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Analysis on genetic variability and heritability of fruit characters in *Citrullus lanatus* (Thunb.) Matsumura and Nakai (Cucurbitaceae) cultivars.

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1 SUMMARY

Offspring performances coming from crosses between two *Citrullus lanatus* (*Bebu* and *Wlêwlê small seeds* (WSS) cultivars) were performed to evaluate various components of variation, heritability and genetic advance of fruit characters. Parents (*Bebu* and *WSS*), F_1, F_2 and BC_1 hybrids were sowed in the same environment at two locations: Manfla (savannah) and Research Station of Nangui Abrogoua University (forest). Means of different parameters varied according to locations, with statistically significant performance observed in savannah (Manfla) than forest (Abidjan), and large variability was found between fruits of parental and hybrid $F_{1,}$ BC_1 and F_2 families. Parental and F_1 individuals were homogenous while F_2 and BC_1 generations were heterogeneous. The early cultivar *Bebu* yields few big fruits per plant than the late cultivar *WSS*. Fruit maturity period and number of hybrids $F_{1,}$ BC_1 and F_2 families were intermediate to those parents. Heterosis was observed in F_1fruit size. Percentage heterosis according to mid-parent average was negative for fruit maturity period and fruit number but positive for fruit size characters. Percentage heterosis according to better parent average was negative for fruit maturity period and fruit number but positive for fruit size. The genotype, phenotypic and additive variance was larger than the environmental variance in the majority of the families at both locations. This involved high broad and narrow-sense heritability for all characters. In conclusion, this study showed a homogeneity between parental and F_1 genotype but a heterogeneity between BC_1 and F_2 one. In addition, heterosis was observed in F_1fruit size and high heritability was observed for all characters.

2 INTRODUCTION

The world population is expected to reach 8 billion by 2030 (FAO, 2002). In order to answer this higher demand for food by the expanding population, high yield can be achieved by improving cultural practices and by developing genetically improved cultivars (Achu et *al*., 2006). High-yielding cultivars, precision-farming systems, increased use of chemicals for fertilization and weed and disease control, and proper training of the local farmers allowed a significant change in agriculture (Gusmini and Wehner, 2005). Consequently, crop yield has increased and many crops are now successfully cultivated worldwide. In Côte d'Ivoire, breeding programs concerning some industrial crops such as coffee, cocoa, rubber, oil palm trees were performed, relegating to the background the main traditional food crops. Despite their agronomic, cultural and culinary importance, these plants lack attention from research and development so that they are categorized as orphan crops (IPGRI, 2002). This is the case of oleaginous cucurbits known as "pistachio" in Côte d'Ivoire. Pistachios contained five species of Cucurbitaceae including *Citrullus lanatus,* which is the most cultivated (Zoro Bi *et al.,* 2003). *Citrullus lanatus* is cultivated in a wide range of tropical, semi tropical and dry regions of the world. It is originally found in Southern Africa (Razaviand Milani, 2006). Plants have a non-climbing creeping habit and deeply-cut lobed leaves and must be grown at a wide spacing because of their long, trailing vines. Flowers are viable for only one day (Whener, 2008a). The staminate flowers are precocious (27 to 29 days after seedling, emerging from the middle of the stem with long peduncles. The female flowers emerge one week later (34 to 37 days after seedling), and emerge at the apices of the stems, with short, fat peduncles, followed by an inferior ovary (Gusmini, 2003; Adjoumani, *et al.*, 2012). Depending on the cultivar, fruits are produced in different sizes: small, medium, and large, different shapes: round and oval or elongate (Gusmini, 2003).The seed have an important role in the people diet because of its full nutritious particles and its general and common usage as roasted seeds, seed oil, or medicine for decreasing the blood pressure. Seeds averagely consist of 31.9% protein, 4.4% carbohydrates, 57.1% fat, 8.2% fibre, 6.2% ash130 mg calcium, 456 mg phosphorus, 7.5 mg Iron. The plants are classified into two groups according to morphologic and agronomic evaluation of *C. lanatus* cultivars in Côte d'Ivoire. The first group is characterized by glossy seeds with a tapered proximal extremity. It includes two cultivars (*Wlêwlê small* and *medium seed*). In contrast, the second group with two cultivars (*Bebu and Wlêwlê large seed*) have seeds with flat ovoid shape, rugged and thick ends (Adjoumani *et al.*, 2012). Low yields were recorded during the different campaigns although these traditional cultivars were well adapted to climatic and ecological conditions (Koffi *et al.*, 2009). Earlier efforts, in *Citrullus* breeding, consisted to the development of new cultivars of different types with good agronomic traits (early maturity, big fruit and seed, large fruit and seed number). However, breeding programs are bound to the knowledge of key traits, genetic systems controlling their inheritance, and genetic and environmental factors that influence their expressions (Chandrababu and Sharma, 1999). It requires stages of selection for parents and progenies. The selection criteria of elite plants and progenies, depends on the variability in the base population and the relative magnitude of the genetic components determining the phenotypic expression of the traits. Individual plant selection can be effective only if the variables under selection have high heritability values (Gatti *et al*, 2005; Akbar *et al.*, 2008). Heritability of a character describes the extent to which it is transmitted from one generation to the next one. Thus, knowledge of heritability of a trait guides a plant breeder to predict behaviour of succeeding generations and helps to predict the response to selection. High genetic advance coupled with high heritability estimates offer a most suitable condition for selection (Akbar *et al.*, 2008; Waqar-Ul-Haq, 2008). Inbreeding has been used in plant breeding programs to fix favourable genotypes of agricultural interest (Allard, 1978), to separate favourable genotypes and to reduce the percentage of heterozygote in the population (Jansen & Jansen, 1990). However, inbreeding reduces population fitness, increases the genetic variance between families and reduces it within families, with a progressive increase in the additive variance at the expense of dominance in totally homozygote lines (Ceballos, 1998). Heterosis refers to the increased yield and overall performance of F_1 hybrids derived from the cross of two inbred lines. Higher levels of heterosis are more likely when the parents carry a high frequency of dominant alleles or when over dominance gene action is present (AVRDC, 2007). In *Citrullus lanatus,* heterosis, as well as general (GCA) and specific (SCA) combining ability, received much attention. Overall, the presence of heterosis in watermelon, and the importance of direction of the crosses and GCA in the choice of parents for hybrid production, was confirmed. Earliness, yield and fruit quality are some of the most frequent traits influenced by heterosis (Gusmini and Wehner, 2004, Gvozdanovic-Varga *et al*, 2011). Breeding of watermelon is largely conducted outside Africa, in particular in the United States (Mujaju, 2009). In *C. lanatus,* the genetics of plant maturity and fruit characters have not been studied in Côte d'Ivoire and there is little published information available to help *C. lanatus* breeders in the choice of the proper breeding. The objectives of this study was to compare the performances of the progenies obtained from crosses between *Bebu* and *Wlêwlê small seeds* and to estimate the magnitude of the various components of variation, heritability and genetic advance of plant maturity and fruit characters.

