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Agronomic evaluation of some progenies resulting from crosses between double self-fertilised genitors of *Deli* and *La Mé* origins used in oil palm (*Elaeis guineensis* Jacq.) seed production in Côte d'Ivoire

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ABSTRACT

Progeny tests carried out between self-fertilised double genitors (DA 115 D AF AF and LM 2 T AF AF) used in seed production in the C 1001 F category were set up in Côte d'Ivoire in 2005, in order to identify crosses producing good oil yields and capable of adapting to current climatic conditions. The aim of this study was to assess the agronomic values and growth rate of palm height of these progenies compared with two first-cycle controls, LM 2 T x DA 10 D and LM 2 T x DA 115. Their susceptibility to Fusarium wilt figurewas also assessed. The results of these tests showed a low bunch yield of around 99% on the one hand, and a 115% increase in oil yield compared with the first cycle on the other. In addition, two progenies, LM 25759 and LM 25753, performed exceptionally well, with oil yields of 125% and 127% respectively and a 97% reduction in palm height growth rate compared with the first cycle. These two progenies were also tolerant to Fusarium wilt with Fusarium index of 40 and 79 respectively.

Keywords: Oil palm, double self-fertilisation, inbreeding depression, Côte d'Ivoire.

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.), native to tropical Africa, is a monoecious, allogamous, diploid plant (2n = 32 chromosomes) of the Arecaceae family. This plant is cultivated mainly for the two types of oil it produces: palm oil extracted from the mesocarp of the fruit and palm kernel oil extracted from the kernel. The oil palm is also the world's leading source of vegetable oil

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(Bessou and Rival, 2020). In 2022, global palm oil production was around 77 million tons, spread over an area covering almost 21 million hectares (Descals et al., 2021; USDA, 2023). Oil palm cultivation offers the highest oil yield per hectare among oilseeds, with an average yield of four to six tons of palm oil per hectare, and can reach seven to nine t/ha/year in favourable agropedoclimatic conditions (Durand-Gasselin et al., 2011; Rival, 2013). This high yield per hectare is due to the mastery of the technical itineraries used to establish plantations and above all, to the remarkable productivity gains achieved by the popularised equipment resulting from oil palm improvement program (Jacquemard, 2013).

In oil palm, varietal improvement is based on a reciprocal recurrent selection (RRS) scheme that exploits the heterosis effect existing between two population groups (A and B) with complementary characteristics (Durand-Gasselin et al., 2009; Cros, 2014). Group A is characterised by palms producing a small number of large bunches of Asian (Deli) and Angolan origin (Adon et al., 2021a). Group B is made up of palms producing a large number of small bunches from various African origins, including *La Mé* (Côte d'Ivoire) (Noumouha, 2015). Two cycles of selections have already been carried out, with significant genetic progress. This progress was marked by an increase in oil production from 2 to 8 t/ha under favourable ecological conditions. Also, the growth rate in palm height of these selected palms has been reduced by around 45 cm/year, with tolerance to Fusarium wilt (Cochard et al., 2001; Durand-Gasselin et al., 2002). In view of the new challenges facing these selected materials, namely climate change, soil degradation and impoverishment, and the strong global demand for palm oil, efforts to improve varieties need to be pursued (Woittiez et al., 2017; Swaray, et al., 2021).

With this in mind, a genetic trial was set up in 2005 involving progeny from double self-fertilisation of certain *Deli* and *La Mé* type genitors used for seed production at the *La Mé* research station in Côte d'Ivoire. The aim of this study was to assess the agronomic values, tolerance to Fusarium wilt and growth rate in palm height of these progenies in order to make better use of the progenitors in the selection scheme for improving oil palm in Côte d'Ivoire. These results will enable conclusions to be drawn for the continuation of the selection scheme.

