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Forage potentials of interspecific hybrids between elephant grass selections and cultivated pearl millet genotypes of Nigerian origin

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This study was conducted to highlight the forage potentials of related *Pennisetum* species through interspecific hybridization. Non-reciprocal crosses were made involving two selections of elephant grass (*Pennisetum purpureum* Schumach) (♂), S.13 and S.15, and five cultivated pearl millet (*Pennisetum glaucum* (L.) R. Br.) (♀) genotypes in Nigeria *viz*., *Dauro*, *Gero* A, *Maiwa 25-2, Maiwa 28-1 and Maiwa 94-2,* in September 2009. In May 2010, germination test and preliminary screening for successful crosses were conducted. Successful hybrids with *Dauro* and *Maiwa* genotypes were transplanted to the field at 90 × 90 cm spacing for forage evaluation from June to December 2010. Three harvests, at six-weekly interval, were obtained from the plants cut at 30 cm above ground level. ANOVA showed significant differences (p = 0.05) between harvest intervals, plant height (cm) and dry matter content (%) of the hybrids, except dry matter yields (g/m^2). Dry matter content of the hybrids negatively correlated with plant height (r = -0.434). Dry matter yield had significant positive correlation with plant height (r = 0.780). *Maiwa* 94-2 x S.13 and *Maiwa* 28-1 x S.13 were not significantly different (p = 0.05) as they out-yielded other hybrids in dry matter yields and were associated with satisfactory forage potentials.

Key words: Breeding genetics, dry matter yields, dry matter content, harvest intervals, *Pennisetum purpureum*, *Pennisetum glaucum*, plant height.

INTRODUCTION

There are about 140 species of the genus *Pennisetum* L. (Rich) in the family Poaceae (Haroun, 2010). Comprising such important species are elephant grass (*Pennisetum purpureum* Schumach) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) (Brunken, 1977; Kativu and Mithen, 1987; Kellogg, 2000). Pearl millet, a diploid (2n = 14) dual-purpose annual species of this genus, is used for food (grain) by humans and as feed (forage or fodder) for livestock. The association of pearl millet with high quality forage earns it greater palatability and acceptability by livestock. Elephant grass, on the other hand, is a tetra-ploid (2n = 28) and a perennial tropical grass species primarily used as forage or fodder owing to its high forage yields. Elephant grass has been highlighted as one of the most important tropical forages for dairy grazing system improvement in the tropics (Pereira, 1994). Its productive potential, associated with other desirable forage traits, such as vigour, persistence, carrying capacity and nutritional quality have stimulated the cultivation and the genetic improvement of the species (Souza et al., 2005).

In Africa, the cut-and-carry ruminant livestock feeding system involving *P. purpureum* has been widely adopted by small-holder farmers for feeding dairy cattle (Valk, 1990). Elephant grass was originally introduced to commercial farming systems early in the 20th century as mulch for coffee, but has subsequently been widely adopted as cattle fodder in small-holder farming systems

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(Boonman, 1993). Predominantly, elephant grass is vegetatively propagated. It is perennial, can withstand repeated cutting and rapidly regenerates producing forage which is palatable to cattle at the leafy stage. However, as the plant grows, the dry matter production increases with decreasing nutritional value (Maria et al., 2010). According to Patel et al. (1967) and Lavezzo (1985), these occur when elephant grass is harvested after 50 to 60 days of re-growth.

It has also been reported that elephant grass is useful for phyto-remediation of petroleum-hydrocarbon-contaminated agricultural soils (Ayotamuno et al., 2006). However, apart from these two species of *Pennisetum* with excellent forage qualities, there are other species which have also been identified to have medicinal values *viz., Pennisetum setaceous*, *Pennisetum villoseum* and *Pennisetum divisum* (Sujatha et al., 1989). In crop breeding programmes, genetic resources have been highlighted as the needed basic materials. On improving allogamous crop species via hybridization, the importance in the exploitation of wide crosses can no longer be overemphasized as it is expected that the existing genetic compatibilities between the genera or species of interest will likely result in heterosis (that is, hybrid vigour) in the hybrids. When genomes of different species combine, either as interspecific or intergeneric hybrids, they present various stages of intergenomic conflicts. The theoretical basis of these genomic conflicts in the hybrids anticipates antagonisms in nucleo-cytoplasmic incompatibilities and compromises chromosome pairing at meiosis (Jones and Pasakinskiene, 2005). Successful crosses involving different species with different ploidy lead to hybrid vigour. This genetic gain also confers useful morphological characteristics, agronomic attributes and chemical composition to the resulting interspecific hybrids in spite of the anticipated genetic bottlenecks (Ortiz, 2004).

