African Crop Science Journal, Vol. 21, No. 4, pp. 303 - 310 ISSN 1021-9730/2013 $4.00

EFFECT OF FRUIT SET ON FRUCTIFICATION OF COCONUT TALL ECOTYPES FOR PRODUCTION OF HYBRID SEEDNUTS IN CÔTE D'IVOIRE

A.E. ISSALI, T.T. LEKADOU, A.E.B. NGUESSAN[1], J.L. KONAN, K. ALLOU and A. ADIKO[2]
Station Cocotier Port Bouët Marc Delorme, CNRA, 07 BP 13 Abidjan 07, Côte d'Ivoire
[1]Direction Régionale de Korhogho du CNRA, BP 856 Korhogo, Côte d'Ivoire
[2]Conseil Scientifique, Chargé de la Coopération Internationale du CNRA. 01 BP 1740. Direction Générale du CNRA. Km 17, route de Dabou, Côte d'Ivoire
Corresponding author: issaliemma@yahoo.com

(Received 18 December, 2012; accepted 15 August, 2013)

ABSTRACT

To assess the effect of coconut fruit set on the variation expression of the number of nuts yielded at the end of the fructification, a modelling approach was used. Four female parents namely Kar Kar Tall (KKT), Kappadam Tall (KPD), Sri Lanka Tall (SLT) and Vanuatu Tall (VTT) as well as four male parents known as Panama Aguadulce Tall (PNT01), Rennell Island Tall (RIT), Tagnanan Tall (TAG) and West African Tall (WAT) were involved in six crosses. The WAT was used as a control. Results showed that fruit set and fructification was female genotype and crossing-independent. Thus, the four female genotypes can be indifferently used in crossings to produce seednuts. In contrast, pollen age discriminated the male parents into two groups, especially 1) PNT01, TAG and 2) WAT and RIT. Nevertheless, the two latter male parents WAT and RIT, having provided the oldest pollen, did not induce significant differences among crosses. Fruit set explained 83.70% fluctuations of the fructification. Hence, it exerted a significant effect on the fructification variation expression. In Côte d'Ivoire, we could predict the seednuts production coming to maturity from the fruit set using the equation Nut = 0.006 + 0.774*Setfruit.

Key Words: *Cocos nucifera,* modelling, pollen age

RÉSUMÉ

Pour évaluer l'effet de la nouaison sur l'expression de la variation du nombre de noix produites au terme de la fructification, la modélisation a été utilisée. Quatre parents femelles de cocotier nommés Grand Kar Kar (GKK), Grand des Indes Kappadam (GND5), Grand Sri Lanka (GSL) et Grand Vanuatu (GVT) ainsi que 4 parents mâles désignés Grand Panama (GPA1), Grand Rennell (GRL), Grand Tagnanan (GTN) and Grand Ouest Africain (GOA) ont été impliqués dans 6 croisements. Le GOA a servi de témoin. Les résultats ont montré que la nouaison est génotype femelle et croisement indépendants. Donc, les 4 génotypes femelles peuvent être utilisés indifféremment dans les croisements pour produire les semences. A l'opposé, l'âge du pollen discrimine les parents mâles en 2 groupes distincts, à savoir : 1) GPA1 et GTN et 2) GOA et GRL. Néanmoins, les 2 derniers parents mâles que sont le GOA et le GRL, ayant fourni le plus vieux pollen, n'induisent pas de différences significatives entre les croisements. La nouaison explique 83.70% des fluctuations de la fructification. En conséquence, elle exerce un effet significatif sur l'expression de la variation de la fructification. En Côte d'Ivoire, nous pourrions prédire la production de semences arrivant à maturité à partir de la nouaison en utilisant l'équation Nut = 0.006 + 0.774*Setfruit.

Mots Clés: *Cocos nucifera*, modélisation, âge du pollen

INTRODUCTION

Coconut (*Cocos nucifera* L.), is a perennial, oleiferous, diploid and monocotyledonous plant of the Arecaceae (Guyot, 1992). It is used as food and source of fat for the oil-industry (Frémond *et al.*, 1966). In world, the area covered by coconut farms is 12 million hectares for yielding of 61 billion nuts (Amrizal, 2003). This is equivalent to 4.9 million tonnes of copra per year (Amrizal, 2003). In Africa, Côte d'Ivoire is the second producing country of copra after Mozambique; and is the top exporting country of coconut products. The Côte d'Ivoire genebank is the most diversified in the world as well as in relation to origins and numbers. It comprises 99 accessions conserved in field.