MATERIALS AND METHODS

Planting material

The plant material consists of 13 oil palm progenies (Table 1). These progenies were obtained from crosses between 12 Dura (*Deli*) palm progenitors and 7 Pisifera (*La Mé*) palm progenitors. The genitors used to obtain these progenies were all obtained by self-fertilisation of certain genitors selected during the second cycle of RRS. The cross was DA 115 D AF AF x LM 2 T AF AF. This trial also included two controls from the first cycle, including LM 2 T x DA10 D and LM 2 T x DA115 D.

Experimental set-up

The trial was set up in 2005 on plots C9/1 and D9/4 at Ehania / PALMCI, located in the south-east of Côte d'Ivoire, 140 km from Abidjan, in the Aboisso Division (5°19' N; 2°46' W; 12 m). The climate is characterised by four seasons, including two rainy seasons and two dry seasons. The average annual sunshine is estimated at 1800 hours. The average annual temperature ranges from 22 to 31°C and rainfall between 1,700 and 2,200 mm with a relative humidity of 80 %. Soil texture is predominantly clay and sand (Kablan, 2020). The trial comprised of 1280 palm trees arranged in a balanced 4 x 4 square lattice with 5 replicates, and the experimental unit was made up of 16 palm trees. However, one offspring was not included in our study. The density was 143 trees per hectare.

Parameters measured

Bunches yield parameters and components

The components of clusters yield, i.e. the bunch number (BN) and the total bunch weight (TWB) were recorded over a four-year (2014-2018) period for each producing palm at maturity nine years after planting (Bakoumé et al., 2010; Allou et al., 2017; Adon et al., 2021b)

- The BN was obtained by counting the number of bunches harvested from each tree and aggregating these monthly values for each year of production.
- The TBW was determined by weighing the bunch harvested from each tree individually. The total weight of bunches, expressed in Kg per year, was obtained by adding up the monthly weight values.
- The average bunch weight (ABW), which is also one of the components of operating efficiency, was determined according to the following relationship:

ABW = TBW / BN **1**

- The bunch yield (BY) was determined using the following formula:

BY (t/ha) = TBW x [143 – (143 x 0,05)] **2**

With: 143 corresponding to the number of palms per hectare; 0.05 constant value representing the proportion of non-productive palms per hectare of oil palm cultivation.

Oil yield and industrial oil extraction rate

The industrial oil extraction rate (OER) was determined following a series of physico-chemical analyses carried out on at least three bunches harvested from all the Tenera palm producers of each progeny. The OER was obtained using the following formula (Bakoumé et al., 2010; Adon et al., 2021b):

OER = (F/B × M/F × O/M × 0.855)/10000 **3**

With % F/B: the percentage of fruit to bunch, % M/F: the percentage of mesocarp to fruit, % H/M: the percentage oil to mesocarp and 0.855 corresponding to the coefficient linked to losses during palm oil extraction.

The oil yield (OY) of the progenies was determined according to the following relationship (Bakoumé et al., 2010; Adon et al., 2021b):

OY = BY x OER **4**

Vertical Growth Rate (VGR)

The growth rate in palm height of the progeny was determined by measuring the palm height as described by Jacquemard (1980) using the following formula:

VGR = H / (N - 3.75) **5**

Where VGR is the vertical growth rate, H is the height of the palm, N is the age of the palms measured and the value 3.75 represents the age of the fictitious take-off from the ground of leaf 33 of the palm, from which the growth rate is constant within the limits of climatic contingencies.

Fusarium wilt index

For the Fusarium wilt susceptibility test, the inoculum (Foe strain 179) was prepared, applied in the prenursery at the two-leaf stage and infected plants were identified using the method described by Gbongué et al. (2012); Diabate et al. (2013). The susceptibility of each of the progenies to Fusarium wilt was obtained using its Fusarium index (IF) according to the following relationship:

IF = [(Percentage of infected seedlings of the progeny) / (Percentage of infected seedlings of all progenies)] x 100. **6**

Progenies with an index below 100 are said to be tolerant, while those with an index above 100 are susceptible to Fusarium wilt (Kablan et al., 2018; Adon et al., 2021b).

