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EVALUATION OF COLD TOLERANT HIGH YIELDING OIL PALM GERMPLASM IN GUANGDONG PROVINCE OF SOUTH CHINA, A NORTHERN TROPICAL REGION

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ABSTRACT

An evaluation of the vegetative growth, yield components and cold resistance traits from 38 pre-selected individual oil palm plants grown in six regions (populations) at the latitude (LAT) range between 20°N and 23°N in Guangdong Province, China was carried out during the period from April 2010 to April 2015. Analysis of variance showed significant differences in traits between the individual palms or the populations [except sex-ratio of female inflorescence and fruit bunch to female inflorescence, male inflorescence and fruit bunch (%) (SR)]. Phenotypic correlation analysis showed that bunch number (NB) was positively correlated with fresh fruit bunch (FFB), but not significantly with average bunch weight (ABW). For the individual palms, it was found that the higher the LAT the lower the frond production (FP) and LT_{50} and the higher fruit compaction rate (FCR), and the higher the LT_{50} the lower the ABW. For the populations, the higher the LAT the higher the ABW and the lower the abortion ratio of female inflorescence to female inflorescence and fruit bunch (%) (RAFM). Path coefficient analysis further revealed that for the individual palms ABW was the major determinant in both FFB and NB, and mainly determined by normal fruit higher per bunch (kg) (ANFW) and percent of ANFW to ABW (%) (F/B). For the populations, the major determining factors were ratio of aborted fruit bunch to fruit bunch (%) (ABR) for FFB and NB, and inflorescence (male, female, bisexual and non-anthesis) and fruit bunch numbers per year (No.) NIB and LT_{50} for ABW. MM5 palm and Huazhou population were selected based on the major determining factors as high-yielding cold tolerant palm and population, respectively, which was consistent with the results of analysis of variance.

Keywords: oil palm, vegetative growth, yield, cold resistance, northern tropical regions.

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INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.), a typical tropical woody oil crop, generally grows at the latitudinal range from 12°S to 15°N with mean monthly minimum temperatures of more than 19°C (Olivin, 1986), and gives the highest oil yield with average yield of 3.5 t ha^{-1} yr^{-1} and the full yield potential estimated at 11-18 t ha^{-1} yr^{-1} under favourable conditions (Barcelos *et al*., 2015). The oil palm was introduced into China in 1926, and mainly distributed at between 18°N and 25°N, the northern tropical regions with occasional damages by typhoon, cold and drought (Zeng *et al*., 2015; Cao *et al*., 2009). Zeng *et al*. (2015) reported that a large number of oil palm were scattered planted as a landscape tree species in Guangdong, Yunnan, Hainan in China. These palms had undergone long-

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term natural domestication in the local conditions and might have important beneficial variations for utilisation.

The main yield components of oil palm are the number and the weight of harvested bunches and determined by sex ratio, bunch failure and mesocarp to total bunch dry mass ratio (Corley and Tinker, 2003). Earlier studies showed the relationships among traits in oil palm such as vegetative growth, yield and its components were proved to be related (Corley and Tinker, 2003). Analysis of variance (ANOVA) phenotypic correlations and path coefficient analysis could be used to determine the nature of relationships among the traits and help the breeder to reduce the number of traits to the minimum in breeding programmes (Rafii *et al*., 2013; Oboh and Fakorede, 1990; Corley *et al*., 1977). Significant negative phenotypic and genotypic correlations have been found to occur between the number of bunches and average bunch weight (ABW), while both two were positively correlated with fresh fruit bunch (FFB) (Corley *et al*., 1977; Obisesan and Fatunla, 1983). Oboh and Fakorede (1990) concluded that percentage of fruit per bunch was the most important determinant for FFB yield and number of bunches. Moreover, the number of leaves per palm, sex ratio (SR), percentage fruit per bunch and percentage mesocarp per fruit would be effective as indirect criteria for yield. Malaysia has drawn the minimum standards for the selection of high yielding *tenera* and *dura* materials, which are ≥170 kg yr^{-1} and ≥150 kg yr^{-1} per palm, respectively, with at least four consecutive years of recording, but the selection standards for each trait of interest may vary in different countries (Kushairi *et al*., 2011).

Studies on cold resistance of oil palm were rarely reported and mostly focused on field investigation of cold damage, microstructure observation and determination of physiological and biochemical indexes (Tarmizi and Marziah, 2000; Lei *et al*., 2014; Ruan *et al*., 2008; Ruan, 2008; Cao *et al*., 2009). However, the cold tolerant oil palm hybrid with D×P progenies (Bamenda×AVROS and Tanzania×AVROS) derived from the higher altitudes, bred in Costa Rica, have been successfully adapted to the higher altitudes up to 1500 m and latitudes (LAT) up to 25°N in Africa and South-east Asia. This indicates the possibility of selection of cold tolerant high yielding oil palm, although there seems to be little demonstrable progress (Chapman *et al*., 2001; Corley and Tinker, 2003).

The objectives of this experiment are to identify high yielding cold tolerant individual palms or populations by evaluating the vegetative growth, yield and cold resistance traits of pre-selected individual palms and populations and to select the major indexes affecting FFB, bunch number (NB) and ABW by analysing the correlation of various traits. The results were expected to provide some useful references for conservation and development of oil palm germplasm resources at a north fringe of tropic in China.

MATERIALS AND METHODS

A total of 38 individual oil palm were selected based on higher mean BN in respective populations in February 2010 from six regions (populations) in Guangdong Province, China at between the LAT of 20°N and 23°N (*Table 1*). Each individual palm was tagged with a short region name plus a code, for example SZ1 which indicates the first plant observed in Shenzheng population.

Data collection on individual palm basis was initiated in April 2010, *i.e*. two months after selection, and then continued until April 2015 at a regular interval of three to six months, namely two to four times per year.

Data on vegetative growth and development including frond production (FP), total number of inflorescences (including male, female and bracts without anthesising inflorescences) and bunches (NIB), sex ratio (the percentage of total number of female inflorescences and fruit bunches in total number of female, male, inflorescences and bunches) (SR), female inflorescence abortion ratio (the percentage of the total number of aborted female inflorescences in total number of female inflorescences and bunches) (RAFM), bunch abortion ratio (the percentage of the total number of aborted bunches in total number of bunches) (ABR) were collected from April 2010 to April 2015.

Yield components, including yield FFB, NB, ABW, were also determined. NB was the total of all the FFB counts; ABW was recorded based on a total of three FFB per individual palm during the period; FFB was thus the product between NB and ABW.

Bunch and fruit quality components, which include average number of fruits (the total number of normal fruits and infertile fruits) per bunch (ANF), total number of normal fruits per bunch (ANNF), average single fruit weight (ASFW), fruit compact ratio (the percentage of the total number of normal fruits in total number of fruits) (FCR), average normal fruit weight (ANFW), fruit to bunch ratio (the percentage of the average normal fruit weight in average fruit bunch weight) (F/B), shell to mesocarp thickness ratio (S/M), shell to kernel thickness ratio (S/K), mesocarp to kernel ration (M/K), were determined based on three FFB per individual palm with 10 normal fruits per bunch. Some measurements of bunch and fruit quality such as the selection methods for fruits and the determination of ASFW using the 'bunch analysis' technique developed at the Nigerian Institute for

Oil Palm Research (NIFOR) (Henson and Dolmat, 2004) were used in this study.

Semi-lethal temperature (LT_{50}) was measured in April 2014 as cold tolerance reference index. The healthy, intact leaflets on both sides of middle leaf rachis of frond in middle canopy toward sunny sides were selected as test materials. After leaves *in vitro* were placed under low temperature stress at 7°C, 4°C, 1°C, -2°C, -5°C and -8°C for 12 hr with artificial low temperature constant temperature bath (equipment model BILON-W-803S), a EC215 conductivity meter was used to measure the conductivity of the solutions. The relative electrical conductivity was calculated with the following formula, *i.e*. (S1 - CK / S2 – CK) × 100%, where S1 is the electrical conductivity value of samples at the first measurement, S2 is the conductivity after boiling and CK is the conductivity of deionised water. The relative electrical conductivity was carried out according to the method described by Premachandra *et al*. (1991) with little modification. Afterwards, a regression analysis was conducted based on relative electrical conductivity with Logistic equation as recommended by Mo (1983), where x represents the relative electrical conductivity, y the processing temperature, k the relative conductivity saturation value, a and b the equation parameters.

One-way repeated randomised block design ANOVA and two-way non-repeated complete randomised block design ANOVA were used for data ANOVA, where the former ANOVA was carried out for all traits to compare the significant differences in individual palms and populations, while the latter ANOVA was performed to evaluate the effects of individual palms and years, populations and years on parameters of FP, NIB, NB, FFB, SR, RAFM and ABR. Statistical analyses were conducted using the statistical software package DPS 7.05 for Windows XP (Tang *et al*., 2007). Multiple comparison method of data was adopted with Duncan's New Multiple Range Method (SSR). All results of ANOVA presented are the mean values ± standard errors obtained from at least three replications.

Phenotypic correlations among the traits including (LAT) were computed with the data of individual palms (38 palms) and populations (six populations) through replications. Of the replications, the observation data on FP, NIB, NB, FFB, SR, RAFM and ABR were determined by years, *i.e*. five replications in a set of data, while the data on ABW, ANF, ANNF, ASFM, ANFW, FCR, F/B, S/M, S/K and M/K were derived from three replications, with only three bunches per plant, and the number of samples per palm used for determining the LT_{50} was obtained in April 2014 with three leaf sample replications.

Path coefficient analysis, developed by Wright (1923), was used to determine the inter-relationships among all traits in a set of data, with FFB, NB or ABW as the dependent variable and the other traits the independent variables. This method aids the partitioning and interpretation of cause-and-effect relationships among a set of variables. A direct casual effect (p) of a trait on the dependent trait (y) is indicated by a single one-directional path. Indirect causal effects are indicated by alternate paths from a trait, i, through another trait, j, to the dependent trait. Thus, a single indirect effect is equal to the product of path coefficient along a given path, *i.e*., indirect effect = (rij) (pjy), where rij = correlation coefficient of trait I with j, $i \neq j$; p_{jy} = direct effect (or path coefficient) of trait j on the end product, y; $r_{ij}\ p_{jy}$ = indirect effect (product of path coefficient along a given path).