3 MATERIALS AND METHODS

3.1 Materials: At the end of diversity study between Ivorian *C. lanatus* cultivars, results had shown that *Bebu* and *Wlêwlê small seeds* (*WSS*) were genetically more distant and possessed several contrasted agronomic characters. *Bebu* plants were precocious and yielded big fruit, which contained few big seeds. *WSS* plants were late maturity and yielded small fruits with a great number of small seeds (Adjoumani *et al.,* 2011). Both cultivars were used to conduct this experiment. Seeds of these cultivars were provided from four successive self-pollination experiments that had been conserved in genetic laboratory of Nangui Abrogoua University under introduction number (NI) NI 121 for *Bebu* cultivar and NI 113 for *WSS* cultivar. *Bebu* and WSS were crossed and three generations (F_1, F_2 and BC_1) were produced. Experiment material was composed of parental seeds (*Bebu* and *WSS*) and hybrids seeds (F_1, F_2 and BC_1).

3.2 Methods: F1, F_2, BC_{1b} and BC_{1w} hybrids had been obtained previously after two crop seasons. The first field test was conducted from March to June 2009 at Research Station of Nangui Abrogoua University. It had permitted to obtain F_1 seeds. This generation comes from reciprocal crosses between *Bebu* and *WSS* cultivars (*Bebu*♀ x *WSS*♂ and *WSS*♀ x *Bebu*♂). Seeds from three fruits from each cross had been selected to generate F_1 plants. F_{1w} and F_{1b} were families developed from respective crosses WSS♀ x *Bebu*♂and *Bebu*♀ x *WSS*♂. The second test was conducted from August to November 2009 at the same Research Station. During this test, parental, F_{1b} and F_{1w} seeds were both sowed on the same parcel to have F_{2b}, F_{2w}, BC_{1b} and BC_{1w} seeds. From F_{1b} and F_{1w} plants, self-pollination was performed to produce respectively F_{2b} and F_{2w} plants. Crosses between F_{1w} plants and each parent produced BC_{1b} and BC_{1w} plants (respectively backcross on *Bebu* and *WSS*).When hybrids seeds were found, the whole generation (parental and hybrids) seeds were sowed from March to June 2010 in the same environment at two different agro-ecologically locations: Manfla (savannah) and Research Station of Nangui Abrogoua University (forest). Manfla is a village closest to Gohitafla city in the department of Zuenoula (District of Marahoue). It is localized centre-west of Côte d'Ivoire precisely between latitude 7°00 N and 7°26 N and longitudes 6°00 W et 6°30 W (Kouassi et Zoro Bi, 2009). The Research Station of Nangui Abrogoua University is inside Nangui Abrogoua University of Abidjan. This University is located in Lagoon District in southern Côte d'Ivoire (48410 N, 48000 W) (Zoro *et al.*, 2006). In both location each field was 6300 m^2 (105 m×60 m) and contained 32 rows distant each over from 3 m. the number of rows for each field was 2 for each parental line, 3 for each F_1 family, 6 for each back cross (BC_1) and F_2 family. Two to three seeds of each family were sowed per hole, with an intra-row spacing of 2

m. Ten days after sowing, seedlings were separated and the most vigorous one were let in place. In each location, individual number in family was 30, 60, 180 and 180 respectively for parent, F_1, BC_1 and F_2. Regular weeding of the fields had been made during plant vegetative cycle. Any fertilization, fungicide and insecticide contribution had been applied in the fields. At the harvest characterized by total plant drying, 3 fruits per plant were selected to evaluate fruit parameters. Five parameters were evaluated during this study:

