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Evaluation of elite cashew hybrids developed in 1998 under the agro-ecological conditions of Nachingwea in Southern Tanzania

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Abstract

Performance of the cashew hybrids developed in 1990s found to be potential in terms of yield and nut quality compared to varieties released for commercialization in Tanzania. Based on these results, breeders in Tanzania directed their efforts toward improving nut quality to cope with modern cashew processing machines, which require medium to large nuts. In 1998, fifty-eight (58) crosses were developed involving a number of parents with contrasting but useful traits. These hybrids were evaluated at Naliendele for seven years from 1999 to 2006 and 26 elite hybrids were selected for advanced genetic trial. The hybrids were evaluated at Nachingwea, one of the major cashew growing districts in the Southern zone of Tanzania to find out if they were suitable in the area. The data on yield and nut quality were recorded for a period of twelve years. Commercial and common variety *Anacardium Ceylon 4* (AC4) was used as a control. Screening of the hybrids against Cashew Leaf and nut blight disease was another parameter under study. Results indicated that 23 hybrids out of 26 had good nut quality particularly on nut weight and kernel weight than AC4 and a total of 13 hybrids gave higher yields compared to control (AC4). Screening of the hybrids against the disease demonstrated that majority of the hybrids were tolerant to the disease opening an opportunity to get new cashew varieties tolerant to the disease. The control variety, which is susceptible to cashew leaf and nut blight disease had higher score and ranked last but one indicating hybrids, had lower score than AC4. These hybrids are therefore recommended for multiplication and distribution in Nachingwea and areas with similar environmental conditions like Nachingwea.

Key words: *Cashew; cashew leaf., hybrid; nut blight disease; nut quality;* y*ield*

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Introduction

Cashew (*Anacardium occidentale* L.) is an evergreen perennial plant cultivated in tropical countries and can tolerate a wide range of altitudes with the economical altitude between 28^0 South and 28^0 North (Masawe and Kapinga, 2016). The optimum production is obtained in areas with deep and well-drained sandy loams without a hard pan, 0 and 800 m altitude, annual rainfall of 800 to 1600 mm, a temperature of 24° to 28° C and a pronounced dry period of 5 – 7 months (Masawe *et al.*, 2020). It is andromonoecious and highly cross-pollinated crop to which insects and wind are the main agents of pollination. Tanzania has a favourable climate for cashew nut production, especially in the southern coastal region bordering Mozambique. The major cashew growing areas in Tanzania are Mtwara, Lindi and Pwani (TIC, 2019). Cashew is a source of income for over 667,437 households producing cashew in Tanzania (URT, 2021). Cashew is currently the leading export crop in Tanzania in terms of foreign exchange earnings (Ministry of Finance, 2023). Cashew nuts exports accounted for USD 226.9 44 million in 2022. The amount earned from cashew nuts exports alone was more than combined earnings from cotton, tea, cloves and sisal (Ministry of Finance, 2023).

Despite the economic importance of cashew crop in Tanzania, research reports on cashew production have shown that some cashew trees produce low yields due to low yield potential and aging of most genotypes in farmers' fields (Madeni, 2016). Most farmers have continued using the half sib progenies of the original introductions or their sibs that are low yielding with poor nut quality and susceptible to disease and insect pests. Such trees have been recycled extensively by farmers resulting into a lot of genetic variations (Lukurugu *et al.*, 2022). Adoption of improved cashew planting materials by cashew farmers in more recent years has led to increases in its production from 16 000 tons in 1989/90 season to 313,826 tons in 2017/18 season (TARI, 2019).

Performance of the first hybrids produced in Tanzania in 1990, 1994 and 1995 demonstrated that hybridisation by controlled hand pollination could significantly improve cashew gene bank (Masawe and Kapinga, 2016). It could also provide stakeholders with more profitable genotypes in terms of productivity and nut quality. In 1998, a total of 58 crosses were developed by hand pollination and were evaluated at Naliendele trial blocks. The data on yield and nut quality was recorded on individual tree basis for a period of seven years (1999 to 2006). Preliminary selection led to identification of 26 elite hybrids that had high yield, nut weight, kernel weight and percentage out turn which were used to establish advanced trial at Nachingwea Lindi in 2007 and hence this genetic trial.