Interspecific hybridization of elephant grass with pearl millet represents one approach to the genetic improvement of elephant grass with the aim of producing perennial sterile hybrids, with high forage yields, improved palatability and high nutritional value, which can be vegetatively propagated. The success in the use of pearl millet in interspecific hybridization with elephant grass is greatly influenced by the level of genetic compatibility (Techio et al., 2002). Elephant grass (2n = 28) with A'A'BB genome and pearl millet (2n = 14) with AA genome are closely related species of *Pennisetum* presenting good genetic combining ability, producing low fertility or sterile interspecific hybrids that are of great forage interest because they are better accepted by livestock than elephant grass itself (Jauhar, 1981; Shank and Chynoweth, 1993; Diz, 1994). Normally, the resulting hybrid (2n = 21) with AA'B genome usually has greater similarity to the elephant grass type due to the larger genetic contribution (66.7% chromosomes) and dominance of the elephant grass B genome over the pearl millet A genome (Gonzalez and Hanna, 1984).

The need for the genetic improvement of forage grasses to sustain the extensive and cut-and-carry systems of ruminant livestock production in Nigeria is a continuous quest. To increase livestock production in Nigeria, forage availability and the use of highly productive good quality pasture grasses are important nutritional factors that have been identified to increase productivity (Agishi, 1971; de Leeuw and Agishi, 1978). In Nigeria, there are three types of cultivated pearl millets *viz*., *Gero* which is an early-maturing genotype, *Dauro* which is a late-maturing genotype and *Maiwa*, the late-maturing short-day photoperiod-sensitive genotype (Aken'Ova et al., 1982). Research into both indigenous and exotic forage species has been going on in Nigeria, particularly in the savannah zones, since the 1950s. Studies at Ibadan, the derived savannah of the low-altitude humid tropics of Nigeria, showed that hybrids that had *Maiwa* outperformed hybrids which had *Tifton,* an early maturing pearl millet variety from Georgia, United States (Chheda et al., 1973; Aken'Ova et al., 1982). The study revealed that the pearl millet genotypes used as parents in crosses with elephant grass were likely to influence the performance, in terms of forage potentials, of the resulting interspecific hybrids. Until now, no study has been conducted involving other widely grown pearl millet genotypes of Nigerian origin such as *Dauro* and *Gero*.

This type of genetic combination tries to gather in the hybrid, some of the desirable characteristics of pearl millet such as vigour, drought resistance, disease tolerance, forage quality and seeds size, whereas rusticity, aggressiveness, perennity, palatability and high dry matter yield are provided by napier grass (that is, elephant grass) (Schank et al., 1996; Jauhar and Hanna, 1998; Souza et al., 2005).

However, there is much variability for maximising forage yields among elephant grass clones used as male parents (Hanna and Monson, 1980). Consequently, the aims of this study were to assess the combining ability of the representative pearl millet parents of Nigeria origin, *Dauro*, *Gero* and *Maiwa* with the two local high forage yielding selections of elephant grass, S.13 and S.15, and highlight satisfactory forage potentials among the successful interspecific hybrids which can be adapted to contribute to livestock production in Nigeria.

MATERIALS AND METHODS

Production of hybrid seeds

On 1st June 2009, two rows each of five pearl millet genotypes of Nigerian origin, *Gero* A, *Dauro*, *Maiwa* 28-1, *Maiwa* 25-2 and *Maiwa* 94-2, were sown at 90 × 90 cm spacing on a separate plot measuring 8.1 × 3.6 m to ensure coincidence of flowering between the pearl millet types and the two elephant grass selections, S.13 and S.15, which are maintained in the Department of Agronomy crop garden, University of Ibadan, Nigeria. Non-reciprocal diallel crosses (Griffing, 1956) were made for the production of inter-

Table 1. Chemical and physical characteristics of the experimental site soil.