Statistical analysis

Descriptive statistics parameters such as means and coefficients of variation were used to assess the average performance of the 15 progenies in the trial. Next, the generalised linear model (GLM) procedure in SAS 9.4 software was used to perform the analysis of variance (ANOVA). Finally, Duncan's Multiple Range Test (DMRT) was used to compare the means of the 15 progenies in the trial (Dagnelie, 2012). These tests were all applied at α threshold of 5%.

Table 1: Origin of plant material assessed.

Progeny number in the trial	Progeny	Cross	Genetics origins of the RRS DA 115 D AF AF x LM 2 T AF AF
1	***LM 25287***	LM 2 T x DA 10 D	Control
2	**LM 25286**	LM 2 T x DA 115 D	
4	LM 25767	LM 7120 D x LM 12426 P	LM 2509 D AF x LM 3387 T AF
5	LM 25772	LM 7106 D x LM 13534 P	
6	LM 25769	LM 10374 D x LM 13545 P	LM 2523 D AF x LM 3387 T AF
7	LM 25771	LM 10374 D x LM 13545 P	
8	LM 25757	LM 10357 D x LM 12417 P	
9	LM 25761	LM 10390 D x LM 13539 P	LM 2523 D AF x LM 2453 T AF
10	LM 25760	LM 10448 D x LM 13534 P	LM 3005 D AF x LM 3387 T AF
11	LM 25763	LM 10440 D x LM 12417 P	
12	LM 25753	LM 10455 D x LM 13535 P	
14	LM 25765	LM 6731 D x LM 12668 P	LM 2515 D AF x LM 3390 T AF
13	LM 25770	LM 7651 D x LM 12417 P	LM 2515 D AF x LM 3387 T AF
15	LM 25766	LM 7655 D x LM 13545 P	
16	LM 25759	LM 6725 D x LM 13534 P	

In bold and italic : control first cycle, In bold : parental control first cycle, Numbered progeny were not taken into account in the study.

RESULTS

Statistical test results

Analyses of variance (ANOVA) performed on each of the different traits in this study revealed significant differences between progeny and controls (Tables 2 and 3). This differentiation was therefore assessed by Duncan's test for each trait.

Bunch Yield

The bunch yield (BY) of the progenies varied from 20.09 t/ha (147.908 kg/palm/year) to 23.31 t/ha (171.62 kg/palm/year) with an average bunch weight (ABW) of 13.82 to 17.87 kg/year and a bunch number (BN) ranging from 8.69 to 11.24 (Table 4). The average values for BY, ABW and BN were 21.46 t/palm/ha, 15.64 kg/year and 10.29 respectively.

With regard to BY and BN, Duncan's test revealed that only two (2) progenies, namely LM 25759 and LM 25753, performed better than the control LM 25287 (LM 2 T x DA 10 D) (Table 4). The average BY values for these two progenies were 23.018 and 23.074 t/ha with BNs of 11.23 and 11.224 respectively. However, all the progenies produced a higher BN than the LM 25286 control (LM 2 T x DA 115 D) and only the LM 25766 progeny produced a low BY than this control. As for ABW, all progenies produced smaller bunches than the control LM 25287 (LM 2 T x DA 115 D) with an AWB of 17.87 kg/year. However, compared the control LM 25287 (LM 2 T x DA 10 D), six (6) the progenies produced large bunches ranging from 15.93 (LM 25761) to 16.356 kg/year than this control (Table 4).

Oil Yield

The oil yield (OY) of the progenies ranged from 4.606 to 5.882 t/ha/year with an industrial oil extraction rate **(**OER) ranging from 21.202 to 26.04% (Table 5). The mean values for OY and OER for the trial were 5.23 t/oil/ha/year and 24.35% respectively.

