Performance of MPOB Nigeria Prospection Materials in Sabah[1]

Seng SY[1], Donough CR[2] and Rajanaidu N[3]

1. Assistant Research Officer (Breeding & Seed Production), IJM Plantations Berhad (seng_sheau@yahoo.com);
2. Consulting Breeder/Agronomist (crdonough@gmail.com) (previously Research Controller IJM Plantations Berhad);
3. Consultant (Oil Palm Breeding) (rajanaidu45@gmail.com)

Abstract

IJM Plantations Berhad (IJMP) initiated an oil palm breeding program in the late 1990s with germplasm obtained from the Malaysian Palm Oil Board (MPOB). Field planting of the first genetic block (GB) commenced in 2001, and todate 4 GBs have been established in IJMP's estates in Sandakan, Sabah.

The germplasm obtained from MPOB included selected families derived from MPOB's prospections in Nigeria. These are intended as a source of genetic variation for continual improvement of IJMP's commercial planting material.

In this paper, the results are reviewed for twenty-six families derived from selected parent palms of the Nigeria (NIG) prospection:

- *Eleven dura (D) families – consisting of six D-selfed families and five DxD families;*
- *Five tenera (T) families – consisting of four T-selfed families and one TxT family;*
- *Eight DxT or TxD families; and.*
- *Two introgressed families i.e. NIG D x Deli D.*

Data considered included fresh fruit bunch (FFB) yield, vegetative growth parameters and indices, and fruit bunch components (from bunch analysis). Performance of the NIG families was also related to advance breeding populations (i.e. Deli D and AVROS T) and standard DxP crosses.

Some of the NIG families showed relatively good FFB yield. The most outstanding yield characteristic of the evaluated NIG families was their high bunch number. The two introgressed families were the highest FFB yielding, surpassing even the pure advanced Deli D families. Five of the NIG families were also planted in a trial on ultrabasic soil – results showed overall much lower FFB yields on this problem soil. Family rankings differed from the normal soil trial, suggesting possible genotype x environment effect.

An outstanding feature of the NIG families was their small vegetative growth – the majority of the evaluated families were derived from parents of Population 12 which was already known to possess small stature from earlier evaluations elsewhere in Malaysia. Many of the NIG families had slow height increment, small petiole cross section, short rachis and small trunk. All these favourable characteristics gave the NIG families the advantages of low vegetative dry matter (VDM) and high bunch index (BI) which are important selection criteria for further oil palm genetic improvement.

For fruit bunch components, some of the NIG D families had relatively thin shell, with the two introgressed families showing relatively thick mesocarp. The main drawback of the NIG families was small fruit size.

Keywords: oil palm breeding, Nigerian prospection materials

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Introduction

In recent years, issues such as labour shortage, rising cost of production and land limitations have been highlighted in oil palm industry (Tek, 2010). Sustainability of the industry highly depends on maximising yield with available resources. Davidson (1993), in an analysis of yield improvement over 40 years (from 1951 to 1991) in Pamol Plantations, attributed the observed yield gain equally between genetic and agronomic factors. Hence, oil palm breeders will play a key role in the sustainability and future viability of the industry.

The advanced parent materials used in Malaysia today to produce commercial oil palm seeds, having gone through many cycles of selection since the 1930s, have very limited potential for further yield improvement that can be easily exploited by breeding (Lee at al, 1990; Maizura et al, 2009). New sources of genetic variation need to be introduced to the germplasm pool (Hayati et al, 2004).

The Malaysian Palm Oil Board (MPOB) has collected wild germplasm from Africa and Latin America since 1973 (Rajanaidu & Jalani, 1994). The collected materials are evaluated and selections then released to breeders in Malaysia for utilization in their breeding programmes (Rajanaidu & Rao, 1988; Rajanaidu et al, 2000). From the Nigerian (NIG) collection, palms of small stature have been found in Population 12 (Kushairi et al, 1999a), as well as palms producing oil with very high iodine value (IV) (Kushairi et al, 1999b). Selections from the NIG collection have been utilized by Peninsula Malaysia-based organizations to develop new planting material (Isa et al, 2008; Junaidah et al, 2008; Musa & Gurmit, 2008; Veriappan et al, 2008).

IJM Plantations Berhad (IJMP) is one among a few Sabah-based organizations that have established an oil palm breeding programme. In 1997, IJMP signed a collaboration Agreement with MPOB and in the ensuing years started receiving crosses of advanced Deli dura (D) and AVROS (Av) tenera (T) families for establishing a seed garden to produce commercial DxP seeds. IJMP also received crosses of NIG D and NIG T selections mostly from Population 12, and some of the high IV selections, for use in a breeding programme. The materials received were planted in IJMP's estates in Sandakan, Sabah. IJMP's first genetic block (GB) was planted in 2001, and todate a total of 4 GBs have been established in IJMP estates. In this paper, we present the results of evaluation of twenty six NIG families in the IJMP oil palm breeding programme.