Materials and methods

Study area

This trial was conducted at Nachingwea substation, which is located at 10°20'S, 38°46'E, altitude 465 m above sea level. The district receives annual rainfall range of between 800 – 1,000 mm and has only one rainy season that normally falls between the months of November to April thus a pronounced dry season of 6 months. Day time temperature ranges from 25^0C to 31^0C and relative humidity ranges from 71% to 86% (Nachingwea District Council, 2023). Dominant soil types include loam, sand, sandy-loam and clay (Wizara ya Kilimo, 2022). Nachingwea is a suitable area for potential production of cashew as it has all characteristics required for economical production. In 2006 season 26 elite hybrids were selected from "Crosses made in 1998" for further evaluation in Nachingwea site using commercial variety AC4 as control. AC4 is the high yielding variety with the average productivity of 69kg/tree at the age of 14 years and nut weight of 10g/nut and percentage out turn of 28% (Masawe and Kapinga, 2017). The hybrids were vegetatively propagated at TARI Naliendele located at a latitude of 10°22'S, longitude of 40° 11'E and at an altitude of 120 m

above mean sea level. The mean annual temperature is around 26 °C and mean annual rainfall is about 1160 mm which falls in a single 6-month season from November to April. They were later transported to Nachingwea for transplanting which took place in 15th February 2007.

Study design

The trial layout was a randomized complete block, four trees per plot planted in a single row at a spacing of 12 m between rows and 12 m within rows, in three replicates. Good agronomic practices were undertaken as recommended by cashew agronomy and crop protection units. The PMD (powdery mildew disease) was controlled using Tridimenol (Transmute) fungicide at a rate of 10-15 mls/litre. Cashew sucking pests were controlled using Lambda cyhalothrin (Ninja) insecticide at a rate of 5 mls/litre of water.

Cashew leaf and nut blight disease

The hybrids were exposed to Cashew leaf and nut blight disease so as to screen the hybrids against the disease hence scoring of the disease was undertaken. Data were collected from the four geographical sides of the test trees using quadrant system. A label was tagged to a central shoot on each of the four sides of the tree. During scoring a 1 m² quadrant was placed so that the tagged shoot was at the centre of the quadrant in order to ensure that at least more or less the same shoots were assessed throughout the trial season. Total number of shoots enclosed within the quadrant and number of shoots showing blights symptoms were recorded. Overall, cashew leaf and nut blight disease score per test tree was recorded using 0 - 6 disease score index, to indicate the levels of blight infection whereby 0 = no disease; 1 = 1-10% infected (average 5.5); 2 =11-25% (average 18); 3 = 26-50% (average 38); 4 = 51-75% (63); 5 = 76 - 99% (87.5) and 6 = 100% infected. The varieties are considered resistant once score 0 and highly susceptible on 6 score index. AC4 is known to be susceptible to the disease hence used as a negative control.

a) Yield

The fallen cashew nuts from every tree were collected daily using collection bags and their weight recorded using weighing balance. Total yield for each hybrid was recorded at the end of the season. The genotype should yield more than 15kg/tree at the age of 8 years to be considered for selection in Tanzania.

b) Nut weight

Nut weight was determined by measuring weight of 500gm of sampled nuts randomly selected and then divided by the number of nuts. The genotype should have 7 gram and above to be considered for selection in Tanzania.

c) Kernel weight

Using the same sample as for nut weight, the nuts were dissected (opened up) longitudinally to take out the kernels and were weighed. The obtained weights were divided by the number of nuts. The genotype should have 2 gram and above to be considered for selection in Tanzania.

d) Percentage kernel out turn

Percentage kernel out turn, simply refers to what proportion of useful kernels obtained in a given unit of raw nuts. Percentage kernel out turn was determined by measuring the weight of useful kernels and dividing it by nut weight and then multiplying by the 100. The genotype should have 25% and above to be considered for selection in Tanzania. Data analysis was carried out using a GenStat statistical software 16th edition. Means were separated using Tukey Test.

Results

The list of crossed parents for the hybrids selected for evaluation at Nachingwea site and the control variety are tabulated below (Table 1).

