers	-0.462 (NS)	0.046 (NS)	0.267 (NS)
Grain yield	-0.177 (NS)	−	0.669 (**)
Biomass	−	-0.177 (NS)	-0.732 (**)
Harvest Index	-0.732 (**)	0.669 (**)	−
Number of Seeds/Panicle	-0.123 (NS)	0.650 (**)	0.374 (NS)
Leaf Area	0.139 (NS)	0.520 (*)	0.061 (NS)
Leaf Area Index	0.019 (NS)	0.449 (NS)	0.103 (NS)
Number of Green Leaves	-0.469 (NS)	0.410 (NS)	0.414 (NS)
Number of Senescent Leaves	0.701 (**)	-0.708 (**)	-0.834 (**)

Table 8. The correlation analysis between physiological, biochemical versus biomass, grain yield and harvest index

Physiological/Biochemical parameters	Biomass	Grain yield	Harvest index
Relative Water Content	-0.303 (NS)	-0.041 (NS)	0.018 (NS)
Water Use Efficiency	-0.166 (NS)	0.947 (**)	0.700 (**)
Ash	0.575 (*)	-0.252 (NS)	-0.513 (*)
Crude protein	0.137 (NS)	0.101 (NS)	-0.050 (NS)
Total soluble sugar	0.214 (NS)	-0.165 (NS)	-0.267 (NS)
Crude fiber	-0.175 (NS)	-0.141 (NS)	-0.124 (NS)
Crude fat	-0.479 (NS)	0.117 (NS)	0.522 (*)

DOI: https://doi.org/10.30564/jbr.v3i3.3319

Days to flowering, days to maturity, plant height, and number of senescence leaves showed a positive and highly significant relationship with biomass yield. This indicates that the increase in the value of these characters resulted in an increase in biomass yield. However, these characteristics showed a highly significant negative correlation with grain yield and harvest index. [34] stated that plant height had a direct correlation with biomass yield and according to [35] days to 75% flowering was positively and significantly correlated with biomass yield which has similarity with this study. However, [30] who studied open pollinating strains of pearl millet mentioned the positive and significant correlation of biomass with harvest index and grain yield.

Similarly, downy mildew disease had a significant but negative correlation with grain yield and harvest index indicating this disease restrict the formation of grains due to its effect on senescence of leaves. [36] and [37] noted the negative and significant correlation between downy mildew incidence and grain yield in pearl millet which is in agreement to this study. On the other hand, [38] did not find any significant correlation between disease incidence and loss in grain yield which is contrary with this study. Panicle length and number of seeds per panicle had significant and positive correlation with grain yield and harvest index. According to [30] panicle length and grain yield were positively and significantly correlated with harvest index which goes in line with the current study. The rest of the agronomic characters did not show a significant correlation with biomass yield, grain yield and harvest index.

The data in Table 8 show that among the physiological parameters, only Water use efficiency had a significant and positive correlation with grain yield and harvest index, indicating accessions which have agronomic characteristics to use the rain water efficiently under semi-arid conditions were able to produce significantly higher yield and harvest index. The higher-yielding varieties such as Bariyay908 Baryay910, Kona, Hagaz, Zibedi, etc. had higher Water Use Efficiency and higher grain yield in the present study.

Out of the biochemical parameters, crude protein and crude fat were the only characters that showed a positive correlation with grain yield but it was not significant. Among the biochemical characteristics, while crude fat had a significant and positive correlation with the harvest index, the ash content was negatively correlated with the harvest index. None of the other biochemical constituents showed a significant correlation with biomass yield, grain yield, and harvest index.

There was a negative and non-significant correlation between grain yield and chemical composition like ash content, total soluble sugar and crude fiber (Table 8).

4. Conclusions and Recommendation

Conclusions

It can be concluded that among the accessions under study, Bariyay908 and Kona being statistically at par with Bariyay910, Hagaz, Zibedi), Shleti, Delkata ,Tokroray, and Kunama produced significantly higher grain yield because of their higher growth in terms of leaf area, LAI, green leaves, early development and lower attack of downy mildew and higher yield contributing components. However, among these Baryay908 because of its superior agronomic characteristics, lower incidence of downy mildew, relatively higher water use efficiency and higher crude protein content were found to be comparatively superior to the check improved varieties Kona and Hagaz. Bariyay910 was found to be the next best accession having higher total soluble sugar and grain yield higher than the improved variety Hagaz.

