AGRONOMY AND HORTICULTURE MARKET DEVELOPMENT DIVISION

RESEARCH AND POLICY DEVELOPMENT SUBDIVISION

NAB - UNAM SEED RESEARCH PROJECT

PEARL MILLET SEED VARIETY TRIALS – 2021/2022

September 2022 **Windhoek, Namibia**

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1. INTRODUCTION

The Namibian Agronomic Board (NAB) is mandated to promote the agronomic industry and facilitate the production, processing, storage, and marketing of controlled crops. The NAB's Strategic Plan for 2019-2024 emphasises that seed research and production is one of the key priority areas. White maize and pearl millet are the top most important cereal crops cultivated in Namibia, whose yields are partially hampered by the limited availability of high-yielding adapted varieties.

The certified seed sector in Namibia is underdeveloped, thus resulting in dependence on seed and food imports. Therefore, to widen the range of and access to seed of locally adapted high-yielding crop varieties, the Namibian Agronomic Board (NAB) and the University of Namibia (UNAM) jointly undertook a Crop Improvement Programme for White Maize and Pearl Millet, through a Memorandum of Understanding (MOU). First-season field trials of early and intermediate maturing varieties of white maize and pearl millet varieties took place in the 2020/2021 cropping season. The University of Namibia (UNAM) and the Namibian Agronomic Board (NAB) are currently conducting collaborative research to identify high-yielding pearl millet varieties that can be multiplied and released to farmers.

Ten pearl millet varieties from ICRISAT were selected based on their high performance in Namibia during the first cropping season (January to June 2021). Pure seeds of the 10 varieties were obtained from ICRISAT Nairobi and together with two (3) local varieties, planted in February 2022 in 5 researcher-managed sites in the Northern Central Regions, Karst, the Kavango, and the Zambezi regions.

1.1. DESCRIPTION OF PEARL MILLET NEW VARIETIES

Pearl millet trials consisted of 24 varieties acquired from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and there were some local checks (Kangara, Kantana, and Okashana No. 2). ICRISAT is a pioneering, international non-profit-scientific-research-for-development (R&D) organisation, specialising in improving dryland farming and agri-food systems. The International Crop Research in Semi-arid Tropics (ICRISAT) has stepped up efforts towards germplasm improvement, agronomic management, markets, and institutions to advance the case of millets and other similar crops like sorghum in the dryland tropics of Africa (ICRISAT 2015).

ICRISAT is active in 55 countries in the semi-arid or dryland tropics. Its gene banks safeguard the biodiversity of sorghum, pearl millet, and six other types of small millets, chickpea, pigeon pea, and groundnut. UNAM/NAB Project is one of the collaborative testing networks for ICRISAT, and upon confirmation of highly performing varieties in Namibia, the project shall apply for Intellectual Property Rights (IPR) for commercialisation of germplasm. This report covers the performance of pearl millet varieties in a second cropping trial conducted in 2021/2022.

1.2. OBJECTIVES

1. To evaluate pearl millet for high yields and adaptation in four agroecological zones in Namibia, and select the best performers under Namibia conditions. (A current activity)
2. To multiply and certify seeds of high-yielding and adapted varieties of pearl millet for use by Namibian farmers. (A future activity)

2. MATERIALS AND METHODS

2.1. Experiment Description

The trial was laid out as a balanced incomplete block alpha design and treatments were randomly assigned to incomplete blocks. The field was divided into two (2) replications, except in Mashare and Zambezi VTC where the treatments were repeated four times. Each replication had 12 plots of 31.5 m^2 (5.25 × 6 m^2) each, with 1m paths between plots and 2 m paths between incomplete blocks.

In sites where irrigation was supplemented like Mashare Irrigation PTY, irrigation was done after planting but this was suspended when there was a good rainfall event. No irrigation was done under farm field conditions (rainfed). However, the dates of planting were different for every experimental site (Table 1).

Table 1: Planting layout for pearl millet

6 m + 1m + 6m + 2 m + 6 m + 1m + 6 m = 28m

5.25 m + 1m + 5.25m + 1m + 5.25 m + 1m + 5.25 + 1 m + 5.25m + 1m + 5.25m = 36.5m

REPLICATION 1

7 rows running down. REP 1 VAR 3 Plot 1	1m path	Each row is 6 m long REP 1 VAR 8 Plot 2	1 m path	REP 1 VAR 1 Plot 3	.1 m path	REP 1 VAR 4 Plot 4	1 m path	REP 1 VAR 11 Plot 5	1 m path	REP 1 VAR 2 Plot 6
1 m path										
REP 2 VAR 6 Plot 7		REP 1 VAR 12 Plot 8		REP 1 VAR 5 Plot 9		REP 1 VAR 9 Plot 10		REP 1 VAR 7 Plot 11		REP 1 VAR 10 Plot 12
2 m path PEPLICATION 2										
REP 2 VAR 9 Plot 13		REP 2 VAR 1 Plot 14		REP 2 VAR 4 Plot 15		REP 2 VAR 7 Plot 16		REP 2 VAR 2 Plot 17		REP 2 VAR 5 Plot 18
2 m path										
REP 2 VAR 3 Plot 19		REP 2 VAR 12 Plot 20		REP 2 VAR 8 Plot 21		REP 2 VAR 10 Plot 22		REP 2 VAR 6 Plot 23		REP 2 VAR 11 Plot 24

Guard rows (8 rows planted around spaced at 75 cm between rows = 6m)

- 12 varieties x 2 replications per site = 24 plots
- Plot size 5.25m wide x 6 m long = 31.5 m^2
- Spacing = 75cm X 20cm (3 seeds per hill, then thin to 1 seed/hill 20 days after sowing)
- 7 rows of 6m long each
- Guard rows = 4 rows all round of 6m wide Experimental area = 36.5m x 28m excluding guard rows = 1022m^2
- Amount of seed per plot = 18.5g (equivalent to 5 Kg/ha)
- The fertilizer applied was Compound Fertilizer 2:3:2 at a rate of 150 Kg/ha
- Data collection and harvesting area = 5 inner rows (leaving out 5 rows on each side) of 5 m each (leaving out 0.5m from each end)

Research sites: Mashare, Ogongo, Dorringboom, Zambezi VTC, and Rupara ADC (5 sites)

VARIETY NAMES: *ICMP 177003, IP 15700, 41518/16, SOSAT C88, IP 18948, IP 16754, CMV 88908, MS 2, IP 17645, MS 11, Okashana 2, Kangara*

Table 2: Experimental sites and their respective planting date

Site	Production zone	Planting Date	Management
1. **Rupara ADC *(17º 50' 16.5 'S, 19º 03' 14.3 "E)***	Kavango	9th February 2022	Rainfed
2. **Mashare Irrigation PTY *(17.90016ºS, 20.13911 ºE)***	Kavango	10th February 2022	Rainfed with supplemental irrigation after planting
3. **Dorringboom UNAM Farm, in Otjiwarongo district, Otjozondjupa Region *(20º 52' 23" S; 17º 07' 47 "E)***	Karst	10th February 2022	Rainfed with supplemental irrigation after planting
4. **Ogongo UNAM campus *(17.682285ºS, 15.301401 ºE)***	North Central	14th February 2022	Rainfed with supplemental irrigation
5. **Zambezi VTC *(17.51149 ºS, 24.26327 ºE)***	Zambezi	17th February 2022	Rainfed

3. RESULTS AND DISCUSSION

3.1. Days to 50% flowering

3.1.1 Site-specific analysis on the number of days to 50% flowering of pearl millet varieties

Days to 50% flowering is the number of days taken from the date of sowing to when 50% of the florets have pollen visibly sticking out. Early maturing varieties take relatively a smaller number of days from planting to flowering/pollen shading. Early maturity is genetically controlled and influenced by the prevailing temperature. Early-maturing varieties tend to form seeds early and avoid late-season drought, therefore obtaining higher yields in drought-prone areas than late-maturing varieties.

Varieties planted at the Ogongo campus attained early maturity as depicted by the number of days to 50% flowering/pollen shading (53 days). This was followed by Mashare (58 days) and Dorringboom (61 days) (Table 3). Each of the sites differed statistically from the others ($P<0.05$). The results agree with the observation that Ogongo is hotter than Mashare and Dorringboom in that order, hence maturity periods increase in that order.

Furthermore, Kangara, SOSAT C88, and ICMP 177003 are the earliest maturing varieties in all the three sites (Table 3). Variety IP 15700 was common among the late-flowering Pearl millet varieties in all the 3 sites. Note: Data on 50% flowering for Rupara and Zambezi was left out of the analysis because the figures were unrealistic.