RESULTS AND DISCUSSION

One-way ANOVA in Vegetative Growth, Yield and Cold Resistance Traits of Pre-selected Individual Palms and Populations

ANOVA in all traits showed significant differences in the selected individual palms (*Table 2*), which indicated high variability. The MM7 in Maoming population had the highest FP (26.80 fronds yr^{-1}) and high NIB (21.8 inflorescences and bunches yr^{-1}), SR (74.25%), NB (8.74 bunches yr^{-1}) and FFB (61.9 kg yr^{-1}). The SZ12 in Shenzhen population had the highest FCR (89.95%) and the maximum thickness of mesocarp with the lowest S/M (0.19) and the highest M/K (0.88), while the lowest FP (12.6 fronds yr^{-1}), NIB (9.00 inflorescences and bunches) and ANNF (166.00 fruits per bunch) were recorded with the lower NB (3.30 bunches yr^{-1}), ABW (7.02 kg per bunch) and FFB (23.18 kg yr^{-1}). The SZ3 in Shenzhen population was recorded with the highest NB (15.33 bunches yr^{-1}) attributed to the highest SR (92.88%), while the lowest F/B (11.67%) did not compensate for the ABW (3.82 kg per bunch), resulting in lower FFB (58.59 kg yr^{-1}). The MM5 produced the highest FFB yield (115.40 kg yr^{-1}) with the highest ABW (13.96 kg per bunch) and comparatively high NB (8.27 bunches yr^{-1}). HZ6 had the highest F/B (54.26%), which might be due to the highest ANF (1040.67 fruits per bunch), ANNF (611.33 fruits per bunch), ANFW (4.43 kg per bunch), S/M (1.77) and the lowest M/K (0.18). However, the highest ABR (54.24%) resulted in low NB (6.40 bunches yr^{-1}) and thus affected its FFB (42.60 kg yr^{-1}) yield. In addition, the highest values for NIB (23.60 inflorescences and bunches yr^{-1}), ASFW (18.61 g per fruit) and RAFM (23.55%) were recorded in MM3 in Maoming population, SZ4 and HZ4 in Shenzhen population, respectively. Previous studies showed that vegetative growth was closely related to bunch yield and both had a balance between the competing sources and sinks (Corley and Breure, 1992). To

TABLE 1. GEOGRAPHICAL DISTRIBUTION INFORMATION OF OIL PALM POPULATIONS ON SITE

Regions (populations)	LAT and LON	ALT (m)	Planting micro-habitats	≤10°C days	Extreme minimum temperature (°C)	Plant sources	Introduction year	Management measures	Total plant number	Plant height (m)	Trunk height (m)	Planting patterns	Mean bunch number per plant	Pre-selected superior individual number	Observed plants
Shenzhen	22°32′ N, 114°01′ E	10	Urban green belt in the middle of two-way roads	15-20	Around 5.0	Hainan island	Unknown	Landscaping	96	9.98	4.32	Spaced at 3-4 m in single linear and curve patterns	3.7	12	SZ1, SZ2, SZ3, SZ3, SZ4, SZ5, SZ6, SZ7, SZ8, SZ9, SZ10, SZ11 and SZ12
Dongguan	22°58′ N, 113°44′ E	26	Sidewalk of sides urban road	20-25	Around 5.0	Hainan island	Unknown	Landscaping	16	9.04	5.03	Spaced at 5 m in single linear pattern	2.9	2	DG1 and DG2
Maoming	21°39′ N, 110°56′ E	30	Green belt with flower beds in urban square	15-20	Around 5.0	Hainan island	2004	Landscaping	99	9.33	5.04	Spaced at 5 m in linear pattern	4.4	8	MM1, MM2, MM3, MM4, MM5, MM6, MM7 and MM8
Huazhou	21°38′ N, 110°30′ E	35	Sidewalk of rural road sides	15-20	Around 5.0	Hainan island	Unknown	Landscaping	121	7.97	3.69	Spaced at 4 m in single linear pattern	4.2	8	HZ1, HZ2, HZ3, HZ4, HZ5, HZ6, HZ7 and HZ8
Zhanjiang	21°12′ N, 110°24′ E	4	Around urban square lawn by the sea	10-15	Around 5.0	Hainan island	Unknown	Landscaping	126	10.11	5.58	Spaced at 4 m in single linear pattern	4.0	5	ZJ1, ZJ2, ZJ3, ZJ4, ZJ5, ZJ6, ZJ7 and ZJ8
Leizhou	20°54′ N, 110°05′ E	8	Sidewalk in public park by the lake	10-15	Around 5.0	Hainan island	Unknown	Landscaping	12	10.39	5.66	Spaced at 3-4 in single linear pattern 3-4	2.0	3	LZ1, ZL2 and LZ3

Note: LON - longitude; LAT - latitude; ALT - altitude; the reference data of ≤10°C days and extreme minimum temperature were derived from the continuous raining and cold weather on 13 January to 13 February 2008 (Huang *et al*., 2008).

further understand the cold resistance of oil palm, LT_{50} was obtained as the reference index. Results showed that SZ7 and SZ1 in Shenzhen population had the highest cold resistance at the lowest LT_{50} (-6.19°C) and the lowest cold resistance at the highest LT_{50} (-2.69°C). However, cold resistance to plants is a complex quantitative trait, which is influenced by different genetic characteristics, organ tissues, environment and cultural conditions.

ANOVA of vegetative growth, yield and cold resistance traits in different populations (*Table 3*) showed that the traits except FP (18.22-22.96 fronds yr^{-1}), NIB (13.46-20.14 inflorescence and bunches yr^{-1}), NB (4.06-9.02 bunches yr^{-1}), ABR (19.09%-33.82 %) and SR (59.80%-81.10 %) in different populations were significantly different, which may be affected by environment and cultural operation factors, such as planting density, fertilisation and water, temperature, palm age, leaf pruning, inflorescence removal and genetic differences and so on (Corley and Tinker, 2003). The FFB yield in different populations was in the ranking order of Maoming (71.88 kg yr^{-1}), Huazhou (61.36 kg yr^{-1}), Shenzhen (50.62 kg yr^{-1}), Zhanjiang (50.34 kg yr^{-1}), Dongguan (31.06 kg yr^{-1}) and Leizhou (10.34 kg yr^{-1}). Dongguan population had the highest ABW, followed by the populations in Maoming, Shenzhen, Huazhou, Zhanjiang and Leizhou, which yielded 8.33, 8.10, 7.17, 7.13, 6.07 and 3.07 kg per bunch, respectively. The highest FFB in Maoming population was attributed to the lowest RAFM (2.83%) and the higher S/M (1.08) and S/K (0.41), while in Leizhou population the FFB, ABW, ANF, ANNF, ASFW, ANFW and LT_{50} were the lowest and the ABR was the highest. FCR was significantly higher in Shenzhen population than in other populations. ABW and LT_{50} were significantly lower in Leizhou population.

Two-way ANOVA in Some Vegetative Growth and Yield Traits in Different Years

During the experimental period from April 2010 to April 2015, ANOVA for the traits of FB, NIB, NB, FFB, RAFM, ABR and SR was computed using the mean values of the data on individual palms (*Table 4*) and populations (*Table 5*). Results indicated that those traits were greatly influenced by years with an obvious inter-annual difference except SR based on populations, and both results showed similar variation trends among years. The FP, NIB, NB and FFB showed similar trends between years with an inverted 'N' shape, while RAFM, ABR and SR were presented as inverted 'V', 'M' and 'V' shapes, respectively.

The NIB (24.79 and 21.68 inflorescences and bunches), NB (19.31 and 15.77 bunches) and FFB (137.33 and 109.12 kg) were observed highest in the first year 2010/2011, and FP and RAFM in the fourth year 2013/2014 with 25.45-25.89 fronds and 10.50%-10.69%, respectively. The highest ABR was recorded in the second year 2011/2012 (36.20%) and the fourth year 2013/2014 (40.27%) based on individual palms and populations, respectively. It was noted that the annual variations of SR were significantly affected by individual palms, and the highest value appeared in 2010/2011 (82.21%), while there were no significant annual variations based on populations with the highest record in 2014/2015 (74.18%). The SR, governing the potential NB and NIB which may be produced, was the major factor determining FFB yield (Turner and Gillbanks, 1974) and was verified in this study on account of each of NB, NIB, FFB and SR appearing highest in the same year 2010/2011. However, the effects on SR might have not only been due to the differences in genotype in individual palms alone but also to environmental factors or the interaction of both factors. Rates of FP were very similar in different environments, implying similar rates of inflorescence development. However, the annual FP and NIB observations showed significant inter-palm and inter-annual differences (*Tables 2, 4* and *5*), which were similar to the results reported in Malaysia (Corley, 1977).

Phenotypic Correlation Analysis

Phenotypic correlation analyses were carried out for all the traits in the selected superior individual palms (*Table 6*) and different populations (*Table 7*). The interpretation of the strength of a relationship is based on correlation of coefficient (r). Cohen (1988) estimated the r ≥0.70 as very high relationship, 0.69 < r > 0.50 as high, 0.49 < r > 0.30 as moderate and 0.29 < r ≥0.10 as low. Significant associations occurred in many cases, but only those involving FFB, NB and ABW in relation to other traits will be discussed.

For individual palms, FFB was positively correlated with ABW (r = 0.71**), NB (r = 0.65**), NIB (r = 0.56**), ANFW (r = 0.56**), S/K (r = 0.49**), ANNF (r = 0.44**), ANF (r = 0.38*) and S/M (r = 0.37**), but negatively with ABR (r = - 0.47**). NB were positively correlated with NIB (r = 0.56**), SR (r = 0.45**) and S/K (r = - 0.35*), and negatively with ABR (r = - 0.58**), but was not significantly correlated with ABW. ABW was positively correlated with each of ANFW (r = 0.67**), ANNF (r = 0.50**), ANF (r = 0.44**) and FCR (r = 0.36*), and negatively correlated with LT_{50} (r = - 0.34**).

