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Evaluation of Some Growth Parameters of Millet (*Pennisetum glaucum* (L.) R.Br.) Landraces Cultivated in Al-Mawaset District, Taiz Governorate, Yemen

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ABSTRACT
Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) is an important crop plant cultivated in many countries, including Yemen, due to its high nutritional value. Landrace, temperatures, and rainfall are crucial factors when it comes to improving the cultivation of crops for the benefit of man and animals. Therefore, the aim of this study was to statistically evaluate the morphological (Plant height, Leaf area, area index and number, and inflorescence length) & physiological (Biomass, Grain Yield, and Seed weight) parameters of 20 Pearl Millet landraces that comply with the amount of rainfall to produce the best grain yielding and/or high biomass production when cultivated in the Al-Mawasit district, Taiz. The Grain Yield of landrace 25508 (mean grain yield of 3.1 t/ha) was found to be greater than the grain yield produced by the other studied landraces. Moreover, landraces 25366 and 25353 were found to give the greatest biomass (mean biomass of 6.7t/ha).

CONTENTS

1. Introduction:

Pearl millet (*Pennisetum glaucum* (L.) R.Br.)) is a widely grown rainfed cereal crop from the section Paniceae, Family Poaceae "grass family". It has been considered one of the oldest cultivated crops cultivated in large areas of the semi-arid tropics (of hot and dry climates) of Africa, especially in the West African Sahel and southern Asia, including India, for food, grain, fodder, and fuel. Millet as stored fodder is used as an alternative to high-quality forage of other crops (Pupo *et al.*, 2022). Pearl millet is the sixth most important cereal crop in the world, and it was believed that it originated from sub-Saharan Africa (Legwaila *et al.*, 2014; Hassan *et al.*, 2021; Ausiku *et al.*, 2022; Traore *et al.*, 2022 and Kokila *et al.*, 2023).

Pearl millet is an upright annual grass that may grow up to 3 meters tall and has a dense fiber root system. Culms are thin, 1-3 cm in width. Leaves simple, sessile, alternating (up to 1.5 m x 8 cm) with linear, pubescent, finely serrated blades. Inflorescence, spike up to 30 cm in length (Kokila *et al.*, 2023). Pearl millet grows in regions with high temperatures above 30 °C and exceptionally low annual rainfall of 300-500 mm (Taylor and Emmambux, 2008). Based on the nutritional composition, Pearl millet has the premier yield potential compared to other types of Millet (Havilah, 2017). According to FAO's estimations, the annual millet world production is about 89.17 million metric tons from 74 million hectares of land. Moreover, FAO reports display that India is the world's largest producer of pearl millet, with average productivity of 1237 kg/ha in the years 2021–2022 (Kargwal *et al.*, 2023). Pearl millet grains are a good source of vitamin B, vitamin A, folic acid, calcium, and magnesium, and they also provide important sources of iron, zinc, copper, manganese, potassium, and phosphorus (Kokila *et al.*, 2023). Moreover, due to the high-fat content (approximately 4.7%), pearl millet grain has a high energy content, approximately 1443 kJ/100 g. The major fatty acids are linoleic acid (43–45% of total contain) followed by Oleic acid (26–27% of total contain), while saturated fatty acids such as palmitic acid are about 20–21% of total content (Serna-Saldivar and Rooney, 1995). In addition, pearl millet grains are a good source of tocopherols, such as vitamin E. (Hadimani *et al.*, 2001). Over numerous generations, several landraces of Pearl millet were created as a consequence of natural selection and/or farmer selection, which can be caused either by weather and/or agricultural techniques (Harlan, 1975 & Yadav *et al.*, 2004). According to Kumar and Rao (1987), there are 10803 true landrace accessions, 6278 inbreds from breeding programs, and 633 weedy kinds.

Yemen is located in the tropical part of the world, which is distinguished from other tropical countries by its significant diversity in elevation, temperature, rainfall, and soil type. Its climate is generally tropical to subtropical, although there are areas with scarce to no rain and others with abundant quantities of rainfall therefore every variant of semi-humid, semi-arid, and arid tropical climate can be found in Yemen (Al-Hubaishi & Muller- Hohenstein, 1984 and Wood, 1997).

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is one of the important grain food and fodder crops in Yemen. About 17.6 percent of the total cultivated land in Yemen (1.4 million hectares) is millet fields, which are located mainly in low elevations, especially in coastal regions (General Administration of Statistics and Agricultural Information, 2022b & Reddy *et al.*, 2004). Based on the General Administration of Statistics and Agricultural Information (2022a), Al-Hodeidah governorate is the highest governorate in terms of millet grain production (52,991 t/ 55,721 ha), followed by Hajjah Governorate (11,225 t/ 17,322 ha), Amran Governorate (5,282 t/ 9,638ha) while Al-Mhrah Governorate produces the lowest amount of millet (14 t/ 23ha). On the other hand, there are around 20 landraces of pearl millet in Yemen that have been deposited in the National Center of Genetic Recourses (NCGR) and AREA, Dhamar, Yemen. These landraces were gathered from various regions (with various climatic and topographical properties) in Yemen (Alkadasy, 2019).