Fruit maturity period: it had been determined by counting days between sowing and the fruit harvest characterized by total plant drying

Fruit number per plant: fruit number per plant was determined by simple fruit counting on each plant

Fruit mass per plant: each fruit was weighed with an electronic balance (*Kein HD5K5;* sensibility 5g). Fruit mass per plant corresponds to average of 3 fruit mass per plant

Fruit diameter per plant: diametric lateral opposite board after fruit median section was measured with "pied à coulisse". Fruit diameter (DFr) per plant corresponds to average of 3 fruit diameter per plant

Fruit volume (VFr) per plant: fruits of *C. lanatus* cultivars are supposed spherical. Their volume are evaluated like spherical volume as follow: $VFr=4/3\pi r^3$, where $r = DFr/2$)

3.3 Statistical analysis: Coefficient of variation (CV) was used to study variability between individuals in the same family. It corresponds to relation between standard error (σ) and average (x)

$$CV = \frac{\sigma}{x} \times 100$$

-If $CV < 25$ %, individuals in the same family are homogeneous or similar

-If $CV \geq 25$ %, individuals in the same family are heterogeneous or different

Parental and hybrid performances were first evaluated by comparing, for each trait, different families by using two ways of analysis of variance [ANOVA 2: families (parents, F_{1b},F_{1w}, F_{2b},F_{2w}, BC_{1b} and BC_{1w}) and locations (Manfla and Abidjan)] using SAS software (SAS, 2006). This test evaluated variability between families, the main effects of location on family production and the interaction between families and locations. Then, the measurements of variance from parents and offsprings were used to estimate environmental, genetic and additive variances. The variance of the F_2 provides an estimate of phenotypic variance, whereas the mean variance of the non-segregating generations (parents and F_1) gives an estimate of environmental effects (Wright, 1968). The additive variance is derived from subtracting the variances of the backcrosses from twice the phenotypic (F2) variance as an extension of the single locus model under the hypothesis of absence of linkage and genetic-by environment interactions (Warner, 1952). Phenotypic (σ^2P), environmental (σ^2E), genotypic (σ^2G) and additive (σ^2A) variance effects were estimated from generation variances as follows (Warner, 1952; Wright, 1968):

$$\sigma^2\ (P) = \sigma^2\ (F_2)$$

$$\sigma^2(E) = \frac{\sigma^2(Pa) + \sigma^2(Pb) + 2\sigma^2(F_2)}{4}$$

$$\sigma^2\ (G) = \sigma^2(P) - \sigma^2(E)$$

$$\sigma^2(A) = 2\sigma^2(F_2) - [\sigma^2(BC_1Pa) + \sigma^2(BC_1Pb)]$$

The broad (H^2) and narrow-sense (h^2) heritability can then be respectively calculated from the available estimates of genetic, additive, and phenotypic variances.

$$H^2 = \frac{\sigma^2(G)}{\sigma^2(P)} = \frac{\sigma^2(F_2) - \sigma^2(F_1)}{\sigma^2(F_2)}$$

$$h^2 = \frac{\sigma^2(A)}{\sigma^2(P)}$$

The predicted gain from selection (Gs) was evaluated according to Kumar (2009).

$$Gs = kh^2\sqrt{\sigma^2(F_2)}$$

k = differential selection which varied with selection intensity (k = 2.063, 1,755 and 1,555 respectively at 5%, 10% or 15% intensity on normal distribution table (Nanson, 1967).

Breeding value of the studied material was demonstrated via the analyses of heterosis and combining abilities in the F_1 generation (Nya and Eka, 2010). Percentage heterosis according to mid-parent (MPH) and better parent heterosis (BPH) was calculated using the formula by Gusmini and wehner (2004) as follows.

$$MPH = \frac{(F_1 - MP) \times 100}{MP}$$

$$BPH = \frac{(F_1 - BP) \times 100}{BP}$$

Where F_1: mean of F_1 family, MP: mean of mid-parent (two parents) and BP: mean of best parent.

4 RESULTS

4.1 Locations and Families effects: According to two ways analysis of variance, experimental site influenced significantly families' performances ($P < 0.05$). Means of different parameters varied according to locations with higher performance observed in savannah (Manfla) than forest (Abidjan). In addition, for a given site, performance differed from families whatever character ($P <0{,}001$). However, no location-family interaction was observed. Savannah was more favourable to these families than the forest and large variability was observed between parental and hybrid F_1, BC_1 and F_2families (Table 1).

