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# Evaluation of Pearl Millet [*Pennisetum glaucum (L.) R. Br.*] Accessions in Karoi and Hwedza, Zimbabwe

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**Abstract:- The research evaluated and characterized the pearl millet accessions in Hwedza and Karoi areas in Zimbabwe. The research was carried out in a field trial alpha lattice design. The pearl millet accessions were planted and the notes recording were done on every stage of growth up to yield weighing. Combined analysis of variance showed that the location had an influence on days to emergence, plant stand (%), number of productive heads, spike girth and stem thickness. However, location had non-significant difference on one thousand grain weight, spike length, plant height, and number of tillers, number of nodes, days to mature and days to flower. Genotype by environment interactions had significant effects ($p<0.05$) on all traits except the number of nodes. There was significance difference in weight per 1000 seeds of the accessions IP 16363 (9.75g), IP 16543 (9.165g), IP 11258 (8.835 g), IP 16447 (8.415 g) and IP 16406 (8 g) noted during the analysis. Among IP 7377 from Tanzania, IP 8753 and IP 8770 from Botswana, had significant difference in yields. Genotypes with bristles for protection against bird attack had significant difference versus those accessions attacked by birds. Yield aspect, adaptation and ability to chock the birds' eyes to protect seeds were the key areas considered for recommendations to the farmers.**

***Keywords:-*** *Accession, Adaptation, Pearl Millet, Yield.*

## I. INTRODUCTION

Pearl millet (*Pennisetum americanum L.*) is a tall, warm season and an annual grass belonging to family *Poaceae* (Andrews and Bramell, 1993). It is a summer crop grown for both fodder and grain. It can grow up to three meters in height under conditions of high temperatures and favorable moisture. Many varieties of millet have been grown for centuries in Indo Pak Sub-Continent, China, Africa and other parts of the world (Gulia et al., 2007). Tall varieties are cultivated for fodder while dwarf varieties are grown for grain purposes (Wilson et al., 1995). It is a nutritious coarse grain cereal (Munyaradzi, 2014). Pearl millet is one of the oldest cultivated foods known to humans. Its green forage is a valuable feed for livestock.

Grappling with hunger and food insecurity is one of the major challenges that global communities, and Zimbabwe in particular, have been experiencing since the 1990s. In 2016, Zimbabwe declared a state of emergency as drought caused crop failures across the country, rendering many communities vulnerable and food-insecure (Tirivangasi 2018). Aapproximately 2.5 million people or more than a quarter of the population require food aid (Buchanan 2016). Mandisvika et al., (2015) concurred with the findings of Chirimuuta and Mapolisa (2011) that 80% of Zimbabwe's total land comprises of fertile agricultural land, and the country is struggling to be food secure. The food insecurity is attributed to many factors, including political and socio-economic factors; however, the most gruesome are the effects of climate change. The Zimbabwe Human Development Report (2017) notes that Zimbabwe's staple food is very sensitive to temperature and precipitation changes that affect production. Zimbabwe farmers grow maize, millet, sorghum and wheat to ensure food security (Tirivangasi 2018). However, maize takes up approximately 80% of cereals production in Zimbabwe (Zimbabwe Human Development Report 2017). This renders the country vulnerable to climate variation as a result of the maize crop sensitivities to climate change. Small grains would be better adapting to climate change than maize.

- *Problem Statement*

New pearl millet accessions need to be evaluated on morphological traits performance under agronomic principles in Zimbabwe for future seed generations recommendation. Uptake of the crop by farmers is low due to bird attack that lead to grain losses while the crop is still in the field. The current pearl millet cultivars are highly susceptible to diseases. Yields are declining season after season due to poor planting materials.

- *Justification*

Pearl millet accessions performing very well in different environmental conditions in Zimbabwe will produce high yields and be used by public and private sector institutions for their hybridization programs. These seed companies are going to use the accessions in breeding programs. The morphological traits information will be known by farmers hence increased productivity of pearl millet in Zimbabwe. Accessions that withstand bird attack will be grown and improve food security among farmers.

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- *Main Objective*

To evaluate pearl millet accessions in Karoi and Hwedza, Zimbabwe.

- *Specific Objectives*

- ✓ *To characterise pearl millet accessions in Karoi and Hwedza*
- ✓ *To assess agronomic performance of pearl millet accessions in Karoi and Hwedza.*

- *Hypothesis*

- ✓ *New pearl millet accessions have better characteristics*
- ✓ *New pearl millet accessions are high yielding.*

## II. LITERATURE REVIEW

- *Introduction*

Pearl millet *(Pennisetum glaucum),* originated in central tropical Africa and is widely distributed in the drier tropics and India (Andrews and Bramel, 1993). It was introduced into the western state in the 1850s and became established as minor forage crop in the southeast and Gulf Coast states (Newman 2010). The plant was probably domesticated as a food crop some 4000 to 5000 years ago along the southern margins of the central highlands of the Sahara ( Drabo et al., 2019). It has since become widely distributed across the semiarid tropics of Africa and Asia (Ndjeunga and Bantilan, 2005).

In Zimbabwe, pearl millet is a crop for the poor resourced people living in low veld dry areas such as, Save Valley, Limpopo valley and Zambezi valley where temperatures are very high during summer and receiving low rainfall per annum. In Africa, pearl millet is grown under 14 million hectares and same area in Asia (Myers, 2002). Global production goes up to 10 million tons per year and India is the largest contributor (Gulia et al., 2007). More than 500 million people are being fed by pearl millet. Countries in Africa such as Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritius and Senegal in the west, and Sudan and Uganda in the east are the most productive areas (Myers, 2002). Zimbabwe has low production of pearl millet due to climate change. Pearl millet has to be introduced in most parts of the countries as the crop can survive under harsh environmental conditions and produce good yields.