Observations based on populations showed FFB and NB, which were positively correlated with each other (r = 0.92*), were positively correlated with NIB (r = 0.95** and 0.82* respectively) and ANF (r = 0.86* and 0.82* respectively), but negatively with ABR (r = - 0.95** and - 0.92** respectively), while ABW showed positive associations with LAT (r = 0.84*). In addition, FFB was positively correlated with S/M

TABLE 2. ONE-WAY ANALYSIS OF VARIANCE (ANOVA) FOR VEGETATIVE GROWTH, YIELD AND COLD RESISTANCE TRAITS IN THE SELECTED INDIVIDUAL PALMS

Populations	No.	Plant No.	FP	NIB	NB	ABW	FFB	ANF	ANNF	ASFW	ANFW
	1	SZ1	(19.00±5.87) abcdef AB	(18.80±6.83) abcd AB	(7.48±7.86) bcdefABCDE	(7.40±2.63) cdefghijk BCDEFGHI	(55.34±58.11) bcdef ABCDE	(271.67±135.02) fgh CD	(158.33±95.47) bc B	(13.05±0.63) cdefg BCDEFGHI	(2.10±1.33) bcdefg ABCD
	2	SZ2	(16.40±4.72) bcdef AB	(14.20±5.40) abcd AB	(7.14±6.79) cdef ABCDE	(8.20±1.04) bcdefg BCDEFGHI	(58.54±55.73) abcdef ABCDE	(235.67±8.14) gh CD	(105.67±34.79) bc B	(11.42±1.66) fghijk DEFGHIJK	(1.17±0.26) efg BCD
	3	SZ3	(17.40±9.84) abcdef AB	(20.20±7.19) abc AB	**(15.33±9.76) a A**	(3.82±0.34) hijklm FGHI	(58.59±37.34) abcdef ABCDE	(315.00±37.99) defgh CD	(64.33±22.72) bc B	(6.95±0.48) l K	(0.45±0.16) g CD
	4	SZ4	(23.80±8.32) abc AB	(21.60±10.64) abc AB	(9.20±10.63) abcdef ABCDE	**(9.76±0.53) bcde ABCD**	(89.72±103.76) abc ABC	(339.67±50.82) cdefgh CD	(171.33±42.77) bc B	**(18.61±3.37) a A**	(3.28±1.43) abcdef ABCD
	5	SZ5	(15.20±4.97) cdef AB	(12.40±6.02) bcd AB	(5.58±7.11) def BCDE	(5.69±0.52) defghijklm CDEFGHI	(31.79±40.46) cdef BCDE	(361.00±52.74) cdefgh BCD	(144.00±72.39) bc B	(10.00±0.00) ghijkl FGHIJK	(1.44±0.72) bcdefg ABCD
	6	SZ6	(20.00±7.18) abcdef AB	(16.00±2.74) abcd AB	(5.10±7.84) def BCDE	**(10.33±1.47) abc ABC**	(52.67±81.00) bcdef ABCDE	(501.67±31.66) bcdefgh BCD	(192.33±83.27) bc B	(15.83±2.21) abcd ABCD	(3.16±1.61) abcdef ABCD
Shenzhen	7	SZ7	(15.80±5.17) bcdef AB	(12.20±4.76) bcd AB	(5.00±6.93) ef BCDE	(3.98±1.48) ghijklm EFGHI	(19.88±27.55) def CDE	(270.33±70.32) fgh CD	(140.67±79.83) bc B	(10.83±1.44) fghijkl DEFGHIJK	(1.58±1.02) bcdefg ABCD
	8	SZ8	(15.80±4.32) bcdef AB	(14.60±5.59) abcd AB	(5.80±8.83) def ABCDE	(7.19±0.39) cdefghijkl BCDEFGHI	(41.65±63.46) cdef ABCDE	(315.00±40.34) defgh CD	(168.67±19.55) bc B	(8.89±1.92) hijkl GHIJK	(1.50±0.39) bcdefg ABCD
	9	SZ9	(21.00±7.52) abcdef AB	(15.40±4.45) abcd AB	(6.62±5.84) cdef ABCDE	(9.19±1.49) bcde ABCDEFG	(60.86±53.71) abcdef ABCDE	(395.67±25.01) cdefgh BCD	(270.33±28.38) bc AB	(12.78±2.55) defgh BCDEFGHIJ	(3.48±0.95) abcde ABCD
	10	SZ10	(20.80±6.42) abcdef AB	(17.60±5.41) abcd AB	(8.75±1.22) abcdef ABCDE	(7.59±1.02) cdefghi BCDEFGHI	(66.42±9.27) abcdef ABCDE	(592.00±49.37) bcdefg ABCD	(282.33±254.16) bc AB	(7.92±1.10) jkl IJK	(2.08±1.64) bcdefg ABCD
	11	SZ11	(20.80±6.02) abcdef AB	(17.20±7.36) abcd AB	(8.21±10.05) abcdef ABCDE	(5.92±0.43) defghijklm CDEFGHI	(48.59±59.53) bcdef ABCDE	(276.00±34.60) fgh CD	(118.00±35.34) bc B	(13.61±8.99) bcdefg BCDEFGH	(1.65±1.22) bcdefg ABCD
	12	SZ12	**(12.60±7.81) df B**	**(9.00±5.44) d B**	(3.30±3.13) f DE	(7.02±0.47) cdefghijklm CDEFGHI	(23.18±22.02) def CDE	**(166.00±65.37) h D**	(148.00±56.45) bc B	(16.67±3.34) abc ABC	(2.56±1.44) abcdefg ABCD
Dongguan	13	DG1	(20.80±6.46) abcdef AB	(18.00±4.85) abcd AB	(4.79±3.14) ef CDE	(4.77±0.20) fghijklm CDEFGHI	(22.81±14.94) def CDE	(359.00±3.61) cdefgh BCD	(83.33±6.66) bc B	(11.67±2.89) efghij CDEFGHIJK	(0.99±0.33) fg BCD
	14	DG2	(17.80±6.22) abcdef AB	(11.80±6.53) cd AB	(3.30±3.07) f DE	**(11.92±2.75) ab AB**	(39.33±36.33) cdef ABCDE	(461.00±77.90) cdefgh BCD	(175.67±108.19) bc B	(10.42±0.72) fghijkl EFGHIJK	(1.86±1.19) bcdefg ABCD
	15	MM1	(21.60±7.33) abcdef AB	(21.20±6.53) abc AB	(8.05±12.36) abcdef ABCDE	(9.06±3.94) bcdef ABCDEFG	(72.99±111.99) abcde ABCDE	(431.67±76.00) cdefgh BCD	(235.67±40.20) bc B	(10.00±0.00) ghijkl FGHIJK	(2.36±0.40) abcdefg ABCD
	16	MM2	(21.20±5.89) abcdef AB	(21.20±7.82) abc AB	(9.03±8.22) abcdef ABCDE	(3.69±0.95) ijklm FGHI	(33.33±30.37) cdef	(318.00±26.91) cdefgh CD	(70.00±7.55) bc AB	(11.67±2.89) efghij CDEFGHIJK	(0.82±0.23) g BCD
	17	MM3	(24.00±17.82) abc AB	**(23.60±14.74) a A**	(12.60±7.02) abcd ABCD	(9.13±5.03) bcdef ABCDEFG	**(115.08±64.13) a A**	(681.00±27.07) abcdef ABCD	(345.00±214.71) b AB	(10.69±1.20) fghijkl EFGHIJK	(3.52±2.03) abcd ABC
	18	MM4	(19.60±7.54) abcdef AB	(17.60±6.43) abcd AB	(7.36±4.43) bcdef ABCDE	**(10.05±4.90) bcd ABC**	(74.00±44.46) abcde ABCDE	(540.00±66.55) bcdefgh ABCD	(243.33±23.03) bc B	(10.00±0.00) ghijkl FGHIJK	(2.43±0.23) abcdefg ABCD
Maoming	19	MM5	(19.80±6.30) abcdef AB	(14.80±6.38) abcd AB	(8.27±8.25) abcdef ABCDE	**(13.96±0.23) a A**	**(115.44±115.10) a A**	(591.00±181.12) bcdefg ABCD	(199.83±72.86) bc B	(12.78±1.92) defgh BCDEFGHIJ	(2.58±1.07) abcdefg ABCD
	20	MM6	(22.20±6.30) abcd AB	(22.20±9.18) ab A	**(11.65±10.41) abcde ABCDE**	(5.55±0.31) efghijklm CDEFGHI	(64.68±57.79) abcdef ABCDE	(312.33±13.58) efgh CD	(84.00±7.00) bc B	(12.78±2.55) defgh BCDEFGHIJ	(1.08±0.29) fg BCD
	21	MM7	**(26.80±9.83) a A**	(21.80±9.36) abc AB	(8.74±6.96) abcdef ABCDE	(7.08±1.06) cdefghijklm CDEFGHI	(61.90±49.30) abcdef ABCDE	(491.33±28.59) bcdefgh BCD	(109.75±20.50) bc B	(10.28±2.10) ghijkl EFGHIJK	(1.15±0.42) fg BCD
	22	MM8	(18.80±4.97) abcdef AB	(18.60±6.69) abcd AB	(6.04±6.70) cdef ABCDE	(6.25±0.34) cdefghijklm CDEFGHI	(37.72±41.83) cdef ABCDE	(519.67±24.34) bcdefgh ABCD	(95.67±11.68) bc B	(10.00±0.00) ghijkl FGHIJK	(0.96±0.12) fg BCD
	23	HZ1	(24.00±8.66) abc AB	(16.20±6.46) abcd AB	(8.35±9.56) abcdef ABCDE	(9.66±0.43) bcde ABCDE	(80.66±92.40) abcd ABCDE	(725.67±589.70) abcde ABC	(310.67±375.44) bc AB	(10.28±3.15) ghijkl EFGHIJK	(2.41±2.21) abcdefg ABCD
	24	HZ2	(21.40±5.86) abcdef AB	(18.80±10.13) abcd AB	**(11.20±12.07) abcde ABCDE**	(9.23±0.99) bcde ABCDEF	**(103.34±111.37) ab AB**	(735.67±418.82) abc ABC	(291.00±222.34) bc AB	(13.06±3.94) cdefg BCDEFGHI	(3.61±2.27) ab AB
	25	HZ3	(25.00±11.25) ab AB	(21.60±8.65) abc AB	**(13.40±8.32) abc ABC**	(6.54±0.43) cdefghijklm BCDEFGHI	(87.59±54.42) abc ABCD	(272.33±28.15) fgh CD	(178.33±30.11) bc B	(11.67±2.89) efghij CDEFGHIJK	(2.07±0.50) bcdefg ABCD
	26	HZ4	(22.20±7.40) abcde AB	(14.60±6.31) abcd AB	(6.53±7.25) cdef ABCDE	(7.54±2.00) cdefghij BCDEFGHI	(49.18±54.68) bcdef ABCDE	(887.33±643.04) ab AB	(262.67±150.07) bc AB	(13.75±2.32) bcdefg BCDEFG	(3.54±1.80) abc ABC
Huazhou	27	HZ5	(25.40±4.22) ab A	(19.60±9.89) abc AB	(8.46±9.18) abcdef ABCDE	(6.81±2.00) cdefghijklm CDEFGHI	(57.59±62.51) abcdef ABCDE	(456.67±52.00) cdefgh BCD	(93.33±22.14) bc B	(14.31±2.37) bcdef ABCDEF	(1.32±0.33) bcdefg BCD
	28	HZ6	(18.60±7.20) abcdef AB	(17.20±10.11) abcd AB	(6.40±9.07) cdef ABCDE	(6.66±3.92) cdefghijklm CDEFGHI	(42.60±60.39) cdef ABCDE	**(1040.67±809.75) a A**	(611.33±667.18) a A	(8.47±1.68) ijkl HIJK	**(4.43±4.26) a A**
	29	HZ7	(23.00±6.96) abc AB	(14.20±7.89) abcd AB	(6.60±6.99) cdef ABCDE	**(2.75±0.19) m I**	(18.15±19.21) ef CDE	(260.67±57.13) fgh CD	(27.33±13.05) c B	(15.28±2.10) abcde ABCDE	**(0.41±0.17) g D**
	30	HZ8	(24.00±7.65) abc AB	(15.20±8.79) abcd AB	(6.44±8.42) cdef ABCDE	(8.06±0.13) bcdefgh BCDEFGHI	(51.93±67.93) bcdef ABCDE	(485.00±16.52) bcdefgh BCD	(95.67±9.29) bc B	(16.95±0.48) ab AB	(1.63±0.21) bcdefg ABCD
	31	ZJ1	(19.00±7.97) abcdef AB	(17.60±8.38) abcd AB	(9.63±10.95) abcdef ABCDE	(3.45±0.38) ijklm GHI	(33.20±37.75) cdef BCDE	(337.33±52.17) cdefgh CD	**(43.33±8.08) c B**	(12.08±3.61) defghi CDEFGHIJK	(0.54±0.27) g BCD
	32	ZJ2	(17.00±5.43) bcdef AB	(15.80±10.52) abcd AB	(7.73±11.99) bcdef ABCDE	(8.47±5.90) bcdef BCDEFGHI	(65.48±101.55) abcdef ABCDE	(735.67±216.34) abc ABC	(281.33±231.07) bc AB	**(7.50±0.83) kl K**	(2.19±1.78) abcdefg ABCD
Zhanjiang	33	ZJ3	(18.80±12.91) abcdef AB	(20.20±8.70) abc AB	**(14.62±11.37) ab AB**	(4.07±1.47) ghijklm DEFGHI	(59.45±46.25) abcdef ABCDE	(191.33±75.75) gh CD	(76.33±34.53) bc B	(10.33±0.58) ghijkl EFGHIJK	(0.80±0.40) g BCD
	34	ZJ4	(20.20±7.19) abcdef AB	(12.80±10.35) bcd AB	(6.74±8.25) cdef ABCDE	(5.80±0.35) defghijklm CDEFGHI	(39.10±47.90) cdef ABCDE	(733.00±55.56) abcd ABC	(122.00±81.19) bc B	(10.00±0.00) ghijkl FGHIJK	(1.22±0.81) cdefg BCD
	35	ZJ5	(20.00±8.75) abcdef AB	(14.60±7.16) abcd AB	(6.38±8.30) cdef ABCDE	(8.53±4.95) bcdef ABCDEFGHI	(54.45±70.83) bcdef ABCDE	(435.67±127.60) cdefgh BCD	(111.33±85.97) bc B	(10.95±1.65) fghijk DEFGHIJK	(1.21±0.86) defg BCD
	36	LZ1	(21.80±3.96) abcdef AB	(11.80±3.49) cd AB	**(2.60±2.41) f E**	(2.90±0.26) lm HI	(7.54±6.98) f E	(288.67±19.50) fgh CD	(77.00±11.00) bc B	(9.08±0.14) hijkl GHIJK	(0.70±0.10) g BCD
Leizhou	37	LZ2	(22.60±5.90) abc AB	(16.60±7.80) abcd AB	(4.23±3.16) ef CDE	(3.20±0.30) jklm HI	(13.54±10.12) ef CDE	(286.67±17.62) fgh CD	(82.67±4.04) bc B	(8.86±0.32) hijkl GHIJK	(0.73±0.02) g BCD
	38	LZ3	(24.20±13.99) abc AB	(12.00±13.87) cd AB	(3.19±3.26) f DE	(3.13±0.25) klm HI	(9.99±10.21) f DE	(295.67±5.86) fgh CD	(72.00±4.00) bc B	(7.81±0.17) jkl JK	(0.56±0.04) g BCD