In terms of both OY and OER, the Duncan test showed that eight (8) progenies performed better than the two controls in the trial (Table 5). The average values of these progenies varied from 5.26 t/oil/ha (LM 25761) to 5.88 t/oil/ha (LM 25753) for OY and from 24.65% (LM 25769) to 26.04% (LM 25767) for OER. In addition, the control LM 25287 (LM 2 T x DA 10 D) was the lowest producer of OER and OY in the trial. Also, all the progenies produced higher percentage of mesocarp on fruit and oil on mesocarp the than controls (result not shown).

Vertical growth rate

The vertical growth rate (VGR) of the progenies varied from 37.40 to 48.68 cm/year, with an average rate of 42.34 cm/year (Table 5).

The Duncan test showed that only two progenies, LM 25770 and LM 25771, had a low GRV than the two controls (LM 25287 and LM 25286) in the trial. The average GRVs of these two progenies were 37.401 and 37.584 cm/year respectively (Table 5). In addition, nine other progenies outperformed the two controls in the trial for the same trait.

Variability the oil production and growth rate in palm height of progenies

The variability observed in the different progenies was assessed by their coefficients of variation (CV%) (Table 6). This variability was high for oil production, with an average CV of 23.22%. However, it moderate for bunch and fruit quality and vertical growth rate, with average CVs of 13.29% and 12.61% respectively.

Fusarium wilt index

All progenies were tested for susceptibility to Fusarium wilt head blight. Only progeny LM 25765 showed susceptibility with a Fusarium disease index of 104 (IF > 100) (Figure 1).

Table 2: Analysis of variance of bunch yield and its components.

Source of variation	Components of bunch yield							Brunch yield (BY)	
		BN		ABW		TBW			
	df	MS	F	MS	F	MS	F	MS	F
Repetition	4	0,30	0,93^{ns}	1,94	8,07**	66,17	0,86^{ns}	1,21	0,85^{ns}
Progeny	14	3,27	10,21**	5,06	21,08**	282,16	3,68*	5,20	3,68*
Residual error	56	0,32		0,24		76,81		1,41	

df: degree of freedom; TBW: total bunch weight; BN: bunch number; ABW: average bunch weight; MS: mean square; F: Fisher value calculated; *: value significant at 5%; **: value significant at 1%; ns: value not significant.

Table 3: Analysis of variance of oil production and vertical growth rate.

Source of variation	industrial oil extraction rate (OER)			Oil yield (OY)		Vertical Growth Rate (VGR)	
	df	MS	F	MS	F	MS	F
Repetition	4	4,42	1,27^{ns}	0,07	0,87^{ns}	38,54	4,97*
Progeny	14	8,03	2,32**	0,58	7,25**	42,57	5,48**
Residual error	56	3,46		0,08		7,75	

MS: mean square; F: Fisher value calculated; *: value significant at 5%; **: value significant at 1%; ns: value not significant.

Table 4: Comparison of mean values of bunch yield and its components.