To date, the effect of the fruit set on the fructification variation in coconut palm, at the Marc Delorme Station, remains uninvestigated. Such an oversight is very harmful both to programming of genebank regeneration and seednuts shipment to customers of the Centre National de Recherche Agronomique (CNRA). Indeed, in relation to genebank regeneration, coconut tall ecotypes are preferentially cross-pollinated, nonetheless natural and artificial selfings can take place. The former via male and female phases partial overlapping in some tall coconuts, while the latter through controlled hand-pollinations. Their regeneration takes place by isolation of the inflorescence, by means of pollination jute-bags. The controlled hand-pollination technique allows the regenerating of tall ecotypes from crosses sib x sister. The weak permeability of jute-cloth reduces air movement, and hence, increases the temperature in bag. This triggers abortions, and hence, reduces yield in seednuts coming from controlled hand-pollinations. This yield, which is in the order of 2-3 seednuts, is weak, against 5-10 seednuts of assisted hand-pollinations (De Nucé and Wuidart, 1992). Due to such a weakness, the fitness quality (R^2) would be also weak, and even null.

Likewise, as for seednuts shipment to customers of CNRA, the lack of a predicting model from set fruits makes it difficult to honour promises to our custumers. Although checking of fruit set takes place three months after pollinating, prediction with accuracy, of the seednuts to be harvested at the end of fructification is often difficult. Consequently, the knowledge of the link between the number of fruit sets and fruits harvested at the end of fructification could allow prediction of the number of fruits to be harvested at the end of fructification. This would permit programming with effectiveness genebank regeneration and fullfill agreement made with customers. Furthermore, on account of the existence of two independent origins of cultivated coconuts, which are the Pacific and Indo Atlantic oceanic basins (Gunn *et al.*, 2011), this would offer opportunities for induction of some differences in the female fertility of ecotypes involved in crosses.

The objective of this study was to assess the effect of fruit set on the expression of fructification in coconut palm from data collected on six tall x tall coconut crosses.

MATERIALS AND METHODS

Experiment was conducted from 2001 to 2002 at the Marc Delorme Coconut Research Station (MDCRS) located at Port Bouet in Côte d'Ivoire (03°10' N and 04°58' E and 20 m above sea). Mean temperature from 2000 to 2009 was 26.26 °C. The yearly mean pluviometric total for the ten years was 1830.09 mm.

Pollination was done in 2001, whereas harvests of seednuts were it in 2002. The number of cross or treatment replications varied from 8 to 9.

Four female parents Kar Kar Tall, Kappadam Tall, Sri Lanka Tall and Vanuatu Tall as well as four male parents Panama Aguadulce Tall, Rennell Island Tall, Tagnanan Tall and West African Tall were involved in six crosses. Some seednuts from these crosses were used to set up the multi-local experiment at the Marc Delorme Coconut Research Station. The common coconut palm, which originated from West Africa, termed West African Tall, was used as a control (Tables 1 and 2). Other seednuts were to be exported to Mozambique.

With respect to male and female parents involved in crosses, a list containing their location in different fields was established (Table 1). The hierarchical crossing system was conceived by researcher and transmitted to controlled

TABLE 1. Treatments, used coconut ecotypes and their origin in the fruitfication verses fruitset study in Côte d'Ivoire

Treatment type	Sex of crossed ecotype	Ecotype	Abbreviation initials	Field	Origin
Tested treatment	Female	Kar Kar Tall	KKT	102	Papua New Guinea (Pacific)
		Kappadam Tall	KPD	101	India (Indo-Atlantic)
		Sri Lanka Tall	SLT	112	Sri Lanka (Indo-Atlantic)
		Vanuatu Tall	VTT	022, 023	Vanuatu (Pacific)
	Male	Panama Aguadulce Tall	PNT01	M63	America (Panama)
		Rennel Island Tall	RIT	M60, 111	Rennel Island (Pacific)
		Tagnanan Tall	TAG	083, 102	Philippines (Pacific)
		West African Tall	WAT	M63	Africa (Indo-Atlantic)
Control	Female/male	West African Tall	WAT	M63	Africa (Indo-Atlantic)