Materials and Methods

A) <u>Trial Details</u>

1) Genetic Block 1 (GB1)

GB1 was planted in March 2001 in Sijas Estate (SJS) including the following NIG families:

a) Two NIG D x Deli D,
b) Four NIG D x NIG D, and
c) Two NIG D selfs.

The trial was laid out as a Randomized Complete Block Design (RCBD) with five replicates of nine palms per plot for each family. Planting density was 148 palms/ha. Soil types in the trial are orthic acrisol and gleyic luvisol according to the FAO classification (Acres & Folland, 1975).

2) Genetic Block 2 (GB2)

GB2 was planted in December 2002 in SJS including the following NIG families:

a) One NIG D x NIG D, and

b) Four NIG D selfs.

The trial design was RCBD with five replicates of twelve palms per plot for each family. Planting density was 148 palms/ha. Soil types in the trial are same with GB1.

3) Pisifera Area 1 (PA1)

PA1 was planted together with GB1. The following NIG families were included:

a) Four NIG D x NIG T,
b) One NIG T x NIG T, and
c) One NIG T self.

Two other families were included:

a) One Av T x Av P, and
b) One MPOB standard DxP cross.

Commercial DxP seed from a Malaysian seed producer was also included as a check.
The design of the trial was RCBD, with five replicates and seven palms per plot. Planting density was 148 palms/ha.

4) Pisifera Area 2 (PA2)

PA2 was planted together with GB2. The trial included the following NIG families:

a) One NIG D x NIG T, and
b) Three NIG T selfs.

Other families included in the trial were:

a) Three Av T x Av P,
b) One Deli D x Av P, and
c) Three MPOB Standard DxP crosses (as checks).

The design of the trial was RCBD with five replicates of twelve palms per plot. However, due to lack of material, two of the Av T x Av P families had only 1 replicate, and one of the NIG T selfs and the sole Deli D x Av P family had three replicates. Planting density was 148 palms/ha.

5) Progeny Test 1 (PT1)

PT1 was planted in Meliau Estate (MLU) in March 2002. Soils in MLU are mainly oxisols derived from ultrabasic rocks, with inherent low fertility (Paramananthan, 2002), requiring proper nutrient management due to high content of iron and other trace metals. The following NIG families were included:

a) Six NIG D x NIG T crosses,
b) One NIG T x NIG D cross.

The trial design was RCBD with five replicates of twelve palms per plot. The planting density was 148 palms/ha.

B) <u>Data Collection</u>

1) Fruit typing

Fruit type i.e. D, T or pisifera (P), of all palms in the trials are recorded to check against expected segregation ratios. In the presentation of results, data for T and D palms are shown separately.

2) Yield Recording

Recording of fresh fruit bunch (FFB) yield started 3 years after planting in all trials, except GB1 and PA1 where recording started 2 years after planting. Target harvest interval in all trials was 10 days, and this was achieved most of the time.

In GB1 and GB2, yield recording was stopped after 5 years. Yield recording in PT1 was stopped after 4 years due to low yield. Yield recording in PA1 and PA2 still continues.

All FFB yield data shown in this paper are averaged over 4 years' of recording and expressed as yield per palm (in kg). Components of FFB yield per palm i.e. bunch number per palm and mean weight per bunch (in kg), are also shown.

3) Bunch Analysis

Bunch analysis (BA) was carried out on bunch samples from GB1 and GB2 from 2003 to 2008, and 2005 to 2009, respectively. In PA1 and PA2, BA started in 2010 and still continues.

Ripe bunches (i.e. with at least 1 detached fruit) are collected for analysis during yield recording. The analysis procedure generally follows Blaak et al (1963) with some variations according to the Pamol method (Rao et al, 1983). Oil extraction was by soxhlet using 5 gram samples of dried mesocarp.

At each stage in the BA process of sub-sampling to determine the bunch and fruit components, it was ensured that samples taken reflected the actual composition of the bunch being analyzed. For example, to determine the fruit per bunch ratio, parthenocarpic fruits were included. Following on, fruit samples for determination of mesocarp & nut fractions included both fertile and parthenocarpic fruits commensurate with the proportion of the two types in each bunch sample. Nuts were oven-dried prior to cracking and data for shell and kernel have not been corrected for the moisture loss.

Hence, the BA data as presented will closely reflect the condition of the sampled bunches and actual conditions in the field. However, the data as shown will variously over- or under-estimate different components when fertile fruits only are considered, e.g. the mesocarp fraction will be over-estimated due to inclusion of parthenocarpic fruits, and conversely shell and kernel fractions will be under-estimated. The latter two components will be further under-estimated due to moisture loss during oven drying.