In breeding of pearl millet, selection for broad adaptation has greater gains and stability and in developing such crops that are grown as landraces and also produced in marginal areas, site specific breeding is very important (Ouendeba et al., 1993).

- *Climatic Conditions Requirement*

Pearl millet seed can germinate at 12˚C (Hannaway and Larson, 2004) and if conditions are optimum, emergence of seeds take four days. The optimal temperature for growth ranges from 25 -30˚C (Hannaway and Larson, 2004). Rainfall ranges from 250mm to 450mm per annum can be enough for the crop to grow.

- *Soil Nutrients Requirement*

Sandy loam to loam is best soils and though other soil types can also do (Newman et al., 2010). Pearl millet requires low nutrients hence few additional nutrients can be done. Use of animal manure or rotations with leguminous cover crop can help pearl millet production (Myers, 2002). When used in rotations, pearl millet gives advantages in controlling root-lesion nematodes in potatoes and in tobacco (Belair, et al., 2002). Also pearl millet can increase yield when rotated by triticale in compacted soils compared to treatments terminated with chiseling (Calonego and Rosolem, 2010).

- *Accessions Characteristics*

The accessions were developed by many breeders through utilization of germplasm lines and have been released and are widely grown in India. In developing these accessions, traits of visual appeal such as flowering dates, plant height, panicle size and shape, grain size, shape and colour are kept sufficiently uniform for varietal identification purposes. Any germplasm collection is of little importance in crop improvement until it is evaluated and characterized. Germplasm accessions and landraces are rich sources of resistance to various biotic and abiotic stresses (Yadav and Weltzein, 2000) as well as traits for improving grain and fodder quality (Kelly et al., 1996).

According to Newman et al., (2010), there are two types of pearl millet that is the dwarf and tall. The former has more leaves and used for grazing and the latter ones produce higher seed yield. The higher yielding variety can produce 9.3-9.9t dry matter per hectare (Newman et al. (2010). The short and tall varieties have approximately the same number of leaves (Hancock seed, 2014). Pearl millet shown to be successful alternative poultry feed in the southeast coastal plain (Davis et al., 2003). Accession selection should be based on local climate, resistance to local pests and intended use.

- *Pearl Millet Plant*

Fig 1 Photograph of pearl millet. Photo by University of Georgia, hosted by the USDA- NRCS PLANTS Database

The above pearl millet plant is showing plant stem, leaves, nodes, inter-nodes, spike and its shape

- *Pearl Millet Seeds*

Fig 2 Photograph of pearl millet. Photo by University of Georgia, hosted by the USDA- NRCS PLANTS Database

The above picture is showing the pearl millet seed shape, size and colour.

- *Nutritional Value*

Pearl millet contains high nutrients as it has deep rooted system to extract soil nutrients and able to convert to nutrients required by consumers than any other cereals such as rice, wheat, maize and sorghum. What is gained in the pearl millet is high amount of iron, magnesium, copper, manganese, potassium and phosphorous. There is high source of energy with calorific value of 361 kcal/100g and high in fiber content (1.2g/100g) (Singh et al. 2018). Protein content in pearl millet is higher than other cereals (Tylor and Emmabux, 2008) and good source of vitamin B, vitamin A, folic acid calcium and magnesium (Pattanashett et al., 2016). However, pearl millet has high fat content as compared to all cereals so has poor keeping shelf life. Pearl millet is the only cereal that reliably provides grain and fodder under dry land conditions on shallow and sandy soils with low fertility and low water holding capacity (Andrews and Bramel, 2015; Wilson et al., 1995). For the different accessions evaluated, there are a lot of traits looked at. Morphological and physiological parameters were measured according to (IPBGR and ICRISAT, 1993).

Pearl millet is used by livestock producers for grazing, silage, hay, and green chop (Newman et al, 2010). Pearl millet production for grains is mainly used in poultry feeds (Myers, 2002). It is considered to be best as compared to typical corn soybean broiler chicken feeds (Gulia et al., 2002). Advantage of pearl millet over other cereals, is that it does not produce prussic acids or have tannins so good to feed horses (Newman et al., 2010). According to Terrill et al., (1998) described pearl millet is effectively used as feed in goats. This crop has a high potential for cumulating toxic levels of nitrates, especially the lower part of the crop stem (Strickland et al., 2007), so should be taken into consideration when preparing for goats feeds.

- *Adoption*

Adoption of new accessions tends to be slow in some places as a result of many factors. These include, seed availability, variety performance or household preferences (Ndjeunga and Bantilan, 2005). The ability of pearl millet to be reliably produced by people on marginal lands and under low rainfall makes it an attractive choice of sand, low fertility and acidic soils (Menezes et al., 1997). In breeding, selection of broad adaptation has greater gains and stability so as to have a wider adoption. The other importance is that having accessions that grow as landraces and produced in marginal areas, site specific breeding becomes essential (Haussmann et al., 2012). The use of agro-morphological parameters for characterization of diversity cannot be enough to classify the accessions as environment can strongly influence the appearance. However, molecular markers can be used in laboratories to assess the genetic variations (Bahram et al., 2014). Improving productivity of small grains particularly pearl millet is the key to food and nutrition security in the contest of climate change and variability (Ndlovu, et al., 2019). Nhemachena et al., (2014) also noticed the importance of benefits of pearl millet in relation to climate change adaptability.