Soil characteristic*	Value
pH (H_2O)	6.6
Organic carbon (g/kg)	14.9
Total nitrogen (g/kg)	0.75
Available phosphorus (mg/kg)	41.2
Trace elements	
Iron (mg/kg)	14.8
Copper (mg/kg)	2.58
Manganese (mg/kg)	129.00
Zinc (mg/kg)	14.08
Exchangeable bases	
Potassium (cmol(+)/kg)	0.59
Calcium (cmol(+)/kg)	3.53
Magnesium (cmol(+)/kg)	5.36
Sodium (cmol(+)/kg)	0.37
Particle size	
Clay (g/kg)	48
Silt (g/kg)	98
Sand (g/kg)	858
Textural class (USDA†)	Loamy sand

*Depth = 15 cm. †USDA = United States Department of Agriculture.

specific hybrid seeds. In the month of September when flowering had occurred in the pearl millet, the panicles were protected with shoot bags to prevent pollination from adjourning plots. The elephant grass panicles were also bagged at the onset of anther emergence with shoot bags with the open end clipped for pollen collection. The collected pollen from the bagged elephant grass selections were dusted on previously protected pearl millet panicles with fully emerged stigmas just before anther emergence. This took place between 9 and 11 am daily, a time when pollen viability is high (Rai, 1997). The pollinated pearl millet plants were re-bagged and the open end of the bags clipped. On the outside, the bags were appropriately marked according to the parent plants crossed and the date of pollination. Harvesting of the panicles followed four weeks later and they were threshed manually to extract the seeds. The seeds were then cleaned of glumes in a tray (sieve) and transferred to seed packets that were appropriately labelled.

Germination test and preliminary screening

Germination tests of all the seeds obtained from the crosses were conducted on 26th May 2010. This was carried out in the Plant Breeding Laboratory of the Department of Agronomy, University of Ibadan, Ibadan, Nigeria, for seven days. Fifty seeds per cross were placed on a moist filter paper laid inside Petri dishes. Proper germination was indicated by full radicle and plumule extensions. Two millilitres of distilled water was applied daily to maintain moist condition within the Petri dishes. Observations of seedlings with purple coleoptiles from each of the crosses were made. The purple colour served as a marker for the identification of hybrid seedlings, as distinct from seedlings with light green plumules as a result of possible selfing that occurred on the pearl millet panicles. The identified purple seedlings were subsequently moved into seed boxes in the nursery on the eighth day.

Preliminary screening was conducted in the screenhouse of the Department of Agronomy, University of Ibadan, Ibadan, Nigeria. Wooden boxes with inside measurements of 50 × 40 × 15 cm with perforations at the base were filled with sieved topsoil and placed on a supporting metal stand at 100 cm above ground level for proper aeration and drainage. The soil in the boxes was manually irrigated till saturation before the seedlings were places at 10 × 5 cm distance. Wetting of the soil was carried out twice daily, in the morning and evening, using 2000 ml of water. This lasted for 21 days. The observed vigorous seedlings were earmarked for transplanting.