The BA data is presented here without any correction. Comparisons made in this paper using the data are valid, but direct comparisons with data reported elsewhere and/or by others will be misleading.

The following parameters are presented in this paper – oil per bunch (OB), kernel per bunch (KB), fruits per bunch (FB), wet mesocarp per fruit (WMF), kernel per fruit (KF), shell per fruit (ShF), oil per dry mesocarp (ODM), oil per wet mesocarp (OWM), and mean fruit weight (FWt).

4) Vegetative measurements

Vegetative measurements (VM) (Corley & Breure, 1981) were taken in the trials starting from 1 year after planting, then in alternate years thereafter. Data taken 7 years after planting are shown in this paper.

The following parameters are presented (units shown in brackets) – annual height increment (Hgt Incr, in m per year, estimated from actual palm height measured in the 5^{th} and 7^{th} years after planting), rachis length (RL, in m), leaf area (LA, in m^2), petiole cross-section area (PCS, in cm^2, calculated as area of triangle), trunk diameter or girth (GRT, in cm), and frond production (FP, i.e. number of new fronds emerged per year).

The data was used to estimate dry matter production and calculate growth indices using the methods of Corley and Breure (1981). Frond production has not yet been collected in GB2 and PA2, so estimates were not calculated for these trials.

The following estimates and indices are presented – above ground vegetative dry matter production (V, in kg/palm), bunch index (BI, i.e. dry weight of FFB yield (B) as a fraction of total above ground dry weight i.e. B+V), and leaf area ratio (LAR in m^2/kg, i.e. the ratio of new LA (i.e. LA x FP) to V).

5) Rainfall data

Daily rainfall records were taken from the nearest rain gauge, usually at the estate office site. Data for SJS and MLU are shown in Appendices 1 and 2 respectively.

For the period 2000 to 2010, annual rainfall averaged 3,463mm and 3,636mm at SJS and MLU respectively. For the same period, average raining days per year was 163 and 193 at SJS and MLU respectively. No significant water deficit was recorded within the period except in 2010 at MLU. The trial at MLU had been terminated before that.

Results

A) <u>NIG T</u>

i) FFB yield (Table 1.1)

The best NIG family was SJ0145TT which recorded the highest average annual FFB yield of 222kg/palm, compared to 219kg/palm for the commercial DxP check, 202kg/palm for the best Av TxP family, and 192kg/palm for the best MPOB Standard DxP cross. The second best NIG family was SJ130DT with annual average FFB yield of 202kg/palm.

In general compared to T in the Av families, the MPOB DxP standard crosses, and commercial DxP, NIG T had comparable FFB yield, but tend to have higher bunch number but lower bunch weight. Thus, when selecting candidates for breeding and introgression with advanced families, FFB yield components of the NIG candidate palms need to be carefully considered so that bunch numbers can be raised without undue reduction in bunch weight in the resulting next generation.

NIG families SJ0130DT and SJ0129DT share a common female parent i.e. D palm O.150/498D. NIG families SJ0130DT and SJ0131DT share a common male parent i.e. T palm O.150/665. Average annual T FFB yield of SJ0131DT, at 195kg/palm, was almost as good as that of SJ0130DT. In contrast, average annual T FFB yield of SJ0129DT was only 167kg/palm. This is indicative that the male parent in SJ0129DT, i.e. T palm O.150/501T, is a poor yielder. This is borne out by the poor performance of SJ0138TS, i.e. O.150/501T selfed, in PA2 with an average annual T FFB yield of only 73kg/palm.

Selfed NIG families in PA1 and PA2 tend to have lower FFB yield than outcrossed NIG families due to inbreeding. Nonetheless, the yield of SJ0138TS compares very poorly with all other NIG T-selfed families in PA1 and PA2. By contrast, the highest yielding NIG T-selfed family, SJ0137TS, recorded an average annual T FFB yield of 150kg/palm.

ii) BA data (Table 2.1)

Based on the limited BA data available at time of writing, T palms in NIG families in PA1 and PA2 generally have poorer characteristics compared to T palms of the Av TxP, MPOB standard DxP and commercial DxP. The NIG T palms generally have lower OB mainly due to lower FB. FWt was generally much lower in the T palms of the NIG families.