Al-Mawaset district is one of 23 districts in Taiz governorate; it lies 70km in the south part of Taiz governorate. It is located in the medium and high mountains region of the country and lies between the longitudinal range of 44°04'5.20" E- 44°05'45" E and a latitudinal range of 13°19'25"N -13°20'16 "N with an altitudinal range 1373m asl. - 1900m asl (Central Statistical Organization, 2012 & Al-Khulaidi, 2013) with a mean rainfall that ranges between 200-450mm per year (Environment Protection Authority, 2000 & Al-Khurasani, 2004).

On the other hand, in Taiz Governorate generally and Al-Mawaset district particularly, agriculture is one of the primary economic activities; farmers in Taiz governorate, including Al-Mawaset district, grow grains that are mostly drought-resistant, such as sorghum and pearl millet. Moreover, in 2021, Taiz governorate (including Al-Mawaset district) produced 26,888 t/ 28,513 ha of sorghum and 1,902 t/ 4,421 ha of pearl millet (General Administration of Statistics and Agricultural Information, 2022a &b).

Therefore, the purpose of this investigation was to carry out a comparison between several Yemeni pearl millet landraces in an attempt to select the landrace that produces the best high grain yielding and/or biomass (best fodder) for livestock that could be cultivated in the Al-Mawasit district.

2. Materials and methods

Plant materials:

Seeds of twenty Yemeni Pearl Millet (*Pennisetum glaucum* (L.) R.Br.) landraces were obtained from the National Center of Genetic Resources (NCGR), AREA, Dhamar, Yemen (Table 1) and cultivated in Al-Mawasit district under the rainfed condition to investigate their Morphological & Physiological parameters to select the landrace of optimal high grain yielding and/or biomass.

Field Description:

Pearl Millet landraces were grown during the rainy season (June -September of 2021) on a private farm in the Al-Mawasit district (13°19'20" N, 44°04'20" E and at Alt. 1720m asl.) to assess the morphological and physiological characters of landraces under investigation. Parameters recorded were Plant height, Leaf area, leaf number, Leaf area index, and inflorescence length as morphological characters, whereas Biomass, Grain Yield, and Seed weight as physiological characters.

Experimental Design:

Twenty landraces were grown in 20 plots (Table 1), each with one landrace planted in six rows (5m long) and of three replicates each (18 replicates of each landrace in a plot), with a spacing maintained of 15 cm between plants. The plots were separated by single rows without planting to avoid overlapping between the plots; moreover, to

Table. 1: Information on The Twenty Yemeni Pearl Millet Landraces obtained from the National Center of Genetic Resources (NCGR), AREA, Dhamar, Yemen.

Landrace No.	Collected Area			Plot No. (Field preparation)
	Locality	Altitude	Local Name	
25313	Taiz; Hamyli, Nugiba.	< 500m asl.	Dhokn	1
25339	IBB; Alqayda.	500-1000m asl	Dhokn	2
25342	Rayma; Blad Altaam, Bany Koly.	500-1000m asl	Dhokn	3
25347	Hadhramout; Aldeas, Alsharkeah market.	< 500m asl.	Mosible	4
25348	Shabwah; Azzan market.	500-1000m asl	Dhokn	5
25349	Al Hudaydah, Almansouri, Almibliah.	< 500m asl.	Khabty	6
25351	Al Hudaydah; Almansouri, Bait Albakare.	< 500m asl.	Garbashi	7
25353	Al Hudaydah; Alkahra Jabal Ras, Almorair	< 500m asl.	Baladi	8
25355	Hajah; Mustabah, Alzahar.	500-1000m asl.	Maheli	9
25357	Hajah; Almaghrabh, Bany Gadyalah, Bany Sadan.	500-1000m asl.	Maheli	10
25363	Al Mahweet; Al Khabt, Bany Amarah, Algarn.	>1000m asl.	Lammae	11
25366	Al Mahweet; Al Khabt, Gaba, Alrabat.	>1000m asl.	Baladi	12
25388	Al Mahweet; Hijrat Aldawaeer.	>1000m asl.	Dhokn	13
25389	Al Mahweet, Al Rujumm, Aljaradi, Hajar Almaayen.	>1000m asl.	Dhokn	14
25405	Lahj; Alkubaitah, Alyusfen, Aljawaraah.	< 500m asl.	Hendi	15
25420	Lahj; Almudarabeh, Aloliyah, Alhuthainah.	< 500m asl.	Aboshaar	16
25428	Al Hudaydah; Al Mansuriyah, Bait Albakari.	< 500m asl.	Dhokn	17
25506	Sana,a, Alhaymah, Alkharagya, Bany Manswr Almqabal.	>1000m asl.	Baladi	18
25508	Amran, Alswd, Alnasarh.	>1000m asl.	Baladi	19
25509	Amran, Alswd, Alnasarh.	>1000m asl.	Baladi	20

avoid border effects, 25 cm at each row end were marked and the central four rows were used for measurement (Yadav and Bhatnagar, 2001). Fertilizers were added, according to Yadav and Bhatnagar (2001), 40 kg/ha. Nitrogen was split into two doses; the first was added at planting time, while the second was added 40 days later.