Field evaluation and data collection

The experimental site was the Teaching and Research Farm of the Department of Agronomy, University of Ibadan, Ibadan, Nigeria (7°27'N; 3°54'E) at 218 m above sea level. Soil samples at 15 cm depth were taken with soil auger for analysis (Ryan et al., 2001). The field was manually cleared and lightly tilled. Vigorous seedlings from all the crosses were then transplanted to the field at a spacing of 90 × 90 cm on 25th June 2010. At four weeks after transplanting, compound fertilizer (NPK 15:15:15) was applied to supply 50, 21.8 and 41.5 kg/ha, of N, P and K respectively. The first harvest was taken at 12 weeks after transplanting (17th September, 2010). The plants were cut manually with machetes. Six weeks later, the second harvest was taken on 29th October, 2010. This was followed by the third harvest on 10th December, 2010, following another six weeks interval. After the first and second harvests, fertilizer (NPK 15:15:15) was applied three days after at the rate of 100, 43.6, and 82.9 kg/ha N, P, K and 50, 21.8, and 41.5 kg/ha, N, P, K respectively. At each harvest, the plant height was measured and the plants cut at 30 cm above ground to achieve good quick regrowth (Andrews and Kumar, 1992; Tudsri et al., 2002; Teutsch, 2009). The experimental plot was manually weeded by slashing within and between rows before each fertilizer application. Six representative plant samples from each cross were bulked from the second harvest and oven-dried at 80°C, for three to five days, to constant weight to determine the dry matter content according to Association of Official Analytical Chemists (AOAC) (1990) methods. The plants were not sampled at first harvest because there were not yet established, that is, acclimatized on the field following transplanting. This is allowed to ensure uniformity of growth of the pasture. The mortality rate (%) were determined on the field as the number of surviving plants (stands) at each harvest divided by the total number of plants at previous harvest × 100. Dry matter content (%) and dry matter yield (g/m^2) were also determined. Harvested plants were dried at 80°C for three to four days to determine dry matter weight. Dry matter yield was the product of dry matter weight of each harvested plant with plant density. Percentage dry matter was calculated as dry matter weight divided by fresh matter weight × 100.

Soil analysis

The physical and chemical properties of the experimental soil prior to planting as presented in Table 1 show that the soil was slightly acidic. The soil was characterized by low nitrogen, relatively high level of organic matter and high level of available phosphorus. However, high level of available phosphorus is often attributed to slightly acidic soils and this also has implication for phosphorus release. Phosphorus as well as nitrogen has a strong influence on

Table 2. Climatological variables of the study area.

Month	Rainfall (mm)	Avg. temp. (°C)	Avg. RH (%)	Evapotranspiration (MJ/m^2/day)
May	0.226	26.8	85.4	9.232
June	0.120	26.1	87.1	8.221
July	0.103	24.6	88.7	7.328
August	0.077	19.7	72.2	5.280
September	0.027	24.9	88.8	9.104
October	Traces	23.7	88.5	9.347
November	Traces	14.3	90.0	7.823
December	Scarce	26.7	73.5	12.817

Source: Department of Geography, University of Ibadan, Ibadan.

the growth and yield of forage grasses (Rao et al., 1999). However, moisture availability often affects the dry matter yield of forage grass more than fertilization (Volesky and Berger, 2010). The exchangeable bases ranged from 0.37 to 5.36 cmol/kg. These low values could partly be attributed to soil erosion and nutrient leaching from the topsoil, which is a characteristic feature of the humid lowland tropics soil. The soil texture was loamy sand.

Climatological conditions

Table 2 shows the prevailing weather conditions of the experimental site. Rainfall peaked in May (0.226 mm) and it scarcely rained in the month of December though there were traces of rainfall in October and November. The mean temperature ranged from 14.3 (November) to 26.8°C (May). Overall, the highest relative humidity (90.0%) was also observed in November with the least mean daily temperature. However, evapotranspiration (solar radiation) ranged from 12.817 (December) to 5.280 MJ/m^2/day (August).

Statistics analyses

Analysis of variance (ANOVA) was carried out in a randomized complete block design (RCBD) using GenStat Discovery Edition 4 software package. Each of the harvest intervals was considered as a source of variation and taken as a block (replicate). Post-ANOVA statistical analysis was conducted using least significant difference (LSD) ($p = 0.05$) to declare significant differences among the harvest intervals. Duncan's multiple range test (DMRT) ($p = 0.05$) was, however, used to determine significant differences among the genotypes since there were more than five treatment means (Gomez and Gomez, 1984). Pearson's bivariate correlation coefficients ($p = 0.05$) between plant height, dry matter content and dry matter yield were also calculated using Predictive Analytics Software (PASW) version 18.

RESULTS AND DISCUSSION

At first and second harvests, mortality (%) and dry matter content (%) were not significantly different ($p = 0.05$) though these observations increased over each harvest. The second harvest was characterized by an increase in dry matter yield (Table 3). This boost in forage yield was partly attributed to an increase in the fertilizer rate to 100 kg/ha of N (that is, double the initial dose of 50 kg/ha of N) after first harvest and the availability of moderately low soil moisture, high relative humidity and solar radiation evidenced in late September to early November, 2010 (Table 2). This result highlighted the need for adequate fertilization alongside moderate moisture availability for high forage yields in the tropics. Observations made on plant height (cm), and dry matter yield (g/m^2) at third harvest were not significantly different ($p = 0.05$) from the first harvest though the highest values of these observations were recorded at second harvest (Table 4).