Based on the available data, it will be difficult to select candidate T palms from the NIG families based only on BA parameters for use in a T and P improvement program. BA is still in progress in PA1 and PA2 to collect more data before selections can be made in the NIG families based on fruit characteristics.

iii) VM data (Table 3.1)

T palms in NIG families in PA1 and PA2 are generally smaller in stature compared to T palms in the Av families, MPOB standard DxP crosses, and commercial DxP. Besides slower height increment and smaller PCS, some NIG families like SJ0136TS and SJ130DT had T palms with thinner trunks. T palms in NIG family SJ0136TS also had very small PCS and short RL. From the results, there appears to be great scope to use T selections from some of these NIG families to breed smaller stature into advanced parent lines like Av.

iv) Dry matter & Growth Indices (Table 4.1)

Results are only available from PA1 at time of writing. T palms in the Av TxP family had the highest frond production of some 30 fronds per year. There was no significant difference in frond production for the other families. As a result of their smaller stature, T palms of the NIG families had much lower V, and hence a much higher BI compared to T palms in the Av TxP and MPOB DxP standard cross. In spite of having generally smaller leaf area, T palms of the NIG families had higher LAR compared to T palms of the Av TxP and MPOB DxP standard cross.

Frond production data from PA2 is still pending, but it is likely that T candidates can be selected from some of these NIG families to breed for better growth indices in advanced parent lines like Av.

B) <u>NIG D</u>

i) FFB yield (Table 1.2)

NIG D families in GB1 and GB2 generally produced FFB yield comparable to the advanced Deli D families. Among the pure NIG families, SJ0115DD was the highest yielder, averaging 163 kg/palm per year. The best NIG D-selfed family, SJ0106DS, produced an annual average FFB yield of 148 kg/palm.

D palms in NIG families produced far higher bunch number than D palms in Deli D families, but average bunch weight was generally lighter. There were some NIG families that produce bunches of similar weight to Deli D families e.g. SJ0106DS.

The highest yielding families in GB1 and GB2 were the two inter-origin crosses between NIG D and Deli D, SJ0122DD and SJ0123DD, each producing annual average FFB yield just under 180 kg/palm, indicating the value of introducing new genes into advanced materials. The superior yield of these two inter-origin crosses came from a much higher bunch number, a trait that is likely to have come from the NIG parent in each cross. Mean bunch weight was slightly lower compared to pure Deli D families, thus when selecting D palms from NIG families for breeding, or for introgression into advanced Deli D families, care is needed to ensure that bunch weight is not unduly reduced in the next generation.

ii) BA data (Table 2.2)

The BA data for D palms in general showed very good OB due to high FB, WMF and OWM. Usually, OB values for D palms or families are below 20%. In this case, family mean OB values for Deli D families, at 22%, were not only much higher than the usual, but were not much lower than the 23-25% values for the T palms under evaluation in PA1 and PA2 (Table 2.1). So far, all checks conducted into the BA process at IJMP have not indicated any systematic errors, thus the data are presented and assessed as they stand.

In general, NIG D families had lower OB compared to Deli D families, due to lower FB and WMF. However, unlike for T palms in NIG families, NIG D families had better mean fruit weight almost comparable to the Deli D families. KF was generally higher in the NIG D families compared to the Deli D families, indicating larger nut size.

NIG D family SJ0103DS in GB2 looks promising as a potential source of D palms for breeding. This family is a self of D palm O.151/146D, also known for producing oil with high IV. NIG D family SJ0114DS, a self of D palm O.150/498D, also looks promising.

In the two inter-origin families, most parameters remain closer to the mean for NIG D families, suggesting that it may be difficult to improve the fruit characteristics of the NIG origin.

iii) VM data (Table 3.2)

NIG D families were smaller in stature compared to Deli D families, but the two inter-origin families were comparable in size to pure Deli D families. This may suggest that it will not be simple to breed the small stature of the NIG origin into advanced Deli D families. However, the NIG parents in the two inter-origin families, i.e. O.149/5616D and O.150/83D, are from populations 27.13 and 45.04 respectively, not population 12 that is known for palms with small stature.

Many of the NIG D families derived from parents selected in population 12 are indeed generally smaller in stature, even compared among pure NIG D families, e.g. SJ0105DS (self of O.150/5375D), SJ0107DS (self of O.150/5112D), SJ0114DS (self of O.150/498D), and SJ0116DD (cross of O.150/1968D and O.150/1908D). Selections can be made in some of these families of candidates for breeding and introgression into Deli D families..

iv) Dry matter & Growth Indices (Table 4.2)

Results are only available for GB1 at time of writing. The NIG D families derived from population 12 parents are outstanding for low V and high BI.

C) <u>Performance in SJS compared to MLU</u>

Four of the NIG DxT families and one NIG D selfed family was planted in PA1 at SJS as well as in PT1 at MLU. FFB yield data for these families are given in Table 5.0, showing that yield at MLU for the same period of recording was only about 50% what was recorded at SJS. The lower FFB yield at MLU was due to much lower bunch number per palm. Average bunch weight was actually higher, a likely consequence of the drastically reduced bunch number.