pollination sub-division. The latter recorded it, then transmitted to pollen harvesting and conditioning sub-division from selection division. The latter identified the number of father trees of which leaf crown was attainable by means of triple ladder with a view to collect the pollen. Indeed, some fields with trees which are planted there are twenty years old. Their leaf crowns are more 20 m tall. For trees taller than 20 m from soil surface, their leafy crown was difficult to attain using double-ladder. The identified trees were visited daily to monitor the spathe dehiscence. Whenever a spathe opened. It was immediately dressed with male pollination bag seven day later, it was emasculated and maintained in the bag. Pollen was extracted from male flowers and conserved in a freezer at -20 ^{o}C. Six days later, the controlled pollination team pollinated it avoiding selfing. Prior, *in vitro* pollen germination rate was assessed. Crosses sib x sister were carried out. In the same way, when the father trees number was insufficient, controlled pollination team chose other father trees. These were also visited every day. Bloomed spathes were emasculated and bagged seven days later.Their pollination took place six days after emasculation and bagging.

Twelve to thirteen days later, the seednuts were harvested and sent to nursery.

The age of pollen (Polage) used to pollinate female flowers was recorded. In the same way, the number of set fruits scored three months after controlled hand-pollination (Setfruit) and number of nuts obtained at the end of fruits ripening (Nut) were scored.

The Statistical Package for Social Sciences (SPSS) and Xlstat softwares, 12 and 2007 versions, respectively, were used for the statistical analyses. The data were subjected to ANOVA as well as linear and non-linear regressions. Mean comparison was carried out according to Dunnett's and Newman-Keuls' tests at 5% significance level. Likewise, the Student t test was performed to compare two means when the number of their modalities was lower than 30. The multiple linear regression of the fruit settings on harvested fruits was performed using backward elimination stepwise multiple regression technique (Table 3). The model equation is:

TABLE 2. Crosses used in the nut seeds production and multi-located experiment planted in field 50 at the Marc Delorme Coconut Research Station in Côte d'Ivoire

Cross type	Cross	Abbreviation initials of cross
Tested cross	Vanuatu Tall x Panama Aguadulce Tall	VTTxPNT01
	Kar Kar Tall x Rennell Island Tall	KKTxRIT
	Kappadam Tall x Rennell Island Tall	KPDxRIT
	Kappadam Tall x West African Tall	KPDxWAT
	Sri Lanka Tall x Tagnanan Tall	SLTxTAG
	Vanuatu Tall x Tagnanan Tall	VTTxTAG
Control	West African Tall x West African Tall	WATxWAT

TABLE 3. Choice of variables involved in the equation of regression line through the backward elimination stepwise regression technique

Model*	Introduced variables*	Eliminated variable*	Steps
1	Setfruit Polage	-	Introduction of all of variables
2	-	Polage	Backward elimination

Model* : tested models to assess the impact of fruitset on the fructification expression. Two models were tested: Model 1 including the two explicative variables. Model 2 only comprising the best one. Introduced variables* : These are all of explicative variables introduced in the first model. Eliminated variable* : variable do not induce significant decrease of the coefficient of correlation of the fitted curve termed R^2

$$Y = b0 + b1X1 + b2X2$$

where "Y" is the dependent variable; "b0" is the intercept; b1 is the first partial regression coefficient; X1 is the first independent variable; b2 is the second partial regression coefficient; X2 is the second independent variable.

To normalise measured distributions and equalise the variances of the analysed sub-populations, the number of set fruits scored three months after controlled hand-pollination (Setfruit) and number of nuts obtained at the end of fruits ripening (Nut) were transformed to square root.

RESULTS

There were no significant difference (P>0.05) between fruit sets scored three months after controlled hand-pollination (Setfruit) and the nuts obtained at the end of fruits ripening (Nut), for the female parents and crosses (Table 4). Therefore, only one homogeneous group was identified from these two variables. For female fertility from four parents, the untransformed means ranged from 0.072 to 2.438 set fruits; while for the nut, the range was between 0.049 and 1.079. Regarding the six crosses, the untransformed means of setfruit stretched from 0.125 to 1.721 set fruits; whereas for nut variable, the range was 0.000 to 2.343 nuts. As far as the female parents and crosses are concerned, the gaps in relation to means varied from 3.25 to 19.99% (Table 4).