- *Quelea Bird Damage*

Pearl millet production is unattractive to smallholder farmers in Zimbabwe due to damage by quelea birds. Taylor (2003), argues that small grains face a major challenge of depredations of quelea birds on millets than does on maize. This led to many people reluctant to grow millet in fear of huge flocks of veracious red – billed quelea birds that are potentially to wipe out crops resulting in low yields (Dhliwayo, 2007). These red – billed quelea birds are a big problem in Zimbabwe. This cultural method of scaring the birds is not enough when the farmer has big land of pearl millet as the birds' moves in large flocks. The smallholder farmers decided to move to maize production hence face climate change issue resulting in poor yields obtained in maize production. Maize is easier to monitor than small grains, therefore, the major reason for the non-adoption of small grains by smallholder farmers is the constant monitoring of the fields due to quelea birds which is deterrent for the production of pearl millet (Mathew, 2015). Crop performance is an observation of phenotypically expression of every accession to be evaluated. Genotype by environment interaction is most observed on difference in performance of accessions under different locations over years of production. Genotype by environment is important only if it is significant and cause significant changes in genotypes' ranks in different environments (Crossa, 1997). Genotype by environment has a negative impact on accession heritability. A significant genotype by environment interaction can seriously impair efforts to selecting superior accessions for crop introduction (Yan and Racjan, 2000).

## III. MATERIALS AND METHODS

➢ *Site Description*

The experiment was carried out in Karoi and Hwedza communal farming areas which are located in agro-ecological regions IV and V respectively. The areas are characterized by sandy loam soils with pH 5.5 and 6.2.

Table 1 Trial Sites Description.

| Site | Karoi | Hwedza |
|---|---|---|
| Agro-ecological region | iv | III |
| rainfall (mm) | 526 | 717 |
| Average maximum temperatures recorded | 29°C | 25°C |
| Province | Mash-west | Mash-east |
| Soil type | Loam | Sandy loam |

➢ *Experimental Design and Treatments*

The trials were planted in an alpha lattice design (0. 1). Treatments: 41 accessions of pearl millet. Emergency date's days to flower, plant height, days to maturity, kernel color and grain yield will be checked. The materials were collected, characterized and evaluated for grain yield and its components traits. Local landraces alone cannot give proper results, so they were mixed with regional.

Table 2 Materials (Pearl Millet Accessions Under Study).

| Line | Country | Line | Country |
|---|---|---|---|
| IP 6801 | Malawi | IP 16593 | Zimbabwe |
| IP 6117 | Cameroon | IP 16359 | Zimbabwe |
| IP 19004 | Namibia | IP 16632 | Zimbabwe |
| IP 19479 | Namibia | IP 16526 | Zimbabwe |
| IP 15875 | Tanzania | IP 16487 | Zimbabwe |
| IP 7493 | Tanzania | IP 16527 | Zimbabwe |
| IP 7389 | Tanzania | IP 16508 | Zimbabwe |
| IP 7377 | Tanzania | IP 14074 | Zimbabwe |
| IP 7413 | Tanzania | IP 16504 | Zimbabwe |
| IP 7431 | Tanzania | IP 11258 | Zimbabwe |
| IP 1583 | Tanzania | IP 16543 | Zimbabwe |
| IP 8770 | Botswana | IP 16578 | Zimbabwe |
| IP 8753 | Botswana | IP 16340 | Zimbabwe |
| IP 8778 | Botswana | IP 16451 | Zimbabwe |
| IP 16640 | Zimbabwe | IP 16642 | Zimbabwe |
| IP 16427 | Zimbabwe | IP 16363 | Zimbabwe |
| IP 16488 | Zimbabwe | IP 16529 | Zimbabwe |
| IP 8831 | Zimbabwe | IP 16447 | Zimbabwe |
| IP 14147 | Zimbabwe | IP 14016 | Zimbabwe |
| IP 13924 | Zimbabwe | IP 16406 | Zimbabwe |
| | | IP 14165 | Zimbabwe |

➢ *Agronomic Practices*

Land preparation was done using ox-drawn plough. A spike harrow was used to destroy the soil crumps as well as levelling the ground. Holes were marked in an alpha lattice design (0. 1). Five planting stations per line were dug. Two to three seeds were placed per station. Fertilizer application was done as from the planting with compound D at 250kg per hectare and later top dressed after three weeks of emergency at 150kgs per hectare. At six weeks, the second application (150kgs) was made to boost the plant growth in preparation of good head development. Weed control was carried out to avoid nutrient competition hence improved growth rate of the plants. Harvesting was done according to maturity and dryness of each accession as the plants had different maturity dates.

➢ *Crop Water Requirements*

The trials were rain fed.

➢ *Data Collected (Growth And Performance Data).*

Plant height (cm), was measured from the ground level to the tip of the spike at dough stage. Stem diameter (mm), was measured between the 3rd and 4th node from the top at dough stage. Stem thickness (cm), number of productive tillers were measured according to number of spikes which bear seeds at dough stage. Spike shapes were recorded at dough stage as cylindrical, conical, spindle, club or candle. Bristle length was measured at dough stage according to length. Days to emergence that is number of days taken from planting to the first shoot of the 50% of planted seeds, were also recorded. Days to flowering that is number of days from emergence to when 50% of plants flower was

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recorded. Days to maturity were recorded that is days from emergency to physiological maturity of seed were recorded. Spikelet glume colour were checked either brown or green. Seed covering was observed as exposed, intermediate or enclosed. Seed weight (g) was measured for1000 seeds using a scale.

Leaf length (cm) was measured from ligule to tip of the leaf on the 4th node below the head on the main tiller at head emergence. Leaf width (mm) was also measured at the widest point on the 4th leaf of the main tiller at head emergence. Leaf color was checked either as green, light green, dark green or variegated. Sheath length (cm) was also measured. Sheath pigmentation was observed at dough stage as green, red, purple or variegated. Node pigmentation was measured at dough stage as green, red, purple or brown. Internode pigmentation (green red, purple brown, white) was also checked as well as anther colours (green, brown, white, dark brown). Ear head exertion was measured as either complete or partial.

- *Data Analysis*

Data for the above traits was analyzed using GenStat Analysis of variance (ANOVA) and Least Square Difference (LSD) was used for data analysis at 95% level of significance. P value = 0.5.