The decrease in characteristics, morphologic and productive, with age is a phenomenon observed throughout tropical grasses (Ademosun, 1973) and young pasture leads to higher organic matter digestibility and intake (Onifade and Agishi, 1990). On the other hand, this study also showed that dry matter content of forage grasses increases with low amount of available soil moisture as the rains receded, resulting in reduced water uptake and accumulation in the plants. Apart from *Gero* A hybrids which had 100% mortality, *Dauro* x S.13 (42.9%) and *Maiwa* 25-2 x S.13 (21.2%) also had the least number of surviving individuals and were not significantly different ($p = 0.05$). Other hybrids *viz., Maiwa* 28-1 x S.13 (12.8%), *Maiwa* 94-2 x S.13 (6.7%), *Dauro* x S.15 (6.2%), *Maiwa* 28-1 x S.15 (5.1%) and *Maiwa* 94-2 x S.15 (1.7%) were also not significantly different ($p = 0.05$) from *Maiwa* 25-2 x S.15 (1.3%) with the highest number of surviving individuals (Table 4).

Overall, hybrids which had S.13 parent recorded the highest mortality, ranging from 6.7 to 42.9%, whereas hybrids with S.15 parent had a range of 1.3 to 6.2% mortality. The mortality rate of the interspecific hybrids on the field was viewed as an aid to selection for crosses with the genetic ability to overcome hybrid inviability which has been earlier reported by Stebbins (1958) as an important post-zygotic barrier to interspecific hybridization. This study also highlighted mortality rate as a measure of the ability of the successful interspecific hybrids to withstand transplanting shock and acclimatization challenges on the field. Consequently, the moderate to high mortality rates observed among interspecific hybrids between pearl millet and elephant

Table 3. Mean squares relevant to the harvest intervals and genotypes.

Source	df	Mortality (%)	Plant height (cm)	Dry matter content (%)	Dry matter yield (g/m^2)
Harvest	2	1157.28**	3204.82***	21.138*	70552.0***
Genotype	7	586.49**	290.62*	14.299*	9193.0^{NS}
Residual	14	99.17	96.37	3.543	4394.0

*, ** and ***significant at the 0.05, 0.01 and ≤0.001 probability levels, respectively. ^{NS} Non-significant difference, df = degree of freedom.

Table 4. Mean effects of harvest interval on survival, morphology and forage yield components of interspecific hybrids between pearl millet and elephant grass.

Harvest	Mortality (%)	Plant height (cm)	Dry matter content (%)	Dry matter yield (g/m^2)
H1 (12WAT)	2.2	112.0	14.36	174.0
H2 (6WAH1)	9.0	149.3	14.52	348.0
H3 (6WAH2)	25.5	117.9	17.25	199.0
±SEM	3.52	3.47	0.665	23.4
F pr.	0.001	<0.001	0.013	<0.001
LSD(p = 0.05)	10.7	10.5	2.02	71.1

H1, H2 and H3 = first, second and third harvests respectively. WAT and WAH = weeks after transplanting and weeks after harvest, respectively.

grass is linked to the fact that pearl millet is an annual crop species and this trait was conferred on the hybrids at varying degrees by the different pearl millet genotypes. The results practically showed that cytogenetic barriers to interspecific hybridization involving Nigerian pearl millet type parents, *Dauro*, *Gero* A and *Maiwa*, with S.13 and S.15 elephant grass selections were at their strongest in crosses involving *Gero* A.