Table 3: Number of days to 50% flowering of pearl millet varieties in Ogongo, Mashare, and Dorringboom

OGONGO			**MASHARE**			**DORINGBOOM**			**3 SITE AVERAGE**	
KANGARA	39		KANGARA	54		KANGARA	51		KANGARA	49
OKASHANA 2	42		ICMP 177003	55		OKASHANA 2	53		OKASHANA 2	52
SOSAT C88	50		SOSAT C88	55		ICMP 177003	58		ICMP 177003	54
ICMP 177003	50		MS 2	55		SOSAT C88	60		SOSAT C88	55
ICMV 88908	54		OKASHANA 2	56		ICMV 88908	60		ICMV 88908	57
IP 17645	56		IP 17645	56		IP 17645	60		KANTANA	57
IP 18948	57		ICMV 88908	57		MS 11	61		IP 17645	57
IP 16754	57		KANTANA	57		IP 18948	62		IP 18948	58
MS 2	57		MS 11	57		41518/K16	63		MS 11	58
41518/K16	57		IP 18948	58		MS 2	64		MS 2	59
IP 15700	58		IP 15700	59		IP 16754	68		IP 16754	61
MS 11	58		IP 16754	61		IP 15700	73		IP 15700	61
			41518/K16	70					41518/K16	65
Site average	**53**		**Site average**	**58**		**Site Average**	**61**		**3-site average**	**57**

Key: Similarly coloured cells represent the same variety giving similar performance across the sites

3.1.2 All-site analysis of 50% flowering of pearl millet varieties

Overall, the local varieties, Kangara and Okashana mature earliest alongside the new varieties SOSAT C88 and ICMP 177003. Figure 1 depicts the average number of days from sowing to 50% flowering of different pearl millet varieties.

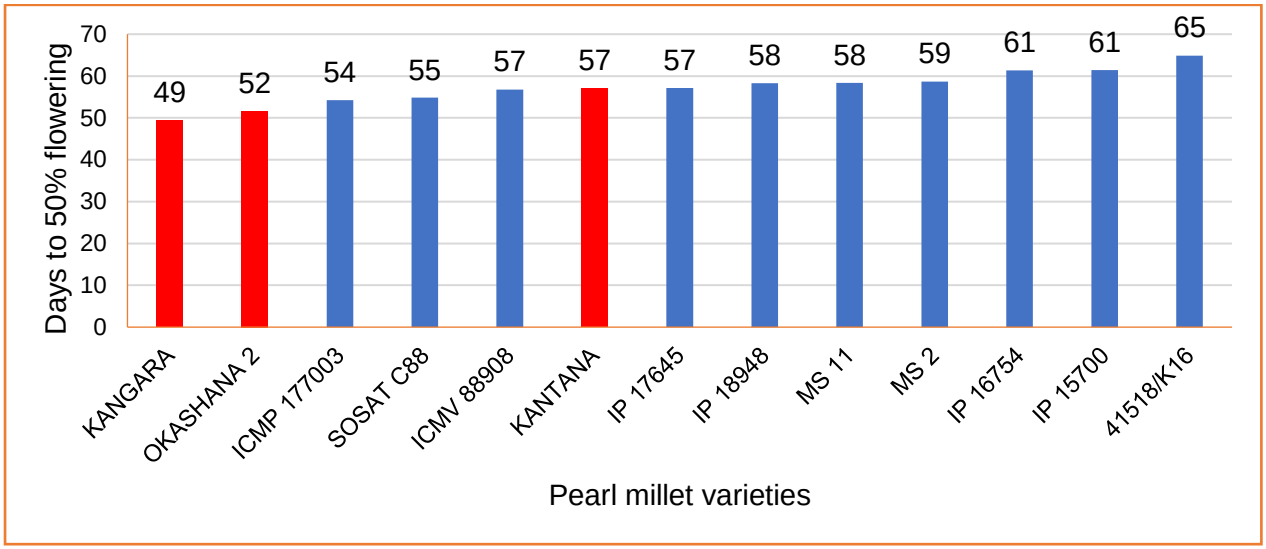

Figure 1: Average number of days to 50% flowering of pearl millet varieties in three sites

3.2. Plant Height

3.2.1 Site-specific analysis on Plant height of Pearl millet varieties

Ogongo produced on average significantly shorter pearl millet varieties (1.7 m) compared to Mashare (2.0m) and Dorringboom (2.1m) (Table 4; Figure 2). The variety, 41518/K16 is the shortest in every site. ICMP 177003 and Okashana 2 are also among the shortest varieties across all sites.

Table 4: Plant height (m) of pearl millet varieties in different geographical sites in Namibia

OGONGO			DORINGBOOM			MASHARE			Average	
41518/K16	1.46		41518/K16	1.50		41518/K16	1.34		41518/K16	1.41
ICMP 177003	1.53		KANGARA	1.98		ICMP 177003	1.74		ICMP 177003	1.76
OKASHANA 2	1.62		OKASHANA 2	2.00		IP 17645	1.88		OKASHANA 2	1.85
KANGARA	1.63		ICMP 177003	2.04		OKASHANA 2	1.89		MS 11	1.92
SOSAT C88	1.66		ICMV 88908	2.10		MS 11	1.91		KANGARA	1.92
IP 18948	1.72		IP 18948	2.13		ICMV 88908	1.94		ICMV 88908	1.96
MS 11	1.72		MS 11	2.14		IP 15700	1.98		IP 17645	1.97
MS 2	1.75		SOSAT C88	2.19		KANGARA	2.04		IP 15700	2.00
IP 17645	1.81		IP 16754	2.21		SOSAT C88	2.18		SOSAT C88	2.01
IP 15700	1.83		IP 17645	2.24		IP 18948	2.18		IP 18948	2.05
ICMV 88908	1.87		MS 2	2.26		MS 2	2.34		MS 2	2.12
IP 16754	2.02		IP 15700	2.29		IP 16754	2.52		IP 16754	2.32
						KANTANA	2.61		KANTANA	2.61
Average	**1.72**		**Average**	**2.09**		**Average**	**2.02**		**Average**	**1.96**

Key: Similar coloured cells represent the same variety giving similar performance across the sites

3.2.2 All sites analysis on plant height of pearl millet varieties

Figure 3 shows the all-sites average plant height of each variety at maturity expressed in meters(m) across research sites. Katana, the local variety, was the tallest variety.

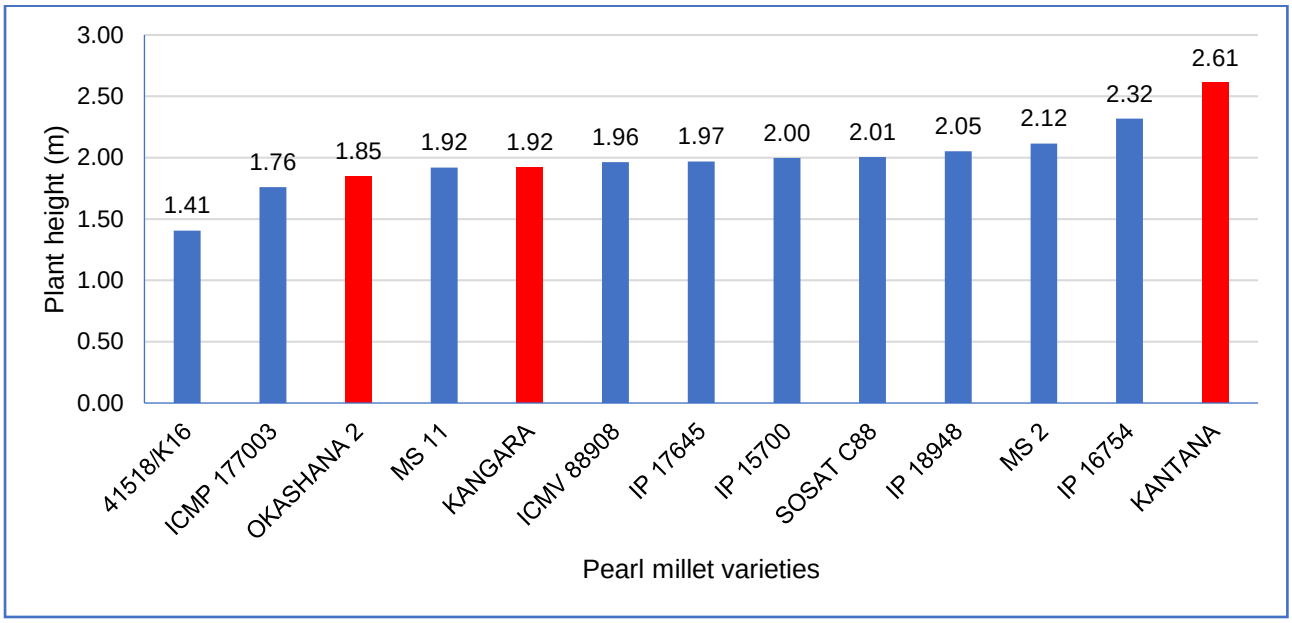

Figure 2: Average plant height (cm) of peal millet varieties in 3 sites; Ogongo, Dorringboom, Mashare

3.3. Dry matter biomass

3.3.1 Site-specific analysis on dry biomass of pearl millet varieties

Mashare produced the highest dry biomass (6.2 t/ha) followed by Dorringboom (4.4 t/ha) and then Ogongo (1.3 t/ha). ICMP 177003 and 41518/K16 produced the least amount of straw as measured by the dry matter weight of above-ground biomass. Table 5 below shows the dry matter weight of each variety at harvesting expressed in tons per ha across each research trial site.

