PAT June, 2016; 12 (2): 117-125 ISSN: 0794-5213

***Online copy available at* www.patnsukjournal.net/currentissue**

Publication of Nasarawa State University, Keffi

Genetic Estimates and Forage Potential of 'Maiwa' Pearl millet (*Pennisetum glaucum* (l.) R. Br)

Lawal, Oluwafemi Oluwatosin,

Department of Crop Production, College of Agriculture, Kwara State University, Malete, Ilorin, PMB 1530. Nigeria.
Phone number +234-8057336667,
Email: oluwatosin.lawal@kwasu.edu.ng, femylawal@gmail.com

Abstract
Three inbred lines namely 25-2, 28-1 and 94-2 were crossed in a full diallel including reciprocal. The six hybrids and three parents were sown in a randomised complete block design with three replicates. Forage was harvested by cutting at 6, 12 and 20 weeks after sowing (WAS). The regrowth after first boot stage (20 WAS) was left to boot stage again. 94-2 was observed to be the best combiner (GCA = +1) in terms of total dry matter DM yield. Thus, all its hybrids namely 28-1 x 94-2, 94-2 x 28-1, 25-2 x 94-2 and 94-2 x 25-2 with 14.41, 11.57, 11.09 and 13.17t DM ha^{-1} formed the highest yielding hybrids. 94-2 x 25-2 and 28-1 x 94-2 had MPH of 241.2 and 217.4 %; BPH of 183.8 and 140.2% respectively. The high values for heterosis showed that genetic gains can be achieved through hybridization. All hybrids with 94-2 as parent can be recombined to produce a new breeding population or synthetic variety. These hybrids can provide herbage as green chop and pasture during the early rains and then ensilage, later in the season. Thus, could reduce feed scarcity and resultant herdsmen/ farmers conflict associated with feed search.
***Key words**: Pearl millet, forage yield, hybridization, heterosis, combining-ability.*

INTRODUCTION

Pearl millet, *Pennisetum glacuum* (L.) R. Br.) is one of the most important species from the about 140 species in the genus Pennisetum L. (Rich), belonging to the family Poaceae (Haroun, 2010). It is one of the few diploid (2n = 14) in the genus that is well spread in the tropics and the subtropics (Upadhyaya *et al.,* 2008). Pearl millet is the most drought tolerant of all domesticated cereals (Newman *et al*., 2010). It is a dual purpose crop used both as forage for animals and food for man. Pearl millet has enormous yield potential as it surpasses either sorghum (*Sorgum bicolor*) or maize (*Zea mays*) (Kevin and Blaine, 1991) as a result of it high tillering ability (Ratikanta and Humberto, 2010). Kevin and Blaine (1991) concluded that pearl millet silage made at early flowering equals maize silage in quality and to have high digestible protein content. Also, pearl millet has high leafiness and succulent stems (Ratikanta and Humberto, 2010). The green fodder is highly nutritious because of relatively high fat and protein content and its free from cyanide at all stages of growth (Newman *et al*., 2010). 'Maiwa' pearl millet is a Nigeria indigenous, late maturing and short day photoperiod sensitive type (Ogbaji and Aken'Ova, 1995).

Heterosis, or hybrid vigor, or outbreeding enhancement, is the superiority or amplified function of any biological quality in a hybrid offspring. It occurs when genetic recombination of parents results in genetically superior offspring. This superiority is seen in improved yield, speedy growth and enlarged dimensions, tolerance, resistance and fertility of various first filiar-generations of plant hybrids (Fu *et al*., 2014) but not in other generations. Species with