Interspecific hybrids have a mosaic of both parental and intermediate morphological characters rather than just intermediate ones. Plant height ranged from 113.1 (*Dauro* x S.13) to 141.2 cm (*Maiwa* 94-2 x S.13). *Maiwa* 94-2 x S.13 which was also not significantly different (p = 0.05) from other hybrids except *Dauro* x S.13. Only *Maiwa* 25-2 x S.15 (116.0 cm) was not significantly different (p = 0.05) from the shortest hybrid, *Dauro* x S.13 (Table 5). Hybrids of all *Maiwa* parents with S.13 elephant grass selection were generally taller than those hybrids with S.15 elephant grass selection except with *Dauro* parent which had its hybrids with S.15 being taller than its counterpart hybrids with S.13. These variations are often expected from interspecific hybrid plants from parents with contrasting agronomic and morphological features. The observations corroborate the reports of Hanna and Monson (1980) and van de Wouw et al. (1999) who reported variations between and within accessions of elephant grass × pearl millet hybrids in terms of plant height, ranging from 120 to 340 cm at ten weeks after cutting. However, distinguishing morphological parental characters expressed by hybrids of closely related species have been reported to show dominant inheritance pattern (Gottlieb, 1984; Hilu, 1993). In any case, the expression of parental or intermediate character in hybrids is significantly attributed to the genetic control of the character, as well as interactions with the environment.

One major forage quality that complements higher yield is digestibility, and it is directly related to succulence of forage which invariably depends on the moisture contents in plant tissues. The drop in water content or decrease in percentage dry matter, caused by stem-hardening, have been reported to decrease digestibility and palatability of forage (stem and leaves) at maturity in pearl millet and pearl millet × elephant grass hybrids (Schank et al., 1993). Mature leaves of plant tissues generally contain water from 75 to 85% of the fresh weight. Succulence of forage depends on the value of moisture contents (%). The least dry matter content was observed for *Maiwa* 94-2 x S.13 (11.74%) and was significantly different (p = 0.05) from *Maiwa* 28-1 x S.15 (17.93%) and *Dauro* x S.15 (17.06%). *Maiwa* 28-1 x S.13 (12.49%) was significantly different (p = 0.05) from *Maiwa* 28-1 x S.15 but similar to hybrids of *Maiwa* 25-2 x S.13 (16.08%), *Maiwa* 94-2 x S.13 (11.74%) and *Dauro* x S.13 (15.27%). Hybrids with *Maiwa* 25-2 parent were not significantly different (p = 0.05) from *Maiwa* 94-2 x S.15 (15.72%) and *Dauro* x S.13 (15.27%). Overall, hybrids with S.15 parent had higher dry matter content than hybrids with S.13 parent (Table 5). This was a trend similar to mortality because hybrids with S.15 had greater number of surviving plant stands after each harvest. McCullough (1977) reported a dry matter content range of 28 to 34% in elephant grass and 19.4% was reported in pearl millet (Aguiar et al., 2006; Fulkerson et al., 2008). Overall, the results of this study

Table 5. Mean genotype effect on plant height and forage yield components of interspecific hybrids between pearl millet and elephant grass.

Genotype	Mortality (%)	Plant height (cm)	Dry matter content (%)	Dry matter yield (g/m^2)
25-2 x S.13	21.2^{ab}	133.4^{a}	16.08^{abc}	171.0^{NS}
25-2 x S.15	1.3^{b}	116.0^{ab}	16.73^{abc}	171.0
28-1 x S.13	12.8^{b}	135.3^{a}	12.49^{bc}	324.0
28-1 x S.15	5.1^{b}	120.9^{a}	17.93^{a}	227.0
94-2 x S.13	6.7^{b}	141.2^{a}	11.74^{c}	308.0
94-2 x S.15	1.7^{b}	123.1^{a}	15.72^{abc}	249.0
Dauro x S.13	42.9^{a}	113.1^{b}	15.27^{abc}	232.0
Dauro x S.15	6.2^{b}	128.2^{a}	17.06^{ab}	239.0
±SEM	5.75	5.67	1.087	38.3
F pr.	0.002	0.037	0.013	0.114

Figures with different letters denote significant genotype differences at 0.05 and 0.01 probability levels using Duncan's multiple range test (DMRT). ^{NS} Non-significant difference.

Table 6. Correlation between plant height and forage yield components of interspecific hybrids between pearl millet and elephant grass.