As for pollen age (Polage) expressing the male fertility, two groups were observed according to both Dunnett and Newman-Keuls tests (Table 4). The first one consisting of PNT01 and TAG was characterised by performances on this side of control WAT. The second one, comprising RIT was distinguishable from the control WAT. The untransformed means varied from 19.76 to 55.93 days after harvesting pollen. The variability around the mean fluctuated from 7.85 to 14.76%.

The regressions of number of nuts obtained at the end of fruits ripening on both pollen age and number of set fruits scored three months after controlled hand-pollination for the Models 1 and

TABLE 4. Classification of means of the number of set fruits scored three months after controlled hand-pollination, number of nuts obtained at the end of fruits ripening , as a function of parents and crosses

Dependent variable	Factor variants	Dunnett	Transformed mean* Newman-Keuls	CV (%)*	Untransformed mean*
Setfruit	KKT	Comparable to control	0.268a	14.70	0.072
	WAT		0.500a	16.32	0.250
	KPD		0.731a	16.33	0.535
	VTT		0.970a	18.49	0.941
	SLT		1.562a	16.33	2.438
Nut	KKT	Comparable to control	0.222a	17.84	0.049
	KPD		0.615a	16.56	0.379
	WAT		0.750	04.50	0.563
	VTT		0.810a	19.15	0.657
	SLT		1.039a	10.89	1.079
Polage	PNT01	On this side of control	4.445a	14.76	19.760
	TAG		4.547a	7.85	20.671
	WAT	Comparable to control	6.484a	9.03	42.042
	RIT		7.479a	6.02	55.934
Setfruit	VTTxPNT01	Comparable to control	0.125a	15.60	0.016
	KKTxRIT		0.268a	13.70	0.072
	WATxWAT		0.500ab	19.56	0.250
	KPDxRIT		0.604ab	03.25	0.364
	KPDxWAT		0.845ab	12.72	0.714
	SLTxTAG		1.562b	16.33	2.438
	VTTxTAG		1.721b	10.98	2.961
Nut	VTTxPNT01	Comparable to control	0.000a	∞	0.000
	KKTxRIT		0.222a	17.84	0.049
	KPDxRIT		0.518ab	12.74	0.269
	KPDxWAT		0.702ab	13.59	0.493
	WATxWAT		0.750ab	16.32	0.562
	SLTxTAG		1.039ab	10.89	1.079
	VTTxTAG		1.531b	19.99	2.343

Transformed mean*: Means were transformed to square root. CV (%)*: Coefficient of variation in percentage. Untransformed mean*: They were obtained by square transformation means

2 were significant (Tables 3 and 5). Regarding Model 1, pollen age and number of set fruits obtained three months after controlled hand-pollination, accounted for 83.70% fluctuations in the number of nuts obtained at the end of fruits ripening. As regards Model 2, the number of set fruits scored three months after controlled hand-pollination, explained 83.70% of variations of the number of nuts obtained at the end of fruits ripening. Thus, the removal of the polage explicative variable did not reduce the prediction represented by the coefficient of determination; namely R^2 (Table 3). Therefore, Model 2 was chosen and used in the rest of the study (Table 5). The linear link between the number of set fruits scored three months after controlled hand-pollination, and number of nuts obtained at the end of fruits ripening, was confirmed through the analysis of Pearson's correlation. Indeed, the number of set fruits obtained three months after controlled hand-pollination and that of nuts obtained at the end of fruits ripening were

TABLE 5. Effect of fruitset on the expression of coconut fructification of cocoa at the Marc Delorme Coconut Research Station in Côte d'Ivoire

Model		SS *	Df*	MS*	F*	P*	R^2 (%)*
1	Regression	53.28	2	26.64	159.265	0.000	83.70%
	Error	10.371	62	0.167			
	Total	63.65	64				
2	Regression	53.267	1	53.267	323.2	0.000	83.70%
	Error	10.383	63	0.165			
	Total	63.65	64				