Recommendation

It is recommended to test these promising accessions which have been found to be at par or superior to the improved check varieties in further studies to come up with suitable varieties for Downy mildew resistance and further improvement for higher productivity under semi-arid conditions.

Acknowledgement

Great thanks to the National Institute for Higher Education and Research (NIHER) for financing this study.

References

[1] FAO and ICRISAT. (1996), The world sorghum and millet economies: Facts, trends and outlook.A joint-study by the Basic Foodstuffs Service International Crops Research Institute for the Semi-Arid Tropics.

[2] Millet-Everything. (2003), http://everything2.com/title/Millet accessed on 26th May 2017.

[3] Nouri, M., J. L Drew, C. M., Stephen, D. G. Tom and H. Rob. (2003), Pearl Millet and Grain Sorghum Yield Response to Water Supply in Nebraska. Alternative crops. Agronomy Journal. 95(6):1618-1624.

[4] Paterson, A. H., J. E. Bowers, and F. A. Feltus. (2008), Genomics of sorghum, a semi-arid cereal and emerging model for tropical grass genomics. In: Genomics of Tropical Crop Plants. pp. 469-482. (Paul H. and Moore R. eds). Springer Science Business Media, New York, USA.

[5] MoA. (2014), Ministry of Agriculture, Asmara, Eritrea.

[6] MoA. (2015), Crop Production. Ministry of Agriculture Zoba Anseba Annual Progress Keren, Eritrea.

[7] Hamelmalo Agriculural College. (2014), Hamelmalo Meteorological station. Hamelmalo, Eritrea.

[8] Stickler, F.C., A.W. Pouli, and A. Paul. (1961), Leaf area determination in grain sorghum. Agron. J. 53:188-198.

[9] Jidda, M.B. and A. B. Anaso. (2017), Effects of crop improvement technologies on downy mildew of pearl millet [Pennisetum glaucum (L.). Department of Crop Protection, Faculty of Agriculture, University of Maiduguri, Maiduguri, Borno State, Nigeria. Article Number: B066FCA63378 ISSN 2141-6591.

[10] Naeem, M. A., R.A Kainth , M. S. M. Chohhan and A.H. Khan. (2005), Comparison of pearl millet Pennisetum americanum, varieties for fodder yield. Journal of Agriculture Resources 43(3): 183-187.

[11] Vinodhana, K. N. , P. Sumathi and M.Sathya. (2013), Gnetic variability and inter-relationship among morpho-economic traits of pearl millet (*Pennisetum glaucum* (L.) R.Br.,) and their implication in selection . www.ijpaes.com (accessed in July 2017).

[12] Imran, M., A. Bakhsh, S. Khan, A. Husain, Z.A. Gurmani and M. Qasim. (2007), Forage yield and quality potential of dual type pearl millet varieties under rain fed conditions of NARC. Islamabad. Pakistan Journal of Agricultural Resources 20:137-141.

[13] National Agricultural Institute. (2005), Annual Pearl Millet Improvement Programme. Ministry of Agriculture, Asmara, Eritrea.

[14] Pawar, K. N. (2007), Physiological Indices for Drought Tolerance in Rabi Sorghum. Dissertation. Dharwad University, Dharwad.

[15] Sharma, K.C., D.I. Singh and D.Singh. (2003), Variation and character association in fodder yield and related traits in pearl millet. Indian Journal of genetics and Plant Breeding 63 (2): 115 -118.

[16] Chohan, M. S. M. , N. Muhammad, H. K. Amed and A. K. Raiz. (2006), Performance of pearl millet (Pennisetum americanum) varieties for green fodder yield. Journal of Agricultural Resources 44 (1): 23-27.

[17] Borrell, A.K., G. Hammer and E.V. Oosterom. (2001), Stay-green: A consequence of the balance between supply and demand for nitrogen during grain filling. Ann. Appl. Biol. 138:91-95.

[18] Saba, I., H.G. Ahmed. And U. Aliyu. (2015), Growth and yield of pearl millet (*Pennisetum galaucum*(L). As influenced by varieties and inrarow spacing in jokota, North western Nigeria. *Journal of global Bioscience*. 4(2): 2641-2648.

[19] Egharevba,P.N.,S.M.abed and D.A.Labe. (1984), Effect of row spacing on some agronomic characteristics and yield of pearl millet*(Pennisetum typhoides*) Maydza XXIX, Pp193-202.