Note: FP - frond production per year (No.); NIB - inflorescence (male, female, bisexual and non-anthesis) and fruit bunch numbers per year (No.); NB - fresh fruit bunch number per year (No.); ABW - average bunch weight (kg); FFB - fresh fruit bunch weight per plant (kg); ANF - average fruit number per bunch (No.); ANNF - average normal fruit number per bunch (No.); ASFW - average single fruit weight (g); ANFW - normal fruit weight per bunch (kg); values followed by the same letter are not significantly different at P<0.05; values followed by the different small letter are significantly different at P<0.05; values followed by the different capital letter are extremely significant difference at P<0.01; similarly herein after.

TABLE 2. ONE-WAY ANALYSIS OF VARIANCE (ANOVA) FOR VEGETATIVE GROWTH, YIELD AND COLD RESISTANCE TRAITS IN THE SELECTED INDIVIDUAL PALMS (continued)

Populations	No.	Plant No.	FCR	F/B	RAFM	ABR	SR	S/M	S/K	M/K	LT_{50}
	1	SZ1	(57.06±8.06) bcd BCD	(26.65±7.95) bcdefgh ABC	(8.38±8.45) abcdef	(30.08±24.20) abc	(83.31±14.16) abcd	(0.30±0.04) k HI	(0.18±0.03) ijkl IJK	(0.59±0.12) bcdefg BCDEFG	(-2.69±0.26) a A
	2	SZ2	(44.70±14.09) bcdefghijk BCDEFGHI	(14.12±1.50) fgh BC	(7.38±7.65) abcdef	(29.17±22.78) abc	(80.77±20.71) abcd	(0.35±0.04) k HI	(0.16±0.03) jkl IJK	(0.47±0.12) efghijkl DEFGHIJ	(-5.10±1.81) lmnopq GHIJKL
	3	SZ3	(20.11±5.33) jklmn FGHIJ	**(11.67±3.88) h C**	(3.90±5.35) cdef	(12.50±21.65) abc	**(92.88±10.44) a**	(0.34±0.06) k HI	(0.15±0.01) kl IJK	(0.48±0.07) efghijkl CDEFGHI	(-3.76±0.11) abcdefghij ABCDEFGH
	4	SZ4	(50.10±6.71) bcdefg BCDEFGH	(33.20±12.59) abcdefgh ABC	**(0.00±0.00) f**	(19.11±26.74) abc	(64.85±20.05) abcd	(0.35±0.05) k HI	(0.27±0.01) efghij DEFGHIJ	(0.78±0.11) ab AB	(-4.93±0.21) jklmnop FGHIJKL
	5	SZ5	(38.58±13.81) defghijklm BCDEFGHIJ	(24.87±10.56) bcdefgh BC	**(0.00±0.00) f**	(11.67±16.24) abc	(69.44±30.48) abcd	(0.48±0.06) jk GHI	(0.20±0.02) hijkl GHIJK	(0.43±0.07) fghijklm DEFGHIJ	(-5.49±0.33) mnopq IJKL
Shenzhen	6	SZ6	(37.97±15.73) defghijklm BCDEFGHIJ	(32.11±18.16) bcdefgh ABC	**(0.00±0.00) f**	(44.81±33.86) ab	(65.49±28.68) abcd	(0.45±0.24) jk GHI	(0.25±0.08) fghijk EFGHIJK	(0.58±0.10) bcdefgh BCDEFG	(-5.00±0.49) klmnop GHIJKL
	7	SZ7	(48.69±19.29) bcdefgh BCDEFGH	(36.94±15.95) abcdef ABC	(21.00±20.12) abcd	(23.33±32.49) abc	(65.58±21.96) abcd	(0.21±0.08) k I	(0.16±0.08) jkl IJK	(0.76±0.10) abc ABC	**(-6.19±1.49) q L**
	8	SZ8	(53.62±1.57) bcde BCDEF	(20.74±4.29) cdefgh BC	(6.50±9.29) abcdef	(40.47±42.46) abc	(72.05±24.17) abcd	(0.30±0.07) k HI	(0.20±0.05) hijkl GHIJK	(0.68±0.22) abcde ABCDE	(-4.37±0.50) efghijklm BCDEFGHIJ
	9	SZ9	(68.21±2.90) b AB	(38.76±14.07) abcd ABC	(4.50±6.22) bcdef	(8.89±19.87) bc	(64.08±18.07) abcd	(0.22±0.04) k I	(0.13±0.01) kl JK	(0.65±0.17) bcdef ABCDEF	(-4.75±0.64) ijklmno EFGHIJKL
	10	SZ10	(47.54±40.56) bcdefghi BCDEFGH	(25.99±19.56) bcdefgh ABC	(2.67±5.96) cdef	(14.50±13.66) abc	(88.23±7.59) ab	(0.31±0.08) k HI	(0.16±0.04) jkl IJK	(0.52±0.02) defghijkl BCDEFGH	(-5.70±0.74) nopq JKL
	11	SZ11	(42.27±7.85) cdefghijkl BCDEFGHIJ	(26.94±18.87) bcdefgh ABC	(2.22±4.97) def	(19.29±31.09) abc	(66.48±26.27) abcd	(0.33±0.02) k HI	(0.16±0.04) jkl IJK	(0.49±0.12) efghijkl CDEFGH	(-5.11±0.58) lmnopq HIJKL
	12	SZ12	**(89.95±7.12) a A**	(35.69±17.73) abcdefg ABC	(13.33±29.82) abcdef	(15.00±33.54) abc	(57.03±22.83) bcd	**(0.19±0.01) k I**	(0.16±0.03) jkl IJK	**(0.88±0.12) a A**	(-3.09±0.17) abcd ABCD
Dongguan	13	DG1	(23.21±1.70) hijklmn DEFGHIJ	(20.86±7.86) cdefgh BC	(4.89±7.91) abcdef	(25.25±25.03) abc	(57.56±30.85) bcd	(0.23±0.03) k I	**(0.10±0.01) l K**	(0.43±0.06) fghijklm EFGHIJ	(-4.92±0.53) jklmnop FGHIJKL
	14	DG2	(36.07±19.52) defghijklmn CDEFGHIJ	(14.51±7.65) fgh BC	(9.82±17.33) abcdef	(27.86±41.68) abc	(62.07±25.71) abcd	(0.35±0.07) k HI	(0.18±0.04) ijkl IJK	(0.51±0.09) defghijkl BCDEFGH	(-5.95±0.31) pq KL
	15	MM1	(55.18±9.48) bcd BCDE	(28.92±11.79) bcdefgh ABC	**(0.00±0.00) f**	(34.00±34.19) abc	(54.48±30.98) cd	**(1.34±0.18) bc BC**	(0.47±0.10) ab AB	(0.36±0.12) hijklmno FGHIJ	(-3.74±0.30) abcdefghij ABCDEFGH
	16	MM2	(22.22±3.83) ijklmn EFGHIJ	(22.80±7.03) bcdefgh BC	(1.43±3.19) ef	(18.73±21.69) abc	(62.36±17.67) abcd	**(0.87±0.22) ghi DEF**	**(0.56±0.15) a A**	(0.72±0.41) abcd ABCD	(-4.62±0.63) hijklmno DEFGHIJK
	17	MM3	(51.51±32.78) bcdef BCDEFG	(40.64±26.33) abc ABC	(0.83±1.86) ef	(6.09±13.61) bc	(70.97±20.48) abcd	**(1.44±0.51) b AB**	(0.43±0.11) bc BC	(0.30±0.07) lmno GHIJ	(-4.54±0.87) ghijklmn DEFGHIJK