Table 1

List of crossed parents for the hybrids selected for evaluation at Nachingwea site

S/N	Crossed Parents Female x Male	Hybrid name
1	AZA17/79 x Brz ex-Za 3.21	H43.4
2	Cook-11 x CP 09	H51.4
3	AC10/14 x Chimika 3.31	H1.3
4	AC4/100 x Chimika 3.31	H64.4
5	AC28 x Chimika 3.31	H19.1
6	AC4/75 x Chimika 1.4	H39.4
7	AZA17/84 x Brz ex-Za 3.21	H59.4
8	Cook-11 x CP 09	H51.2
9	AC28 x Chimika 3.31	H34.1
10	Cook-07 x CP 09	H13.1
11	AC10/271 x Chimika 3.31	H8.1
12	Cook-11 x CP 09	H26.1
13	NTP 88/66 x Brz ex-Za 1.5	H2.1
14	AC10/271 x Chimika 3.31	H8.3
15	AZA17/84 x Brz ex-Za 3.21	H24.3
16	AC4 x Chimika 1.4	H6.3
17	AZA17/84 x Brz ex-Za 3.21	H49.4
18	Cook-10 x CP 09	H37.4
19	Cook-10 x CP 09	H23.3
20	AC4 x Chimika 1.4	H6.1
21	AZA17/84 x Brz ex-Za 3.21	H7.3
22	AC4 x Chimika 1.4	H68.4
23	Cook-10 x CP 09	H42.4
24	AC4/75 x Chimika 1.4	H29.1
25	AC10/271 x Chimika 3.31	H38.4
26	AC28 x Chimika 3.31	H34.3
27	Control	AC4

The analysis of variance for yields in years (2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019 and 2020), nut weight, kernel weight, %OT and blight are presented in Table 2.

Table 2

Analysis of variance for yield, nut weight, kernel weight, %OT and blight for 26 selected hybrids developed in 1998 at Nachingwea site

Source of Variation	df	Mean square														Mean
		Y2010	Y2011	Y2012	Y2013	Y2014	Y2015	Y2016	2017	2018	Y2019	Y2020	NutWt	Kern Wt	%OT	Blight
Rep	2	13.9403*	51.195	213.03	241.05*	183.15*	11.68	1149.79*	103.72*	3.167	4.99	283.16	2.21	0.25	0.06	8.74**
Hybrid	26	6.1634***	35.190	139.17	100.49*	160.44*	100.63	621.82**	88.68**	15.21*	26.57*	355.01*	11.74**	0.95**	37.47*	0.75**
Error		1.087	6.466	18.82	14.43	14.31	30.86	78.86	12.09	1.41	8.32	60.39	1.31	0.11	2.50	0.32
Mean		1.91	6.46	9.46	8.34	13.14	18.2	34.17	9.31	8.87	7.64	21.18	8.44	2.68	31.90	0.55
CV(%)		54.5	39.4	45.9	45.5	28.8	30.5	26	37.3	13.4	37.8	36.7	13.6	12.3	5.0	102.4

Note: **P ≤0.01
*** P ≤ 0.001
Y 2010= Yield (kg) in 2010
NutWt = Nut weight (g)
KernWt = Kernel weight (g)
%OT = Percentage kernel out-turn

There were highly significant differences between hybrids (P≤ 0.01) for all parameters under observation that tell the possibility of identifying good performing hybrids than AC4. The trial means for yield in 2020 was 21.18 kg/tree. For quality attributes the mean were 8.44 g, 2.68 g and 31.90% for nut weight, kernel weight and percentage outturn (%OT) respectively. Regarding cashew leaf and nut blight disease the trial mean was 0.55. The coefficient of variation for this trial ranged from 5.0 (%OT) to 102.4 (blight).

Results on effects of the hybrids are presented in Tables 3.