Performance indicators:

Five morphological parameters; Plant height, leaf area, Leaf area index, number of leaves, and length of inflorescence were measured as follows:

Plant height of ten plants (randomly selected from each landrace) was measured using a measuring tape from the base to the terminal leaf (Legwaila *et al.,* 2014). The number of leaves was determined quantitatively in ten plants (randomly selected from each landrace) by counting immediately after true leaves had fully grown or expanded. (Legwaila *et al.,* 2014). Leaf area in cm^2 was determined by using the formula, LA = K (LB), where LA = leaves area (cm^2), L = leaves length (cm), B = maximum leaf width (cm), and K =0.75 (Rad Ford, 1967). The leaf area index was calculated by using the formula mentioned by Franklin et al. (1985), LAI = 1/2 (LA1 + LA2) × 1/GA where, LA1 = leaves area (m^2) at the date of the first sample (T1), LA^2 = leaves area (cm^2) at the date of the second sample (T2) whereas, GA = ground area (cm^2). Inflorescence length of ten plants (randomly selected from each landrace) was measured using a measuring tape from the base of the inflorescence to its tip (Neethu *et al.,* 2019).

In addition, three Physiological parameters were observed and recorded according to Franklin et al. (1985) as follows:

Biomass (t/ha): Estimated at the maturity stage as the average of 10 plants harvested from the soil surface, weighed, and then calculated. Grain Yield (t/ha): Estimated from the central rows, 10 ears were harvested, threshed, weighed, and then calculated.1000 kernel weight (g): Estimated as the average weight of 1000 kernel, taken randomly from each landrace.

Statistical Analysis:

The collected data were statistically analyzed using PC-ORD Windows version 7.09 (Two Way Cluster Analysis (TWCA)) using the Least Significant Difference (LSD) at P- value = 0.05 to compare the significant differences among means (Murshed, 2023).

3. Results and discussion

Based on Table 2 and Figure 1(A) &4, landrace 25313 produced the largest leaf area (mean leaf area of 156.9 cm2) among the investigated landraces, followed by landraces 25428, 25353, 25405, 25366, 25355, 25342, 25363, 25347, 25339, 25420, 25348, 25351, 25508, 25506, 25357, 25349, 25388, 25509, and 25389 with mean leaf areas of 146.7, 132.6, 125.9, 125.5, 123.7, 117.1, 116.8, 116.4, 114.7, 114.6, 113.1, 112.8, 107.9, 99, 97.2, 96.2, 91.5, 79.2, and 69.31 cm2 respectively. Moreover; landrace, 25313 has the highest leaf area index (mean leaf area index of 77.2), followed by landraces 25351, 25355, 25506, 25508, 25349, 25347, 25363, 25428, 25357, 25366, 25405, 25339, 25348, 25353, 25420, 25342, 25389,25388, and 25509 with mean leaf area index of 69.1, 67.2,62.2, 61.3, 58.9, 57.3, 57,56.3, 56.3, 56.2, 54.7, 53.8, 53.6, 53.3, 51.3, 51.1, 49.1, 46.6, and 37.5 accordingly (Table 2 and Figure 1(B) &4). However; landrace 25349 carries the largest number of leaves (mean leaf number of 9.37) out of all studied landraces (Table 2 and Figure 1 (C) & 4), while landraces 25508, 25347, 25355, 25428, 25313, 25339, 25353, 25351, 25509, 25342, 25388, 25405, 25363, 25389, 25420, 25348, 25366, 25506 and 25357 produced lesser leaves, with mean leaf numbers; 9, 8.93, 8.9, 8.87, 8.87, 8.83, 8.76, 8.5, 8.4, 8.38, 8.37, 8.37, 8.23, 8.18, 8.09, 8.06, 8, 7.97 and 7.8, correspondingly. Furthermore; landrace 25508 recorded the longest inflorescence compared to all examined landraces (mean length 18.8 cm), while landraces; 25313, 25363, 25355, 25339, 25388, 25348, 25428, 25357, 25420, 25353, 25347, 25389, 25366, 25349, 25506, 25351, 25509, 25342, and 25405, attained a mean inflorescence length of, 18.5, 18.5, 17.4, 17.1, 17, 16.9, 16.8, 16.7, 16.2, 16, 15.7, 15.6, 15.5, 15.4, 15.4,15.3, 15.2, 14.4, and 13.9 cm sequentially (Table 2 and Figure 2(A) &4). On the other hand, landrace 25347 gave the longest plant length of 187.6 cm mean value) among the studied landraces (Table 2 and Figure 2 (B) & 4), while landraces 25349, 25508, 25388, 25342, 25339, 25355, 25428, 25313, 25366, 25363, 25353, 25357, 25506, 25351, 25420, 25405, 25389, 25509, and 25348 presented a mean total length of; 185.7, 179.7, 178.2, 177.7, 176.8, 175.8, 173.3, 172.9, 172.2, 169.8, 169.1, 162.8, 162.1, 160.7, 160.5, 153.5, 152.9, 150.8, and 150.4 cm consecutively.