Table 5: Average dry matter biomass (t/ha) of pearl millet varieties

OGONGO		DORINGBOOM		MASHARE		Average of 3 sites	
ICMP 177003	0.34	41518/K16	1.60	41518/K16	2.25	41518/K16	1.62
41518/K16	0.39	ICMP 177003	3.00	ICMP 177003	4.83	ICMP 177003	3.25
KANGARA	0.93	MS 11	3.70	MS 11	5.00	SOSAT C88	3.69
SOSAT C88	0.97	KANGARA	3.95	OKASHANA 2	5.33	MS 11	4.02
MS 2	1.14	SOSAT C88	4.10	IP 18948	5.75	MS 2	4.15
IP 18948	1.27	OKASHANA 2	4.45	SOSAT C88	6.00	OKASHANA 2	4.16
ICMV 88908	1.47	MS 2	4.50	IP 17645	6.03	IP 18948	4.54
IP 15700	1.54	IP 17645	5.25	IP 15700	6.50	IP 15700	4.66
OKASHANA 2	1.56	IP 18948	5.40	MS 2	6.80	KANGARA	4.93

IP 16754	1.90		IP 15700	5.65		ICMV 88908	7.00		IP 17645	5.29
MS 11	2.37		IP 16754	5.65		IP 16754	7.03		ICMV 88908	5.33
IP 17645	2.40		ICMV 88908	5.85		KANGARA	7.43		IP 16754	5.40
						KANTANA	10.75		KANTANA	10.75
Average	**1.32**		**Average**	**4.43**		**Average**	**6.19**		**Average**	**4.53**

Key: Similar coloured cells represent the same variety giving similar performance across the sites.

3.3.2 All sites analysis on dry biomass of Pearl millet varieties

Figure 3 below shows the average dry matter weight of each variety at harvesting expressed in tons per ha across all research trial sites. It depicts that Kantana, the local variety, recorded the highest average dry matter weight of 10.8 tons per hectare, while variety 41518/K16 recorded the lowest dry matter weight of 1.6 tons per ha. Dry biomass was highly correlated to plant height (r=0.675**). Therefore, the short variety, ICMP 177003, had the smallest dry biomass, and tall varieties like Kantana had the highest dry biomass.

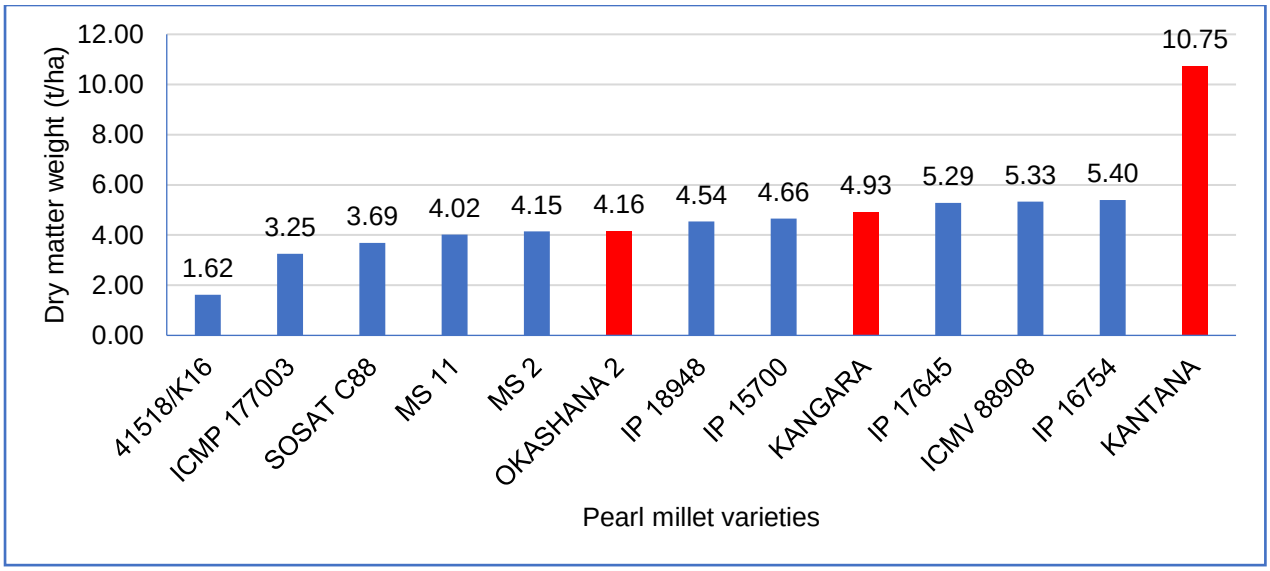

Figure 3: Average dry matter weight (t/ha) of pearl millet varieties in 3 sites - Ogongo, Dorringboom, and Mashare

3.4. Number of tillers and number of productive tillers per plant

3.4.1 Site-specific analysis of the number of tillers of pearl millet varieties

Dorringboom gave the highest number of tillers per plant (9.5 tillers/plant) followed by Mashare (7.5 tillers/plant) and the lowest recording was from Ogongo (6.4 tillers/plant). Each site was statistically different from the others (P<0.05) (Table 6).

Shorter plants tend to have more tillers and vice versa, as taller plants appropriated resources on apical growth than tillering. For instance, Kantana is the tallest plant and also has the least number of tillers.

Table 6: Average number of tillers per plant ranked per site

OGONGO			DORINGBOOM			MASHARE			Average of 3 sites	
41518/K16	4.5		KANGARA	5.5		MS 11	6.0		KANTANA	6.3
SOSAT C88	4.5		IP 18948	7.0		KANTANA	6.3		SOSAT C88	6.7
MS 2	4.8		SOSAT C88	8.5		OKASHANA 2	6.3		MS 11	6.8
IP 17645	5.3		MS 11	9.0		IP 18948	6.9		MS 2	6.9
OKASHANA 2	6.2		MS 2	9.0		MS 2	7.0		OKASHANA 2	7.0
IP 16754	6.4		IP 15700	9.5		IP 16754	7.2		IP 18948	7.3
MS 11	6.4		OKASHANA 2	9.5		IP 17645	7.2		KANGARA	7.4
ICMV 88908	6.5		ICMP 177003	10.0		SOSAT C88	7.2		IP 15700	7.7
IP 15700	6.8		IP 16754	10.5		ICMV 88908	7.5		IP 16754	7.8
KANGARA	8.0		IP 17645	11.0		IP 15700	7.6		IP 17645	8.0
IP 18948	8.5		41518/K16	12.0		KANGARA	8.1		ICMV 88908	8.5
ICMP 177003	8.7		ICMV 88908	12.5		ICMP 177003	9.8		41518/K16	9.1
						41518/K16	10.0		ICMP 177003	9.6
Average	**6.4**		**Average**	**9.5**		**Average**	**7.5**		**Average**	**7.7**

3.4.2 All sites analysis on the number of tillers per plant of pearl millet varieties

On average, Kantana, which is the tallest variety under test had the least number of tillers per plant (6.3), while ICMP 177003 had the highest number of tillers per plant (9.6) (Table 6 and Figure 4).

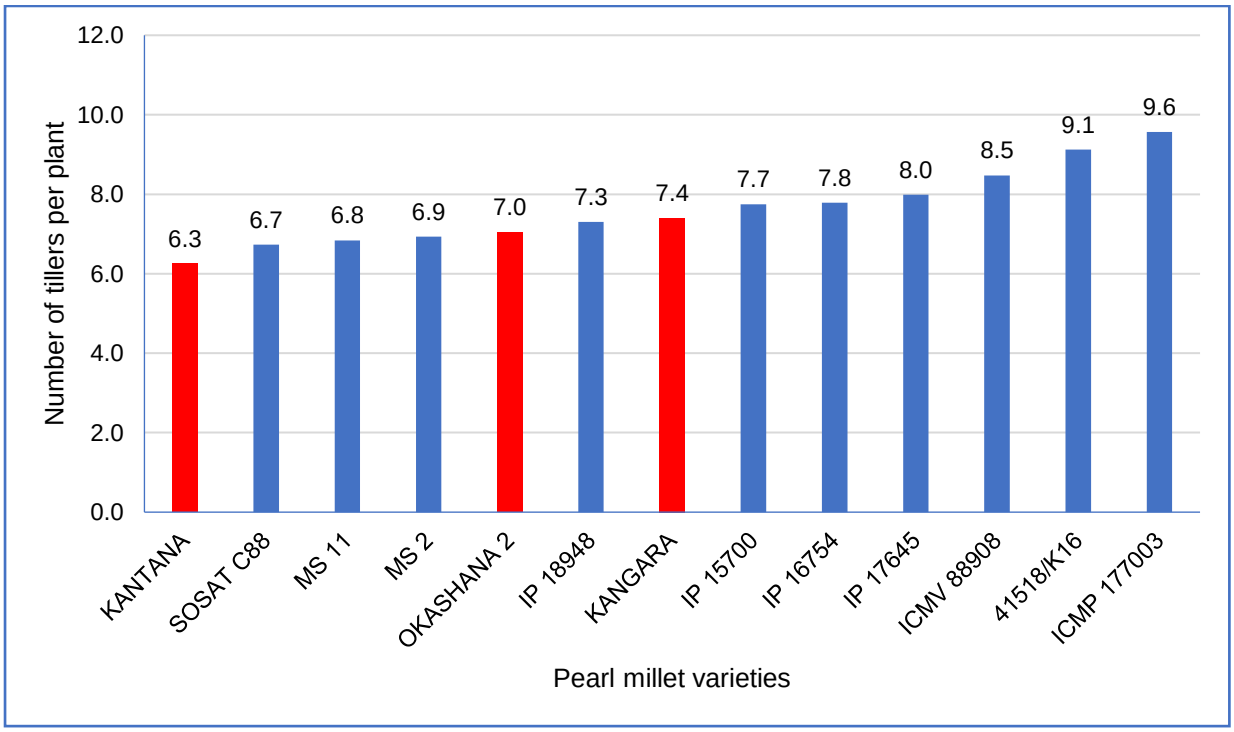

Figure 4: Average number of tillers per plant for pearl millet varieties in three sites - Ogongo, Dorringboom, and Mashare