marked heterosis are usually favoured in natural selection hence enhancing genetic variability. The superiority of hybrids over their parents can either be mid-parent (superiority of F_1 hybrid performance over the average of their parents) (Falconer, 1987) or heterbeltiosis/ better-parent (superiority of F_1 hybrid performance over the performance of the better parents) heterosis. The fullest gain of heterosis is exploitable when divergent individuals within a species are crossed. These individuals can be determined with molecular markers (Lima *et al.*, 2011).
The improvement of forage yields of pearl millet like any crop depends on the understanding of the type of the gene action involved in its inheritance (Rezaei *et al.*, 2004), which also determines the most efficient breeding strategy (Pal and Prodham, 1994). The effects of General Combining Abilities (GCA) and Specific Combining Abilities (SCA) are important indicators of potential value of an inbred line in hybrid combinations. Differences in GCA effects have been attributed to additive, the interaction of additive x additive, and the higher-order interactions of additive genetic effects in the base population, while differences in SCA effects have been attributed to non-additive genetic variance such as dominance (Falconer, 1981). The concept of GCA and SCA has become increasingly important to plant breeders because of the widespread use of hybrid cultivars in many crops (Rezaei *et al.,* 2004). A Diallel analysis provides good information on the gene action of genotypes especially on dominance-recessive relations and some other genetic interactions. Diallel crosses have been used in genetic research to determine the inheritance pattern of trait of interest and to identify superior parents for hybrid production (Yan and Kang, 2003).
Although, maiwa pearl millet is used for delicacies in Northern Nigeria, the drive for its use as forage crop is from the south west (Aken'Ova, 1976). Its genetic variability for forage has not been fully exploited. More so, the gene action of forage potential of 'maiwa' will determine the breeding strategies to employ for its subsequent improvement. Hence, there is a need to develop of improved genotypes for hybrid production with higher DM yield all year long, faster vegetative growth, with good adaptation to the different ecosystems of the country (Ogbaji and Aken'Ova 1995; Souza-Sobrinho *et al.*, 2005). Hence, this research was initiated and investigated the combining ability of different inbred lines in hybrid production and also evaluate the heterosis in the hybrids for forage production.

MATERIALS AND METHODS

Experimental site

The study was mini experimental site of the Department of Agronomy, University of Ibadan, Ibadan (7º 26'N and 3º 54'E).

Production of hybrids

Three pearl millet inbred lines were collected from the Department of Agronomy, University of Ibadan. Crosses in all possible combinations were carried out to produce hybrids (Lawal, 2017). The inbred lines and their hybrids are shown below:

1. 25-2 x 28-1
2. 28-1x 25-2
3. 25-2 x 94-2
4. 94-2 x25-2
5. 28-1 x 94-2
6. 94-2 x 28-1

} F1 hybrids (with reciprocals)

7. 25-2
8. 28-1
9. 94-2

} inbred lines

Soil sampling and test

A soil auger was used to collect soil sample at a soil sampling depth of 15cm from the experimental site. The soil was air dried to determine some of its physical and chemical properties.

Field establishment and management

The six hybrids and three parents were laid out in a randomised complete block design with three replicates as 1.5m single row plot with a 30cm gap between plots in the same block and 90cm apart. Dressed seeds were hand drilled at the rate of 10kg ha^{-1}. Due to insufficient seed of 94-2 x 28-1, it was only sown in blocks I and II. This was taken into consideration in statistical analysis in terms of missing plot.

Six weeks after sowing, plants were harvested by cutting 30cm above ground level and the cut herbage weighed. A second harvest was carried out six weeks later. The re-growth after the second harvest was allowed to boot stage i.e. when 50% of the plants in a plot had reached boot stage, the stage when millet is harvested for silage production. Following the third harvest, which was at boot stage, there was some re-growth which was generally poor. This re-growth was also harvested when boot stage was reached about 4 to 6 weeks later. Plant height was measured prior to each harvest. Plots were manually weeded as necessary five to seven days after each harvest. Fertilizer NPK 15-15-15 was applied to supply 100 kg N ha^{-1} in split dose of 50 kg three weeks after sowing and 25 kg after each of the first and second harvests.

Data analysis

Data collected were subjected to Analysis of Variance (ANOVA) using Gen Stat Discovery Edition 3. Linear correlations between plant height and DM yield were also calculated. Means showing significant differences were separated at 5% probability using Duncan's Multiple Range Test (DMRT) (Steel and Torrie, 1980).

Estimation of heterosis

Heterosis was computed using the formulas given by Fehr (1987).

Mid-parent (MP) heterosis and Better-parent (BP) heterosis are as follows:

Mid-parent heterosis MPH (%) = $(F_1\text{-MP}) \times 100/\text{MP}$

Better-parent heterosis BPH (%) = $(F_1\text{- BP}) \times 100/\text{BP}$

Where F_1 and BP are mean performances of the hybrid and better parent respectively and

MP = $0.5(P_1 + P_2)$ with P_1 and P_2 being the mean performances of the parents (Fehr, 1987).

Estimation of general combining ability (GCA)

General combining ability values of the inbreds in respect of dry matter (DM) yields were computed using the formula given by Simmonds (1979) for diallel combinations with reciprocals.

$$G_{CA} \left(\frac{T_A + T'_A}{2N} \right) - \frac{T}{N^2}$$

Where G_{CA} is the general combining ability of inbred A, T_A is row total in respect of inbred A in a diallel arrangement, T'_A is column total in respect of inbred A in a diallel arrangement as shown below.