Table 3

Ranked order of means for yield (2010 – 2018) of 26 hybrids developed in 1998 at Nachingwea site

No	Hybrid	Y2010	Y2011	Y2012	Y2013	Y2014	Y2015	Y2016	Y2017	Y2018
1	**H2.1**	2.60a-c(7)	8.633a-c(4)	11.38b-e(7)	6.888f-i(18)	12.20e-i(15)	15.99c-f(22)	39.58b-g(7)	6.11g-i(25)	8.508e-g(19)
2	**H51.4**	0.96e-f(26)	5.664e-g(16)	5.99h-i(23)	4.834i(25)	10.55g-j(19)	15.64d-f(24)	25.73j-l(24)	4.19i(27)	10.27b-f(7)
3	**H1.3**	2.39b-d(9)	6.631c-f(12)	9.36e-i(13)	9.427c-g(8)	16.16b-d(6)	22.09a-b(3)	28.26h-l(21)	6.92f-i(22)	9.59c-g(11)
4	**H24.3**	1.29d-e(20)	5.585e-g(18)	8.16e-i(16)	4.413i(26)	10.54g-j(20)	15.97c-f(23)	20.88l(27)	7.39f-i(19)	8.86d-g(14)
5	**H51.2**	0.99e-f(25)	4.866e-g(24)	5.55i(25)	4.285i(27)	10.51g-j(21)	17.87a-d(13)	31.17g-k(19)	6.88f-i(23)	5.31h(25)
6	**H59.4**	1.36d-e(18)	5.379e-g(20)	7.67e-i(18)	5.507h-i(23)	9.77h-j(23)	11.36f(27)	24.64kl(25)	6.98f-i(21)	11.09a-d(4)
7	**H42.4**	1.27d-e(21)	4.990e-g(23)	5.52i(26)	5.337h-i(24)	8.73i-j(25)	15.45d-f(25)	31.28g-k(18)	6.86f-i(24)	5.48h(24)
8	**H23.3**	1.94c-e(11)	6.625c-f(13)	9.32e-i(14)	9.893c-f(7)	13.26d-h(11)	17.74a-d(16)	34.32e-i(15)	8.41d-h(15)	8.70e-g(16)
9	**H64.4**	1.88c-e(12)	5.830d-g(15)	7.36e-i(19)	7.271e-i(15)	14.74c-f(8)	17.71a-d(17)	45.03ab(2)	7.89e-h(16)	13.00a(1)
10	**H34.1**	0.96e-f(27)	5.341e-g(21)	5.76h-i(24)	6.579f-i(20)	13.53d-g(10)	12.27e-f(26)	31.13g-k(20)	7.56f-h(18)	7.91g(21)
11	**H68.4**	2.80a-c(3)	7.156b-e(7)	11.40b-e(6)	9.350c-g(9)	14.93c-e(7)	18.21a-d(12)	37.29b-g(8)	9.29c-g(13)	7.85g(23)
12	**H34.3**	1.26d-e(22)	6.578c-f(14)	8.06e-i(17)	7.619e-i(14)	13.04d-h(13)	18.43a-d(10)	34.83d-i(12)	12.01a-c(7)	9.61c-g(10)
13	**H49.4**	1.86c-e(15)	6.992b-e(10)	9.12e-i(15)	8.901c-h(10)	11.39e-j(17)	19.00a-d(9)	35.53c-i(11)	9.14c-h(14)	7.85g(22)