3.4.2 Number of Productive Tillers of Pearl millet varieties

Not all tillers were productive (head bearing), hence the need to account for the fate of each tiller/shoot. The number of tillers per plant and the number of productive tillers per plant were closely related (r=0.618***), meaning that plants with more tillers also have more productive tillers and vice versa (compare Figure 5 and Figure 6). All sites have an almost similar number of productive tillers, ranging between 4.6 and 5.0.

A comparison of the number of tillers and the number of tillers with heads showed that Okashana (77% of all tillers have heads) and Kangara (75% of all tillers have heads) had a higher ability than other varieties to form heads in most of their tillers. In the case of IP 16754 and Kantana, about half of the tillers contained a head, while the rest of the shoots were headless. Pearl millet varieties with more headless tillers are therefore more suitable for biomass than for grains. The ratio of headed tillers to total tillers is a character that can be used to select Pearl millet lines for grains and biomass.

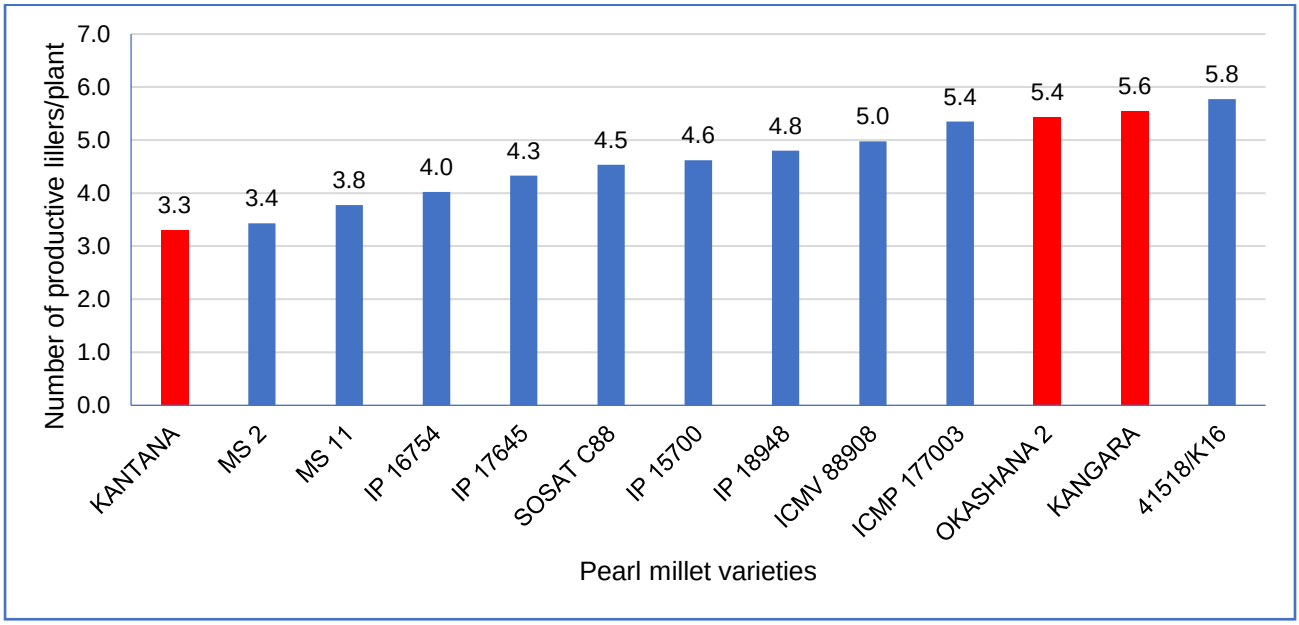

Figure 5: Average number of productive tillers per plant for pearl millet varieties in three sites - Ogongo, Dorringboom, Mashare

3.5. Bird damage and seed set

3.5.1 Site-specific Analysis of Bird Damage

Bird damage and seed set are two properties that determine the number of seeds in a head, hence the yield. Variety IP 17645 was the least damaged by birds in Mashare and Ogongo, thus making it the least bird-damaged variety overall (Table 7). ICMP 177003 and SOSAT C88 also scored low bird damage to heads in Dorringboom. Conversely, Kantana was more severely damaged than all varieties because it was late maturing and therefore the only one at the damageable stage when

grains from other varieties were too hard to be picked. Kantana being taller than other varieties meant that the birds could easily locate and settle on the heads and eat the grains.

Bird damage was an important contributor to grain yield as determined by correlation analysis. The higher the bird damage, the lower the yield, and vice versa (r=-0.447**). The percentage of heads not eaten by birds and the percentage of heads with no grains also determined the number of grains harvested (r = 0.750*** and r = -814*** respectively).

In Mashare alone, heads from each plot were separated according to the degree of bird damage. SOSAT C88 had the highest number of heads (51%) whose seeds had not been eaten at all by birds. This was followed by IP 17645 (48%) and then ICMP 177003 (38%). On the contrary, only 4% of the seeds in Kantana's heads were not eaten, meaning that the remainder (96%) were either partially or completely eaten by birds (Table 8).

3.5.2 Overall analysis of bird damage and seed set

SOSAT C88, IP 17645, and ICMP 177003 had the least bird damage, the least percentage of heads with no grains, and the largest number (%) of heads not eaten (Figure 6 and Table 8).

Table 7: Bird damage score

DORINGBOOM		MASHARE		OGONGO		AVERAGE	
ICMP 177003	1	IP 17645	1.5	IP 17645	1	IP 17645	1.6
SOSAT C88	1.5	MS 11	1.5	41518/K16	1.5	ICMP 177003	1.9
41518/K16	2	MS 2	1.5	ICMP 177003	2	ICMV 88908	2.0
ICMV 88908	2	SOSAT C88	1.5	ICMV 88908	2	SOSAT C88	2.0
IP 17645	2	IP 18948	1.75	MS 2	2	MS 11	2.1
MS 11	2.5	OKASHANA 2	1.75	OKASHANA 2	2	MS 2	2.2
IP 16754	3	ICMV 88908	2	KANGARA	2.5	OKASHANA 2	2.3
MS 2	3	IP 16754	2	IP 15700	3	IP 16754	2.5
IP 15700	3.5	ICMP 177003	2.25	IP 16754	3	IP 18948	2.5
IP 18948	3.5	IP 15700	2.25	IP 18948	3	41518/K16	2.8
KANGARA	3.5	KANGARA	2.5	MS 11	3	KANGARA	2.8
OKASHANA 2	3.5	41518/K16	3.75	SOSAT C88	3	IP 15700	2.8
		KANTANA	4.5			KANTANA	4.5
Average	**2.6**		**2.3**		**2.4**		**2.4**

Key: 1 = Slight or no damage; 2-3 = Moderate damage; 4-5 = Severe damage

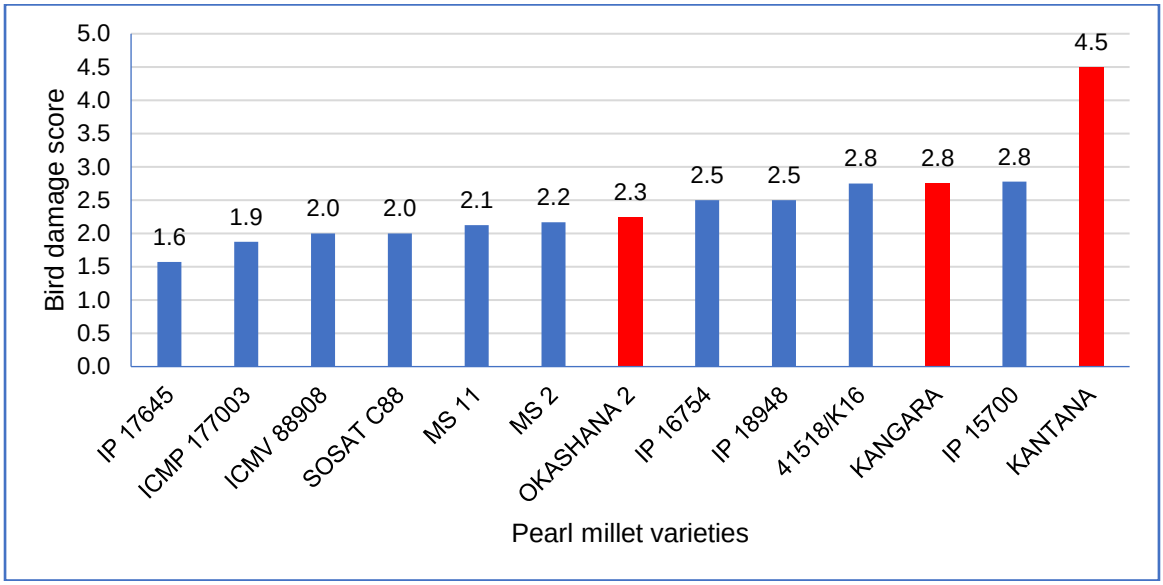

Figure 6: Average bird damage score on pearl millet heads in 3 sites - Ogongo, Dorringboom, Mashare