SS* : Sum of squares. Df* : Degree of freedom. MS* : Mean square. F*: Ratio of factorial mean square out of mean error square. P* : Calculated probability. This one is significant at $P < 5\%$. R^2 (%)*: Coefficient of correlation of the fitted curve in percentage or fitness quality

TABLE 6. Relationship among the three used variables from the Pearson's linear correlation

Variables	Age	Setfruit	Nut
Age	1	-0.174	-0.146
Setfruit	-0.174	1	0.915**
Nut	-0.146	0.915**	1

Values accompanied by two asterisks are very significantly correlated according to Pearson's correlation

strongly correlated (r/Setfruit-Nut = +0.915**). In contrast, pollen age and number of nuts obtained at the end of fruits ripening were not correlated (r/Polage-Nut = -0.146, Table 6).

From Model 2, sole number of set fruits scored three months after controlled hand-pollination significantly influenced the variation of the number of nuts obtained at the end of fruit ripening (Table 5). The number of set fruits scored three months after controlled hand-pollination accounted for 83.70% of fluctuations in the number of nuts obtained at the end of fruits ripening. The regression line which modeled these fluctuations is:

$$Nut = 0.006 + 0.774*Setfruit$$

On account of variable transformation, this equation showed that the number of nuts obtained at the end of fruits ripening increased by an average of 0.599 when the number of set fruits scored three months after controlled hand-pollination increased by one fruit. The number of nuts obtained at the end of fruits ripening would be 0.000036 if the number of set fruits scored three months after controlled hand-pollination was null (Table 5).

DISCUSSION

There was lack of influence of genotype, parent sex, pollen age and cross nature on the expression of fruit set and fructification of parents used in crosses at Marc Delorme Coconut Research Station. Fruit set explained 83.70% variations of the fructification. The works from Peiris *et al.* (2008) on annual national coconut production (ANCP) in Sri Lanka, showed that fructification was influenced by rainfall and technology. In the same way, Regi *et al.* (2012) revealed that genotype, cross combination and climatic variables exert a significant influence on the expression of fruit set in coconut palm in India.

The four KKT, KPD, SLT and VTT used as parents in this study expressed the same female fertility, assessed through fruit set and fructification (Table 2). This proves that fruit set and fructification are female genotype-independent. The response to controlled hand-pollination of female parents did not seem to depend on geographical genetic structuring proposed in Gunn *et al.* (2011). Indeed, the Indo-Atlantic oceanic basin sub-population represented by KPD, SLT and WAT female parents did not differ from the Pacific one constituted by female genotypes KKT and VTT. Also, the yield of controlled hand-pollinations was comparable to the one reported in De Nuce and Wuidart (1992). This yield ranged from 2 to 3 nut seeds per pollinated bunch (De Nuce and Wuidart, 1992). Likewise, the six crosses VTTxPNT01, KKTxRIT, KPDxRIT, KPDxWAT, SLTxTAG and VTTxTAG showed the same fruit set and fructification potentials (Table 2), implying that female parents used have got the same fertility.

Our results contrast with those from Regi *et al*. (2012), postulating that fruit set is genotype-dependent, cross nature-dependent and climate-dependent. Such a difference might be due to the nature of used variables, because R^2 widely depends on gaps between means and each modalities. It is calculated according to formula:

$$R^2 = 1 – SS\ factorial/ SS\ total$$

with SS, the sum of squares. We have scored the number of set fruits scored three months after controlled hand-pollination, whereas the afore-mentioned authors measured the rate of fruit set (Regi *et al*., 2012). Thus, our results show that the genetic differences related to sex and geographical origins do not influence the expression of the fruit set and fructification. In brief, these four female parents could be indifferently used in controlled hand-pollination operations at Marc Delorme Coconut Research Station.

The two male parents, WAT and RIT, provided the oldest pollens (Table 2). All of the three hybrid combinations, KKTxRIT, KPDxRIT and KPDxWAT, in which these two parents were involved did not differ from three others; namely VTTxPNT01, SLTxTAG and VTTxTAG, in terms of fruit set and fructification. The fruit set and fructification were cross-independent (Table 4). On account of such an old-age, we could have expected low fruit set and fructification for the three first crosses. The oldest pollen came from WAT and RIT, with 131 and 102 days of conservation, respectively (data not shown). This result reveals that when pollen is well conditioned and conserved, there is no difference in female fertility in coconut palm. This assertion is confirmed by the regression equation in which the pollen age was dropped (Table 3). Indeed, using the backward elimination stepwise multiple regression technique, its removal did not diminish the prediction represented by R^2. Hence, this independent variable does not contain information related to fluctuations of the number of nuts obtained at the end of fruits ripening.