## IV. RESULTS

From the planted forty one accessions, twenty-one managed to germinate from all sites. Table 3 shows the ones successfully grew from both locations. Others were discarded as they were not enough to be evaluated. On morphological characterization, the accessions were able to distinguish themselves according to the traits looked at.

Fig 3 Picture Showing how to Protect Pearl Millet from Birds

Table 3 Morphological Characterization

| Origin | Name | Sheath | Anther | Internode | Nodal Pigmentation | Ear Head Exertion | Spikelet Glume Colour | Bristle Length (Cm) |
|---|---|---|---|---|---|---|---|---|
| TANZANIA | IP 7377 | present | yellow | brown | brown | complete | brown | short |
| BOTSWANA | IP 8770 | absent | brown | green | brown | complete | brown | short |
| MALAWI | IP 6801 | present | brown | green | green | complete | green | short |
| TANZANIA | IP 15875 | present | yellow | green | brown | complete | brown | medium |
| ZIMBABWE | IP 16427 | absent | brown | green | green | complete | green | medium |
| ZIMBABWE | IP 13924 | absent | green | green | brown | complete | green | short |
| TANZANIA | IP 1583 | absent | brown | green | green | complete | green | short |
| ZIMBABWE | IP 16447 | absent | white | brown | brown | complete | green | medium |
| ZIMBABWE | IP 16359 | present | brown | green | green | complete | green | medium |
| ZIMBABWE | IP 16526 | absent | brown | brown | brown | complete | brown | medium |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ZIMBABWE | IP 11258 | absent | yellow | brown | green | complete | brown | short |
| ZIMBABWE | IP 14074 | absent | yellow | green | green | complete | brown | short |
| ZIMBABWE | IP 16593 | absent | yellow | brown | green | complete | brown | medium |
| ZIMBABWE | IP 16406 | present | brown | green | green | complete | brown | medium |
| ZIMBABWE | IP 16578 | absent | brown | green | green | complete | brown | medium |
| ZIMBABWE | IP 16640 | absent | yellow | brown | green | complete | brown | medium |
| NAMIBIA | IP 19004 | absent | brown | brown | green | complete | brown | short |
| ZIMBABWE | IP 16363 | absent | brown | green | brown | complete | brown | short |
| CAMEROON | IP 6117 | present | yellow | brown | green | complete | brown | short |
| BOTSWANA | IP 8753 | absent | brown | green | brown | complete | brown | medium |
| ZIMBABWE | IP 16543 | present | green | green | green | complete | brown | short |

Table 3 Morphological Characterization continue

| Origin | Name | Bristle Colour | Spike Shape | Spike Tip Sterility | Spike Density | Leaf Mid Rib Colour | Ligule Hair | Seed Covering |
|---|---|---|---|---|---|---|---|---|
| TANZANIA | IP 7377 | brown | candle | absent | compact | white | absent | exposed |
| BOTSWANA | IP 8770 | brown | cylindrical | present | compact | white | absent | exposed |
| MALAWI | IP 6801 | green | candle | present | compact | white | absent | exposed |
| TANZANIA | IP 15875 | brown | cylindrical | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16427 | brown | candle | present | compact | white | absent | exposed |
| ZIMBABWE | IP 13924 | brown | candle | present | compact | white | absent | exposed |
| TANZANIA | IP 1583 | brown | candle | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16447 | yellow | cylindrical | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16359 | brown | cylindrical | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16526 | brown | cylindrical | present | compact | white | absent | exposed |
| ZIMBABWE | IP 11258 | brown | cylindrical | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 14074 | brown | candle | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16593 | brown | candle | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16406 | brown | cylindrical | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16578 | brown | candle | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16640 | brown | candle | absent | compact | white | absent | exposed |
| NAMIBIA | IP 19004 | brown | candle | absent | compact | white | absent | exposed |
| ZIMBABWE | IP 16363 | brown | cylindrical | absent | compact | white | absent | exposed |
| CAMEROON | IP 6117 | brown | cylindrical | absent | compact | white | absent | exposed |
| BOTSWANA | IP 8753 | brown | candle | present | compact | white | absent | exposed |
| ZIMBABWE | IP 16543 | brown | candle | present | compact | white | absent | exposed |

Table 4 Agronomic performance The means of seed and yield components (number of nodes, number of tillers, plant height, spike girth, spike length and stem thickness) in 2020-21 rain season. The Table 4 indicates the traits performance.