Components of bunch yield									Bunch yield (BY)		
Bunch number (BN)			Average bunch weight (ABW)			Total bunch weight (TBW)					
Progeny	**Mean**	**Grouping**	**Progeny**	**Mean (kg)**	**Grouping**	**Progeny**	**Mean (kg)**	**Grouping**	**Progeny**	**Mean (t/ha)**	**Grouping**
LM 25769	11,244	A	**LM 25286**	17,872	A	LM 25761	171,620	A	LM 25761	23,316	A
LM 25759	11,23	A	LM 25770	16,356	B	LM 25753	169,838	AB	LM 25753	23,074	AB
LM 25753	11,224	A	LM 25765	16,342	B	LM 25759	169,448	ABC	LM 25759	23,018	ABC
LM 25757	11,1	A	LM 25763	16,318	B	LM 25770	161,260	ABCD	LM 25770	21,906	ABCD
LM 25287	11,016	AB	LM 25767	16,168	BC	***LM 25287***	159,872	ABCDE	***LM 25287***	21,72	ABCDE
LM 25761	10,92	AB	LM 25772	16,050	BCD	LM 25771	158,646	BCDE	LM 25771	21,55	BCDE
LM 25760	10,478	ABC	LM 25761	15,930	BCD	LM 25765	157,216	CDE	LM 25765	21,36	CDE
LM 25771	10,282	BCD	LM 25771	15,652	BCDE	LM 25760	156,964	CDE	LM 25760	21,324	CDE
LM 25770	10,068	CDE	LM 25766	15,624	BCDE	LM 25772	156,940	CDE	LM 25772	21,32	CDE
LM 25772	9,932	CDE	LM 25753	15,302	CDE	LM 25769	152,652	DE	LM 25769	20,738	DE
LM 25765	9,728	CDE	LM 25759	15,206	DE	**LM 25286**	152,610	DE	**LM 25286**	20,732	DE
LM 25766	9,586	DE	LM 25760	15,176	DE	LM 25767	151,150	DE	LM 25767	20,534	DE
LM 25767	9,534	DE	***LM 25287***	15,002	E	LM 25757	151,140	DE	LM 25757	20,534	DE
LM 25763	9,392	EF	LM 25769	13,836	F	LM 25763	151,136	DE	LM 25763	20,532	DE
LM 25286	8,698	F	LM 25757	13,828	F	LM 25766	147,908	E	LM 25766	20,092	E

In bold and italic : control first cycle, In bold : parental control first cycle, Progeny with the same letter are not significantly different.

Table 5: Comparison of mean values of oil production and vertical growth rate.

industrial oil extraction rate (OER)			**Oil yield (OY)**			**Vertical Growth Rate (VGR)**		
Progeny	Mean (%)	Grouping	Progeny	Mean (t/ha)	Grouping	Progeny	Mean (cm/yr)	Grouping
LM 25767	26,04	A	LM 25753	5,882	A	LM 25765	48,686	A
LM 25763	26,015	A	LM 25759	5,768	AB	LM 25760	44,674	AB
LM 25760	25,795	AB	LM 25760	5,496	ABC	LM 25767	44,221	ABC
LM 25766	25,736	AB	LM 25765	5,476	BC	LM 25772	44,133	ABC
LM 25765	25,652	AB	LM 25767	5,354	CD	**LM 25286**	43,907	BC
LM 25753	25,463	AB	LM 25770	5,342	CD	LM 25759	43,187	BC
LM 25759	25,25	AB	LM 25763	5,338	CD	LM 25766	42,984	BC
LM 25769	24,652	ABC	LM 25761	5,26	CD	LM 25769	42,949	BC
LM 25770	24,34	ABCD	LM 25766	5,182	CDE	***LM 25287***	42,510	BC
LM 25771	23,62	ABCD	LM 25769	5,112	CDE	LM 25757	42,436	BC
LM 25757	23,421	ABCD	LM 25771	5,1	CDE	LM 25761	40,854	BCD
LM 25772	23,227	ABCD	LM 25772	4,952	DEF	LM 25753	40,339	BCD
LM 25286	23,007	BCD	**LM 25286**	4,782	EF	LM 25763	39,254	CD
LM 25761	22,513	BCD	LM 25757	4,774	EF	LM 25771	37,584	D
LM 25287	21,202	CD	***LM 25287***	4,606	E	LM 25770	37,401	D

In bold and italic : control first cycle, In bold : parental control first cycle, Progeny with the same letter are not significantly different.

Table 6: Coefficient of variation (CV %) of the oil production and the vertical growth rate.