In contrast, the number of set fruits obtained three months after controlled hand-pollination, exerted a significant influence on the fructification (Table 5). A total of 83.70% fructification variations was due to fruit set, suggesting that the weak yielding of controlled hand-pollinations seems to be a phenomenon adapted to the experiments in Côte d’Ivoire. Hence, the weak yielding of artificial fertilisation does not reduce fitness quality, namely R^2. Thus, to predict the production, it will be necessary to replace the number of set fruits in the equation:

$$Nut = 0.006 + 0.774*Setfruit$$

the value related to quantity of set young fruits obtained three months after the pollination.

Our results fundamentally differ from those from Saraka *et al.* (2010), in a study under similar circumstances in Côte d’Ivoire. These authors postulated that beyond one month, pollen progressively lost viability. In contrast, our work revealed that until four months, pollen viability is well conserved. Currently, the pollen conditioning instruments are not the same. Until year 2005, a lyophiliser was used, while since 2006, the suction-pump is using in harvesting and conditioning sub-division, to extract and condition pollen. Therefore, 16.30% of variations of number of nuts obtained at the end of fruit ripening are not explainable by the number of set young fruits scored three months after controlled hand-pollination. Such a percentage could include climatic factors, pests and diseases, technician blunder and quality of pollination bag.

Truly, rainfall and relative humidity influence fruit set in coconut palm (Regi *et al*., 2012). Likewise, rainfall influences the seednuts production (Peiris *et al*., 2008). Pests can also be responsible for fluctuations in fruit set and fructifications. Indeed, insects such as

Pseudotheraptus devastans can trigger production losses in the order of 80% (Allou *et al*., 2010).

ACKNOWLEDGEMENT

Authors are grateful to Miss Cathérine Brou Ama, Mrs. André Gnimadi, Euloge Akoueté and Wossio Kéi Emmanuel for technical assistance.

REFERENCES

Allou, K., Konan, K. J.L., Issali, A.E., Lekadou, T.T., Zakra, A. N. et N'Guessan, A. 2010. Bien utiliser les fourmis rouges pour protéger les cocoteraies contre les punaises. Fiche cocotier n° 4. Réalisation: Direction des Programmes de Recherche et de l'Appui au Développement / Direction des Innovations et des Systèmes d'Information. E-mail : info.sqr@cnra.ci. p 4.

Amrizal, A. 2003. Coconut statical yearbook. Publisher: Asian and Pacific Coconut Community. Jakarta (Indonesia). pp. 1-6.

De Nuce de Lamothe, M. et Wuidart, W. 1992. La production de semences hybrides de cocotier : cas des semences hybrides Nain x Grand. *Oleagineux* 47:93-96.

Fremond, Y., Ziller, R. et De Nuce de Lamothe, M. 1966. Le cocotier. Edition Maisonneuve et Larose, Paris, France. pp. 257.

Gunn, F.B., Baudouin, L. and Olsen K.M. 2011. Independent origins of cultivated coconut (*Cocos nucifera* L.) in the old world tropics. *Plos ONE* 6:1-8.

Guyot, M. 1992. Systématique des angiospermes: Référence à la flore du Togo. Edition financée par la Mission Française de Coopération et d'Action Culturelle de Lomé. Diffusion auprès de la bibliothèque de l'Université du Benin, Togo. 217pp.

Regi, T.J., Nair, R.V., Mathews, C., Ajithkumar, R., Sasikala, M. and Nampoothiri, C.K. 2012. Studies on fruit set in coconut upon artificial pollination in various cross combinations. *Indian Journal of Horticulture* 69:7-12.

Saraka, Y.D.M. and Konan, J.L., Sié, R.S., Assa, A.R.R. and Allou, K. 2010. Effet de la durée de conservation sur la qualité du pollen en production de semences chez le cocotier (*Cocos nucifera* L.). *Sciences and Nature* 7:87 - 96.