Maoming	18	MM4	(45.28±3.81) bcdefghijk BCDEFGHIJ	(27.61±10.52) bcdefgh ABC	(1.67±3.73) ef	(10.16±14.09) bc	(64.48±7.92) abcd	**(1.00±0.05) efgh CDEF**	(0.41±0.08) bc BCD	(0.42±0.10) ghijklm EFGHIJ	(-3.82±0.44) abcdefghijk ABCDEFGH
	19	MM5	(33.37±3.36) defghijklmn CDEFGHIJ	(18.56±7.80) cdefgh BC	(3.65±5.19) cdef	(20.33±21.11) abc	(81.70±13.09) abcd	**(1.03±0.08) defgh CDEF**	(0.36±0.07) cde BCDEF	(0.36±0.09) ijklmno FGHIJ	(-4.46±0.46) ghijklm DEFGHIJK
	20	MM6	(26.99±3.44) fghijklmn DEFGHIJ	(19.36±4.27) cdefgh BC	(8.33±9.21) abcdef	(18.53±17.00) abc	(87.95±9.36) ab	**(1.10±0.19) cdefgh BCDE**	(0.42±0.03) bc BC	(0.40±0.09) ghijklmn EFGHIJ	(-4.32±0.43) efghijklm BCDEFGHIJ
	21	MM7	(22.24±3.16) ijklmn EFGHIJ	(16.98±7.62) defgh BC	(4.72±6.48) abcdef	(21.43±24.74) abc	(74.25±12.25) abcd	**(0.65±0.05) ij FGH**	(0.34±0.06) cdef BCDEFG	(0.52±0.09) defghijkl BCDEFGH	(-3.04±0.46) abcd ABCD
	22	MM8	(18.40±1.98) lmn GHIJ	(15.31±1.58) efgh BC	(2.00±4.47) def	(32.38±40.88) abc	(61.98±16.28) abcd	**(1.22±0.17) bcde BCD**	(0.29±0.02) defgh CDEFGHI	(0.24±0.04) mno HIJ	(-3.21±0.23) abcdef ABCDE
Huazhou	23	HZ1	(33.84±16.58) defghijklmn CDEFGHIJ	(24.51±21.77) bcdefgh BC	(20.00±27.39) abcde	(11.67±16.24) abc	(82.24±19.87) abcd	**(0.81±0.11) hi EFG**	(0.28±0.07) efghi CDEFGHIJ	(0.34±0.04) klmno GHIJ	(-4.02±0.35) cdefghijkl ABCDEFGHI
	24	HZ2	(35.93±10.74) defghijklmn BCDEFGHIJ	(37.75±22.13) abcde ABC	(4.52±6.54) bcdef	**(0.00±0.00) c**	(61.33±28.99) abcd	**(0.91±0.28) fghi DEF**	(0.38±0.09) bcd BCDE	(0.42±0.03) ghijklm EFGHIJ	(-4.42±0.15) fghijklm CDEFGHIJK
	25	HZ3	(65.21±4.32) bc ABC	(31.73±8.50) bcdefgh BC	(2.11±4.71) def	**(0.00±0.00) c**	(68.72±32.29) abcd	**(0.82±0.09) hi EFG**	(0.41±0.03) bc BCD	(0.50±0.02) efghijkl CDEFGH	(-4.22±0.75) defghijkl ABCDEFGHIJ
	26	HZ4	(33.37±8.09) defghijklmn CDEFGHIJ	(44.44±14.54) ab AB	**(23.55±24.22) a**	(7.50±16.77) bc	(73.73±16.73) abcd	**(1.33±0.25) bcd BC**	(0.41±0.09) bc BCD	(0.31±0.01) lmno GHIJ	(-3.49±0.30) abcdefgh ABCDEFG
	27	HZ5	(20.31±3.56) jklmn FGHIJ	(19.57±1.16) cdefgh BC	**(0.00±0.00) f**	(20.67±31.13) abc	(66.55±32.95) abcd	**(1.18±0.10) bcdef BCDE**	(0.37±0.05) bcde BCDE	(0.32±0.02) lmno GHIJ	(-4.46±0.69) ghijklm DEFGHIJK
	28	HZ6	(45.73±25.14) bcdefghij BCDEFGHI	**(54.26±31.84) a A**	(1.67±3.73) ef	**(54.24±46.21) a**	(74.74±19.42) abcd	**(1.77±0.39) a A**	(0.33±0.12) cdefg CDEFGH	**(0.18±0.03) o J**	(-3.54±0.28) abcdefghi ABCDEFGH
	29	HZ7	**(10.60±5.33) n J**	(14.79±5.89) efgh BC	(4.00±8.94) cdef	(28.00±43.82) abc	(71.16±34.08) abcd	**(1.14±0.32) cdefg BCDE**	(0.22±0.05) ghijk FGHIJK	(0.20±0.03) no IJ	(-3.59±0.68) abcdefghi ABCDEFGH
	30	HZ8	(19.70±1.25) klmn FGHIJ	(20.17±2.85) cdefgh BC	(5.00±11.18) abcdef	(30.67±41.26) abc	**(51.08±22.89) d**	**(0.97±0.06) efgh CDEF**	(0.34±0.08) cdef BCDEFG	(0.35±0.06) jklmno GHIJ	(-5.74±0.12) opq JKL
	31	ZJ1	(12.90±1.94) mn IJ	(15.68±7.34) efgh BC	(16.33±17.34) abcdef	(14.45±24.09) abc	(86.04±13.25) abc	(0.37±0.02) jk HI	(0.19±0.04) hijkl HIJK	(0.51±0.10) defghijkl BCDEFGH	(-2.80±0.04) ab AB
	32	ZJ2	(34.52±24.78) defghijklmn CDEFGHIJ	(22.04±12.57) bcdefgh BC	(23.14±33.11) ab	(23.33±32.49) abc	(82.43±5.38) abcd	(0.46±0.09) jk GHI	(0.20±0.01) hijkl GHIJK	(0.45±0.10) fghijklm DEFGHIJ	(-4.11±0.11) defghijkl ABCDEFGHI
Zhanjiang	33	ZJ3	(39.28±7.46) defghijkl BCDEFGHIJ	(19.07±4.56) cdefgh BC	(7.37±16.48) abcdef	(9.09±20.33) bc	(90.42±9.67) a	(0.32±0.08) k HI	(0.15±0.02) kl IJK	(0.51±0.23) defghijkl BCDEFGH	(-3.17±0.35) abcde ABCDE
	34	ZJ4	(17.19±12.22) lmn HIJ	(21.04±14.38) cdefgh BC	(7.53±12.40) abcdef	(36.44±43.17) abc	(84.70±14.11) abc	(0.35±0.08) k HI	(0.15±0.02) kl IJK	(0.42±0.04) ghijklm EFGHIJ	(-4.05±0.34) defghijkl ABCDEFGHI
	35	ZJ5	(26.35±23.11) fghijklmn DEFGHIJ	(13.57±5.40) gh C	(7.30±10.38) abcdef	(21.67±33.12) abc	(61.93±17.71) abcd	(0.31±0.03) k HI	(0.14±0.01) kl JK	(0.46±0.07) fghijklm DEFGHIJ	(-3.99±0.66) bcdefghijkl ABCDEFGHI
	36	LZ1	(26.58±2.02) fghijklmn DEFGHIJ	(24.08±2.01) bcdefgh BC	(5.83±8.12) abcdef	(40.00±54.77) abc	(56.62±13.66) bcd	(0.32±0.03) k HI	(0.18±0.01) ijkl IJK	(0.57±0.03) cdefghi BCDEFG	(-2.82±0.24) abc ABC
Leizhou	37	LZ2	(28.87±1.42) efghijklmn DEFGHIJ	(23.00±2.46) bcdefgh BC	(21.56±19.03) abc	(20.50±33.75) abc	(68.02±20.79) abcd	(0.29±0.03) k HI	(0.17±0.01) jkl IJK	(0.57±0.06) cdefghij BCDEFG	(-3.18±0.31) abcde ABCDE
	38	LZ3	(24.37±1.77) ghijklmn DEFGHIJ	(18.05±2.22) cdefgh BC	(6.67±14.91) abcdef	(40.97±40.63) abc	(87.43±19.02) ab	(0.29±0.02) k HI	(0.16±0.01) jkl IJK	(0.56±0.01) cdefghijk BCDEFG	(-3.38±0.72) abcdefg ABCDEF