Key:
1 = Slight or no damage; 2-3 = Moderate damage; 4-5 = Severe damage

Table 8: Percent of bird damage to Pearl millet heads in Mashare

ENTRY NAME	% number of heads not eaten by birds	% heads partially eaten by birds	% number of heads with no grains
KANTANA	4	7	89
41518/K16	10	24	66
KANGARA	14	40	46
MS 2	20	43	37
IP 16754	20	29	50
IP 15700	25	32	43
ICMV 88908	27	33	40
IP 18948	28	32	39
MS 11	29	34	37
OKASHANA 2	35	35	30
ICMP 177003	38	31	30
IP 17645	48	32	20
SOSAT C88	51	22	27
Average	**26**	**30**	**44**

3.6. Grain Yield and Agronomic Score

3.6.1 Site-specific analysis of grain yield

Mashare (1.98 t/ha) (Figure 7) produced the highest average grain yields than Rupara (1.61 t/ha) (Figure 8), Dorringboom (1.27 t/ha) (Figure 9), and Ogongo (0.95 t/ha) (Figure 10) (Table 9). This was despite higher bird damage at Mashare compared to Dorringboom, Rupara, and Ogongo which had less bird damage. Each trial site had a significantly different yield from the other ($P<0.05$). Pearl millet varieties also varied significantly ($P<0.001$) in grain yield. SOSAT C88 performed very well in areas with slight supplementary irrigation (3.6t/ha in Mashare), while Kangara (2.3 t/ha in Ogongo) tended to do better in traditionally hot and dry environments. The better performance of Mashare could be associated with booster irrigation after planting.

Table 9: Grain yield (t/ha) of pearl millet varieties grown in different agroecological zones

OGONGO			**DORINGBOOM**			**MASHARE**			**RUPARA**			**AVERAGE**	
ICMP 177003	0.36		IP 15700	0.78		41518/K16	0.37		41518/K16	0.62		41518/K16	0.71
IP 15700	0.47		IP 16754	0.79		KANTANA	0.41		ICMV 88908	1.34		KANTANA	1.04
ICMV 88908	0.50		KANGARA	1.06		IP 15700	1.89		ICMP 177003	1.52		IP 15700	1.24
MS 2	0.59		ICMV 88908	1.15		IP 16754	1.93		IP 17645	1.55		ICMV 88908	1.38
41518/K16	0.61		IP 18948	1.16		KANGARA	1.95		IP 15700	1.55		MS 2	1.45
SOSAT C88	0.97		OKASHANA 2	1.29		ICMV 88908	1.96		MS 11	1.57		MS 11	1.67
OKASHANA 2	1.02		ICMP 177003	1.35		MS 11	1.96		OKASHANA 2	1.61		ICMP 177003	1.71
IP 17645	1.13		MS 11	1.41		IP 18948	2.10		KANTANA	1.66		IP 16754	1.71
MS 11	1.20		MS 2	1.43		MS 2	2.32		IP 18948	1.80		KANGARA	1.87
IP 16754	1.53		41518/K16	1.58		IP 17645	2.63		KANGARA	2.10		IP 18948	1.90
IP 18948	2.07		SOSAT C88	1.81		ICMP 177003	2.66		IP 16754	2.29		OKASHANA 2	1.94
KANGARA	2.29		IP 17645	2.07		OKASHANA 2	2.90					IP 17645	2.10
						SOSAT C88	3.59					SOSAT C88	2.12
Average	**0.95**		**Average**	**1.30**		**Average**	**1.98**		**Average**	**1.61**		**Average**	**1.60**

Key: Similar coloured cells represent the same variety giving similar performance across the sites

Figure 7 shows that Mashare's average grain yield was 1.98 t/ha while the highest was 3.59 t/ha.

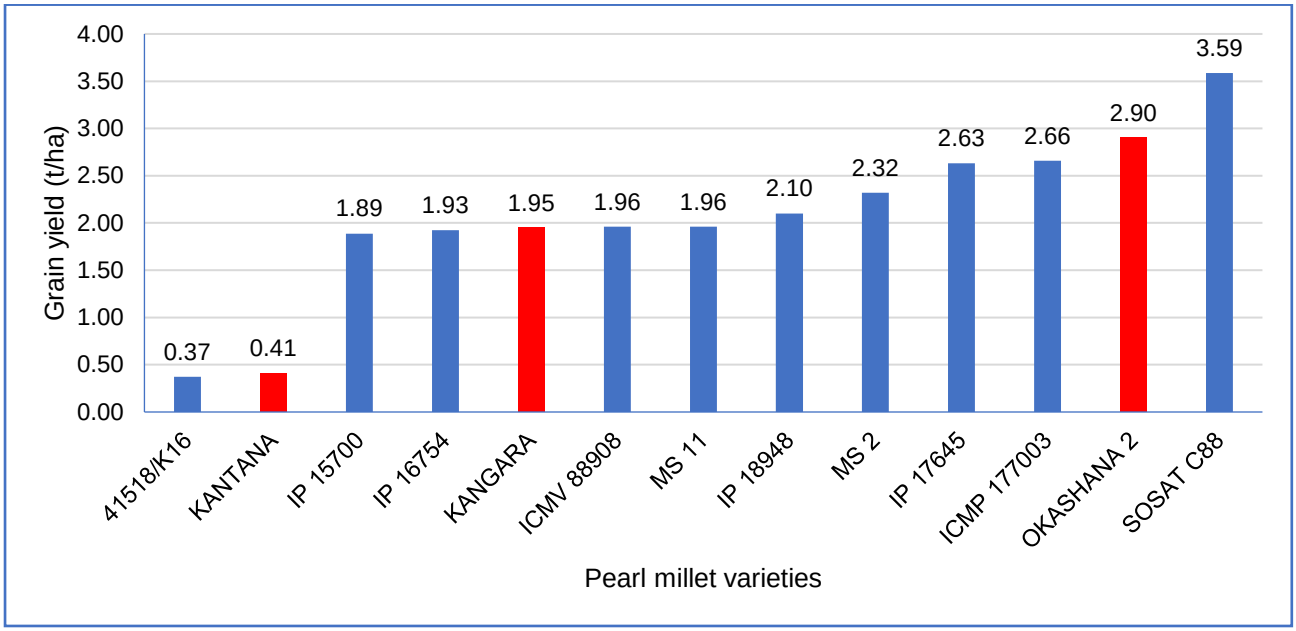

Figure 7: Average grain yield (t/ha) of pearl millet varieties at Mashare in 4 sites

Figure 8 shows that Rupara's average grain yield was 1.60 t/ha while the highest grain yield was 2.29 t/ha.

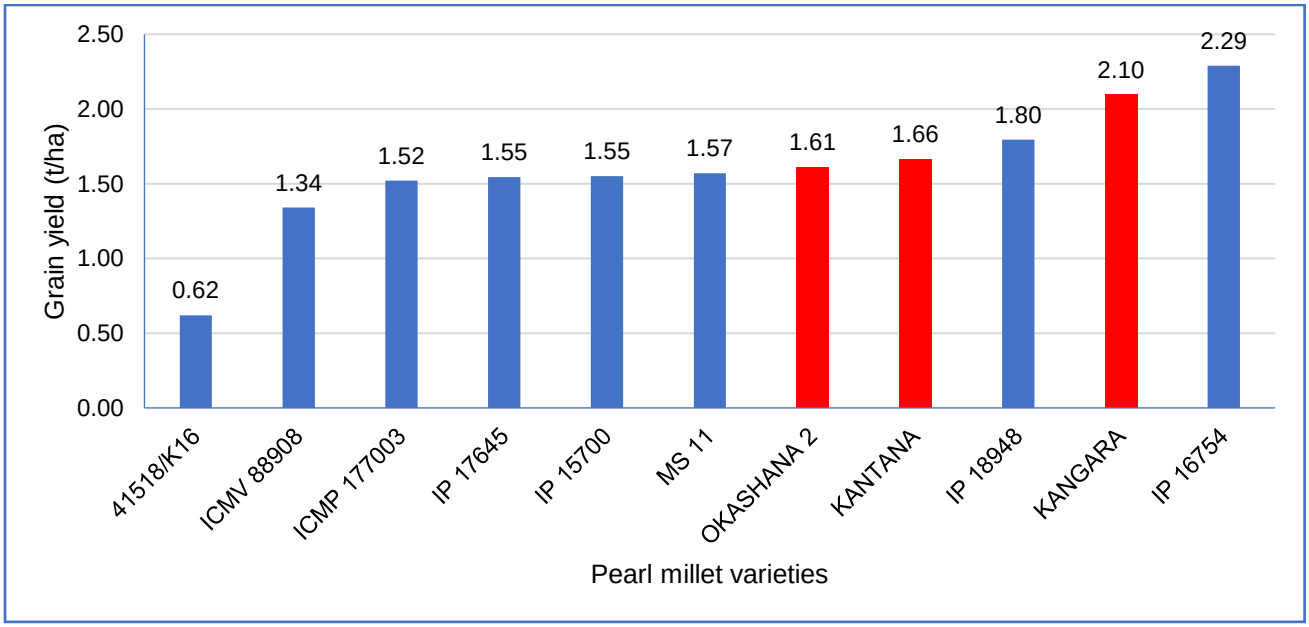

Figure 8: Grain yield (t/ha) of pearl millet varieties at Rupara

Figure 9 shows that Dorringboom's average grain yield was 1.27 t/ha with the highest grain yield of 2.07 t/ha.