| Treatments | Days To Emergence | | Plant Stand % | | Days to Flower | | Number of Heads | | Days to Mature | | Leaf Length (Cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IP 7377 | 5.75 | bcd | 67.25 | b | 67.25 | b | 20.5 | ab | 105.5 | b | 92.25 | a |
| IP 8770 | 5.25 | cd | 59 | de | 59 | de | 22.75 | a | 87.25 | e | 56.25 | cd |
| IP 6801 | 6 | abc | 51 | hij | 51 | hij | 19.75 | ab | 79 | h | 72 | abc |
| IP 15875 | 5.75 | bcd | 60.5 | cde | 60.5 | cde | 12.75 | ab | 99 | c | 65.75 | bcd |
| IP 16427 | 5 | d | 51.25 | hij | 51.25 | hij | 15 | ab | 87.5 | e | 70.75 | abc |
| IP 13924 | 5.75 | bcd | 50 | ij | 50 | ij | 17.75 | ab | 75.75 | ij | 53.75 | cd |
| IP 1583 | 5 | d | 58 | ef | 58 | ef | 13.5 | ab | 83.5 | fg | 81.25 | ab |
| IP 16447 | 5.5 | bcd | 52 | hi | 52 | hi | 10.75 | ab | 77.5 | hi | 70.25 | bc |
| IP 16359 | 6.25 | ab | 53.5 | gh | 53.5 | gh | 14.75 | ab | 77.75 | hi | 60.5 | bcd |
| IP 16526 | 6 | abc | 62.75 | c | 62.75 | c | 12.25 | ab | 94.5 | d | 61.25 | bcd |
| IP 11258 | 6.25 | ab | 69.25 | ab | 69.25 | ab | 16 | ab | 110 | a | 71.5 | abc |
| IP 14074 | 5.5 | bcd | 55.5 | fg | 55.5 | fg | 7.5 | ab | 85 | f | 47.25 | d |
| IP 16593 | 5.75 | bcd | 51.75 | hij | 51.75 | hij | 18.5 | ab | 81.5 | g | 65.5 | bcd |
| IP 16406 | 6 | abc | 61.75 | cd | 61.75 | cd | 8.25 | ab | 96 | d | 60.5 | bcd |
| IP 16578 | 5.5 | bcd | 49 | j | 49 | j | 8 | ab | 76 | ij | 55.25 | cd |
| IP 16640 | 5.5 | bcd | 55.25 | fg | 55.25 | fg | 7.25 | ab | 78.5 | h | 62.5 | bcd |
| IP 19004 | 5.5 | bcd | 70.5 | a | 70.5 | a | 9.5 | ab | 98.25 | c | 60.75 | bcd |
| IP 16363 | 6.75 | a | 51.75 | hij | 51.75 | hij | 4.75 | b | 75.25 | j | 47.25 | d |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IP 6117 | 5 | d | 61.5 | cd | 61.5 | cd | 14.25 | ab | 110.5 | a | 71.5 | abc |
| IP 8753 | 5.5 | bcd | 68.5 | ab | 68.5 | ab | 10 | ab | 105.8 | b | 62.5 | bcd |
| IP 16543 | 5 | d | 59 | de | 59 | de | 4.5 | b | 99.25 | c | 54.75 | cd |
| l.s.d | 0.6 | | 37.5 | | 2.2 | | 12.9 | | 1.59 | | 16.26 | |
| Cv% | 5.5 | | 44.1 | | 1.9 | | 50.1 | | 0.9 | | 12.6 | |
| site p | 0.01 | | <.001 | | 0.333 | | 0.015 | | 0.68 | | 0.563 | |
| Genotype p | <.001 | | 0.02 | | <.001 | | 0.004 | | <.001 | | <.001 | |
| G*E p | <.001 | | 0.044 | | <.001 | | 0.024 | | <.001 | | 0.003 | |

G-genotype, E-environment. The means of seed and yield components (number of nodes, number of tillers, plant height, spike girth, spike length and stem thickness) in 2020-21 rain season.

Table 4 Continue The means of seed and yield components (number of nodes, number of tillers, plant height, spike girth, spike length and stem thickness) in 2021-22 rain season

| Treatments | Number of Nodes | | Number of Tillers | | Plant Height in Cm | | Spike Girth Mm | | Spike Length Cm | |
|---|---|---|---|---|---|---|---|---|---|---|
| IP 7377 | 12 | a | 14 | abc | 246.5 | a | 6.25 | a | 31 | abc |
| IP 8770 | 7.5 | bc | 20.25 | ab | 172 | abc | 4.4 | bcd | 28.25 | bc |
| IP 6801 | 9.75 | abc | 25 | a | 195 | abc | 4.55 | bcd | 32.75 | abc |
| IP 15875 | 9.5 | abc | 12.75 | abc | 184 | abc | 3.55 | bcd | 31.25 | abc |
| IP 16427 | 10.75 | abc | 12.75 | abc | 238.2 | ab | 4.35 | bcd | 34.75 | abc |
| IP 13924 | 9.5 | abc | 15 | abc | 223 | ab | 4.7 | abc | 35 | abc |
| IP 1583 | 9.75 | abc | 12.5 | abc | 157.5 | bc | 3.25 | cd | 25.25 | c |
| IP 16447 | 8.25 | abc | 4 | c | 181.5 | abc | 5.1 | ab | 43 | ab |
| IP 16359 | 8.75 | abc | 11.75 | abc | 155 | bc | 3.6 | bcd | 23.5 | c |
| IP 16526 | 8.5 | abc | 13 | abc | 172.2 | abc | 3.975 | bcd | 35.75 | abc |
| IP 11258 | 10.25 | abc | 15.25 | abc | 215 | abc | 4.5 | bcd | 46.75 | a |
| IP 14074 | 7.75 | abc | 7 | bc | 154.5 | bc | 3.25 | cd | 30 | bc |
| IP 16593 | 9.5 | abc | 15.75 | abc | 168 | abc | 4 | bcd | 36 | abc |
| IP 16406 | 8 | abc | 10.5 | abc | 133.2 | c | 3.625 | bcd | 27.5 | bc |
| IP 16578 | 9 | abc | 7.5 | bc | 166 | abc | 4.25 | bcd | 22.5 | c |
| IP 16640 | 8.25 | abc | 9 | bc | 174.5 | abc | 4.25 | bcd | 29.75 | bc |
| IP 19004 | 8.75 | abc | 7.75 | bc | 191.5 | abc | 4 | bcd | 35.25 | abc |
| IP 16363 | 6.5 | c | 8.75 | bc | 165 | abc | 4.125 | bcd | 26.5 | c |
| IP 6117 | 11 | ab | 15.25 | abc | 209.5 | abc | 4.35 | bcd | 35.25 | abc |
| IP 8753 | 8.75 | abc | 10 | bc | 196.2 | abc | 3.3 | cd | 29.5 | bc |
| IP 16543 | 8.25 | abc | 10.75 | abc | 179 | abc | 3 | d | 31 | abc |
| l.s.d | 3.27 | | 11.01 | | 64.95 | | 35.23 | | 12.18 | |
| Cv% | 17.9 | | 44.3 | | 17.4 | | 14.4 | | 18.9 | |
| site p | 0.947 | | 0.968 | | 0.501 | | <.001 | | 0.774 | |
| genotype p | 0.007 | | 0.002 | | <.001 | | <.001 | | <.001 | |
| G*Ep | 0.119 | | <.001 | | 0.044 | | <.001 | | 0.002 | |

G-genotype, E-environment. The means of seed and yield components (number of nodes, number of tillers, plant height, spike girth, spike length and stem thickness) in 2020-21 rain season.