Commercial block yield data from MLU shows that the yield trend on the oxisols there builds up more slowly. Elsewhere in Sabah, e.g. Tawau region where rainfall is much lower and similar soils have a more gentle topography compared to that at MLU, high FFB yields up to 30t/ha are possible.

Rankings by yield for some of the families differed at both sites, e.g. SJ0128DT and SJ0130DT, suggesting some genotype-environment interaction. Nonetheless, the data from PT1 indicates that none of the NIG families planted there are better suited for the environment than current DxP.

Discussion

Overall, the NIG families in the trials reported here produced large numbers of small bunches. The lower bunch weight was not sufficiently compensated for by the higher bunch number, so the NIG families had lower FFB yield than Deli D and Av families.

Bunch number and bunch weight are negatively correlated. Both these components of FFB yield can be improved through introgression, as shown by the results for the two inter-origin cross, SJ0122DD and SJ0123DD. NIG selections should be crossed with high bunch weight candidates to improve average bunch weight.

The environment is clearly very important for proper evaluation of genetic materials, as shown by the contrasting performance of the same families at SJS and MLU. Breeders must ensure that the environment of the trial allows the materials under evaluation to express their yield potential.

Fruit qualities of the NIG families were also much poorer especially for NIG T palms. NIG families tended to have larger kernels but smaller fruit. Fruit components such as kernel, shell and fruit weight are highly heritable (Rafii et al, 2002). With lower mean fruit weight and larger kernels, mesocarp is reduced which was one of the factors limiting potential oil yield in the NIG families. Higher average fruit weight and thinner shell should be emphasized in selection of candidate parents from NIG families to improve its WMF (Sharma & Tan, 1997).

The best features of the NIG families were their vegetative growth characteristics, with generally much lower height increment, smaller PCS, shorter RL and thinner trunks. These characteristics gave the NIG families low V and high BI. Shorter palms and smaller PCS will benefit harvesting. Palms with shorter RL, smaller LA, low V and high BI are less competitive, so candidates with these characteristics can be selected to breed materials suited for planting at higher density (Corley & Breure, 1983).

High density planting is an important consideration today, as it will allow planters the option of earlier replanting without sacrificing profitability (Donough & Kwan, 1991; Nazeeb et al, 2008). The current labour problems facing planters are mainly in the harvesting operation, particularly in tall palm areas. Most other field operations can be mechanized. If replanting can be advanced as early as 15 years into a planting cycle, then the tall palm harvesting problem can be reduced or eliminated.

Some of the promising NIG families in IJMP are known to be derived from parents with oil of high iodine value (IV), e.g. SJ0142TS (self of O.151/128T) and SJ0103DS (self of O.151/146D) (Rajanaidu et al, 2008). These families, especially SJ0142TS, have small bunches. Determinations of IV are planned in the IJMP programme, so candidate palms with high IV oil and acceptable bunch weight can be selected for further breeding.

Conclusion

To conclude, the results show that currently the most promising, and probably the quickest, way to utilize the NIG materials in the IJMP breeding programme is to exploit their outstanding vegetative characteristics. The poorer fruit characteristics of the NIG materials are their main drawback.

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Table 1.1: FFB Yield Tenera of PA1 and PA2

Trial					3-6 YAP (Apr 2004- Mar 2008)		
Progeny	Cross	Female	Male	D:T:P	FFB	Bno	Bwt
PA1							
SJ0128DT	Nig D x T	O.150/2356	O.149/2704	17:18:0	171.91	27.81	6.18
SJ0129DT	Nig D x T	O.150/498	O.150/501	19:15:0	166.70	22.58	7.38
SJ0130DT	Nig D x T	O.150/498	O.150/665	22:13:0	202.56	24.17	8.38
SJ0131DT	Nig D x T	O.150/2194	O.150/665	12:22:0	194.73	25.61	7.60
Mean (Nig DxT)					***183.98***	***25.04***	***7.39***
SJ0145TT	Nig T x T	O.150/5974	O.149/11526	5:24:6	221.68	25.77	8.60
SJ0136TS	Nig TS	O.150/5060		5:20:9	139.46	26.79	5.21
SJ0096TP	AVROS TxP	O.174/773	O.174/4211	0:20:15	202.45	21.75	9.31
SJ0001DP	MPOB Std DP	O.212/270	O.159/149	23:10:0	191.51	15.60	12.28
	DxP Commercial				218.52	20.72	10.55
PA2							
SJ0127DT	Nig D x T	O.151/2106	O.149/3648	42:18:0	121.23	17.42	6.96
SJ0137TS	Nig TS	O.150/1969		15:34:7	149.70	13.05	11.47
SJ0138TS	Nig TS	O.150/501		14:15:6	73.06	12.72	5.75
SJ0142TS	Nig TS	O.151/128		15:30:14	102.23	22.15	4.62
Mean (Nig TS)					***108.33***	***15.97***	***7.28***
SJ0097TP	AVROS TxP	O.174/288	O.174/480	0:4:4	106.14	17.94	5.92
SJ0099TP	AVROS TxP	O.174/307	O.174/656	0:36:23	115.89	15.20	7.63
SJ0100TP	AVROS TxP	O.182/103	O.174/655	0:5:7	102.62	17.30	5.93
Mean(3 AVROS TP Families)					***108.22***	***16.81***	***6.49***
SJ0006DP	MPOB Std DP	O.212/272	O.174/655	1:59:0	162.63	15.53	10.47
SJ0007DP	MPOB Std DP	O.212/270	O.159/149	3:57:0	146.89	13.94	10.54
SJ0008DP	MPOB Std DP	O.212/203	O.174/480	1:59:0	165.49	14.33	11.55
Mean (3 MPOB Std DP)					***158.34***	***14.60***	***10.85***
SJ0027DP	Deli Dx AVROS Test Cross	O.212/738	O.174/480	0:36:0	142.40	12.16	11.71