Inbreds	**A**	**B**	**C**	**Row total**
A	AA	AB	AC	T_A
B	BA	BB	BC	T_B
C	CA	CB	CC	T_C
Column total	T'_A	T'_B	T'_C	Grand total (T)

N is the number of parents, and
T is the grand total of DM yield summed over all inbreds.
Specific combing ability effect was computed using Griffing (1956) model 1, method 1.

RESULTS AND DISCUSSION

Soil analysis

Soil analysis is pivotal in agronomic trial as such result chemical and physical characteristic of the experimental site is reveal that the soil is slightly acidic with a pH of 6.6 a high available P (12.51 mg kg^{-1}) and a low (0.288-0.91 cmol/kg) level of exchangeable bases described in Lawal (2017).

Plant height

Table 1 shows that there were no significant differences in plant height of 'maiwa' inbreds and their hybrids at the second (12 WAS) and the fourth (26 WAS) harvest, the re-growth after the first boot stage harvest. However, in the first harvest, 6 WAS, 94-2 x 25-2 had the greatest height of 104.53cm which was not significantly different from its reciprocal 25-2 x 94-2 but was significantly different from other inbreds and hybrids. At boot stage, 20 WAS, 94-2 x 25-2, also had the greatest height of 240cm which was not significantly different from its reciprocal as well as 28-1 x 94-2 and 94-2 x 28-1. In the present study, there is significant (P= 0.05) correlation, r = 0.80, between plant height and herbage yield. Therefore, all high herbage yielding 'maiwa' lines were taller, thus showing a close relationship between plant height and herbage yield as found among forage grasses (Akinola *et al.*, 1971; Dillon, 2010).

Dry matter yield

As also shown in Table 1, the total yield of 'maiwa' inbreds and hybrids ranged from 3.08t DM ha^{-1} for inbred 94-2 to 14.41t DM ha^{-1} for 28-1 x 94-2 hybrid. The average DM yield of 10.33 t ha^{-1} of the F_1 hybrids is higher than the yields of 6.84t DM ha^{-1} reported by Barnard (1972) and 8.70t DM ha^{-1} reported by Amodu *et al.* (2007) under semi-arid conditions in Nigeria. The higher yields in the present study could be a reflection of more favourable environment in terms of increased rainfall at Ibadan in the forest zone. The higher yields could also reflect genetic superiority of the hybrids. Thus the average F_1 hybrids yield of 10.33t ha^{-1} was 126% better than the average yield (4.57t ha^{-1}) of the inbreds. At the first harvest, six weeks after sowing, yields ranged from 0.98 (hybrid) to 2.35t DM ha^{-1} (hybrid). However, yields were lower at the second harvest, six weeks later, ranging from 0.6 (inbred) to 2.27t DM ha^{-1} (hybrid). The highest yields were at the third harvest, when plants were at boot stage and ranged from 1.31 (inbred) to 10.57t DM ha^{-1} (hybrid). The yields partly reflect the age of the plants i.e. 20 WAS, the extended interval of eight weeks after the previous harvest as well as their physiological maturity. There had therefore been more time to accumulate dry matter with internodal elongation taking place. Hassanat, (2007) also obtained the highest DM yield at boot stage in pearl millet. Although also taken at boot stage, the lowest yields between 0.004 and 0.511t DM ha^{-1} were obtained at the fourth harvest, about 24 to 26 WAS i.e. four to six weeks after the third harvest, which was also at boot stage. The re-growth at this stage was poor. For an annual like pearl millet, re-growth is likely to be poor when plants had already reached physiological maturity at the previous harvest (NCR, 2014). Furthermore, the harvest was at the onset of the dry season.

Although there were no significant differences in DM yields among the inbreds and their hybrids at the second harvest (12 WAS) as well as the fourth harvest (26 WAS), there were significant differences at first harvest (6 WAS), boot stage (20 WAS) and for total yield, summed over all harvests. At 6 WAS, 94-2 x 25-2 had the highest DM yield of 2.35t ha^{-1} which was not significantly different from the yields 25-2 x 94-2, 28-1 x 94-2 and 94-2 x 28-1. Hybrid 28-1 x 94-2 had the highest yield of 10.57t DM ha^{-1} at boot stage but was not significantly different from 25-2 x 94-2, 94-2 x 25-2 and 94-2 x 28-1. In terms of total DM yield, 28-1 x 94-2, again had the highest yield of 14.41t ha^{-1} which was not significantly different from its reciprocal as well as 94-2 x 25-2 and 25-2 x 94-2 but was significantly different from all their inbreds viz: 25-2, 28-1 and 94-2. All the hybrids were not significantly different from their reciprocals. Thus, maternal effects on DM yield were not present in the 'maiwa' lines. Maternal effects for yield have been reported by Ogbaji and Aken'Ova (1995) in the crosses between 'maiwa' and 'gero'. 'Gero' is a different pearl type.