Table 4 Continue The means of seed and yield components (number of nodes, number of tillers, plant height, spike girth, spike length and stem thickness) in 2021-22 rain season

| Treatments | Spike Girth Mm | | Spike Length Cm | | Stem Thickness(Cm) | | 1000 Seeds Grain Weight (G) | |
|---|---|---|---|---|---|---|---|---|
| IP 16363 | 87 | abc | 26.5 | c | 4.125 | bcd | 9.75 | a |
| IP 16543 | 95 | abc | 31 | abc | 3 | d | 9.165 | ab |
| IP 11258 | 99.75 | abc | 46.75 | a | 4.5 | bcd | 8.835 | ab |
| IP 16447 | 115 | abc | 43 | ab | 5.1 | ab | 8.415 | ab |
| IP 16406 | 81.25 | bc | 27.5 | bc | 3.625 | bcd | 8 | ab |
| IP 1583 | 70.25 | c | 25.25 | c | 3.25 | cd | 7.835 | ab |
| IP 16526 | 132.5 | a | 35.75 | abc | 3.975 | bcd | 7.683 | ab |
| IP 16359 | 120 | ab | 23.5 | c | 3.6 | bcd | 7.585 | ab |
| IP 16593 | 104.5 | abc | 36 | abc | 4 | bcd | 7.585 | ab |
| IP 6801 | 108.5 | abc | 32.75 | abc | 4.55 | bcd | 7.335 | ab |
| IP 16427 | 112.5 | abc | 34.75 | abc | 4.35 | bcd | 7.25 | ab |
| IP 16640 | 79.5 | bc | 29.75 | bc | 4.25 | bcd | 7.25 | ab |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IP 15875 | 90 | abc | 31.25 | abc | 3.55 | bcd | 7.085 | ab |
| IP 14074 | 96.5 | abc | 30 | bc | 3.25 | cd | 6.75 | ab |
| IP 19004 | 101 | abc | 35.25 | abc | 4 | bcd | 6.585 | ab |
| IP 7377 | 100 | abc | 31 | abc | 6.25 | a | 6.5 | ab |
| IP 13924 | 80 | bc | 35 | abc | 4.7 | abc | 6.25 | ab |
| IP 16578 | 77.5 | bc | 22.5 | c | 4.25 | bcd | 5.665 | ab |
| IP 6117 | 99.75 | abc | 35.25 | abc | 4.35 | bcd | 5.415 | ab |
| IP 8753 | 92.5 | abc | 29.5 | bc | 3.3 | cd | 5 | ab |
| IP 8770 | 110 | abc | 28.25 | bc | 4.4 | bcd | 4.915 | b |
| l.s.d | 35.23 | | 12.18 | | 1.2 | | 3.59 | |
| Cv% | 17.8 | | 18.9 | | 14.4 | | 24.4 | |
| site p | 0.035 | | 0.774 | | <.001 | | 0.11 | |
| genotype p | <.001 | | <.001 | | <.001 | | 0.028 | |
| G*E p | <.001 | | 0.002 | | <.001 | | 0.022 | |

G-genotype, E-environment. The means of seed and yield components (number of nodes, number of tillers, plant height, spike girth, spike length and stem thickness) in 2020-21 rain season.

Table 5 Mean squares and significant tests after analysis of variants for grain yield and yield components for twenty-one accessions evaluated in Hwedza and Karoi areas for the season 2021-22.

| **Source Of Variance** | **DF** | **Days To Emergence** | **Plant Stand %** | **Days To Flower** | **Days To Maturity** | **Leaf Length Cm** | **Number Of Nodes** |
|---|---|---|---|---|---|---|---|
| Location | 1 | 0.76** | 133376.2*** | 1.19ns | 0.10ns | 22.01ns | 0.01 |
| Genotype | 20 | 0.86*** | 735.7** | 184.69*** | 585.35*** | 459.51*** | 6.52** |
| G*E | 20 | 0.76*** | 6456.2** | 4.29*** | 2.08*** | 176.91** | 4.04 |

D F (degrees of freedom), ns (no significant difference), *p<.05, **p<.01, and ***p<.001

Table 5 Continue

| **Source of Variance** | **DF** | **Number of Tillers** | **Plant Height Cm** | **Spike Girth Mm** | **Spike Length Mm** | **Stem Thickness Cm** | **Grain Weight(G) /1000 Seeds** |
|---|---|---|---|---|---|---|---|
| Location | 1 | 0.05 | 476 | 1441.70* | 3.05 | 13.36*** | 8.41 |
| Genotype | 20 | 88.07** | 3327.00*** | 970.30*** | 139.45*** | 2.14*** | 6.74* |
| G*E | 20 | 112.82*** | 1941.00* | 1609.30*** | 108.17** | 2.58*** | 7.07* |

D F (degrees of freedom), ns (no significant difference), *p<.05, **p<.01, and ***p<.001

## V. DISCUSSION

➢ *Location*

Hwedza received 717mm rainfall for the crop growth throughout the rain season. The crop never had moisture stress but the rainfall was excess in the first two weeks after planting. This however affected seed germination hence plant numbers were few per row. Sand loamy soil leached the nutrients applied during heavy rains. The accessions that managed to perform well in terms of yield were, IP 16447(11g), IP 16543(10.5g), IP 16359(10g) and IP 16593 (10g) in Hwedza. Yield was measured per 1000 seed weight.