Mean	Total Progeny			
Nig DxT	5	171.43	23.52	7.30
Nig T x T	1	221.68	25.77	8.60
Nig TS	4	116.11	18.68	6.76
AVROS TxP	4	131.77	18.05	7.20
MPOB Std DP	4	166.63	14.85	11.21
Deli Dx AVROS Test Cross	1	142.40	12.16	11.71

Table 1.2: FFB Yield Nig Dura of GB1 & GB2

Trial				3-6 YAP		
IJM	Cross	Female	Male	FFB	Bno	Bwt
GB1						
SJ 0122 DD	Nig D x Deli D	O.149/5616	O.212/694	179.29	22.65	7.92
SJ 0123 DD	Nig D x Deli D	O.152/83	O.212/179	179.88	21.65	8.31
Mean (Nig Dx Deli D)				***179.58***	***22.15***	***8.11***
SJ 0115 DD	Nig D x D	O.149/13130	O.150/5375	162.80	24.59	6.62
SJ 0116 DD	Nig D x D	O.150/1968	O.150/1908	131.88	24.74	5.33
SJ 0117 DD	Nig D x D	O.149/14674	O.150/2036	144.39	25.21	5.73
SJ 0118 DD	Nig D x D	O.150/2356	O.149/13130	139.27	26.77	5.20
Mean (NIg DxD)				***144.59***	***25.33***	***5.72***
SJ 0104 DS	Nig DS	O.149/13252		126.34	25.05	5.04
SJ 0105 DS	Nig DS	O.150/5375		103.78	23.19	4.48
Mean (Nig DS)				***115.06***	***24.12***	***4.76***
GB2						
SJ 0103 DS	Nig DS	O.151/146		140.42	17.01	8.25
SJ 0106 DS	Nig DS	O.150/5278		148.27	14.25	10.40
SJ 0107 DS	Nig DS	O.150/5112		97.95	16.84	5.82
SJ 0114 DS	Nig DS	O.150/498		60.25	12.36	4.87
SJ 0119 DD	Nig D x D	O.149/14674	O.150/5375	131.37	19.56	6.71
Mean (Nig DS)				***109.46***	***15.76***	***6.95***
	Mean	Total Progeny				
	Nig Dx Deli D	2		179.58	22.15	8.11
	Nig D x D	5		141.94	24.17	5.92
	Nig DS	6		112.84	18.12	6.48
	Deli DxD	26		148.34	15.06	10.02
	Deli DS	20		104.42	15.80	6.73