Table 1: Locations, families and interaction location x family effects on fruit characters

Traits	location	Family	Interaction location-family
Fruit maturity period(das)	37.15	110.89***	1.69^{ns}
Fruit number per plant	2.11**	62.89***	1.44^{ns}
Fruit mass (g)	7.45*	59.07***	0.11^{ns}
Fruit diameter (cm	8.40**	61.50***	0.20^{ns}
Fruit volume (cm^3)	34.36***	60.84***	0.67^{ns}

ns: no significant *: significant at 5% **: significant at 1% ***: significant at 0.1%das: days after sowing

4.2 Variability inside each family: Coefficient of variation (CV) of each trait was evaluated according to families (Table 2). These coefficients of variation were inferior to 25 % in parental and F_1 families for all traits. The individuals of these parental and F_1 population were homogeneous. However, except fruit maturity period, the coefficient of variation was higher than 25% for fruit characters in F_2, BC_{1b} and BC_{1w} families. There is a large heterogeneity inside these F_2 and BC_1 generations.

4.3 Variability between families: Genetic variability between families had been examined and results details had been consigned on table 3.

4.3.1 Fruit maturity period: fruit maturity period varied significantly ($P < 0{,}001$) between families on the both locations (table 3). *Bebu* cultivar was precocious while *WSS* cultivar was late. *Bebu's* fruits reached maturity stage 80 days after sowing while those of *WSS* can be harvested 104 to 108 days after sowing according to location. The fruit maturity period of hybrid F_1, BC_1 and F_2 were intermediate to those of parents. In addition, crossway had not significant effect on the fruit maturity period of F_1 and F_2. Therefore, fruits of F_{1w} and F_{1b} families can be harvested respectively 92 and 96 days after sowing. Average of F_1 families corresponded to geometric average from both parent. Semi-dominance effect exists between early and late fruit maturity. Fruits from F_{2w} and F_{2b} families can be harvested earlier than F_1 families since fruit maturity were produced around 90 days after sowing. However, hybrid BC_1 fruit maturity period depends on cross direction. There is maternal effect for this generation because BC_1 fruit maturity, were near to that one which is used as female plant during the cross. So, fruits of BC_{1b} family can be harvested 10 days after those of *Bebu* and around 21 days before WSS. Fruits of BC_{1w} family can be harvested 10 days before those of WSS and around 14 days after *Bebu*.

Table 2: Coefficients of variation of each fruit character on the both experiment

Traits	**Locations**	***Bebu***	**BC_{1b}**	**F_{1b}**	**F_{1w}**	**F_{2b}**	**F_{2w}**	**BC_{1w}**	***WSS***
Fruit maturity period (das)	Abidjan	4.48	6.28	3.11	4.62	12.15	11.82	7.00	4.63
	Manfla	4.65	7.02	2.42	4.69	9.33	8.92	7.69	0.45
Fruit number per plant	Abidjan	20.44	72.48	22.12	22.35	44.49	47.22)	80.07	22.93
	Manfla	19.59	64.85	24.54	22.47	29.31	48.42	70.29	24.83
Fruit mass (g)	Abidjan	15.36	29.07	23.36	9.20	31.68	37.49	24.81	10.45
	Manfla	17.95	29.72	22.52	9.00	40.75	35.57	28.65	17.18
Fruit diameter (cm)	Abidjan	4.94	30.14	7.50	4.20	30.06	32.82	28.97	3.89
	Manfla	5.92	29.58	7.68	6.02	34.00	31.60	28.71	5.53
Fruit volume ($cm^{3)}$	Abidjan	9.78	29.63	21.64	22.96	31.58	38.89	25.60	7.65
	Manfla	17.25	29.73	19.88	16.73	40.68	34.75	25.28	17.17

Das: days after sowing, *WSS*: *Wlêwlê Small Seed*, BC_{1w}: back cross on *WSS* cultivar, BC_{1b}: back cross on *Bebu* cultivar, $F_{1w:}$ F_1 from Wlêwlê♀ × Bebu♂ cross, $F_{1b:}$ F_1 from Bebu♀ × Wlêwlê♂ cross, F_{2w}: F_2 from self-pollination of F_{1w} individuals, F_{2b}: F_2 from self-pollination of F_{1b} individuals

4.3.2 Fruit number per plant: fruit number from each plant differed significantly among families on both sites (*P<0,001*).WSS plant yielded more fruits than plants of other families with approximately 11 fruits per plant (table 3). *Bebu* and BC_1 plants yielded less fruits with respectively 3 to 5 fruits per plant. The number of fruits produced by F_1 and F_2 plants was intermediate to those of parents. F_1 plants yielded 6 to 7 fruits per plant according habit. This average of F_1 families corresponded to geometric average from both parent. So, semi-dominance effect exists between more and less fruit characters. According to environmental site, each F_2 plant yields on the average 7 to 9 fruits. Cross-way had not significantly effect on the number of fruits yielded by hybrids $F_{1,}$ BC_1 and F_2

4.3.3 Fruit mass: fruit mass varied significantly (*P < 0,001*) between families in the both locations (table 3). Fruits of *Bebu* cultivar were heavier than other families' fruits with magnitude slightly superior to 1100 g. Fruits of *WSS* cultivar were higher and weighted less than 750g. Heterosis effect was observed for this trait because F_1 fruit mass magnitude was higher than *Bebu*, the best parent for this character. Fruit mass of F_1 weighted more than 1200 g against 1100 g for *Bebu's* fruits. Cross way had no effect on fruit mass yielded in F_1 because fruits yielded on F_{1w} and F_{1b} families had statistically the same mass average. Fruit mass average from BC_1 and F_2 was intermediate to parental fruit mass average. There is maternal effect for this generation because fruit mass of BC_1 and F_2 families was closest to female plant during the cross. Thus, fruits from BC_{1b} and F_{2b} families on the one hand and BC_{1w} and F_{2w} families on the other hand, had approximately the same mass and their fruit mass was closest to respectively *Bebu* and *WSS*. According to habit, fruits from BC_{1b} and F_{2b} families weighted between 956 to 1000 g (next to 1100 g from *Bebu*) while those from BC_{1w} and F_{2w} families varied from 816 to 903 g (next to 750 g from *WSS*). Cross way had no significant effect on fruit mass of F_1 hybrids but it influenced BC_1 and F_2 fruit mass with high magnitude observed when *Bebu* was considered as maternal plant during crosses.