According to Table 2 and Figure 2(C) &4, landrace 25366 and landrace 25353 showed the highest biomass production (mean biomass production of 6.7t/ha) competing with the other landraces under investigation, while landraces; 25313, 25405, 25351, 25506, 25348, 25349, 25355, 25508, 25342, 25363, 25428, 25420, 25347, 25339, 25388, 25357, 25509, 25389, produced a lower biomass (5.4, 4.8, 4.6, 4.5, 4.3, 4.3, 4.1, 3.9, 3.9, 3.9, 3.7, 3.3, 3.2, 3.1, 2.9, 2.9, 2.6, 2.4 t/ha, sequentially). Moreover; landrace 25508 recorded the highest mean grain yield of 3.1 t/ha) among the investigated landraces (Table 2 and Figure 3(A) &4), followed by landraces 25428, 25363, 25366, 25342, 25351, 25388, 25357, 25353, 25313, 25355, 25506, 25405, 25349, 25389, 25420, 25347, 25348, 25509, and, 25339, with a mean grain yield of 3, 2.7, 2.7, 2.6, 2.4, 2.3, 2.3, 2, 1.9, 1.8, 1.8, 1.8, 1.7, 1.6, 1.6, 1.6, 1.5, 1.4, and 1.2 t/ha, respectively. On the other hand, landrace 25348 recorded the highest 1000 seed weight means 0f of 9.8g compared to all examined landraces (Table 2 and Figure 3(B) &4), while landraces; 25347, 25357, 25508, 25389, 25313, 25353, 25405, 25428, 25420, 25363, 25349, 25388, 25339, 25355, 25509, 25342, 25506, 25366, and 25351 obtained a mean seed weight of, 9.7, 9.6, 9.4, 9.4, 9.1, 9.1, 8.9, 8.9, 8.9, 8.9, 8.8, 8.8, 8.8, 8.7, 8.6, 8.5, 8.2, 8.2, and 7.7g, correspondingly.

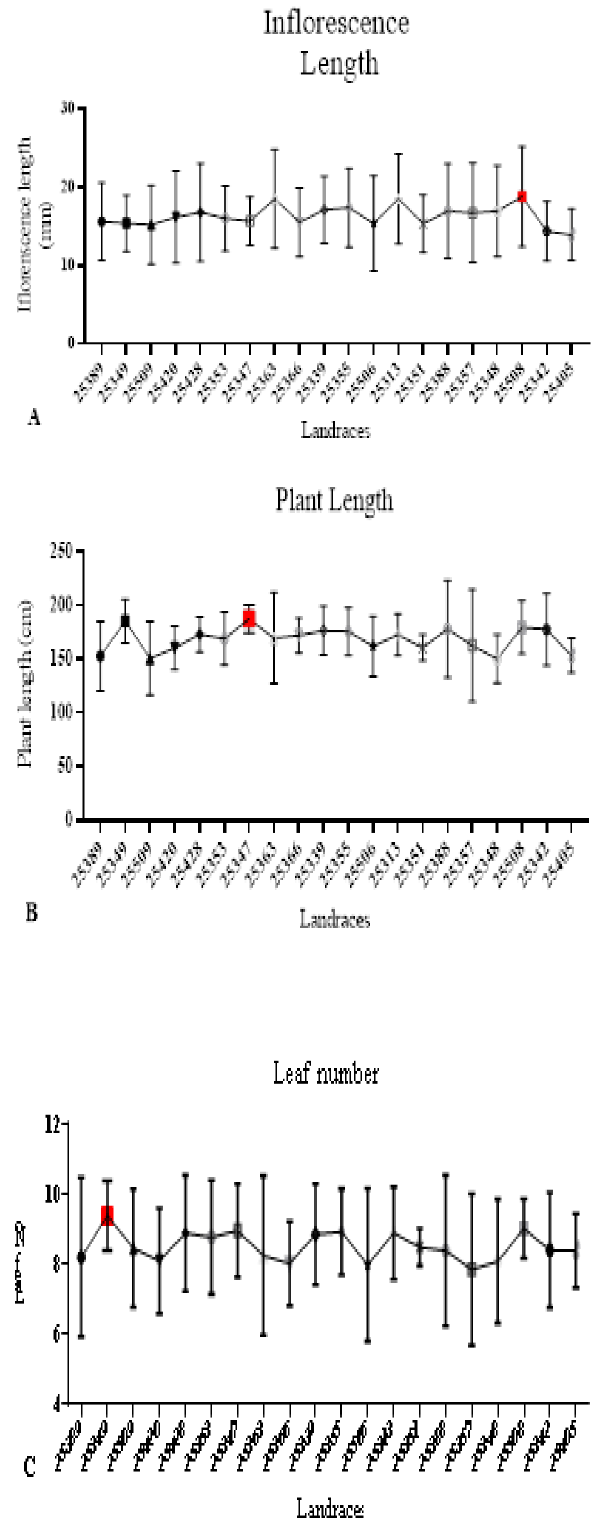


Figure. 1: Growth and Development parameters of the20invistigated landraces: A. Leaf Area; B. Leaf Arae Index; C. Leaf Number

Table 2: Growth and Development Parameters (means) of 20 Landraces of Millet (*Pennisetum glaucum*) Cultivated in 6 Plots.