Table 2.1: Bunch Analysis Tenera of PA1 and PA2

Trial Progeny	Cross	Female	Male	D:T:P	n	OB	KB	FB	WMF	KF	SF	OWM	FWt	ODM
PA1														
SJ0128DT	Nig D x T	O.150/2356	O.149/2704	17:18:0	29	22.33	6.05	60.13	74.12	9.98	10.34	50.52	6.70	77.00
SJ0129DT	Nig D x T	O.150/498	O.150/501	19:15:0	31	22.77	5.06	58.08	74.92	9.04	9.84	51.41	9.04	77.18
SJ0130DT	Nig D x T	O.150/498	O.150/665	22:13:0	17	19.77	6.39	57.53	71.02	11.01	11.65	48.62	8.06	74.51
SJ0131DT	Nig D x T	O.150/2194	O.150/665	12:22:0	37	19.34	5.78	53.29	73.39	10.66	10.07	48.55	9.49	74.76
Mean (Nig DxT)						***21.05***	***5.82***	***57.26***	***73.36***	***10.17***	***10.47***	***49.78***	***8.32***	***75.86***
SJ0145TT	Nig T x T	O.150/5974	O.149/11526	5:24:6	56	21.89	6.37	58.75	72.45	12.47	10.89	49.97	9.95	74.80
SJ0136TS	Nig TS	O.150/5060		5:20:9	35	23.79	6.23	62.91	75.74	9.76	9.30	50.36	5.84	76.78
SJ0096TP	AVROS TxP	O.174/773	O.174/4211	0:20:15	39	23.90	5.72	61.86	80.14	9.32	7.59	50.87	10.87	78.59
SJ0001DP	MPOB Std DP	O.212/270	O.159/149	23:10:0	4	24.55	6.52	67.31	76.12	9.65	8.47	48.05	9.94	77.71
	DxP Commercial				64	24.82	5.69	64.49	78.94	8.64	7.77	48.93	10.28	77.17
PA2														
SJ0127DT	Nig D x T	O.151/2106	O.149/3648	42:18:0	19	20.09	5.13	59.82	74.28	8.54	11.98	45.13	8.06	70.69
SJ0137TS	Nig TS	O.150/1969		15:34:7	49	20.76	6.62	65.04	73.27	10.17	10.79	43.54	9.31	71.16
SJ0138TS	Nig TS	O.150/501		14:15:6	5	16.06	3.22	47.14	84.11	6.71	5.65	41.17	5.14	66.40
SJ0142TS	Nig TS	O.151/128		15:30:14	9	19.86	11.13	57.68	78.28	7.46	9.62	44.42	5.44	71.20
Mean (Nig TS)						***18.89***	***6.99***	***56.62***	***78.55***	***8.11***	***8.69***	***43.04***	***6.63***	***69.59***
SJ0097TP	AVROS TxP	O.174/288	O.174/480	0:4:4	4	26.72	5.03	67.05	80.68	7.53	7.08	49.41	13.39	79.95
SJ0099TP	AVROS TxP	O.174/307	O.174/656	0:36:23	45	22.08	5.09	59.87	79.60	8.25	7.23	46.66	11.04	72.76
SJ0100TP	AVROS TxP	O.182/103	O.174/655	0:5:7	5	21.31	5.67	62.39	76.47	9.08	9.08	44.79	11.81	73.41
Mean(3 AVROS TP Families)						***23.37***	***5.26***	***63.10***	***78.92***	***8.29***	***7.80***	***46.95***	***12.08***	***75.37***
SJ0006DP	MPOB Std DP	O.212/272	O.174/655	1:59:0	103	22.69	5.11	64.18	79.90	7.87	7.61	45.47	12.44	72.26
SJ0007DP	MPOB Std DP	O.212/270	O.159/149	3:57:0	112	23.47	6.64	65.06	76.62	8.95	9.47	47.33	13.03	73.68
SJ0008DP	MPOB Std DP	O.212/203	O.174/480	1:59:0	122	22.80	6.45	66.46	75.65	9.62	9.28	46.22	12.54	72.76
Mean (3 MPOB Std DP)						***22.99***	***6.06***	***65.24***	***77.39***	***8.81***	***8.79***	***46.34***	***12.67***	***72.90***
SJ0027DP	Deli Dx AVROS Test Cross	O.212/738	O.174/480	0:36:0	66	20.82	11.67	67.45	71.80	10.77	10.90	42.82	10.37	72.50

Mean	Total Progeny	OB	KB	FB	WMF	KF	SF	OWM	FWt	ODM
Nig DxT	5	20.86	5.68	57.77	73.55	9.85	10.77	48.85	8.27	74.83
Nig T x T	1	21.89	6.37	58.75	72.45	12.47	10.89	49.97	9.95	74.80
Nig TS	4	20.12	6.80	58.19	77.85	8.53	8.84	44.87	6.43	71.38
AVROS TxP	4	23.50	5.38	62.79	79.22	8.55	7.75	47.93	11.78	76.18
MPOB Std DP	4	23.38	6.18	65.75	77.07	9.02	8.71	46.77	11.99	74.10
Deli Dx AVROS Test Cross	1	20.82	11.67	67.45	71.80	10.77	10.90	42.82	10.37	72.50