Note: FCR - fruit compaction rate (%); F/B - percent of ANFW to ABW (%); SR - sex-ratio of female inflorescence and fruit bunch to female inflorescence, male inflorescence and fruit bunch (%); RAFM - abortion ratio of female inflorescence to female inflorescence and fruit bunch (%); ABR - ratio of aborted fruit bunch to fruit bunch (%); S/M - thickness-ratio of shell to mesocarp (No.); S/K - thickness-ratio of shell to kernel (No.); M/K - thickness-ratio of mesocarp to kernel (No.); LT_{50} - semi-lethal temperature (°C); similarity herein after.

TABLE 3. ONE-WAY ANALYSIS OF VARIANCE (ANOVA) FOR VEGETATIVE GROWTH, YIELD AND COLD RESISTANCE TRAITS OF OIL PALM IN DIFFERENT POPULATIONS

No.	Populations	FP	NIB	NB	ABW	FFB	ANF	ANNF	ASFW	ANFW	FCR	F/B	RAFM	ABR	SR	S/M	S/K	M/K	LT_{50}
1	Shenzhen	18.22±4.99	15.78±4.44	7.30±6.66	(7.17±0.25)	(50.62±47.54)	(336.63±29.38)	(163.67±43.10)	(12.23±1.86)	(2.03±0.71)	(49.90±4.95)	(27.3±7.50)	(5.82±5.52)	22.40±18.49	72.52±12.47	(0.31±0.03)	(0.18±0.01)	(0.61±0.06)	(-4.68±0.12)
					a A	ab	b	ab	ab AB	a	a A	ab	ab			b B	c C	a A	d D
2	Dongguang	19.30±6.08	14.90±5.41	4.06±1.78	(8.33±1.32)	(31.06±17.17)	(410.00±40.75)	(129.50±55.81)	(11.03±1.79)	(1.47±0.71)	(29.60±10.05)	(17.7±6.66)	(7.35±23.31)	26.56±23.91	59.80±22.96	(0.29±0.05)	(0.14±0.02)	(0.47±0.05)	(-5.44±0.23)
					a A	ab	ab	ab	bc AB	ab	b B	c	ab			b B	c C	b B	e E
3	Maoming	21.74±6.22	20.14±6.29	8.98±7.69	(8.10±1.54)	(71.88±61.37)	(485.63±31.63)	(172.90±25.31)	(11.00±1.22)	(1.87±0.12)	(34.40±1.91)	(23.8±3.70)	(2.83±2.76)	20.21±17.37	69.76±9.95	(1.08±0.06)	(0.41±0.03)	(0.41±0.05)	(-3.97±0.17)
					a A	a	ab	ab	bc AB	ab	b B	abc	b			a A	a A	b B	bc BC
4	Huazhou	22.96±5.75	17.18±6.67	8.44±8.19	(7.13±1.03)	(61.36±60.82)	(608.00±308.64)	(233.80±181.53)	(12.97±2.20)	(2.40±1.35)	(33.10±6.91)	(30.9±11.86)	(7.61±6.23)	19.09±14.44	68.70±12.80	(1.11±0.16)	(0.34±0.04)	(0.33±0.01)	(-4.18±0.11)
					a A	a	a	a	a A	a	b B	a	ab			a A	b B	c C	c C
5	Zhanjiang	19.00±5.76	16.20±8.42	9.02±9.80	(6.07±2.52)	(50.34±59.05)	(486.60±79.38)	(126.87±79.71)	(10.17±1.17)	(1.20±0.72)	(26.03±11.38)	(18.3±6.75)	(12.34±10.12)	21.00±17.11	81.10±5.77	(0.36±0.05)	(0.17±0.01)	(0.47±0.06)	(-3.62±0.18)
					a AB	ab	ab	ab	cd BC	ab	b B	bc	a			b B	c C	b B	b B
6	Leizhou	22.88±5.51	13.46±6.56	3.34±2.20	(3.07±0.06)	(10.34±6.80)	(290.33±10.99)	(77.23±3.11)	(8.57±0.15)	(0.70±0.00)	(26.63±0.25)	(21.7±0.44)	(11.35±3.89)	33.82±36.57	70.70±11.62	(0.30±0.02)	(0.17±0.01)	(0.56±0.02)	(-3.13±0.24)
					b B	b	b	b	d C	b	b B	abc	a			b B	c C	a A	a A

Note: FP - frond production per year (No.).
NIB - Inflorescene (male, female, bisexual and non-anthesis) and fruit bunch number per year.
NB - fresh fruit bunch number per year (No.).
ABW - average bunch weight (kg).
FFB - fresh fruit bunch (kg).
ANF - average fruit number per bunch (No.).
ANNF - average normal fruit number per bunch (No.).
ASFW - average single fruit weight (g).
ANFW - normal fruit weight per bunch (No.).
FCR - fruit compaction rate (%).
F/B - percent of ANFW to ABW (%).
RAFM - abortion ratio of female inflorescence and fruit bunch (%).
ABR - ratio of aborted fruit bunch to fruit bunch (%).
S/M - thickness-ratio of shell to mesocarp (No.).
S/K - thickness-ratio of shell to kernel (No.).
M/K - thickness-ratio of mesocarp to kernel (No.).
LT_{50} - semi-lethal temperature (°C).

TABLE 4. TWO-WAY ANALYSIS OF VARIANCE (ANOVA) FOR SOME VEGETATIVE GROWTH AND YIELD TRAITS BASED ON INDIVIDUAL PALMS IN DIFFERENT YEARS

Years	FP	NIB	NB	FFB	RAFM	ABR	SR
2010/2011	(22.23±4.91) b A	(24.79±8.73) a A	(19.31±8.94) a A	(137.33±81.07) a A	(1.16±4.23) c B	(1.48±6.49) c C	(82.21±20.23) a A
2011/2012	(13.63±4.52) d B	(12.99±4.60) c C	(3.50±2.74) b B	(22.34±17.46) b B	(3.08±6.52) c B	(36.20±30.73) a A	(70.78±18.26) b AB
2012/2013	(24.01±8.66) ab A	(16.07±8.30) b BC	(4.69±3.80) b B	(32.54±30.97) b B	(10.69±16.64) ab A	(17.54±30.80) b BC	(65.61±24.16) b B
2013/2014	(25.89±7.41) a A	(17.68±5.39) b B	(5.37±3.67) b B	(38.89±30.43) b B	(13.01±13.61) a A	(35.11±28.69) a A	(65.86±21.23) b B
2014/2015	(16.66±4.81) c B	(12.53±5.45) c C	(5.28±4.65) b B	(34.46±29.97) b B	(6.77±17.52) bc AB	(20.55±30.51) b AB	(72.80±22.67) b AB

Note: FP - frond production per year (No.); NIB - inflorescene (male, female, bisexual and non-anthesis) and fruit bunch number per year; NB - fresh fruit bunch number per year (No.); FFB - fresh fruit bunch (kg); RAFM - abortion ratio of female inflorescence and fruit bunch (%); ABR - ratio of aborted fruit bunch to fruit bunch (%); SR – sex ratio of female inflorescence and fruit bunch to female inflorescence, male inflorescence and fruit bunch (%).

TABLE 5. TWO-WAY ANALYSIS OF VARIANCE (ANOVA) FOR SOME VEGETATIVE GROWTH AND YIELD TRAITS BASED ON POPULATIONS IN DIFFERENT YEARS

Years	FP	NIB	NB	FFB	RAFM	ABR	SR
2010/2011	(22.02±3.57) a AB	(21.68±9.95) a	(15.77±10.98) a A	(109.12±79.26) a A	(1.44±2.46) d C	(2.17±4.44) b B	72.22±27.24
2011/2012	(14.17±3.24) b C	(12.80±2.51) b	(3.87±1.16) b B	(22.80±8.23) b B	(3.24±2.80) cd BC	(33.13±16.14) a AB	71.02±5.41
2012/2013	(24.32±5.00) a A	(17.22±3.81) ab	(4.84±1.10) b B	(32.67±13.91) b B	(10.50±6.27) ab AB	(19.20±12.58) ab AB	66.52±12.81
2013/2014	(25.45±2.77) a A	(17.45±2.91) ab	(4.87±2.54) b B	(35.72±20.87) b B	(15.50±6.85) a A	(40.27±26.03) a A	68.22±6.24
2014/2015	(17.47±3.89) b BC	(12.23±4.81) b	(4.91±1.22) b B	(29.37±14.36) b B	(8.73±7.35) bc ABC	(24.47±21.48) ab AB	74.18±10.28

Note: FP - frond production per year (No.); NIB - inflorescene (male, female, bisexual and non-anthesis) and fruit bunch number per year; NB - fresh fruit bunch number per year (No.); FFB - fresh fruit bunch (kg); RAFM - abortion ratio of female inflorescence and fruit bunch (%); ABR - ratio of aborted fruit bunch to fruit bunch (%); SR – sex ratio of female inflorescence and fruit bunch to female inflorescence, male inflorescence and fruit bunch (%).