Landraces		Characters							
No.	**Landraces**	**leaf area (cm^2)**	**leaf area index**	**leaf number**	**Inflorescence length (cm)**	**Plant length (cm)**	**Biomass (t/ha)**	**Grain Yield (t/ha)**	**1000 Seed weight (g)**
1	25389	24.8 (69.3 ± 27.3) 101.3	39.7 (49.1 ± 9) 61.1	5 (8.18± 2.3) 11	7 (15.6 ± 5) 22	125 (152.9± 32.5) 206	2.1(2.4±0.6) 3.6	0.89 (1.6±0.7) 2.5	5.3(9.4±3.8)13.9
2	25349	54.2 (96.2 ±47.9) 183	48.8(58.9±12.1)78.8	8 (9.37±1)11	9 (15.4±3.6)22	163.7(185.7±20.3) 220	2.5(4.3±1) 5.5	0.9 (1.7±0.7) 2.8	4.6 (8.8±3.6) 13.9
3	25509	26.2 (79.2±39.1) 124.8	19.7(37.5±15.7)55.1	7 (8.4±1.7) 11	7(15.2±5) 22	88 (150.8±34.2) 189.7	1.5 (2.6±0.6) 3.2	1.1(1.4±0.4) 2.1	5(8.6±3.7) 13.5
4	25420	46.3 (114.6±47.5) 193.2	45.9(51.3±5.4) 60	6 (8.09±1.5)10	7 (16.2±5.9) 22	132(160.5±20.4) 186	1.9(3.3±0.8)3.8 7	0.8 (1.6±0.8) 2.7	5.7 (8.9±3.1) 12.4
5	25428	71.5(146.7±49.9) 198.9	44.9(56.3±9.1)70.2	7 (8.87±1.7) 11	10 (16.8±6.3) 28	155.3(173.3±16.3) 200.7	2.8(3.7±0.9) 5.1	1.8(3±1.2) 4.6	5.2 (8.9±3.6) 13
6	25353	53.6(132.6 ±72.3) 253.8	44.1(53.3±9.4) 67.9	7 (8.76±1.6)12	8(16±4.1)19.7	140 (169.1±24.7)213	4.1(6.7±1.6) 9.6	0.9(2±0.7) 2.5	5.3(9.1±3.4) 13.1
7	25347	46.6 (116.4±50.4)168.2	49.1(57.3±9.7)76.1	7 (8.93±1.3)11	10 (15.7±3.1) 18	170.3(187.6±13)204	2.7(3.2±0.3) 3.6	1.2(1.6±0.3) 2	5.1(9.7±4.7)16.1
8	25363	53.6(116.8±47.6) 162	42.1(57±14.7) 80.3	4 (8.23±2.3)11	8(18.5±6.3) 25.7	118(169.8±42.5) 226.7	2.9(3.9±0.7) 4.6	1.1(2.7±1.5) 5	6(±2.9) 12.3
9	25366	53.1(125.5±65.7) 240.9	50.9(56.2±6.9) 69.4	6 (8±1.2) 9	7(15.5±4.4) 19	152(172.2±16.2) 193.7	2.5(6.7±2.8) 9.6	1.4(2.7±0.8) 3.3	5.5(8.2±2.7) 11.4
10	25339	64(114.7±37.6) 158.4	47.7(53.8±6.3) 62.2	6 (8.83±1.4)10	9(17.1±4.3) 21	149(176.8±22.6) 207.7	1.7(3.1±2)7.1	0.5(1.2±0.4)1.5	5.6(8.8±3.1)12.3
11	25355	79.2(123.7±34.7) 164	49.8(67.2±15.7)95.1	7(8.9±1.2)11	9(17.4±5) 24	151.7(175.8±22.1) 206.7	3.6(4.1±0.4) 4.8	1 (1.8±0.5) 2.5	4.6(8.7±3.1)13.1
12	25506	64.7(99±28.7) 147.1	50.4(62.2±13.2) 78	5 (7.97±2.2) 10	5(15.4±6.1) 23	128(162.1±28.3) 194.7	3.1(4.5±0.8) 5.2	1.2(1.8±0.5) 2.5	5 (8.2±2.8) 11.4
13	25313	91.65(156.9±59.8)247.8	42.5(77.2±26.9)108.2	7 (8.87±1.3) 10	8(18.5±5.8) 24	152.7(172.9±19.7) 200.3	4.9(5.4±0.6) 6.4	1.1(1.9±0.5) 2.3	4.9(9.1±4) 15.3
14	25351	70.2(112.8±37.3) 163.7	53.3(69.1±20) 106.8	8 (8.5±0.5) 9	8(15.3±3.7) 17.3	147.7(160.7±12.1) 183	3.2(4.6±1.1) 5.9	1.3(2.4±0.8) 3.1	5.6(7.7±2.3) 11.6
15	25388	23.3(91.5±58.3)182.3	28.3(46.6±20.3)75.3	5 (8.37±2.2)11	7(17±6)23	119(178.2±45.3)228.3	2.4(2.9±0.4)3.4 7	0.9(2.3±1.2)3.4	4.7(8.8±3.4)12.6
16	25357	23.8(97.2±63.8)176.3	42.6(56.3±12.5)74.9	5 (7.8±2.2)11	6(16.7±6.4)23	117(162.8±52.2)231	2.1(2.9±0.6)3.3	1.2(2.3±0.8)2.9	6(9.6±3.7)14.1
17	25348	33(113.1±49.8) 170.4	46.9(53.6±6.3) 61.3	6 (8.06±1.8) 10	6(16.9±5.8)23	124(150.4±22.6) 183	2.9(4.3±1.2) 6.4	0.7(1.5±0.7) 2.1	5.4(9.8±4.2) 16.2
18	25508	39.5(107.9±59.1) 180.9	47.3(61.3±11.9) 80.9	7 (9±0.9) 9	9(18.8±6.4) 29	154(179.7±24.8) 221	3.5(3.9±1) 5.9	1.9(3.1±0.9) 4	5.2(9.4±3.8) 14.1
19	25342	54.4(117.1±45) 190.4	44.9(51.1±8.5) 67	6 (8.38±1.6)11	8(14.4±3.8)19	145(177.7±33.4) 230	2.9(3.9±0.7) 4.7	1.9(2.6±0.5) 3.2	5.2(8.5±3.1) 11.5
20	25405	51.6(125.9±39)164.7	50.5(54.7±6.1) 66.8	7 (8.37±1.1)10	8(13.9±3.3) 18	140(153.5±16) 183	3.5(4.8±2.3) 9.3	1.1(1.8±0.5) 2.3	4.3(8.9±3.8) 13