Variable	Dry matter content (%)	Dry matter yield (g/m^2)
Plant height (cm)	-0.434*	0.780**
Dry matter content (%)		-0.430*

* and ** = significant correlation at 0.05 and 0.01 probability levels, respectively.

showed that none of the hybrids had over 18% dry matter content because the pasture was still at its early stage of establishment. Increase in dry matter content of forage increases with age (maturity) of forage (Maria et al., 2010). Thus, low dry matter content will impart on the succulence and palatability of the hybrids as forage (fodder) (Schank et al., 1993; Wadi et al., 2004). However, the digestibility of forage dry matter by ruminants is the summation of the digestibility of the component tissues as affected by morphology, anatomy and chemical composition (Murphy and Colucci, 1999). Where silage is to be made, forages with low dry matter content are selected against but this should not exceed 30% dry matter content (Aganga and Tshwenyane, 2003; Snijders and Wouters, 2003). Moreover, wet forages are difficult to ensile because high moisture content has implications for the development of clostridial fermentation, dilution of plant sugar concentration and slowing the decline in silage pH (Henderson, 1993). On the other hand, mature forage grass with high dry matter content supports good silage quality, though it may also have high fibre content and consequently low digestibility (Aganga and Tshwenyane, 2003).

Nonetheless, dry matter yield is a more meaningful way of comparing fodder yield (Faridullah et al., 2010). From the study, there was no significant difference (p = 0.05) in all the hybrids in terms of dry matter yield (g/m^2) (Table 5). The highest dry matter yield was obtained from *Maiwa* 28-1 x S.13 (324.0 g/m^2) and the least yield was obtained from hybrids with *Maiwa* 25-2 parent. Generally, hybrids of *Maiwa* parents with S.13 elephant grass selection were higher in dry matter yield than hybrids of *Maiwa* parents with S.15 elephant grass selection. Hybrids of *Dauro* parent with S.13 elephant grass selection, however, had lower dry matter content over those with S.15 elephant grass selection. According to Arshadullah et al. (2011), higher production of fodder is appreciable only if its quality is acceptable as well and the production of milk, meat and associated products of livestock depends upon hereditary factors by approximately 25%, while 75% is dependent on the feed (forage) quality and quantity. The results showed that the genotypes producing higher dry matter yield (biomass) also had lower dry matter content (that is, greater moisture contents). Consequently, this highlighted that all the genotypes had similar moderate moisture content presenting them with more succulence and digestibility as forage.

Pearson's bivariate correlation coefficients between plant height, dry matter content and dry matter yield were calculated and these showed significant relationships between these parameters (Table 6). Dry matter content was negatively and significantly correlated with dry matter yield (r = -0.430) of the hybrids, implying that these two attributes cannot be significantly improved. Though plant height was also negatively correlated with dry matter content (r = -0.434), there was a significantly strong positive correlation between plant height and dry matter yield (r = 0.780), indicating that plant height had the highest effect on dry matter yield. These results were at par with the report of Vidyadhar et al. (2007) where there was a significant positive correlation (r = 0.65) between plant height and fodder yield of pearl millet. This report agreed with those of Faridullah et al. (2010) on pearl millet and Zhang et al. (2010) on elephant grass. Wadi et al. (2004) reported that there exit a positive high significant correlation, r = 0.917 and r = 0.938, between dry matter yield and plant height in hybrids of both reciprocal crosses between elephant grass and pearl millet (hybrid napier grass) and pearl millet with elephant grass hybrids (king grass), respectively. The positive significant (p = 0.05) correlation recorded for plant height suggests that this morphological attribute is of value for selecting interspecific hybrids of pearl millet × elephant grass with high forage yield.

Conclusion

The significant genetic incompatibility status of *Gero* A presents it as an unsuitable pearl millet type for interspecific hybridization between elephant grass and further cytogenetic and genomic analyses that would help explain the differences among the pearl millet types as suitable parents are suggested. Overall, hybrids between *Maiwa* and S.13 (*Maiwa* 94-2 x S.13 and *Maiwa* 28-1 x S.13) were the most promising in terms of dry matter yields and should be subjected to further studies such as forage yield evaluation over a number of seasons as well as animal trials. The significantly strong correlation between these forage attributes *viz.,* plant height and dry matter yield, showed that these could be used as selection and adaptability indices.

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