(r = 0.83*) and S/K (r = 0.81*), and negatively with M/K (r = - 0.85*).

Corley *et al*. (1971) suggested that significant, negative, phenotypic and genotypic correlations have been found to occur between NB and ABW, while NB and ABW were positively related to FFB. Oboh and Fakorede (1990) reported that NB was positively correlated with FFB and ABW. But our study showed that ABW was not significantly correlated with NB, which indicated that these two traits might be important evaluation factors. Owing to the lack of obvious correlation between ABW and FFB yield in populations, the ABW, as one of major components of FFB yield, might not be feasible in the selection of high FFB yielding populations. ABW depends on FCR and ASFW, and appears to have seasonal fluctuations, but ABW changed much less than NB (Broekmans, 1957). Moreover, some of useful correlations with ABW had been found, *i.e.* LT_{50} and LAT.

Bunch failure (bunches fail to develop from anthesis, leading to absence of fruit set), is one of yield determining factors and may result from poor pollination, bunch rot, over bearing and heavy pruning, *etc*. (Corley and Tinker, 2003). The above-mentioned results also revealed that the ABR played a key role in FFB and NB in northern tropical regions of China since the growth, flowering, fruiting and maturing of oil palm would greatly suffer from continuous drought and low temperature at times. Cao *et al*. (2009) investigated that drought for continuous nine months in Hainan Province (3.4-20.9 mm per month from September 2004 to April 2005) caused a 38%-57% decrease in frond production, and the development of inflorescence, sex ratio, pollen quality, fruiting and maturing were also subjected to drought damage. Furthermore, the continuous low temperature for 32 days (mean temperature 8°C-15°C with extreme minimum temperature 5°C-8°C from 15 January 2008 to 25 February 2008) gave rise to cold injury to nearly all of inflorescences and immature bunches, resulting in a 20% decrease in FFB yield in the current year.

Path Coefficient Analysis from Stepwise Regression Analysis

Path coefficient analysis was used to further investigate the cause-and-effect relationships among the individual palms and populations for the traits FFB, NB, ABW.

For individual palms (*Table 8*), ABW gave the highest direct effect (p_{3y} = 0.710) on FFB, followed by NB (p_{2y} = 0.613), and FFB had the highest positive direct effect (p_{7y} = 0.763) on NB. ABW, although not significantly correlated with NB, had the highest negative direct effect on NB (p_{3y} = - 0.544). Indirect effects of ABW via FFB (r_{37} p_{7y} = 0.542) and FFB via ABW (r_{73} p_{3y} = - 0.386) on NB were high and moderate, respectively. Although FFB had the highest correlation (r = 0.71**) with ABW, ANFW (p_{2y} = 1.164) had the highest positive direct effect on ABW while F/B (p_{4y} = - 0.997) had the highest negative direct effect. Likewise, the indirect effects of ANFW via F/B (r_{24} p_{4y} = -0.839) and F/B via ANFW (r_{42} p_{2y} = 0.979) on ABW were very high. Furthermore, FCR had negligible direct effect on ABW (p_{3y} = 0.154), although these two traits were positively correlated (r = 0.36*) with each other, but the indirect effects of FCR via ANFW (r_{32} p_{2y} = 0.667) and FCR via F/B (r_{34} p_{4y} = - 0.580) on ABW were high. Wong and Hardon (1971) found that FCR had significant correlations with ABW, and that ABW showed a linear increase with FCR. Results from *Table 7* showed that FCR had significant correlations with ABW (r = 0.36*). The results indicated ANFW and F/B played more important roles than NB in the ABW of individual palms, which is different from the previous studies of Corley *et al*. (1971) who considered that ABW was highly determined by NB, the higher NB the lower ABW. It was clear that ABW was the most important factor influencing the FFB of individual palm, and that ANFW and F/B may be the main contributors to ABW.

Among the traits in different populations (*Table 9*), for FFB, ABR exerted the highest negative direct effect (p_{4y} = - 0.578) and the highest negative relationship (r = - 0.95**); NIB had the second highest direct effect (p_{1y} = 0.492) and the highest positive relationship (r = 0.95**); indirect effects of M/K via ABR (r_{34} p_{4y} = -0.502) was high, and NIB via ABR (r_{14} p_{4y} = 0.467), M/K via NIB (r_{31} p_{1y} = - 0.345) and ABR via NIB (r_{41} p1y = - 0.398) were moderate. For NB, ABR showed the highest negative relationship (r = - 0.92**) and the highest direct effect (p_{3y} = - 1.267), LT_{50} had the second highest direct effect but the strength was moderate (p_{4y} = 0.331). ANF and ASFW had low direct effects on NB (p_{1y} = - 0.204 and p_{2y} = - 0.105, respectively), and were not significantly correlated with NB. But the indirect effects of ANF via ABR, and ASFW via ABR on NB were very high (r_{13} p_{3y} = 1.188 and r_{23} p_{3y} = 0.998 respectively). The ANF and ASFW had very highly negative correlations (r = - 0.95** and r = - 0.94**, respectively) with ABR. Obviously, the NB, ANF and ASFW of oil palm populations were mainly determined by ABR. The LT_{50} and NIB had no significant correlations with ABW, but had the highest negative direct effect (p_{4y} = - 0.828) and highest positive direct effect (p1y = 0.804) on ABW, respectively. The S/K had a very low and negative direct effect (p_{2y} = -0.056) and the highest positive indirect effect via NIB (r_{21} p_{1y} = 0.713) on ABW. RAFM also had a highly negative indirect effect (r_{31} p_{1y} = - 0.617) on ABW, although the direct effect (p_{3y} = 0.208) was low. Unlike the individual palms, ABR in populations was the common and principal factor affecting FFB and NB, or in another word lower ABR may increase FFB through a higher

TABLE 6. PHENOTYPIC CORRELATION ANALYSIS OF VEGETATIVE GROWTH, YIELD, COLD RESISTANCE TRAITS AND LATITUDE IN THE SELECTED INDIVIDUAL PALMS

Correlation coefficient	Traits																		
Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. FP	1.00	0.51**	0.23	-0.01	0.27	0.16	-0.04	0.17	0.01	-0.34*	0.00	-0.06	0.36*	0.44**	-0.31	-0.21	-0.13	0.11	-0.42**
2. NIB		1.00	0.76**	0.03	0.56**	0.06	0.09	0.01	0.09	-0.07	0.05	0.13	0.40*	0.56**	-0.21	-0.37*	-0.32*	0.12	-0.09
3. NB			1.00	0.01	0.65**	0.03	0.05	-0.04	0.04	-0.02	-0.03	0.45**	0.24	0.35*	-0.19	-0.22	-0.58**	0.07	-0.10
4. ABW				1.00	0.71**	0.44**	0.50**	0.24	0.67**	0.36*	0.20	-0.16	0.21	0.26	-0.11	-0.15	-0.10	-0.34*	0.28
5. FFB					1.00	0.38*	0.44**	0.14	0.56**	0.26	0.21	0.14	0.37*	0.49**	-0.23	-0.26	-0.47**	-0.17	0.03
6. ANF						1.00	0.77**	-0.18	0.63**	-0.13	0.46**	0.08	0.57**	0.34*	-0.57**	0.10	0.06	-0.02	-0.22
7. ANNF							1.00	-0.17	0.86**	0.43**	0.76**	0.00	0.46**	0.27	-0.27	-0.02	0.03	-0.09	0.06
8. ASFW								1.00	0.27	0.16	0.19	-0.40*	0.08	0.17	0.16	-0.15	-0.13	-0.18	0.25
9. ANFW									1.00	0.57**	0.84**	-0.20	0.38*	0.32*	-0.07	-0.07	-0.12	-0.18	0.22
10. FCR										1.00	0.58**	-0.19	-0.14	-0.03	0.48**	-0.03	-0.20	-0.11	0.44**
11. F/B											1.00	-0.25	0.33*	0.28	0.06	0.03	-0.09	-0.07	0.12
12. SR												1.00	-0.13	-0.21	-0.12	0.23	-0.08	0.23	-0.15
13. S/M													1.00	0.80**	-0.73**	-0.25	0.02	0.13	-0.32*
14. S/K														1.00	-0.32*	-0.26	-0.20	0.03	-0.28
15. M/K															1.00	0.15	-0.07	-0.10	0.34*
16. RAFM															1.00	-0.13	0.18	-0.21	
17. ABR																	1.00	0.08	-0.03
18. LT_{50}																		1.00	-0.58**
19. LAT																			1.00

Note: *Significant at p≤0.05;** significant at p≤0.01; similarly herein after; FP – frond production per year (No.); NIB - inflorescene (male, female, bisexual and non-anthesis) and fruit bunch number per year.

NB - fresh fruit bunch number per year (No.).
ABW - average bunch weight (kg).
FFB - fresh fruit bunch (kg).
ANF - average fruit number per bunch (No.).
ANNF - average normal fruit number per bunch (No.).
ASFW - average single fruit weight (g).
ANFW - normal fruit weight per bunch (No.).
FCR - fruit compaction rate (%).
F/B - percent of ANFW to ABW (%).
RAFM - abortion ratio of female inflorescence and fruit bunch (%).
ABR - ratio of aborted fruit bunch to fruit bunch (%).
S/M - thickness-ratio of shell to mesocarp (No.)
S/K - thickness-ratio of shell to kernel (No.).
M/K - thickness-ratio of mesocarp to kernel (No.).
LT_{50} - semi-lethal temperature (OC).
LAT - latitude.