General combining ability test

Table 2 shows that the inbred line 94-2 had a positive general combining ability (GCA) of 0.90 and 1.0 in terms of DM yield at boot stage and total harvest, respectively. Thus 94-2, despite having the lowest total yields of 3.08 t DM ha^{-1} combined well with 28-1 and 25-2 to produce the highest yielding hybrids viz: 28-1 x 94-2, 94-2 x 28-1, 25-2 x 94-2 and 94-2 x 25-2 with 14.41, 11.57, 11.09 and 13.17t DM ha^{-1}, respectively. It is implied that 94-2 is the best tester (Zine *et al.,* 2013)

Specific combining ability test

Table 2 also shows that 94-2 positive specific combining ability (SCA) in hybrid production. It has 4.6 in 28-1 x 94-2, 4.5 in 94-2 x25-2, 2.8 in 94-2 x 28-1 and 2.7 in 25-2 x 94-2. High

Table 1. Dry matter yields (tha^{-1}) and Plant height (cm) of 'maiwa' inbred lines and their hybrids at different harvests

Lines	6 WAS	12 WAS	20 WAS	26 WAS	Total	6 WAS	12 WAS	20 WAS	26 WAS
	.................DM yield.........t ha^{-1}...........................					..................Plant height......cm.....................			
25-2 x 28-1	1.30cde	1.20	3.44bc	0.225	6.16bcd	84.47c	71.50	185.00ab	60.00
28-1 x 25-2	0.98e	0.83	3.56bc	0.183	5.55bcd	84.20c	99.50	133.33b	110.00
25-2 x 94-2	2.13ab	1.28	7.44abc	0.237	11.09abc	97.93ab	80.33	178.33ab	101.67
94-2 x 25-2	2.35a	1.48	9.02ab	0.319	13.17ab	104.53a	85.33	240.00a	108.33
28-1 x 94-2	2.03ab	1.51	10.57a	0.299	14.41a	92.73bc	86.67	233.33a	118.33
94-2 x 28-1	1.92abc	2.27	6.87abc	0.511	11.57abc	91.10bc	97.35	226.67a	115.00
F_1 average	1.79	1.43	6.82	0.296	10.33	92.5	86.78	199.44	102.22
25-2	1.61bcde	1.48	1.51c	0.032	4.64cd	90.37bc	79.33	167.50b	36.67
28-1	1.80abcd	0.93	3.10bc	0.178	6.00bcd	85.47c	67.67	140.00b	56.67
94-2	1.16de	0.60	1.31c	0.004	3.08d	89.87bc	71.67ns	160.00b	35.00ns
Inbred Ave.	1.53	1.00	1.97	0.07	4.57	88.57	72.89	155.83	42.78
Overall Ave.	1.66	1.22	4.40	0.221	8.41	91.19	82.15	184.91	82.41
CV**%**	55.90	197.2	174.8	316.2	136.4	18.53	47.33	66.22	133.76

*Values in columns with the same letter(s) are not significantly different P> 0.05.

[1]ns: non-significant differences [2]CV: Coefficient of variation

Table 2. Estimates of the general (GCA) and specific combining abilities (SCAs) of 'maiwa' inbred lines in respect of total and boot stage harvest (20 WAS) DM yield
Total dry matter yield

	---------------------------SCA---------------------			GCA
Inbred	25-2	28-1	94-2	
25-2	-	-0.6	2.7	-0.9
28-1	-2.5	-	4.6	-0.1
94-2	4.5	2.8	-	1.0
		Boot stage (20 WAS)		
25-2	-	0.0	2.1	-0.8
28-1	-1.6	-	3.7	-0.1
94-2	3.8	1.9	-	0.9

values for SCA signifies the presence of dominance indicating prevalence of non additive gene which can be exploited in hybrid is production, because heterosis is positive (Cruz *et al.,* 2012). This implies that genetic gains in pearl millet forage DM yield can be accelerated by using hybridization as a breeding strategy (Bhandari *et al*., 2014).