4.3.4 Fruit size: Various fruit size was observed (*P < 0,001*) between families on both locations (table 3). *Bebu* plants yielded big fruits with approximately 13 cm and 1100 cm^3 for respectively diameter and volume traits. In contrast, *WSS* plants yielded small fruits with respectively a diameter and a volume close to 11 cm and 730 cm^3. Heterosis effect was observed for fruit size because fruits of F_1 were bigger than *Bebu* and *WSS* fruits (Fig. 1). F_1 plants yielded big fruits with volume varying from 1173.44 to 1358.11 cm^3. Cross direction had no effect on fruit size in F_1. Fruits yielded from BC_1 and F_2 families had intermediate mean size. Cross direction influenced significantly fruit size on these families. Fruits from BC_1 were bigger during the backcross, when *Bebu* cultivar was used as female (BC_{1b}) and smaller when *WSS* was used as female (BC_{1w}) (Figure 2). Likewise, fruits from F_2 were bigger when before self pollination in F_1 families, *Bebu* cultivar had been used as female (F_{2b}) and smaller when *WSS* had been used as female (F_{2w}) (Fig. 3). These results showed existence of maternal effect in these generations for these traits.

4.4 Genetic effect

4.4.1 Heterosis effect: Percentage heterosis according to mid-parent average (MPH) is negative for number of fruits and positive for all other traits (Table 4). Percentage heterosis according to better parent average (BPH) was negative for fruit maturity and number. The F_1 hybrid had 8.75 to 13.41 % less fruit maturity and 37.48 to 39.55% less fruit number per plant than *WSS*, the best parent for these characters. However, BHP was positive for the traits relative to fruit size. The fruit diameter of the F_1 hybrid was more 17.26 to 23.40 % than Bebu one. Concerning the fruit mass, it was more 65.81 to 74.74 % than *Bebu*, the best parent for these fruit size traits.

Figure 1: Parent (*Bebu* and *WSS*) and F_1 hybrid fruits illustrating heterosis in *C. lanatus* cultivars

Figure 2: Fruits yielded on BC_{1w} (left) and BC_{1b} (right) families

Figure 3: Fruits yielded on F_{2w} (left) and F_{2b} (right) families

Figure 4: fruits variability yielded on F_2

Table 3: Variability between families according characters

Traits	**locations**	***Bebu***	**BC$_{1b}$**	**F$_{1b}$**	**F$_{1w}$**	**F$_{2b}$**	**F$_{2w}$**	**BC$_{1w}$**	***WSS***	**Statistical test**	
										F	**P**
Fruit maturity period (das)	Abidjan	78.04± 3.61^{e*}	87.45 ± 5.81^{d}	92.52± 2.88^{bc}	95.13± 4.40^{b}	90.14± 8.41^{c}	90.79± 10.73^{c}	103.70± 7.26^{a}	104.25 ± 4.67^{a}	124.46	<0.001
	Manfla	79.91 ± 3.59^{e}	88.56 ± 6.22^{d}	93.08± 2.25^{b}	95.54± 4.48^{b}	90.23± 10.96^{c}	91.08± 9.44^{c}	105.78± 8.13^{a}	107.50 ± 5.00^{a}	32.53	<0.001
Fruit number per plant	Abidjan	3.1± 0.72^{d}	3.74± 2.7^{d}	6.41± 1.42^{c}	6.44± 1.44^{c}	7.51± 3.34^{bc}	8.47± 4.00^{b}	4.62± 3.70^{d}	10.30± 2.1^{a}	22.37	<0.001
	Manfla	3.35± 0.83^{d}	3.81± 2.4^{d}	6.71± 1.65^{c}	6.78± 1.52^{c}	8.19± 1.58^{b}	8.89± 4.30^{b}	4.83± 3.37^{d}	11.10± 2.1^{a}	45.67	<0.001
Fruit mass (g)	Abidjan	1123.03±117.37^{b*}	996.12± 289.5^{c}	1258.74± 294.05^{a}	1208.97± 111.65^{ab}	956.63± 389.86^{c}	885.87± 332.11^{d}	816.23± 202.54^{de}	729.11± 112.01^{e}	32.2	0.001
	Manfla	1146.6± 196.96^{b}	998.90± 296.91^{c}	1275.69± 287.25^{a}	1243.40±111.89^{ab}	973.92± 308.56^{c}	902.61± 321.05^{d}	834.50± 239.06^{de}	744.87± 133.69^{e}	28.9	0.001
Fruit diameter (cm)	Abidjan	12.80± 0.50^{a}	12.27 ± 1.24^{b}	13.13 ± 0.98^{a}	12.99±0.55^{a}	11.99± 1.68^{b}	11.46± 1.47^{c}	11.18± 1.00^{d}	10.64± 0.53^{e}	29.61	<0.001
	Manfla	13.01± 0.72^{a}	12.333± 1.18^{b}	13.13±1.01^{a}	13.04±0.78^{a}	12.12± 1.22^{b}	11.85± 1.37^{c}	11.53± 1.00^{d}	11.12± 0.66^{e}	35.00	<0.001
Fruit volume (cm$^{3)}$	Abidjan	1054.71± 80.74^{b}	972.73± 288.26^{c}	1187.61± 256.96^{a}	1173.44± 269.48^{a}	932.41± 379.34^{c}	848.71± 330.05^{d}	790.17± 202.29^{e}	689.81± 67.48^{e}	30.32	<0.001
	Manfla	1214.93± 208.58^{b}	1079.16± 320.82^{c}	1358.11± 270.00^{a}	1346.69± 225.25^{a}	1023.81± 323.34^{c}	937.20± 325.70^{d}	871.84± 220.40^{de}	777.18± 134.09^{e}	32.91	<0.001