Karoi received 526mm rainfall and managed to sustain the crop growth throughout the season. Seasonal rainfall distributions were as follows. November second dekad was 88mm, third dekad was 55mm, December first dekad was 66mm, second dekad was 90mm and third dekad was 76mm. January total month received 87mm. February had 79mm and finally March had 64mm.

There was significant difference in rainfall received in Karoi (526mm) and Hwedza (717mm). Availability of moisture was able to make seeds to germinate. Newman et al., (2010), rainfall of 25mm is ideal for seeds to germinate after planted. Time seeds were planted in November; there was good soil moisture that promoted germination. Those seeds failed to germinate was as a result of soil capping and compaction. Soil type (loam) was able to hold enough moisture for the crop. The accessions did best in Karoi include, IP 11258(11.17g), IP 16363(10g), IP 16406(9g) and IP 16640(8.5g), all measured per 1000 seed weight.

➢ *Morphological Traits*

- *Bristle Length*

There was significant difference among the accessions on bristle length. Kumar et al., (1993), noted that the bristles protect birds from feeding on pearl millet seeds. Ten accessions that had bristles gave high yields as compared to non-bristle accessions. According to Dhliwayo (2007), the red billed queleas are controlled by spike bristles as this was noted in marginal areas where pearl millet is mostly grown by farmers. Accessions without bristles are very vulnerable to birds and gave much extra work done by farmers to chase the bird's early morning before they feed on the crop.

Sheath covered the seeds give self-protection to the crop and those without the sheath were prone to attack by birds as described by Rana, (2004). The sheath also helps to differentiate the accessions and grouping them to guide when doing varietal selection.

- *Bristle Colour*

The accessions had different bristle colours noted and help to identify them accordingly. They were three colours that noted among the accessions. Those colours showed significant differences in identifying and differentiate the accessions as indicated by (Yadav et al., 2007) when he was characterizing some pearl millet accessions.

- *Spike Shape*

There was significant difference in spike shapes. Two shapes were noted as candle and cylindrical. Those that had candle in shape had spike tip sterility that affected yield. Then the accessions that had cylindrical spike shape had no spike tip sterility thereby produced higher yields. According to AICPMIP (2006), yield calculated on similar spikes from the same accession with tip sterility and without tip sterility, there was a great yield significant difference.

- *Anther Colour*

There was significant difference in anther colours of the studied accessions. For identification of the accessions when flowering, the anther colour is important (AICPMIP, 2006). Accessions produce different anther colours, brown, yellow or green and this helped in differentiating the accessions. Accession selection is guided by anther colours as reported by (Bahram et al., 2014).

- *Internode Colour*

The accessions had internode colours showed significant difference depending on genotype. Brown colour internodes and green colour internodes separated the accessions. It is very important to know the internode colour to differentiate the accessions (Yadav et al., 2007). Secondary or tertiary culms arise from the nodes. The internodes are usually light green and sometimes show purple pigment when exposed (Kumar et al., 1993). The nodes are often marked by a ring of long white cilia pointing upwards, which bear a ring of adventitious roots on the basal side (Yan and Racjan 2000).

- *Nodal Pigmentation*

There was significant difference in nodal pigmentation on the studied accessions. This pigmentation is important to separate the accession when characterising them. Brown and green nodal pigmentation were observed respectively. There was no significant difference in ear head exertion; all the accessions had complete exertion heads. Complete heads will contribute to yield of the crop (Kumar et al., 1993).

- *Spike Density, Mid Rib Colour and Ligule Hairs.*

All the accession had compact spike density, mid-rib white colour and absent ligule hairs. The seeds of every accession studied were also exposed and not covered. One can easily see the colour of seeds also whether they are mature or not. However, according to Kumar et al., (1993) and (Rana, 2004) being seeds exposed can attract the birds thereby cause loses to the yields. This was noted in the field as birds came and feed on crop grains that led to put the crop head covers to protect them against birds.

➢ *Agronomic Traits Performance*

- *Days to Emergence*

There was significant difference in days to emerge among the accessions. Effect of location determined the emergency of the accessions as indicated by p 0.01, the genotypes also vary in performance and shown by $p<0.001$. Genotype by environment interaction had highly positive significant difference as indicated by $p<0.001$. Changes in days to emerge are as a result of the environmental conditions such as moisture availability, temperature and soil type (Yadav et al., 2007). Days to emerge assist in knowing whether the planted seeds were viable or not (Menezes et al., 1997).

- *Plant Stand (%)*

There was significant difference in plant stand as some seeds failed to germinate. According to (Menezes et al., 1997), seed viability differs with maturity thereby affect germination percentage as shown by poor seed germination noted in the field. That poor germination led to discarding of some accessions that failed to germinate. The more the plants germinated the better the crop stand. Those few plants germinated produced more tillers to compensate the missing gaps. Location had highly significant difference in plant stand as shown by $p<0.001$. The genotypes were significantly shown differences as indicated by p 0.02. Then the Genotype by environment interaction was slightly affected the plant stand as indicated by p 0.04. When choosing a crop variety, it has to be area specific in-order to achieve potential yields (Rana, 2004).

- *Days to Flower*

The accessions flowered differently depending on days and variety. The days ranged from forty to seventy as similarly reported by (Yadav et al., 2007). Location had no effect on the performance of the accessions as shown by p value of 0.33. However, the genotypes alone had an effect on performance ($p<0.001$). Also Genotype by environment had an effect on plant flowering as indicated by $p<0.001$. According to (Haussmann et al., 2012), days to flower are different depending with location, weather and genotype. The studies done by IPBGR and ICRISAT, 1993), also showed the same results that days to flower are different depending on the accession.