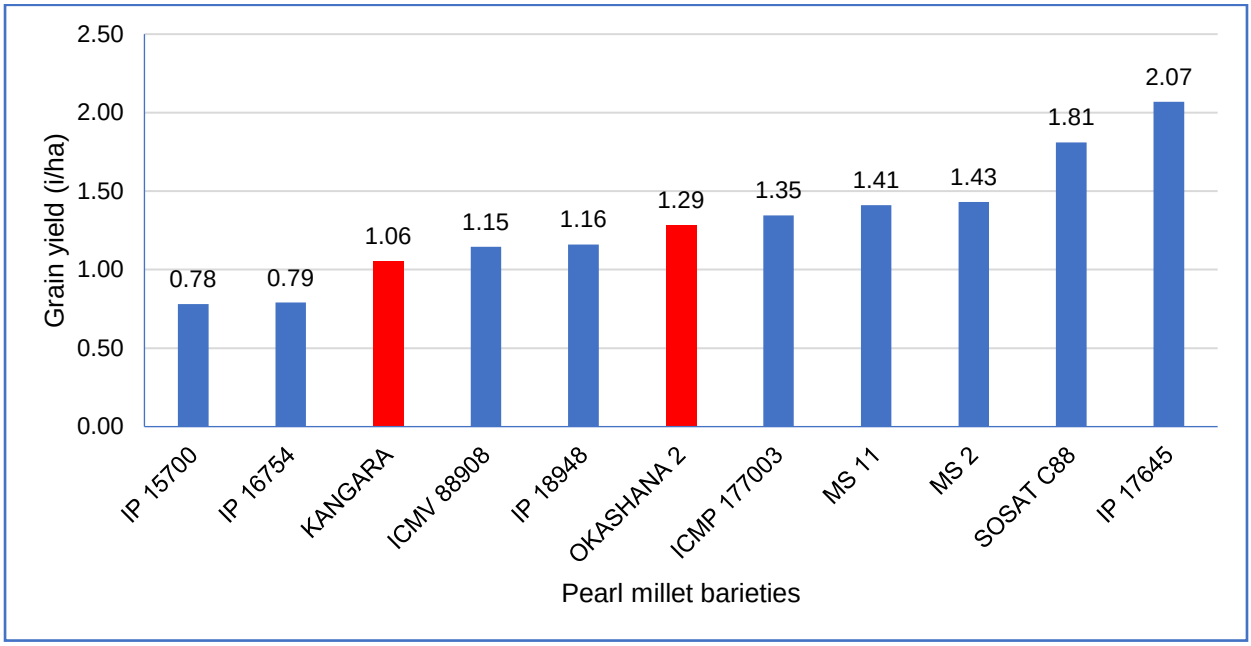

Figure 9: Grain yield (t/ha) of pearl millet varieties at the Dorringboom site

Figure 10 shows that Ogongo's average grain yield was 0.95 t/ha with the highest grain yield of 2.29 t/ha.

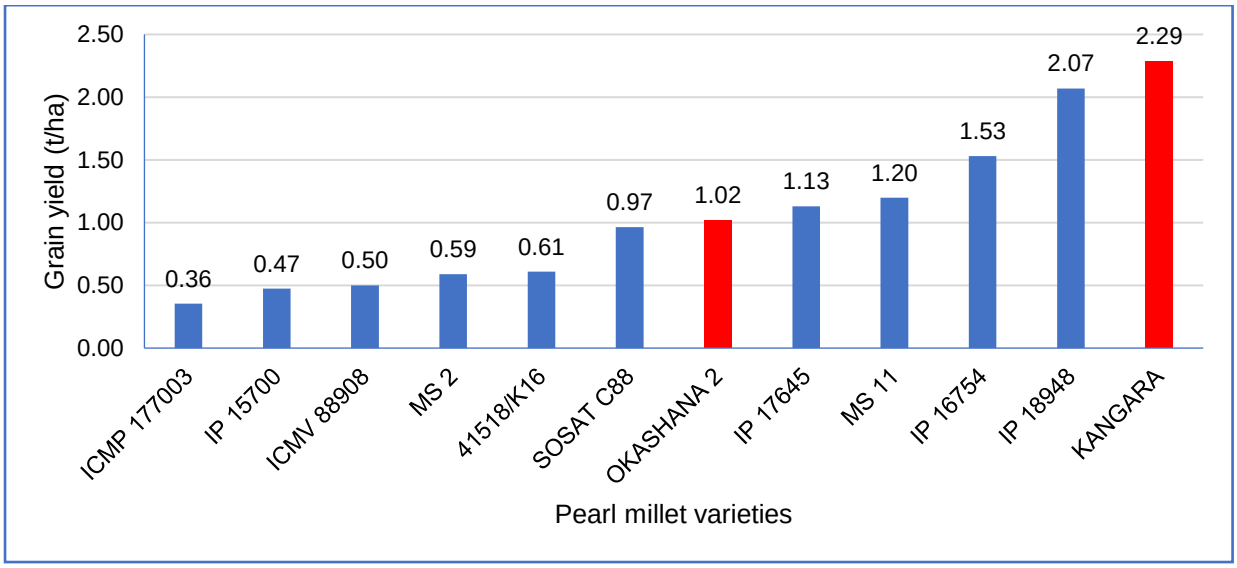

Figure 10: Grain yield of pearl millet varieties at Ogongo

3.6.2 All-site analysis of grain yield

Overall, 2 new varieties, SOSAT C88 (2.12 t/ha) and IP 17645 (2.10 t/ha) were on average better than Okashana 2 (1.94 t/ha) (improved local). These, together with IP 18948 (1.90 t/ha) were better than Kangara (1.87 t/ha) (Improved local) (Figure 11). However, the 41518/K16 new pearl millet

variety, which has poor germination, recorded the lowest yield below all varieties tested including all three local varieties.

Figure 11 shows that the average grain yield in all 4 sites was 1.59t/ha while the highest average yield was 2.12 t/ha.

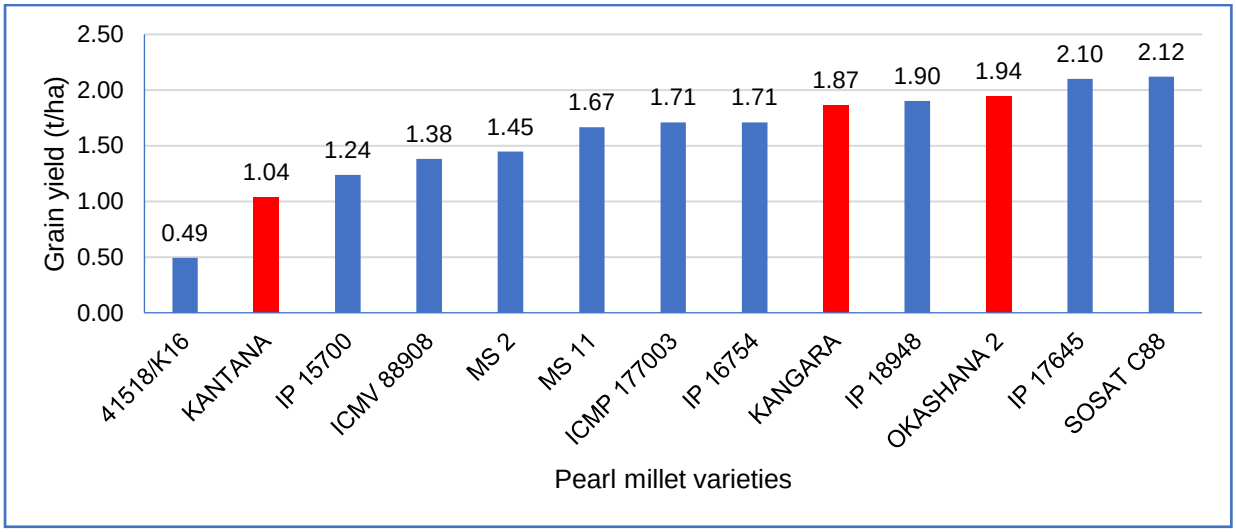

Figure 11: Average grain yield (t/ha) of pearl millet varieties in 4 sites in Namibia

3.6.3 Site-specific Analysis on Agronomic Score

Grain yield was highly correlated to the agronomic score captured on a scale of 1 – 5, where the agronomic score is defined as the overall performance of a variety on a scale of 1 – 5 based on visual impression before harvesting, where varieties with the greatest phenotypic performance were scored 1 and the worst were scored 5. Pearl millet variety Okashana 2 attained the best agronomic performance score in one site, and the second-best score in two sites (Table 10). The variety 41518/K16 and Kantana attained the least scores.