Das: days after sowing, *WSS*: *Wlêwlê Small Seed*, BC$_{1w}$: back cross on *WSS* cultivar, BC$_{1b}$: back cross on *Bebu* cultivar, F$_{1w:}$ F$_1$ from Wlêwlê♀ × Bebu♂ cross, F$_{1b:}$ F$_1$ from Bebu♀ × Wlêwlê♂ cross, F$_{2w}$: F$_2$ from self-pollination of F$_{1w}$ individuals, F$_{2b}$: F$_2$ from self-pollination of F$_{1b}$ individuals. *Equal letters correspond to statistically equal means, based upon one way of analysis of variance

Table 4: Mean and Percentage heterosis according mid-parent (MPH) and better parent heterosis (BPH) for the studied fruit traits

Families	**Fruit maturity period**		**Fruit number per plant**		**Fruit mass**		**Fruit diameter**		**Fruit volume**	
	Manfla	**Abidjan**	**Manfla**	**Abidjan**	**Manfla**	**Abidjan**	**Manfla**	**Abidjan**	**Manfla**	**Abidjan**
Bebu	79.91	78.04	3.35	3.1	1146.6	1123.03	13.01	12.8	1214.93	1054.71
WSS	107.5	104.25	11.1	10.3	744.87	729.11	11.12	10.64	777.18	689.81
Bebu and *WSS*	92.70	91.14	7.22	6.7	945.73	926.07	12.065	11.72	996.055	872.26
F_{1w}	95.54	95.13	6.78	6.44	1243.4	1208.97	13.04	12.99	1346.69	1173.44
MPH (%)	01.96	04.37	-06.16	-03.90	31.474	30.55	8.08	10.83	35.20	34.53
BPH (%)	-11.12	-08.74	-38.92	-37.48	66.93	65.81	17.26	22.09	73.27	70.11
F_{1b}	93.08	92.52	6.71	6.41	1275.69	1258.74	13.13	13.13	1358.11	1187.61
MPH (%)	0.40	1.51	-7.13	-4.33	34.89	35.92	8.83	12.03	36.34	36.15
BPH (%)	-13.41	-11.25	-39.55	-37.78	71.26	72.64	18.08	23.40	74.74	72.16

WSS: *Wlêwlê Small Seed*, $F_{1w:}$ F_1 from Wlêwlê♀ × Bebu♂ cross, $F_{1b:}$ F_1 from Bebu♀ × Wlêwlê♂ cross, MPH: percentage heterosis according mid-parent, BPH: percentage heterosis according better parent.

Percentage heterosis according mid-parent (MPH) and better parent heterosis (BPH) was calculated using the formula by Gusmini and Wehener (2004) as follows.

$$MPH = \frac{(MF_1 - MP) \times 100}{MP}, \qquad BPH = \frac{(MF_1 - BP) \times 100}{BP}$$

Where MF_1: mean of F_1 family, MP: mean of mid-parent (two parents) and BP: mean of best parent

4.5 Phenotypic variance: Phenotypic variances varied according to locations, families and characters (Table 5). Phenotypic variances were higher in Manfla than Abidjan for parents, F_1 and BC_1 families for all fruit traits. In contrast for the F_2 family; this parameter were higher on Abidjan location than Manfla one. This indicated that parents, F_1 and BC_1 were more heterogeneous on Manfla location than Abidjan while F_2 family was more heterogeneous in Abidjan location than Manfla.Values of phenotypic variances were also high for fruit mass and volume for all families on the both locations. Fruits recorded on the both locations were heterogeneous. Among families, parents and F_1 hybrids had low phenotypic variances while F_2 and BC_1 had high phenotypic variances. Parents and F_1 hybrids were more homogeneous than F_2 and BC_1, thus indicating a great phenotypic variability of F_2 (Fig. 3 and 4) and BC_1 (Figure 2) in our experiment. Among parent, fruit were more heterogeneous in Bebu than *WSS* while fruit number and days to harvest were more homogenous in *Bebu* than *WSS*.