[20] Shah, I.A., H. U.-Rahman, S. M. A. Shah, Z. Shah, S. R. Interamullah and M. Noor. (2012), Characterization of pearl millet germplasm for various morphology and fodder yield parameters. Pakistan Journal of Botany 44 (1): 273-279.

[21] Hassen, A.M. and A.T.S. Bibin. (2010), Response of three millet varieties to N fertilizers in the semi-arid region of North-East Nigeria. Continental Journal of Agronomy 4: 10-14.

[22] Hussain N., M.S. Baloch, M.Y.M. Naeem, A. Z. Khakwani and I.Begun. (2011), Performance of sorghum varieties in Potohar region. Gomal University Journal of Research 27 (2): 26-30.

[23] Roden, P., A.Negusse, T.Eskinder and K. Thomas. (2006), Participatory on-farm appraisal of improved pearl millet varieties in Eritrea. SLM Eritrea report 8. http//www.cde.unibe.ch./CDE/pdf/Report ERI12 (Accessed on 18 July 2017).

[24] National Agricultural Research Institute. (2006), Annual report. Asmara, Eritrea.

[25] Mustapha, O.T and Y. Mustapha. (2007), Growth and yield of pearl millet (Pennisetum glaucum L.R.Br.) Influenced by downy mildew and smut diseases in Kabunga area of Kano State, Nigeria. Ethnobotanical leaflets 11(5): 27-31.

[26] Bhasker Raj, A.G., F.R. Bidinger, V.P. Panduranga Rao, and Negusse Abraha. (2000), A Survey Report of Downy Mildew Incidence in Farmers' Fields of Anseba and Gash Barka Regions.

[27] Totok, A. D. H., T.K.Shon. and T. Yoshida. (1998), Effects of Selection for Yield Components on Grain Yield in Pearl Millet (Pennisetum typhoideum Rich). Plant Production Science 1(1): 52-55.

[28] Kumar, A. and A. Roa. (1987), Diversity and utilization of pearl millet germplasm. Proceedings international pearl millet workshop. ICRISAT, Patancheru, India. 69- 82.

[29] Zelalem, G.T. (2014), Physiological and Agronomic performance evaluation of stay green sorghum (*Sorghum bicolor L.*) varieties at Shewa Robit,Amhara Regional State, Ethiopia.

[30] Chaudhry, H. M., G. M. Subhani , M.S. Sahaheen, and U. Saleem. (2003), Correlation and path coefficient analysis in pearl millet (*Pennisetum americanum L.*). Pakistan Journal of Biological Sciences

  DOI: https://doi.org/10.30564/jbr.v3i3.3319

6(6):597-600.

[31] Wani, S.P., M.A. Zambre and K.K. Lee. (1990), Genotypic diversity in pearl millet (Pennisetum glaucum) for nitrogen and phosphorus and potassium use efficiencies. Plant Nutrition - Physiology and Applications 22(8): 595-601.

[32] Seghatoleslami, M., M. Kafi and E. Majid. (2008), Effect of drought stress at different growth stages on yield and water use efficiency of five Prosomillet (*Pannicummillaceum*L.) genotypes. *Pak. J. Bot.* 40:1427-1432.

[33] Al Hakimi, A., P. Monneveux and G. Galiba. (1995), Soluble sugars, proline and Relative Water Content (RWC) as traits for improving drought tolerance and divergent selection for RWC from *T. polonicum*into *T. durum*. J. Genetics and Breeding 49:237-244.

[34] Obeng, E., E. Cebert, B. P. Singh, R. Ward, M. N. Leopold and D. A. Mays. (2012), Growth and grain yield of pearl millet genotypes at different levels of nitrogen fertilization in southern united states. Journal of agricultural sciences 4(12): 155-163.

[35] Akromah, R., D. Afribeh and M.S. Abdulai. (2008), Genetic variation and trait correlations in bird resistant pearl millet landrace population. Africa Biotechnology 7(12):1847-1850.

[36] Gilijamse, E., H.D. Frinking, M.J. Jeger. (1997), Occurrence and epidemiology of pearl millet downy mildew, Sclerospora graminicola in Southwest Niger. International Journal of Pest Management 42: 279-283.

[37] Anaso, A.B. (1996), Pearl millet downy mildew in Maiduguri, Nigeria. Disease incidence and loss estimates. Nigerian Journal of Plant Protection 16(5): 82-92.

[38] Quendeba, B., G. Ejeta, W.W. Hanna, A.K. Kumar. (1995), Diversity among African pearl millet landrace populations. Crop Science 35(9): 919-924.