Table 10: Agronomic score of pearl millet varieties grown in different agroecological zones

OGONGO		DORINGBOOM		MASHARE		RUPARA		AVERAGE	
OKASHANA 2	1.5	MS 11	1.0	SOSAT C88	1.0	KANGARA	1.0	OKASHANA 2	1.5
ICMP 177003	2.0	MS 2	1.5	OKASHANA 2	1.3	OKASHANA 2	1.0	MS 2	1.7
ICMV 88908	2.0	ICMP 177003	2.0	IP 16754	1.5	ICMP 177003	1.5	MS 11	1.8
IP 17645	2.0	IP 17645	2.0	MS 2	1.5	MS 11	1.5	SOSAT C88	1.8
IP 18948	2.0	SOSAT C88	2.0	IP 18948	2.0	IP 16754	2.0	ICMP 177003	2.0
KANGARA	2.0	IP 16754	2.5	MS 11	2.0	IP 17645	2.0	IP 16754	2.0
MS 2	2.0	IP 18948	2.5	ICMP 177003	2.3	41518/K16	2.5	KANGARA	2.1
IP 15700	2.3	OKASHANA 2	2.5	IP 17645	2.3	ICMV 88908	2.5	IP 17645	2.1
IP 16754	2.5	ICMV 88908	3.0	KANGARA	2.3	IP 15700	3.0	IP 18948	2.3
MS 11	2.5	IP 15700	3.0	KANTANA	2.5	IP 18948	3.0	ICMV 88908	2.6

SOSAT C88	2.5		KANGARA	3.0		ICMV 88908	2.8		KANTANA	3.5		IP 15700	2.7
41518/K16	3.0		41518/K16	4.0		IP 15700	2.8					KANTANA	3.0
						41518/K16	4.0					41518/K16	3.5
Average	**2.2**		**Average**	**2.4**		**Average**	**2.2**		**Average**	**2.3**		**Average**	**2.3**

Key: 1 = Very good, 2 = Good, 3 = Average, 4 = Below average, 5= Poor

3.6.4 All sites analysis on agronomic score

Overall, Okashana 2 (locally improved pearl millet variety) recorded the best overall agronomic score of 1.5 (Figure 12), while Kantana (local unimproved variety) has the least score at 3.0. It is important to note that the poor score given to 41518/K16 was biased due to very poor germination.

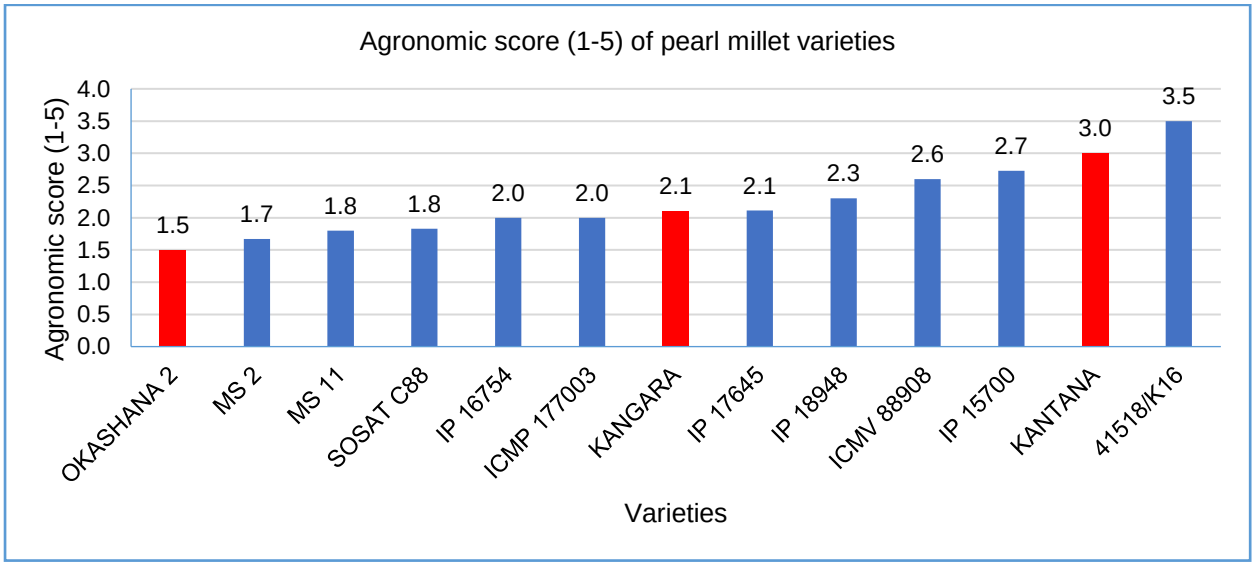

Figure 12: Agronomic score (1-5) of pearl millet varieties (where 1 is best and 5 is worse)

Key:
1 = Very good; 2 = Good; 3 = Average; 4 = Below average; 5= Poor

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

1. Two (2) new varieties (SOSAT C88 and IP 17645) were better than Okashana 2 (improved local) and three (3) new varieties (SOSAT C88, IP 17645, and IP 18948) were better than Kangara (improved local). These are the three most recommended varieties for introduction to Namibia.
2. Farmers' visual analysis of the pearl millet varieties is generally in agreement with scientific analysis (Table 11)
3. There was a drop in the overall grain yield in Season 2 compared to Season 1 due to a drastic drop in yield at Ogongo in Season 2 (Table 11)
4. SOSAT C88, IP 17645, and ICMP 177003 were the least affected by birds across all sites.
5. Early maturing combined with high yields were recorded by Kangara, Okashana 2, ICMP 177003, and SOSAT C88.

6. Kantana is the least preferred variety due to its late maturity, high vulnerability to bird damage, and low seed set. However, it has vigorous growth, is tall, and has a high biomass. The new varieties, IP 18946 and IP 16754, with an average of 1.9 t/ha and 1.7 t/ha respectively also have a high biomass, are tall and are late maturing. They may have better value than Kantana in regions with average rainfall like Kavango West and where farmers need the biomass to build houses and fences.
7. Most tall and late-maturing varieties were lower-yielding and easily affected by birds. Hence, they did not make it into the top selected varieties.

4.2. Recommendations

1. It is recommended that the new varieties (SOSAT C88, IP 17645, ICMP 177003, and IP 18948) be considered for seed bulking based on their yield potential and low bird damage.
2. It is recommended to replace Kantana with the new IP 18948 variety which has better yields. IP 18948 can replace the local Kantana, which has similar growth characteristics but with much lower yields, headless tillers, and seedless heads.
3. It is recommended to import the top 4-6 varieties and plant at least 1 ha per site for pre-seed multiplication and observations. This is the initiation of seed bulking.
4. There is a need to submit first and second season results to the Ministry of Agriculture, Water, and Land Reform for variety approval for Namibia.
5. Kangara remains the most suitable for the hot North Central production zone.
6. Supplementary irrigation tremendously increases the yield of SOSAT C88 (3.59 t/ha), and it is recommended for farmers who can afford it.
7. It is recommended to host research symposium in April/May 2023 for results sharing and mapping the way forward together with relevant stakeholders.

5. ANNEX 1 - STATISTICAL PARAMETERS

Annex Table 1: NUMBER OF DAYS TO 50% FLOWERING

Days to 50% pollen shading
Duncan[b,c]

		Subset				
ENTRY NAME	N	1	2	3	4	5
KANGARA	8	49.38				
OKASHANA 2	8	51.63	51.63			
ICMP 177003	8	54.25	54.25	54.25		
SOSAT C88	6	54.83	54.83	54.83		
ICMV 88908	8		56.75	56.75	56.75	
KANTANA	4		57.00	57.00	57.00	
IP 17645	7		57.14	57.14	57.14	
IP 18948	8			58.25	58.25	
MS 11	8			58.38	58.38	
MS 2	6			58.67	58.67	
IP 16754	8				61.38	61.38
IP 15700	9				61.44	61.44
41518/K16	8					64.88
Sig.		.071	.080	.172	.147	.231

Means for groups in homogeneous subsets are displayed.
Based on observed means
The error term is Mean Square (Error) = 26.160
a. Uses Harmonic Mean Sample Size = 7.076
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05.