Table 5: Phenotypic variances by generation for *C. lanatus* cultivars families tested for days to harvest and fruit characters

Locations	Popula-tions	Fruit maturity period (das)	Fruit number per plant	Fruit mass (g)	Fruit diameter (cm)	Fruit volume(cm³)
Manfla (Abidjan)	*Bebu*	12.90 (13.04)	0.69 (0.52)	38793.86 (13775.05)	0.52 (0.25)	43506.88 (5518.53)
	WSS	25.00 (21.78)	4.73 (4.43)	17874.33 (12547.15)	0.43 (0.28)	17980.46 (4553.84)
	BC_{1b}	38.64 (33.79)	8.10 (7.35)	88153.81) (83856.06)	1.40 (1.55)	102922.43 (83095.03)
	BC_{1w}	66.11 (52.64)	11.52 (13.69)	57151.52 (41022.69)	1.01 (1.00)	78578.21 (70922.19)
	F_{2W}	89.05 (115.10)	18.53 (16.00)	103075.51 (110295.45)	1.89 (2.16)	106082.74 (108931.35)
	F_{1W}	20.07 (19.32)	2.32 (2.07)	13251.43 (12365.89)	0.62 (0.30)	50737.84 (42621.22)

das: days after seedling, *WSS*: *Wlêwlê Small Seed*, BC_{1w}: back cross on *WSS* cultivar, BC_{1b}: back cross on *Bebu* cultivar, F_{1W}: F_1 from Wlêwlê♀ × Bebu♂ cross, F_{2W}: F_2 from self-pollination of F_{1w} individuals

4.6 Variance, heritability and genetic gain estimation: the genotypic σ^2_G, phenotypicσ^2_P, environmental σ^2_E and additive σ^2_A variances, broad (H^2) and narrow (h^2) sense of heritability and genetic gain of characters were grouped in table 6. The genotypic, phenotypic and additive variance was higher than the environmental variance in the majority of the families at both locations. This involved high broad ($H^2 \geq 0,50$) and narrow-sense heritability ($h^2 \geq 0,50$) for all traits. More than 50 % of variation observed between individuals and families were imputable to genetic effect. In addition, fruit number had higher heritability in Manfla location than Abidjan location while all other characters had higher heritability in Abidjan location than Manfla. Genetic gain was high for fruit mass and volume and for days to harvest.

Table 6: Variance, heritability and genetic gain to selection estimates for families for each character

Locations	**Traits**	**Variances**				**heritability**		**genetic advance**		
		σ^2_P	σ^2_E	σ^2_G	σ^2_A	H^2	h^2	**5%**	**10%**	**15%**
Manfla (Abidjan)	Fruit maturity period (days)	89.04 (115.10)	19.51 (18.37)	69.54 (96.73)	63.34 (93.77)	0.78 (0.84)	0.71 (0.81)	0.39 (0.67)	0.78 (1.34)	1.17 (2.01)
	Fruit number per plant	18.53 (16.00)	2.51 (3.52)	17.21 (12.48)	16.42 (10.96)	0.93 (0.78)	0.88 (0.69)	0.23 (0.14)	0.45 (0.27)	0.68 (0.41)
	Fruit mass (g)	103075.51 (110295.45)	20426.76 (12763.49)	82648.75 (97531.96)	60845.69 (95712.15)	0.80 (0.88)	0.59 (0.87)	9.48 (14.41)	18.96 (28.82)	28.43 (43.23)
	Fruit diameter (cm)	1.89 (2.16)	0.55 (0.28)	1.38 (1.88)	1.22 (1.76)	0.71 (0.87)	0.64 (0.82)	0.05 (0.06)	0.10 (0.12)	0.15 (0.18)
	Fruit volume (cm³)	106082.74 (108931.35)	40740.76 (39078.71)	65341.98 (69852.65)	60664.83 (63845.48)	0.62 (0.64)	0.57 (0.59)	9.31 (14.22)	18.63 (28.43)	27.94 (42.65)

Phenotypic (σ^2P), environmental (σ^2E), genotypic (σ^2G), additive (σ^2A) variance effects, heritability and genetic advance of each character were estimated from generation variances as follows (Warner, 1952; Wright, 1968): $\sigma^2(P) = \sigma^2(F^2)$, $\sigma^2(E) = \frac{\sigma^2(Pa)+\sigma^2(Pb)+2\sigma^2(F_1)}{4}$

$\sigma^2(G) = \sigma^2(P) - \sigma^2(E)$, $\sigma^2(A) = 2\sigma^2(F_2) - [\sigma^2(BC^1Pa) + \sigma^2(BC^1Pb)]$. $H^2 = \frac{\sigma^2(G)}{\sigma^2(P)}$, $h^2 = \frac{\sigma^2(A)}{\sigma^2(P)}$, $Gs = kh^2\sqrt{\sigma^2(F_2)}$

k = selection differential which varied with selection intensity (K = 2.063, 1,755 and 1,555 respectively at 5%, 10% or 15% intensity on normal distribution table (Nanson, 1967).