Heterosis

As shown in Table 3, better parent heterosis (BPH) for total DM yield was highest (183.8%) in 94-2 x 25-2 hybrid which has inbred 94-2 with high general combining ability, as the seed parent. This also confirmed the superiority of the hybrids over their inbreds in the present study as heterosis confers higher productivity on hybrids (Souza-Sobrinho *et al.,* 2005). However, 28-1 x 94-2 was 17.32% better than 94-2 x 25-2 when compared with the highest yielding (6.0t DM ha^{-1}) inbred, 28-1. The negative value (-7.5) and low value (2.7) of BPH for total yield of 28-1 x 25-2 and its reciprocal, 25-2 x 28-1 respectively confirmed their poor combining abilities. High levels of heterosis for pearl millet forage yield have also been reported by Patil (1992). Ogbaji and Aken'Ova (1995) reported 20.7 and 23.2% heterosis in 'gero' x 'maiwa' and 'maiwa' x 'dauro' crosses, respectively.

Conclusively, the relatively high average hybrid yields of 1.79t DM ha^{-1} and 1.43t DM ha^{-1} obtained at the first (6 WAS) and second (12 WAS) harvest, respectively before allowing the plants to re-grow to boot stage was indicative of the possibility of grazing 'maiwa' at least twice before ensilage at boot stage when the highest average hybrid yield was obtained. Also, the high DM yield of 10.57t ha^{-1} at boot stage and 14.41t ha^{-1} in terms total herbage shows that 28-1 x 94-2 is highly promising in terms of meeting animal feed requirements. The late maturing nature of 'maiwa' type pearl millet provides for this favourable seasonal distribution of herbage production. Also, 94-2 is identified as the best tester in this study. The high values of MPH and BPH indicate the superiority of hybrids over their inbreds while high SCA depict that significant genetic gain can be achieved in improving forage yield of 'Maiwa' pearl millet through hybridization.

Table 3. Estimates of heterosis in 'maiwa' inbred lines for total and boot stage (20 WAS) DM yield

Hybrids	Total yield		Boot stage (20 WAS)	
	MPH	BPH	MPH	BPH
	..........%..........			
25-2 x 28-1	15.8	2.7	48.9	11.0
28-1 x 25-2	4.3	-7.5	54.1	14.8
25-2 x 94-2	187.3	139.0	427.7	392.7
94-2 x 25-2+	241.2	183.8	539.7	497.4
28-1 x 94-2	217.4	140.2	378.3	241.0
94-2 x 28-1	154.8	92.8	210.9	121.6

+ 94-2 x 25-2 is 119.5% better than 28-1.

REFERENCES

Amodu, J.T, Adeyinka, I.A, Kallah, M.S.and Alawa, J.P. (2007). Evaluation of pearl millet accessions for yield and nutrient composition. *Journal of Biological Science* **7**: 379-383.

Barnard C, (l972). Register of Australian Herbage Plant Cultivars. *CSIRO, Australia, Canberra.* 260.

Bhandari, H.S., Webb, S.L., Bouton, J.H. and Saha, M.C. (2014). Reciprocal effects for biomass yield in lowland switchgrass. *Crop Science* 54:955-962. doi:10.2135/cropsci2013.08.0532.

Cruz, C.D., Regazzi, A.J. and Carneiro e P.C.S. (2012). Biometric methods applied to genetic improvement. Publisher UFV, Viçosa, Brazil. Embrapa. 1997. Manual 514 p.

Dillon, P. (2010). Practical aspects of feeding grass to dairy cows. Book: *Recent advances in animal nutrition* - 2009 Ed: Garnsworthy, PC; Wiseman, J, 77-98

Falconer, D.C., (1981). An introduction to quantitative genetics. / 2nd edition, Longman, New York , 67-68.

Falconer, D.S. 1987. Introduction to quantitative genetics. 279 p. Federal University of Viçosa

Fehr, WR. (1987). Heritability. Principles of cultivar development theory and technique. W.R. Fehr, (Ed.) McMillan Publisher. Co., New York. 95- 105.

Fu, D., M. Xiao, A. Hayward, Y. Fu, G. Liu, G. Jiang, et al. (2014). Utilization of crop heterosis: a review. *Euphytica* 197:161-173. doi:10.1007/s10681-014-1103-7.