Annex Table 2: AVERAGE PLANT HEIGHT

Average Plant height (m)
Duncan[a,b,c]

ENTRY NAME	N	Subset 1	2	3	4	5	6
41518/K16	8	1.4063					
ICMP 177003	8		1.7600				
OKASHANA 2	8		1.8475	1.8475			
MS 11	8		1.9187	1.9187	1.9187		
KANGARA	8		1.9225	1.9225	1.9225		
ICMV 88908	8		1.9638	1.9638	1.9638		
IP 17645	7		1.9686	1.9686	1.9686		
IP 15700	9			1.9967	1.9967		
SOSAT C88	6			2.0050	2.0050		
IP 18948	8			2.0512	2.0512		
MS 2	6				2.1150		
IP 16754	8					2.3175	
KANTANA	4						2.6100
Sig.		1.000	.061	.074	.086	1.000	1.000

Means for groups in homogeneous subsets are displayed
Based on observed means
The error term is Mean Square (Error) = .033
a. Uses Harmonic Mean Sample Size = 7.076
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05

Annex Table 3: AVERAGE DRY MATTER YIELD

Dry matter (t/ha)
Duncan[a,b,c]

ENTRY NAME	N	Subset 1	2	3	4	5	6
41518/K16	8	1.6225					
ICMP 177003	8		3.2463				
SOSAT C88	6		3.6900	3.6900			
MS 11	8		4.0162	4.0162	4.0162		
MS 2	6		4.1450	4.1450	4.1450		
OKASHANA 2	8		4.1638	4.1638	4.1638		
IP 18948	8			4.5413	4.5413	4.5413	
IP 15700	9			4.6578	4.6578	4.6578	
KANGARA	8				4.9313	4.9313	
IP 17645	7					5.2857	
ICMV 88908	8					5.3288	

IP 16754	8					5.4000	
KANTANA	4						10.7500
Sig.		1.000	.063	.054	.069	.088	1.000

Means for groups in homogeneous subsets are displayed
Based on observed means
The error term is Mean Square (Error) = .670
a. Uses Harmonic Mean Sample Size = 7.076
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05

Annex Table 4: NUMBER OF TILLERS PER PLANT

The average number of tillers per plant
Duncan[a,b,c]

		Subset		
ENTRY NAME	N	1	2	3
KANTANA	4	6.250		
SOSAT C88	6	6.733		
MS 11	8	6.837	6.837	
MS 2	6	6.933	6.933	
OKASHANA 2	8	7.038	7.038	
IP 18948	8	7.300	7.300	7.300
KANGARA	8	7.400	7.400	7.400
IP 15700	9	7.744	7.744	7.744
IP 16754	8	7.788	7.788	7.788
IP 17645	7	7.986	7.986	7.986
ICMV 88908	8	8.475	8.475	8.475
41518/K16	8		9.125	9.125
ICMP 177003	8			9.563
Sig.		.065	.056	.054

Means for groups in homogeneous subsets are displayed.
Based on observed means
The error term is Mean Square (Error) = 3.488
a. Uses Harmonic Mean Sample Size = 7.076
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05

Annex Table 5: NUMBER OF PRODUCTIVE TILLERS

NUMBER OF TILLERS PER PLANT

Duncan[a,b,c]

ENTRY NAME	N	Subset 1	2	3
KANTANA	4	3.3000		
MS 2	6	3.4333		
MS 11	8	3.7750	3.7750	
IP 16754	8	4.0250	4.0250	4.0250
IP 17645	7	4.3286	4.3286	4.3286
SOSAT C88	6	4.5333	4.5333	4.5333
IP 15700	9	4.6222	4.6222	4.6222
IP 18948	8	4.8000	4.8000	4.8000
ICMV 88908	8	4.9750	4.9750	4.9750
ICMP 177003	8		5.3500	5.3500
OKASHANA 2	8		5.4375	5.4375
KANGARA	8		5.5500	5.5500
41518/K16	8			5.7750
Sig.		.083	.068	.072

Means for groups in homogeneous subsets are displayed

Based on observed means

The error term is Mean Square (Error) = 2.298

a. Uses Harmonic Mean Sample Size = 7.076

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = 0.05

Annex Table 6: BIRD DAMAGE SCORE

Bird damage score

Duncan[a,b,c]

ENTRY NAME	N	Subset 1	2	3
IP 17645	7	1.5714		
ICMP 177003	8	1.8750	1.8750	
ICMV 88908	8	2.0000	2.0000	
SOSAT C88	6	2.0000	2.0000	
MS 11	8	2.1250	2.1250	
MS 2	6	2.1667	2.1667	
OKASHANA 2	8	2.2500	2.2500	
IP 16754	8	2.5000	2.5000	
IP 18948	8	2.5000	2.5000	

41518/K16	8		2.7500	
KANGARA	8		2.7500	
IP 15700	9		2.7778	
KANTANA	4			4.5000
Sig.		.103	.118	1.000

Means for groups in homogeneous subsets are displayed
Based on observed means
The error term is Mean Square (Error) = .801
a. Uses Harmonic Mean Sample Size = 7.076
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05

Annex Table 7: PERCENT NUMBER OF HEADS NOT EATEN BY BIRDS

% NUMBER OF HEADS NOT EATEN BY BIRDS

Duncan[a,b,c]

		Subset						
ENTRY NAME	N	1	2	3	4	5	6	7
KANTANA	4	4.175						
41518/K16	4	10.425	10.425					
KANGARA	4	13.775	13.775	13.775				
MS 2	2	20.200	20.200	20.200	20.200			
IP 16754	4	20.250	20.250	20.250	20.250			
IP 15700	4		24.925	24.925	24.925	24.925		
ICMV 88908	4		26.725	26.725	26.725	26.725		
IP 18948	4			28.400	28.400	28.400		
OKASHANA 2	4			29.575	29.575	29.575		
MS 11	4				34.700	34.700	34.700	
ICMP 177003	4					38.175	38.175	38.175
IP 17645	4						47.950	47.950
SOSAT C88	2							51.350
Sig.		.052	.053	.064	.088	.115	.091	.092

Means for groups in homogeneous subsets are displayed
Based on observed means
The error term is Mean Square (Error) = 89.843
a. Uses Harmonic Mean Sample Size = 3.467
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05

Annex Table 8: PERCENT NUMBER OF HEADS WITH NO GRAINS

% number of heads with no grains

Duncan[a,b,c]

		Subset				
ENTRY NAME	N	1	2	3	4	5
IP 17645	4	19.750				
SOSAT C88	2	26.850	26.850			
ICMP 177003	4	30.375	30.375	30.375		
MS 11	4	33.625	33.625	33.625		
OKASHANA 2	4	33.675	33.675	33.675		
MS 2	2	36.500	36.500	36.500		
IP 18948	4	39.475	39.475	39.475		
ICMV 88908	4	39.825	39.825	39.825		
IP 15700	4		42.725	42.725		
KANGARA	4		46.250	46.250	46.250	
IP 16754	4			50.425	50.425	
41518/K16	4				65.825	
KANTANA	4					89.300
Sig.		.077	.090	.080	.059	1.000

Means for groups in homogeneous subsets are displayed

Based on observed means

The error term is Mean Square (Error) = 156.676

a. Uses Harmonic Mean Sample Size = 3.467

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = 0.05

Annex Table 9: AVERAGE GRAIN YIELD

Grain yield (t/ha)

Duncan[a,b,c]

		Subset						
ENTRY NAME	N	1	2	3	4	5	6	7
41518/K16	10	.7110						
KANTANA	8	1.0350	1.0350					
IP 15700	11		1.2391	1.2391				
ICMV 88908	10		1.3810	1.3810	1.3810			
MS 2	6			1.4467	1.4467			
MS 11	9				1.6667	1.6667		
ICMP 177003	10				1.7080	1.7080	1.7080	
IP 16754	9				1.7100	1.7100	1.7100	

KANGARA	10					1.8660	1.8660	1.8660
IP 18948	8					1.9025	1.9025	1.9025
OKASHANA 2	10					1.9440	1.9440	1.9440
IP 17645	8						2.1013	2.1013
SOSAT C88	6							2.1200
Sig.		.074	.070	.278	.105	.181	.056	.212

Means for groups in homogeneous subsets are displayed
Based on observed means
The error term is Mean Square (Error) = .136
a. Uses Harmonic Mean Sample Size = 8.544
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05

Annex Table 10: AVERAGE AGRONOMIC SCORE

Agronomic score
Duncan[a,b,c]

		Subset					
ENTRY NAME	N	1	2	3	4	5	6
OKASHANA 2	10	1.50					
MS 2	6	1.67	1.67				
MS 11	10	1.80	1.80				
SOSAT C88	6	1.83	1.83				
IP 16754	10	2.00	2.00	2.00			
ICMP 177003	10	2.00	2.00	2.00			
KANGARA	10	2.10	2.10	2.10	2.10		
IP 17645	9	2.11	2.11	2.11	2.11		
IP 18948	10		2.30	2.30	2.30		
ICMV 88908	10			2.60	2.60	2.60	
IP 15700	11				2.73	2.73	
KANTANA	8					3.00	3.00
41518/K16	10						3.50
Sig.		.076	.066	.074	.057	.200	.090

Means for groups in homogeneous subsets are displayed
Based on observed means
The error term is Mean Square (Error) = .376
a. Uses Harmonic Mean Sample Size = 8.902
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = 0.05