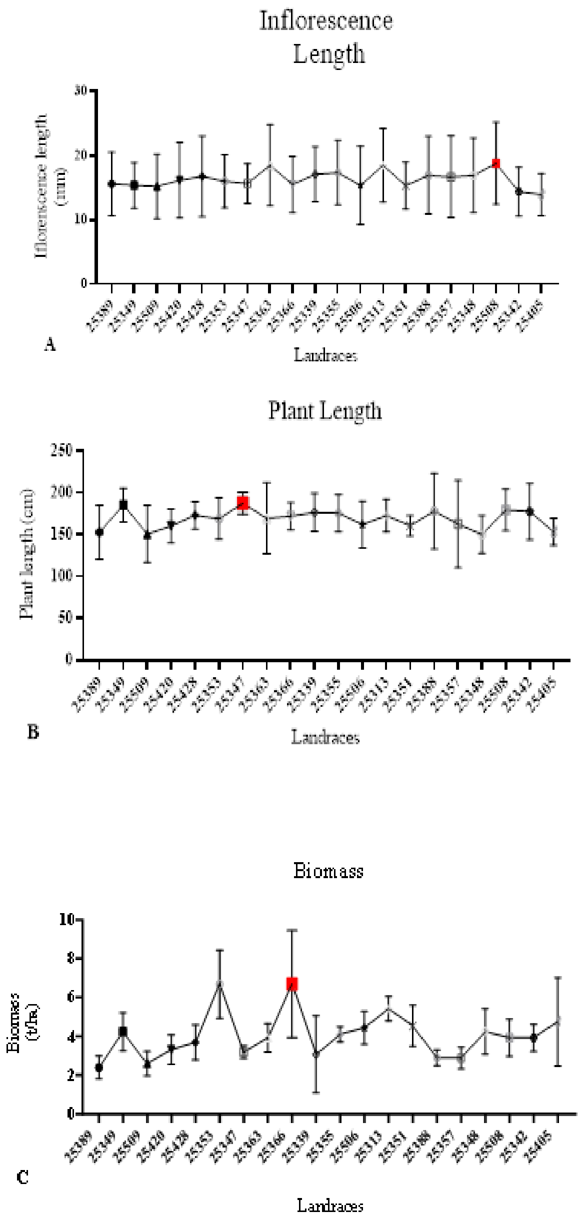


Figure. 2: Growth and Development parameters of the 20 investigated landraces: A. Inflorescence Length; B. Plant Length; C. Biomass

Based on the means of 8 monitored growth and developed parameters (leaf area, leaf area index, leaf number, inflorescence length, plant length, biomass production, grain yield, and seed weights), the 20 millet landraces under investigation (Table1 &2) were divided into two main groups (I &II) at a distance level 88.38 (Figure. 4). Group, I included two landraces; 25389 and 25509 separated at a distance level of 95.85 while; Group II included the remaining 18 landraces. Moreover, Group, II is divided into two subgroups; Subgroup A (including one landrace; 25313) and Subgroup B contains the remaining 17 landraces at a distance level of 90.79 (Figure 4). Furthermore, Subgroup B is divided into two main clusters (i & ii) at a distance level of 93.43, cluster i comprises two landraces; 25388 and 25349 separated at a distance level of 96.08; while cluster ii comprises two clusters (1 &2) separated at a distance level of 94.39 (Figure 4). Cluster 1 contains 6 landraces (25506, 25357, 25351, 25405, 25420, and 25348) while Cluster 2 contains 9 landraces (25428, 25366, 25353, 25355, 25508, 25347, 25363, 25342, and 25339). From the current results, two landraces, 25366 and 25353, displayed the highest biomass production (6.7t/ha). This is possible because of the high rainfall amount, which has a positive correlation with biomass production (Traore *et al.*, 2022).