Griffing B (1956). Concept of general specific combining ability in relation to diallel crossing systems. *Aust. J. Biol. Sci*., 9: 463-493. H

Haroun, S.A. (2010). Cytogenetic Studies on Some Species of Genus Pennisetum L. (Rich) Poaceae. J. Am. Sci., 6(9): 208-215. Henderson N (1993). Silage additive. *Anim. Feed Sci.* Technol., 45: 35- 56 Hilu KW (1993). Polyploidy and the evolution of domesticated plants.

Hassanat, F. (2007). Evaluation of Pearl millet forage. PhD Thesis, Department of Animal Science, Mc Gill University, Montréal, Québec, Canada http://digitool.Library.McGill.CA:80/R/-?func=dbin-jump-full&object_id=18698&cur.

Kevin KS, Blaine GS. 1991. Pearl millet forage production in North Dakota. K.S. Kevin and G.S Blaine. (Eds.) North Dakota University Press, 19pp.

Lang B, 2001. Millet forage management. IOWA State University, Fact Sheet BL-55. 1-3.

Lawal, O.O. (2017). Nutritional composition of a full diallel-crossed forage pearl millet *Pennisetum glacuum* of Nigeria origin African *Crop Science Journal* (in press).

Lima, R.S.N., Daher, R.F., Gonçalves, L.S.A., Rossi, D.A., Amaral Júnior, A.T. Pereira, M.G. *et al.* (2011). RAPD and ISSR markers in the evaluation of genetic divergence among accessions of elephant grass. *Genetics and Molecular Research* 10:1304- 1313. doi:10.4238/vol10-3gmr1107.

Newman Y, Jennings E, Vendramini J, Blount A. (2010). Pearl Millet (*Pennisetum glaucum*): Overview and Management. *SS-AGR-337 series, Institute of Food and Agricultural Sciences*. Retrieved June 20, 2011 from http://edis.ifas.ufl.edu.

NCR 547 Alfalfa management guide October, 2014.

Ogbaji MI, and Aken'Ova, ME. 1995. Forage yield and quality of three Nigerian pearl millet (*Pennisetum glaucum* (L) types and their F1 hybrids. *Nigeria Agricultural Journal* 28: 91-94.

Pal ,A.K. and Prodham. (1994). Combining ability analysis of grain yield and oil content along with some other attributes in maize(Zea mays L.)Indian J.Genetisc .54:376-380.

Patil FB, Bhoite K, Surana PP. 1992. Heterosis for green forage yield in pearl millet. *Journal of Maharashta Agricultural Universities* 17: (2): 301-302.

Rai KN, Hash CT, Singh AK, Velu G. 2008. Adaptation and quality traits of a germplasm-derived commercial seed parent of pearl millet. *Plant Genetic Resources* 154: 20-24.

Ratikanta and Humberto, 2010. Pearl millet: potential alternative for grain and forage for livestock in semi-arid regions of Mexico. *Int journal of Bio- resource Mgt* **1**: 45-47.

Rezaei A et al (2004) Estimate of heterosise and combining ability in maize (zea mays L.), Genetic Variation for plant breeding, 395-398, Vienna.

Souza-Sobrinho, F., Pereira, A.VLedo, . F.J.S. Botrel, M.A., Oliveira, J.S. and Xavier. D.F. (2005). Agronomic evaluation of interspecific hybrids between elephantgrass and millet. Brazilian Agricultural Research 40:873-880. doi:10.1590/S0100-204X2005000900006.

Simmonds NW, 1979. Combining ability. In N.W Simmonds *Principles of crop improvement.* English Language Book Society/ Longman, England 408pp.

Steel RGD, Torrie JH. 1980. *Principles and procedures of statistics*: A Biometrical Approach. 2nd Edition, McGraw Hill, New York, USA, ISBN-13: 978-0070609259.

Upadhyaya HD, Reddy KN, Sastry DVSSR. 2008. Regeneration guidelines: pearl millet. *Crop specific regeneration guidelines.* M.E. Dulloo, I. Thormann, M.A. Jorge and J. Hanson (Eds). CGIAR System-wide Genetic Resource Programme, Rome, Italy. 9 pp.

Yan W., Kang, M. (2003). GGE Biplot Analysis,207-228, New York.

Zine, E. F., Abderrahmane, H., Hamenna, B. and Ammar B. (2013). Line × Tester Mating Design Analysis for Grain Yield and Yield Related Traits in Bread Wheat (Triticum aestivum L.) *International Journal of Agronomy* http://dx.doi.org/10.1155/2013/201851