Progeny	Oil prodcution	Bunch and fruit quality	Vertical growth rate
LM 25753	22,96	11,03	14,22
LM 25757	22,04	15,36	12,83
LM 25759	21,65	11,22	15,37
LM 25760	23,07	14,16	12,47
LM 25761	22,77	6,39	10,1
LM 25763	23,44	12,26	12,69
LM 25765	25,52	13,08	11,76
LM 25766	22,41	15,97	9,95
LM 25767	24,4	12,57	12,32
LM 25769	22,93	14,95	11,9
LM 25770	23,73	14,44	18,98
LM 25771	23,73	13,7	12,18
LM 25772	23,27	17,6	9,14

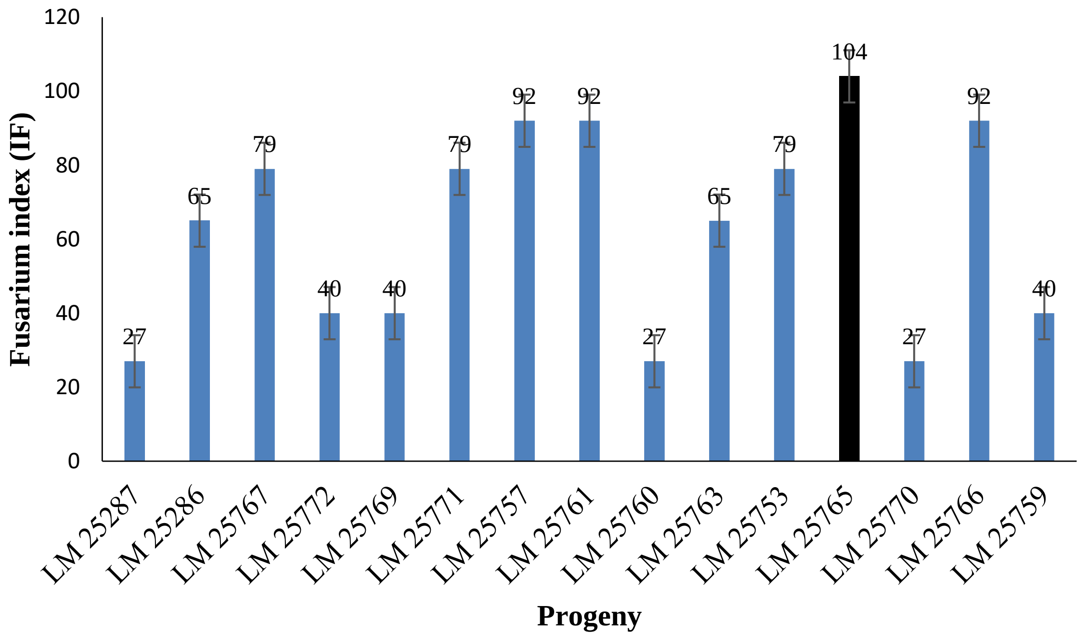

Figure 1: Behaviour of progenies in relation to *Fusarium*, **in black**: *Fusarium*-susceptible progeny.

DISCUSSION

After two cycles of reciprocal recurrent selection for oil palm in Côte d'Ivoire, a third-cycle trial was carried out between self-fertilised double progenitors used for seed production in the C 1001 F category. The progeny from these crosses were expected to show genetic progress in terms of bunch and oil yield, reduction in palm height growth and tolerance to Fusarium wilt. These progenies did not meet expectations in terms of bunch yield. In fact, all the progenies produced a bunch yield and bunch number respectively of around 99% and 94% compared with the LM 2 T x DA 10 D control. They also produced an average bunch weight of 87% compared with the LM 2 T x DA 115 D control. This low bunch yield could be due to the fact that the double self-fertilisation of the two parents probably exposed their offspring to the inbreeding effect. These results are in agreement with those obtained by Mayes et al. (2008); Mathews et al. (2021, 2023). According to these authors, progeny from self-fertilisation of both parents were exposed to inbreeding depression for bunch yield and its components. However, four progenies, namely LM 25770, LM 25759, LM 25753 and LM 25761 produced a bunch yield of around 101 to 107% compared to the LM 2 T x DA 10 D control.