Considering that those two landraces were collected from two different locations: Al Khabt (Al-Mahweet) and Al-Hudaydah, respectively, in which the two landraces were adapted to the climatic element of their locations, especially rainfall (mean rainfall per year was 50-100mm), while the mean rainfall in Al-Mawaset is 200-450mm per year (Environment Protection Authority, 2000 & Al-Khurasani, 2004).

Moreover, landrace 25313 produced the largest leaf area (156.9cm2), longest inflorescence (18.5cm), and high biomass production (5.4 t/ha when compared with other landraces under investigation, although its grain yield is low (1.9 t/ha) This may be due to the high rainfall amount which has a positive impact on biomass production (Traore *et al.*, 2022) and a negative correlation with grain yielding (Ojo *et al.*, 2020). After all, this landrace is adapted to low altitude regions (< 500) climatic elements, especially rainfall; where precipitation is low (mean rainfall per year is 50-100mm per year) in comparison with the mean rainfall in Al-Mawaset; 200-450mm per year (Environment Protection Authority, 2000 & Al-Khurasani,2004).

Furthermore, landrace, 25508 gave the highest grain yield (3.1 t/ha) out of all studied landraces. This landrace collected from Alswd – Amran governorate (with a rainfall amount of 200-450mm per year) is adapted to the climatic elements, especially rainfall, which is the same amount of precipitation in Al-Mawaset; 200-450 mm per year (Environment Protection Authority, 2000 & Al-Khurasani, 2004).

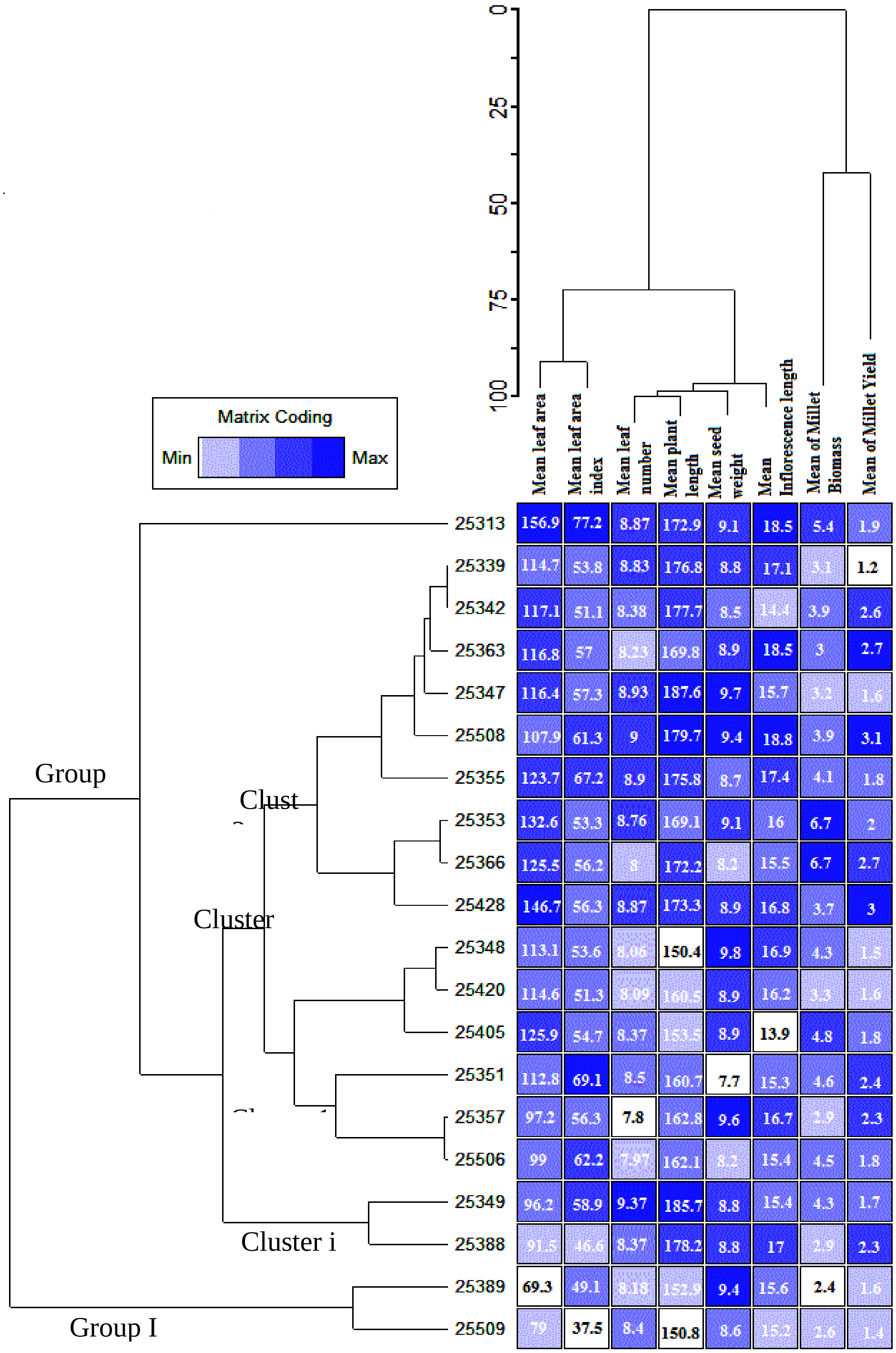
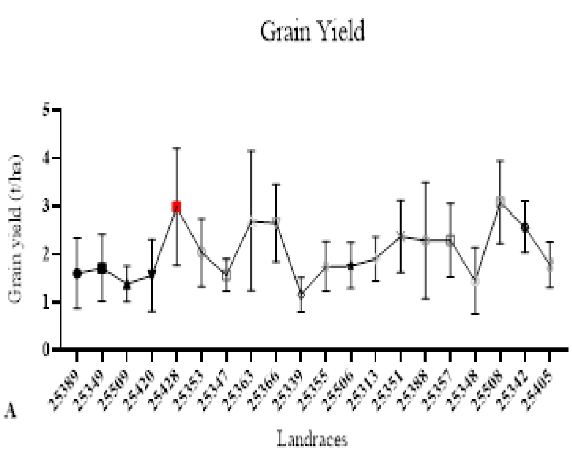