TABLE 7. PHENOTYPIC CORRELATION ANALYSIS OF VEGETATIVE GROWTH, YIELD, COLD RESISTANCE TRAITS AND LATITUDE IN DIFFERENT POPULATIONS

Correlation coefficient	Traits																		
Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. FP	1.00	0.09	-0.06	-0.38	0.00	0.03	0.28	0.09	0.25	0.40	0.80	-0.11	0.54	0.54	-0.17	-0.22	0.16	0.46	-0.29
2. NIB		1.00	0.82*	0.64	0.95**	0.66	0.67	0.55	0.70	0.80	0.40	0.12	0.83*	0.89*	-0.71	-0.77	-0.81	-0.06	0.68
3. NB			1.00	0.43	0.92**	0.82*	0.67	0.53	0.62	0.44	0.38	0.56	0.67	0.66	-0.71	-0.28	-0.92**	0.16	0.25
4. ABW				1.00	0.69	0.62	0.62	0.74	0.70	0.68	0.07	-0.42	0.45	0.41	-0.69	-0.72	-0.70	-0.79	0.84*
5. FFB					1.00	0.86*	0.81	0.71	0.81	0.73	0.46	0.20	0.83*	0.81*	-0.85*	-0.62	-0.95**	-0.12	0.54
6. ANF						1.00	0.94**	0.91*	0.91*	0.60	0.62	0.14	0.74	0.61	-0.96**	-0.34	-0.94**	-0.23	0.21
7. ANNF							1.00	0.96**	0.99**	0.80	0.79	-0.12	0.87*	0.74	-0.99**	-0.54	-0.83*	-0.28	0.29
8. ASFW								1.00	0.97**	0.74	0.64	-0.29	0.72	0.56	-0.97**	-0.51	-0.79	-0.53	0.34
9. ANFW									1.00	0.85*	0.74	-0.22	0.87*	0.75	-0.99**	-0.63	-0.82*	-0.38	0.39
10. FCR										1.00	0.66	-0.42	0.90*	0.89*	-0.79	-0.92**	-0.59	-0.34	0.66
11. F/B											1.00	-0.06	0.84*	0.73	-0.71	-0.34	-0.41	0.17	-0.13
12. SR												1.00	-0.04	0.01	0.10	0.51	-0.24	0.75	-0.45
13. S/M													1.00	0.97**	-0.84*	-0.71	-0.70	0.02	0.36
14. S/K														1.00	-0.72	-0.77	-0.63	0.11	0.45
15. M/K															1.00	0.55	0.88*	0.34	-0.35
16. RAFM																1.00	0.43	0.42	-0.86*
17. ABR																	1.00	0.21	-0.41
18. LT_{50}																		1.00	-0.60
19. LAT																			1.00

Note: FP - frond production per year (No.); NIB - inflorescene (male, female, bisexual and non-anthesis) and fruit bunch number per year; NB - fresh fruit bunch number per year (No.);
ABW - average bunch weight (kg); FFB - fresh fruit bunch (kg); ANF - average fruit number per bunch (No.); ANNF - average normal fruit number per bunch (No.);
ASFW - average single fruit weight (g); ANFW - normal fruit weight per bunch (No.); FCR - fruit compaction rate (%); F/B - percent of ANFW to ABW (%);
RAFM - abortion ratio of female inflorescence and fruit bunch (%);
ABR - ratio of aborted fruit bunch to fruit bunch (%).
S/M - thickness-ratio of shell to mesocarp (No.).
S/K - thickness-ratio of shell to kernel (No.).
M/K - thickness-ratio of mesocarp to kernel (No.).
LT_{50} - semi-lethal temperature (OC).
LAT - latitude.
* Significant at p≤ 0.05.
** Significant at p≤ 0.01; similarly herein after.

TABLE 8. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF VEGETATIVE GROWTH, YIELD, COLD RESISTANCE TRAITS AND LATITUDE ON EACH OF FRESH FRUIT BUNCH (FFB), BUNCH NUMBER (NB) AND AVERAGE BUNCH WEIGHT (ABW) IN THE SELECTED INDIVIDUAL PALMS

Trait i	Path coefficient for FFB				
	Trait j				
	1	2	3	4	5
1. FP	0.102	0.142	-0.005	0.000	0.034
2. NB	0.024	0.613	0.005	-0.003	0.008
3. ABW	-0.001	0.004	0.710	0.020	-0.022
4. F/B	0.000	-0.019	0.141	0.098	-0.009
5. LAT	-0.043	-0.059	0.198	0.011	-0.080

Trait i	Path coefficient for NB						
	Trait j						
	1	2	3	4	5	6	7
1. FP	-0.172	0.164	0.003	-0.012	0.017	0.024	0.209
2. NIB	-0.087	0.325	-0.016	0.027	0.031	0.059	0.425
3. ABW	0.001	0.009	-0.544	-0.033	0.012	0.019	0.542
4. SR	0.010	0.043	0.089	0.202	-0.019	0.015	0.107
5. RAFM	0.035	-0.120	0.082	0.046	-0.083	0.024	-0.201
6. ABR	0.022	-0.105	0.057	-0.017	0.011	-0.181	-0.362
7. FFB	-0.047	0.181	-0.386	0.028	0.022	0.086	0.763

Trait i	path coefficient for ABW						
	Trait j						
	1	2	3	4	5	6	7
1. NB	-0.344	0.043	-0.003	0.031	0.035	-0.007	0.252
2. ANFW	-0.013	1.164	0.088	-0.839	0.032	0.017	0.218
3. FCR	0.007	0.667	0.154	-0.580	-0.003	0.011	0.100
4. F/B	0.011	0.979	0.090	-0.997	0.028	0.007	0.082
5. S/K	-0.122	0.376	-0.005	-0.277	0.100	-0.003	0.190
6. LT_{50}	-0.023	-0.207	-0.017	0.068	0.003	-0.099	-0.065
7. FFB	-0.222	0.649	0.039	-0.210	0.049	0.016	0.390

Note: FP – frond production per year (No.); NB – bunch number; F/B - percent of ANFW to ABW (%); LAT - latitude; ANFW - normal fruit weight per bunch (kg); FRC - fruit compaction rate (%); S/K - thickness-ratio of shell to kernel (No.); LT_{50} - semi-lethal temperature (°C).

TABLE 9. DIRECT (on diagonal) AND INDIRECT (off diagonal) EFFECTS OF VEGETATIVE GROWTH, YIELD, COLD RESISTANCE TRAITS AND LATITUDE ON EACH OF FRESH FRUIT BUNCH (FFB), BUNCH NUMBER (NB) AND AVERAGE BUNCH WEIGHT (ABW) IN DIFFERENT POPULATIONS

Trait i	Path coefficient for FFB			
	Trait j			
	1	2	3	4
1. NIB	0.492	0.029	-0.042	0.467
2. F/B	0.197	0.073	-0.041	0.236
3. M/K	-0.345	-0.050	0.060	-0.502
4. ABR	-0.398	-0.030	0.052	-0.578

Trait i	Path coefficient for NB			
	Trait j			
	1	2	3	4
1. ANF	-0.204	-0.094	1.188	-0.074
2. ASFW	-0.183	-0.105	0.998	-0.176
3. ABR	0.191	0.083	-1.267	0.071
4. LT_{50}	0.046	0.056	-0.273	0.331

Trait i	Path coefficient for ABW			
	Trait j			
	1	2	3	4
1. NIB	0.804	-0.050	-0.160	0.047
2. S/K	0.713	-0.056	-0.158	-0.093
3. RAFM	-0.617	0.043	0.208	-0.352
4. LT_{50}	-0.045	-0.006	0.088	-0.828

Note: NIB - infloresceне (male, female, bisexual and non-anthesis) and fruit bunch number per year; F/B - percent of ANFW to ABW (%); M/K - thickness-ratio of mesocarp to kernel (No.); ABR - ratio of aborted fruit bunch to fruit bunch (%); S/K - thickness-ratio of shell to kernel (No.); RAFM - abortion ratio of female inflorescene to female inflorescene and fruit bunch (%); LT_{50} - semi-lethal temperature.

NB. However, as one of yield components, ABW was determined by LT_{50} and NIB, namely, the higher cold resistance and the higher NIB would lead to a higher ABW. These results are different from those reported by Oboh and Fakorede (1990) who thought that the number of male inflorescence and sex ratio were major determinants of ABW.

CONCLUSION

In this study, the variations in all traits appeared to have significant influence on individual palms. Some traits, such as FP, NIB, NB, ABR and SR had no apparent variations between populations, while other traits, such as FP, NIB, NB, FFB, RAFM and ABR, showed strong inter-annual changes except SR based on populations data.

Phenotypic correlation analysis showed FFB was positively correlated with NIB, NB, ANF and negatively correlated with ABR in either individuals or populations. NB was positively correlated with FFB, NIB and S/K, and negatively with ABR. However, ABW had no significant correlation with other traits. For individual palms, the higher LAT was found to have lower FP and LT_{50} and higher FCR, and that the higher LT_{50} had the lower ABW. However, the results for populations showed that the higher LAT had the lower RAFM and the higher ABW.

Path coefficient analysis further revealed that for individual palms, ABW was the major determining factor in both FFB and NB with the highest positive and negative direct effect, respectively, but ABW was mainly directly determined by ANFW and F/B, not by FFB or NB. However, for the populations, ABR was the most important factor in the determination of FFB and NB, and LT_{50} and NIB were common determining factors with the highest negative and positive direct effect on ABW, respectively. From this study, it seems that NIB, ANFW and FCR in individual palms and NIB, ABR, S/K, RAFW, M/K, ANF and ASFW in oil palm populations, would be effective as indirect evaluation criteria for NB, ABW and FFB, but only NIB was likely to be selected as the common indirect factor in both individual palms and oil palm populations.

Based on the results of path coefficient analysis, MM5 with the highest ABW in individual palms and Huazhou population with the lowest ABR would hence, be selected as the highest FFB yield palm and population with a higher cold resistance, respectively, which was consistent with the results of one-way ANOVA.

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