5 DISCUSSION

Cross direction, Variability of segregating offspring, heritability and genetic gain of days to harvest and fruits characters were evaluated in two cultivars of *C. lanatus*. Among results, location effect on offspring performance was observed. Offspring performances were higher when they were grown in savannah (Manfla) than forest (Abidjan). Savannah could be more favourable for *C. lanatus* cultivars and their offsprings than forest. This result may be related to rainfall difference between both locations. In fact, rain was regular and abundant in forest than savannah. These abundant rains involved high humidity that was mentioned to be unfavourable to *Citrullus lanatus* crop as observed by Wehner (2008b). Cross direction did not affect F_1 performance but it affected significantly BC_1 and F_2 fruit size where maternal effect had been observed. Therefore, fruits from F_{2b} and BC_{1b} were big as fruits yielded by *Bebu* while those from F_{2w} and BC_{1w} were small as their WSS maternal parents. These results suggested cross direction importance in *C. lanatus* genetic breeding. Variability in qualitative and quantitative character expression according to cross direction had already been observed in *C. lanatus* (Gusmini *et al.,* 2004). Variability inside families throughout coefficient of variation showed homogeneity inside parental and F1 families. Individuals of these families were practically similar whatever characters and cross direction. Fruits were yielded at the same period and fruit size and number were similar in these families. This result could be probably bound to multiple self-fecundations, which had increased homozygoty race involving pure genotype in these families according to Mendel laws (Vedele et Loudet, 2001). Gusmini et Wehner (2008) had also mentioned possibility to observe hybrid homogeneity in *C. lanatus* after hybridization. However, high phenotypic variability had been observed inside BC_1 and particularly F_2. This variability could justify segregation characters produced in parents and could show existence of phenotypic divergence between them. These phenotypic divergences observed in parents were appeared in their offsprings according to Mendel laws (characters disjunction). Difference between BC_1 and F_2 families was the evidence that some individuals could be identical to one of both parents while others were recombinant showing at different proportions both parents characters (Vedele et Loudet, 2001). Gusmini *et al.* (2004) had also observed segregation characters during crosses between two *C. lanatus* cultivars: *Charleston Gray* 3 PI 560006 and *Calhoun Gray* 3PI 490383w. These segregation characters justified also high variability between families, which showed difference between parents and their offspring on the one hand, and between offspring on the other hand. For many characters, intermediate forms were obtained. Fulks *et al.* (1979) and Zamir (2001) had also observed intermediate form during crosses between *C. lanatus* and his ancestor *C.colocynthis*. However, heterosis effects were observed for fruit size (fruit mass, diameter and volume). Means of F_1 families were superior to those of parents for these characters involving high percentage heterosis according to mid-parent and better parent. This higher level of heterosis arises from the fact that both cultivars (*Bebu* and *WSS*) were genetically different (Adjoumani *et al.*, 2012). Cross breeding tends to cause more gene pairs to be heterozygous (the offspring receives different genes from its parents). This arises from the fact that different offsprings tend to have high frequencies of different genes. Consequently, more heterozygocity and heterosis were produced. Heterozygocity and heterosis will result in better performance if there is non-additive gene action (dominance and epistasis) and the recessive allele results in inferior performance (AVRDC, 2007). Other researches such as Brar and Sidhu (1977), Brar and Sukhija (1977) and Gusmini and Wehner (2005), had mentioned high heterosis phenomenon in *C. lanatus* for different agronomic traits. This can contribute to increase production in some cultivars.

In addition, maternal effects have been found in back cross families. Phenotypes of Back cross offsprings were influenced by that of its mother independently of the direct effects of the genes that it inherits. Therefore, back cross realized on *WSS* offsprings were similar to *WSS* individuals and back cross on *Bebu* offspring were similar to Bebu individuals. Phenotypic similarity between these hybrids and their maternal parent suggest existence of more number of parental genes than F_1 hybrid genes during back cross in characters expression evaluated. Maternal effects may be more caused by genes inherited from mother than the environment effect in the experiences (Wilson *et al.*, 2004). Previous studies have demonstrated maternal effect in *C. lanatus* (Henderson *et al.,* 1998). Heritability varied according to environment and parameters as had revealed by Bodzon (2004), Akbar *et al.* (2008) and Waqar-Ul-Haq *et al.* (2008). All characters evaluated, had shown high broad and narrow-sense heritability whatever experimental environment. High heritability indicates less environmental influence in the observed variation because genetic and additive variances were largely higher to environmental variances (Eid, 2009; Ogbonna and Obi, 2010). It also indicates the extent of genetic control for expression of a particular trait and the reliability of phenotype in predicting its breeding value (Chopra, 2000; Tazeen *et al.*, 2009). Here, more than 50 % of variations observed between individuals and families were related to genetic effect or variability. All of these characters must be exactly transmitted from a generation to another one whatever environmental conditions. This high heritability confirmed agronomical and morphological differences between selected parents (*Bebu* and *WSS*) as had mentioned by Singh and Westermann, 2002). In addition, high heritability went with high selection gain for fruit size (fruit mass and volume) on the both site. Similar observation had been mentioned by Gusmini (2005) and Kumar (2009) on fruit size and number. In breeding program, selections must be done according to these characters to sample individuals possessing big fruits.

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