Despite their low bunch yield, the progenies had an oil yield of around 115% compared to the LM 2 T x DA 10 D control. In addition, this oil yield reached 125% and 127% respectively for progenies LM 25759 (5.768 t/oil/ha) and LM 25753 (5.882 t/oil/ha). Since oil production is the resultant of the product of bunch yield and bunches and fruit quality components, this improvement in oil production can be attributed to bunches and fruit quality components, more specifically the percentages of mesocarp on fruit and oil on mesocarp. Similar results were obtained by Luyindula et al (2005); Tano et al. (2019). According to these authors, progeny derived from parental self-fertilisation were not very affected by inbreeding depression for the components of bunch and fruit quality. However, it should be noted that the progeny nevertheless recorded low percentages of fruit on the bunch. This low fruit rate is thought to be due to the reduced vigor of the progenies under the effect of inbreeding depression, leading to the formation of abnormal fruit. These results corroborate those obtained by Tano et al. (2020). These authors showed that progenitors derived from self-fertilisation were characterised by a low percentage of bunch on fruit and a high percentage of pulp on mesocarp.

With regard to growth rate height, all the progenies showed a growth rate in palm height of around 99% compared with the LM 2 T x DA 10 D control. In addition, they were all homogeneous for this trait, with the exception of progeny LM 25765, which showed rapid growth in palm height of around 115%, i.e. 48.21 cm/year. These results show that double self-fertilisation of the two parents led to an increase in the frequency of homozygosity in the various progeny for the vertical palm growth trait. Similar results were obtained by Mathews et al. (2008); Bakoumé et al. (2010). According to these authors, self-fertilisation of oil palms has exposed their progeny to inbreeding depression, leading to homogenisation and reduced growth in palm height. In addition, the growth rate of our progenies is comparable to the results obtained from the progenies the third cycle of the studies conducted by Assouman et al. (2019); Fofana et al. (2023).

With regard to tolerance to Fusarium wilt, all the progenies were tolerant to Fusariun wilt with the exception of the progeny of LM 25765 which was susceptible with an IF = 104. These results could be explained by the fact that the double self-fertilisation of Fusarium-tolerant progenitors favoured the accumulation of the genes responsible for resistance to this disease. These progenitors then passed on these genes to their offspring. These results are in line with those obtained by Corley and Tinker (2003); Noumouha et al. (2014). According to these authors, tolerance to Fusarium wilt is consistently transmitted to their progeny.

Taking into account all the traits in this study, only two progenies, LM 25759 and LM 25753, performed better than the controls, with oil yields of 125% and 127% respectively compared to the first cycle. This result from the progeny test is hardly surprising, since the parents were inbred material from double self-fertilisation of DA 115 D and double self-fertilisation of LM 2 T.

Conclusion

This study involved evaluating progenies from crosses between DA 115 D AF AF and LM 2 T AF AF in the third cycle of reciprocal recurrent selection for oil palm in Côte d'Ivoire in order to identify crosses that are highly productive in terms of oil yield and that respond to current climatic conditions. To do this, the bunch and oil yields, growth rate in palm height and tolerance to Fusarium wilt of these progenies, including the two controls from the first cycle, were determined and compared. The results of this study showed that the progenies produced a yield of 99% in bunch and 115% in oil, with a 99% reduction in growth rate in palm height compared with the first selection cycle. The progenies were also tolerant to fusarium wilt with the exception of one. Comparison of the performance of these progenies with each other and with that of the controls for all the traits assessed in this study revealed that only progenies LM 25759 and LM 25753 were exceptional, with a 106% bunch yield and a 97% reduction in palm height growth rate. In addition, these two progenies produced oil yields of 125 and 127% and Fusarium wilt index of 40 and 79 respectively. Given the new selection criteria such as palm oil acidification, it is therefore imperative to assess the acidity of the oil produced by these progenies before integrating their progenitors into commercial seed production.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All the authors contributed to the realization of this work, and SOUMAHORO Mègbê was the principal investigator. All of them contributed to the correction of the manuscript.

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