14	**H29.1**	3.24a-b(2)	8.253a-d(5)	14.07b-c(3)	14.889a(1)	19.16b(2)	21.67a-b(5)	42.79a-e(5)	12.67ab(4)	10.50b-e(6)
15	**H6.3**	2.21b-e(10)	9.072a-b(3)	13.80b-d(4)	14.106a-b(2)	17.67b-c(5)	22.89a(1)	36.44c-h(9)	9.88b-f(12)	7.97f-g(20)
16	**H6.1**	1.37d-e(17)	4.411f-g(25)	6.61g-i(21)	7.251e-i(17)	8.68i-j(26)	17.86a-d(14)	22.38l(26)	5.84hi(26)	4.69h-i(26)
17	**H38.4**	2.70a-c(4)	6.852b-f(11)	13.57b-d(5)	11.759a-c(4)	18.54b(3)	22.88a(2)	42.22a-f(6)	11.07a-e(9)	8.78d-g(15)
18	**H26.1**	1.33d-e(19)	4.028g(26)	6.02h-i(22)	6.370f-i(21)	7.99i(27)	16.65b-e(21)	27.31i-l(22)	10.01b-f(11)	3.23i(27)
19	**AC4**	1.61c-e(16)	5.395e-g(19)	9.40e-i(12)	7.255e-i(16)	12.69d-h(14)	19.78a-d(8)	42.94a-d(4)	7.11f-i(20)	10.09c-g(8)
20	**H39.4**	3.76a(1)	10.473a(1)	18.84a(1)	13.443a-c(3)	22.53a(1)	22.01a-b(4)	48.88a(1)	13.79a(1)	8.68e-g(17)
21	**H19.1**	2.69a-c(5)	9.899a(2)	15.24b(2)	11.418a-d(5)	18.53b(4)	17.50a-e(18)	34.68d-i(14)	11.49a-d(8)	8.87d-g(13)
22	**H8.1**	2.43b-d(8)	5.602e-g(17)	10.45c-g(9)	10.789b-e(6)	11.20f-j(18)	17.37a-e(19)	34.69d-i(13)	7.81e-h(17)	10.54b-e(5)
23	**H8.3**	2.62a-c(6)	7.002b-e(9)	9.84d-g(11)	6.824f-i(19)	11.40e-j(16)	18.40a-d(11)	35.7c-i(10)	10.10b-f(10)	9.56c-g(12)
24	**H37.4**	1.27d-e(23)	5.006e-g(22)	6.80f-i(20)	8.665c-h(11)	10.31g-j(22)	17.77a-d(15)	33.94f-j(16)	13.76a(2)	9.78c-g(9)
25	**H43.4**	1.88c-e(13)	7.319b-e(6)	9.90d-g(10)	8.559c-h(12)	13.97d-g(9)	20.80a-d(7)	25.87j-l(23)	12.04a-c(6)	12.44a-b(2)
26	**H13.1**	1.18d-f(24)	3.623g(27)	5.31i(27)	5.807g-i(22)	9.65h-j(24)	16.74b-e(20)	31.61g-k(17)	12.36a-c(5)	8.59e-g(18)
27	**H7.3**	1.87c-e(14)	7.142b-e(8)	10.94c-f(8)	7.833d-i(13)	13.19d-h(12)	21.35a-c(6)	43.43a-c(3)	13.71a(3)	11.72a-c(3)