- *Days to Maturity*

There was significant difference on days to mature on the studied accessions. Maturity days of each accession guide the area of crop production (AICPMIP, 2006), hence seed recommendation and distribution is easy. Location had no effect on days to mature (p 0.68), but the genotype shown significant difference as indicated by $p<0.001$. Genotype by environment interaction had influence on days to mature as indicated by $p<0.001$. Classification of accessions as early, medium and late maturity variety can be done to recommend according to climatic regions. Area of crop production is guided by days to mature of a variety (Ndjeunga and Bantilan, 2005).

- *Plant Height (Cm)*

There was significant difference in plant height as some accessions were less than 150 cm (short), 151-200 cm (medium), 201 -250 cm (tall) as noted by (AICPMIP, 2006) in the other studies. According to (Newman et al. (2010), the plants have different heights but with the same number of leaves. Some nodes are shorter and some are longer thereby determining the plant height. The tall accessions were difficult to measure height, harvest, also attracted birds. Pearl millet height has an effect on scouting, spraying, and some activities maybe not easy to do as noted by (Hannaway, 2004). Most of the studied accessions were medium as they gave height of 151 -200 cm tall. Medium accessions are workable as other practices can be applied without any challenges. The dwarf accessions are best to work with (Crossa, 1997). There was high significance difference in height represented by $p<0.001$ as a result of genotype. The location (p 0.5), did not affect the plant height performance. Genotype by environment has slightly influenced the plant height as indicated by p value of 0.04.

- *Spike Length (Cm)*

There was significant difference in spike length of the pearl millet accessions. AICPMIP 2006) reported that the different accession produce different spike length on the studied materials. The bigger and longer the spikes determine the yield (Newman et al., (2010). Location did not affect the spike length of the accessions. The p value 0.77 indicates non-significant differences. The genetic make-up of the accessions determines the spike length as shown by $p<0.001$. Also genotype by environment interaction influenced the spike length as indicated by p 0.002.

- *Spike Girth (Mm)*

There was also significant difference in spike girth on studied accessions. The spike girth determined the size of the spike (Kumar, 1993). It contributes to the yield to be obtained from the accession heads. The accessions with small girth can yield higher depending on spike length (Rana, 2004). The spike girth was influenced by location (p 0.035), genotype ($p<0.001$) and G*E ($P<0.001$).

- *Stem Thickness (Cm).*

There was significant difference among the genotypes shown by $p<001$. The thinner the stems then the plants are prone to lodging as the head might be bigger (AICPMIP, 2006). The thicker the stems are the better ones as they are strong to withstand against wind.

- *Best Yielding Genotypes*

There was significant difference in yield of the studied accessions. The location (p 0.11) had no significant difference in performance of the accessions. The genotype (p0.028) determined the yield of the accessions. Also genotype by environment interaction influenced the yield of all the accessions and shown by p 0.022. AICPMIP (2006) noted that yield of an accession is determined by so many biotic and abiotic factors. Same accession can produce different yields when grown in different agro-ecological areas. However, the accessions that may closely produce similar results from different areas are recommended in various places. Crossa (1997) reported that the accessions that have yield of high significant difference can be recommended as per specific area.

## VI. CONCLUSION

The study has shown variation in terms of morphology and agronomic performance amongst the pearl millet accessions used. Performance of each genotype was as a result of location, genotype by environment interactions and the genetic make-up. The accession identification in terms of the appearance considering was as a result of aspects looked at and analyzed. The days to emergence differ with the accession, days to flower were also determined by each genetic built- up of the material. The maturity of each accession has been realized and be able to classified as long season (IP 6117 and IP 11558), medium season (IP 16406, 16526, IP 16427, IP 8770 and IP 14074) and low season (IP 16578, IP 13924 and IP 16363) crops. The other important aspect studied was the bird attack assessment. Some accessions exhibited some characteristics that prevent birds to feed on the pearl millet seeds. For example, the accessions with long bristles could not allow the birds to feed from the seeds on the spike. Better accessions include IP 15875, IP 16427, IP 16447, IP 16359, IP 16526, IP 16593, IP 16406, IP 16578, IP 16640, and IP 8753. Other useful traits contributed to yield were analysed such as spike length and girth as they measure the size of the head that produce grains. On yield component, there were very good accessions that gave highest yield such as IP 16363, IP 16543, IP 11258, IP 16447 and IP 16406. However, genotype and environment can affect the production of accessions as in most cases there were significant differences indicated by $P<0.001$. Most of the traits had no significant differences in their performance.

## RECOMMENDATION

Pearl millet is a highly cross- pollinated crop and possesses enormous natural variability for quantitative, qualitative and quality traits. It's a drought tolerant crop that can be planted by most farmers in all areas. The crop is able to reach productive stage under very low rainfall and high temperature regions. With the current climate change, this is the best crop to plant and reduce hunger among people from all over the places. The issue of crop being vulnerable to birds, it is best to go for accessions such as Tanzania IP 15875, Zimbabwe IP 16427, Zimbabwe IP 16447, Zimbabwe IP 16359, Zimbabwe IP 16526, Zimbabwe IP 16593, Zimbabwe IP 16406, Zimbabwe IP 16578, Zimbabwe IP 16640 and Botswana IP 8753. For high yielding accessions as a major trait accepted by most farmers, IP 16363 (9.75g), IP 16543 (9.165g) are recommended to choose. Also, area specific accession performance, IP 11258 is recommended to be grown in Karoi but in Hwedza cannot be grown. IP 16447 and IP 16543 are recommended to be grown in Hwedza as they produce high yield. IP 16363 can be grown in both areas because of its stability in yield production. Pearl millet is the key crop among all other cereals to be considered by all level of farmers, both commercial and marginal areas.

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