Figure. 3: Cluster analysis illustrates the relationship among the 20 Millet (*Pennisetum glaucum*) Cultivated in Al-Mawaset, Taiz governorate based on 8 Growth and Development Parameters by using the Two-Way Cluster Analysis (TWCA) - Group average linkage method.

Based on Two-way cluster analysis (TWCA) in Figure 4, the studied landraces were divided into two main groups (I &II) at a distance level of 88.38. Group I included two landraces, 25389 and 25509, which are separated from the other landraces by having 3 low and close values of growth and development parameters; plant length (152.9 &150.8cm), biomass (2.4 & 2.6 t/ha) and grain yield (1.6&1.4 t/ha); Moreover Group II is subdivided into two subgroups (A&B) Subgroup A includes one landrace, 25313, which is distinguished from the other remaining landraces by having the largest value of two growth and development parameters; leaf area (156.9 cm2) & leaf area index (77.2), and a high value of two other growth and development parameters; length of inflorescence (18.5cm) and biomass (5.4t/ha) Furthermore; subgroup B is subdivided into two clusters; Cluster i, comprises two landraces; 25388 and 25349 which are differentiated from the other landraces in Cluster ii by having the same value of seed weight (8.8g) and the lowest leaf area value (91.5 & 96.2 cm2). On the other hand, Cluster ii is subdivided into two clusters (1&2) based on Plant length; Cluster 1 includes 6 landraces (25506, 25357, 25351, 25405, 25420, and 25348) which have length ranges between 150.4 to 162.8 cm while Cluster 2 includes 9 landraces (25428, 25366, 25353, 25355, 25508, 25347, 25363, 25342, and 25339) which are characterized by having a length ranging between 169.1 to 187.6 cm.



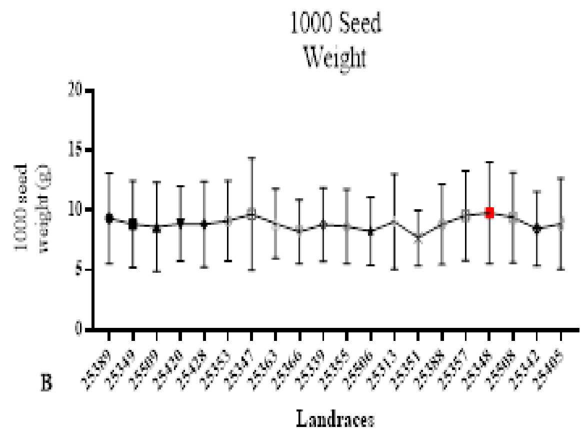


Figure. 4: Growth and Development Parameters of the20 investigated landraces: A.Grain Yield; B. 1000 Seed Weight

4. Conclusion

Rainfall is a limiting factor for the cultivation of many crops, including Pearl Millet in Yemen. Yield of landrace 25508 in this study was found to be greater (mean grain yield of, 3.1t/ha) than others, moreover, landrace 25366 and landrace 25353 were found to give the greatest biomass (mean biomass production of 6.7t/ha). On other hand, this study serves farmers as a reference when it comes to cultivating Millet. Similar work on other landraces can give the farmer a head start to decide what landrace/s corresponds to biotic and abiotic conditions available. Trial and tribulation are needed to improve yield (food) and biomass (fodder & forage) outcomes for the present and future as well.

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