Means with the same letter(s) in the same column are not significantly different following Tukey Test ($P \leq 0.05$).
Numbers within parentheses following the letter(s) stand for rank.

Y 2010= Yield (kg) in 2010

The yield ranged from 13.03 kg/tree to 33.57 kg/tree in the 2020/2021 season (Table 4).

Table 4

Ranked order of means for yield, nut weight, kernel weight, %OT and blight score of 26 hybrids developed in 1998 at Nachingwea site

No	Hybrid	Y2019	Y2020	NutWt	KernWt	%OT	Blight (%)
1	**H2.1**	3.42bh-j(25)	23.76b-h(8)	9.35a-e(6)	2.976a-e(6)	31.85e-g(17)	16.66a(27)
2	**H51.4**	2.09j(27)	22.86c-h(11)	8.825b-g(10)	2.867a-e(8)	32.47c-e(11)	14a-c(25)
3	**H1.3**	7.26b-j(5)	29.5a-c(3)	8.75c-h(11)	2.953a-e(7)	33.8b-d(4)	8.66a-d(13)
4	**H24.3**	4.94e-j(22)	19.7e-k(16)	9.809a-c(3)	2.817a-f(10)	28.72j(26)	7.83a-d(12)
5	**H51.2**	3.94g-j(24)	17.94f-k(19)	9.263b-e(7)	3.044a-c(3)	32.95c-e(5)	10a-d(18)
6	**H59.4**	5.76c-j(20)	21.84d-i(12)	9.866a-b(2)	2.833a-e(9)	28.72j(27)	5.33b-d(5)
7	**H42.4**	5.46d-j(21)	13.03k(27)	9.115b-f(8)	2.993a-d(4)	32.95c-e(6)	9.5a-d(15)
8	**H23.3**	2.51i-j(26)	27.9a-d(4)	7.367k-n(23)	2.664e-h(17)	36.22a(1)	12.33a-c(21)
9	**H64.4**	8.07a-i(14)	20.67d-j(13)	8.601d-i(12)	2.78b-f(12)	32.49c-e(10)	9a-d(14)
10	**H34.1**	9.45a-g(9)	17.11g-k(21)	8.93b-g(9)	2.719d-g(14)	30.61g-i(20)	6.83a-d(8)
11	**H68.4**	10.62a-e(5)	18.42f-k(18)	8.413e-l(15)	2.467g-i(19)	29.44i-j(25)	1.6d(1)
12	**H34.3**	9.98a-f(7)	27.08a-e(5)	10.367a(1)	3.112a(1)	30.03i-j(23)	7.33a-d(9)
13	**H49.4**	7.01b-j(17)	23.59b-h(9)	8.51d-j(13)	2.677d-g(16)	31.49e-h(18)	7.5a-d(11)
14	**H29.1**	12.64a-b(2)	25.26b-f(6)	9.542a-d(5)	3.061a-b(2)	32.19e-f(15)	11a-d(19)
15	**H6.3**	7.04b-j(16)	33.57a(1)	7.6i-m(20)	2.306i-j(25)	30.38h-i(22)	9.6a-d(17)
16	**H6.1**	4.34f-j(23)	15.14i-k(24)	7.675h-m(19)	2.509f-i(18)	32.67c-e(8)	11.16a-d(20)
17	**H38.4**	13.10a(1)	24.67b-g(7)	8.37e-l(16)	2.69d-g(15)	32.08e-f(16)	12.83a-c(22)
18	**H26.1**	6.32c-j(18)	13.83j-k(25)	7.556i-n(21)	2.443g-i(20)	32.34d-e(13)	7.33a-d(10)
19	**AC4**	8.18a-i(13)	20.16e-k(14)	7.323l-n(24)	2.357i-j(23)	32.64c-e(9)	15.16ab(26)
20	**H39.4**	11.34a-c(3)	30.66a-b(2)	8.125f-m(17)	2.797a-f(11)	34.67b(2)	4.16cd(4)
21	**H19.1**	10.38a-e(6)	23.09c-h(10)	9.701a-c(4)	2.976a-e(5)	30.79f-i(29)	4.16cd(2)
22	**H8.1**	8.64a-h(11)	16.5h-k(22)	8.447d-k(14)	2.728c-g(13)	32.24e(14)	9.66a-d(16)
23	**H8.3**	8.88a-h(10)	16.16h-k(23)	7.893g-m(18)	2.353i-j(24)	29.91i-j(24)	5.5b-d(6)
24	**H37.4**	8.48a-h(12)	17.14g-k(20)	7.146m-n(26)	2.422g-i(21)	33.92b-c(3)	13.16a-c(23)
25	**H43.4**	10.73a-d(4)	19.5f-k(17)	7.269m-n(25)	2.367h-j(22)	32.86c-e(7)	13.33a-c(24)
26	**H13.1**	6.19c-j(19)	13.1j-k(26)	7.497j-n(22)	2.261i-j(26)	30.39h-i(21)	4.16cd(3)
27	**H7.3**	9.54a-g(8)	19.82e-k(15)	6.509n(27)	2.106j(27)	32.45c-e(12)	6.83a-d(7)

Numbers within parentheses following the letter(s) stand for rank.
Y 2020= Yield (kg) in 2020
NutWt = nut weight, KernWt = Kernel weight, %OT = Percentage out turn

The hybrid H6.3 had the highest yield which was not significantly different (P ≥ 0.05) from four other hybrids H39.4 (30.66 kg), H1.3 (29.50 kg), H23.3 (27.90 kg) and H34.3 (27.98 kg). The lowest yield was recorded by hybrid H42.4 which did not differ significantly (P ≥ 0.05) from other 13 hybrids.

Regarding nut size the hybrid H34.3 attained the highest nut weight (10.36 g) which did not differ significantly (P ≥ 0.05) from H59.4 (9.86 g), H24.3 (9.81 g), H19.1 (9.70 g), H29.1 (9.54 g) and H2.1 (9.35 g). Hybrid H7.3 was the last in terms of nut size and was not significantly different (P ≥ 0.05) from other six hybrids. On kernel weight H34.3 (3.11 g) ranked first

however, it was not significantly different (P ≥ 0.05) from ten other hybrids. On the other hand, H7.3 (2.11 g) had a least kernel weight which was not significantly different (P ≥ 0.05) from five other hybrids. For percentage out-turn, H23.3 (36.22 g) had the highest out-turn compared to other hybrids and was statistically significant (P≤0.05). In contrast hybrid H59.4 recorded the lowest percentage out turns (28.72%) which did not differ significantly (P ≥ 0.05) from other four hybrids.

The lowest disease incidence of 1.6% was recorded from H68.4 and did not differ significantly (P ≥ 0.05) from all hybrids with scores of less than 11.16%. The highest incidence (16.66%) was recorded by H2.1. However, it was statistically (P ≥ 0.05) the same with all hybrids having the disease incidence of more than 5.5%.

Discussion

Results from this study showed high significant difference on all parameters among the hybrids opening a wide room of making effective selection. In 2020/2021 season the cashew trees in this trial were thirteen years old. The yield data revealed that over the past four years, the control variety AC4 ranked 20th (2017), 8th (2018), 13th (2019) and 14th (2020) indicating that majority of the hybrids were potentially higher yielding compared to the control variety. Yield for the hybrids in 2020 ranged from 13.03 kg/tree to 33.57 kg/tree. The range was higher than the one reported by Aliyu and Awopetu (2007a) of 7.82 to 14.04 kg/tree for Nigeria cashew germplasm collections. Desai (2008) obtained yields of 0.25, 2.41, 8.65, 10.02 and 30.50 kg/tree for some Tanzania cashew varieties. The yield was also comparable higher than the one reported by Dadzie *et al.* (2014) of 11.2 to 14.43 kg/tree for cashew clones in Ghana and the improved varieties reported by Desai *et al*. (2010) in India producing 10-15 kg/tree. The wide margin in yield per tree is dependent on the genetic source of the materials (Aliyu, 2006). The mean yield of this trial for 2020 was 21.18 kg/tree. The mean yields are far higher than the one reported by Adeigbe *et al.* (2015) for cashew genotypes in Nigeria yielding an average of 10 kg/tree.

Regarding nut and kernel weights, a number of hybrids were superior to the control variety AC4 which ranked 24th and 23th respectively. The mean nut weight ranged from 6.51 g to 10.36 g which was within the range of the results from Blaikie *et al.* (2002) who reported a range of 5.3 g to 10.9 g. The mean for nut weight was 8.44 g implying the nut count per kilogram would be 118 which was quite good. Processors accept nut count of equal or less than 200 as the nut count above that nuts are not easily processed due to its small size (Masawe and Kapinga, 2016).

All hybrids had kernel weight greater than 2 g. Today, because of the emphasis on quality of the nut, there is greater focus on identification of varieties with kernel weights over 2 g (Costa and Bocchi, 2017). The percentage out turn ranged between 28.72 and 36.22%. The range was also comparable higher than the one reported by Blaikie *et al.* (2002) of 26% and 34% for cashew hybrids in Australia. According to Gyedu-Akoto *et al.* (2014), nuts with a good kernel yield have outturn ranging from 24-28% (standard grade) and an excellent one from 28-32% (excellent grade).

A total of 17 hybrids had the blight disease incidence of less than 10% which imply that they are partially resistant. It was interesting to note that a number of genotypes were below the control variety in percentage blight disease incidence suggesting that there is possibility of obtaining hybrids which are intermediate to resistant against the disease, paving way for release.

Conclusion

The study showed a number of hybrids to outperform the control variety AC4 in both yield, nut quality and resistance to cashew leaf and nut blight disease. Percentage out turn of the hybrids ranged from 28.72 to 36.22% hence these attributes is of paramount importance to cashew processors. On average 3 kg of raw nuts from these elite hybrids can produce 1 kg

of cashew kernels compared to 5 kg from local cashew trees or 4 kg from the majority of other improved cashew varieties. This open an opportunity of getting new cashew varieties superior to the existing varieties.

Recommendations

As far as yield, nut quality and resistance to cashew leaf and nut blight disease are concerned H68.4, H19.1, H39.4, H8.3, H7.3, H34.3, H49.4, H1.3, H64.4, H8.1, H6.3, H29.1, H23.3, H38.4 and H43.4 are recommended for commercialization in Nachingwea and areas with similar climatic conditions as they excelled and outperformed the control cashew variety AC4.

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Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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