Table 2.2: Bunch Analysis Nig Dura of GB1 & GB2

Trial IJM	Cross	Female	Male	n	OB	KB	FB	WMF	KF	SF	OWM	FWt	ODM
GB1													
SJ 0122 DD	Nig D x Deli D	O.149/5616	O.212/694	308	21.89	4.75	66.43	63.09	7.16	23.91	52.35	11.82	75.52
SJ 0123 DD	Nig D x Deli D	O.152/83	O.212/179	279	21.46	5.45	66.64	61.93	8.14	23.59	51.94	9.38	73.44
Mean (Nig Dx Deli D)					***21.68***	***5.10***	***66.54***	***62.51***	***7.65***	***23.75***	***52.15***	***10.60***	***74.48***
SJ 0115 DD	Nig D x D	O.149/13130	O.150/5375	95	19.20	5.26	61.87	58.37	8.58	26.63	53.06	10.42	77.13
SJ 0116 DD	Nig D x D	O.150/1968	O.150/1908	19	21.43	5.69	66.39	61.46	8.53	23.95	52.15	7.06	75.84
SJ 0117 DD	Nig D x D	O.149/14674	O.150/2036	250	20.94	4.8	64.29	63.49	7.59	23.36	51.12	11.87	74.45
SJ 0118 DD	Nig D x D	O.150/2356	O.149/13130	81	20.84	5.46	65.08	60.16	8.64	25.31	53.54	9.70	77.22
Mean (NIg DxD)					***20.60***	***5.30***	***64.41***	***60.87***	***8.34***	***24.81***	***52.47***	***9.76***	***76.16***
SJ 0104 DS	Nig DS	O.149/13252		57	17.56	4.11	55.41	56.41	7.41	29.44	55.39	10.88	80.09
SJ 0105 DS	Nig DS	O.150/5375		32	17.28	4.52	55.78	60.79	8.17	24.76	51.31	10.56	75.27
Mean (Nig DS)					***17.42***	***4.32***	***55.60***	***58.60***	***7.79***	***27.10***	***53.35***	***10.72***	***77.68***
GB2													
SJ 0103 DS	Nig DS	O.151/146		36	22.77	6.67	66.48	68.89	8.81	16.73	49.95	9.14	74.27
SJ 0106 DS	Nig DS	O.150/5278		32	21.84	6.12	68.75	64.69	8.03	21.39	49.38	11.77	72.38
SJ 0107 DS	Nig DS	O.150/5112		20	21.49	4.55	63.39	65.56	7.18	21.75	51.80	9.84	73.73
SJ 0114 DS	Nig DS	O.150/498		17	22.51	4.98	65.66	65.11	7.55	21.72	52.84	10.74	75.51
SJ 0119 DD	Nig D x D	O.149/14674	O.150/5375	32	22.55	4.69	65.3	65.02	7.16	22.21	53.65	12.81	75.65
Mean (Nig DS)					***22.10***	***5.09***	***65.78***	***65.10***	***7.48***	***21.77***	***51.92***	***11.29***	***74.32***
	Mean	Total Progeny											
	Nig Dx Deli D	2			21.68	5.10	66.54	62.51	7.65	23.75	52.15	10.60	74.48
	Nig D x D	5			20.99	5.18	64.59	61.70	8.10	24.29	52.70	10.37	76.06
	Nig DS	6			20.58	5.16	62.58	63.58	7.86	22.63	51.78	10.49	75.21
	Deli DxD	26			22.27	4.77	67.06	64.77	6.90	22.50	51.34	11.68	75.06
	Deli DS	20			22.09	4.94	65.42	65.42	6.93	22.06	51.68	11.25	75.00

Table 3.1:Vegetaive Measurement Tenera of PA1 and PA2

Trial Progeny	Cross	Female	Male	Hgt Incr	PCS	RL	LA	GRT
PA1								
SJ0128DT	Nig D x T	O.150/2356	O.149/2704	0.47	10.37	5.40	8.90	55.82
SJ0129DT	Nig D x T	O.150/498	O.150/501	0.42	10.76	5.10	8.76	49.54
SJ0130DT	Nig D x T	O.150/498	O.150/665	0.37	11.24	5.03	7.82	48.75
SJ0131DT	Nig D x T	O.150/2194	O.150/665	0.28	11.61	5.12	8.28	53.80
Mean (Nig DxT)				***0.39***	***11.00***	***5.16***	***8.44***	***51.98***
SJ0145TT	Nig T x T	O.150/5974	O.149/11526	0.38	14.26	5.69	9.10	55.40
SJ0136TS	Nig TS	O.150/5060		0.33	8.96	4.71	6.03	43.90
SJ0096TP	AVROS TxP	O.174/773	O.174/4211	0.73	13.91	5.52	8.12	57.05
SJ0001DP	MPOB Std DP	O.212/270	O.159/149	0.49	16.25	5.70	9.24	56.66
	DxP Commercial			0.54	16.96	5.68	9.75	57.89
PA2								
SJ0127DT	Nig D x T	O.151/2106	O.149/3648	0.26	11.43	5.15	7.80	65.53
SJ0137TS	Nig TS	O.150/1969		0.23	13.18	5.37	9.48	64.88
SJ0138TS	Nig TS	O.150/501		0.33	7.74	4.16	6.25	54.64
SJ0142TS	Nig TS	O.151/128		0.29	9.96	4.58	7.11	58.89
Mean (Nig TS)				***0.28***	***10.29***	***4.70***	***7.61***	***59.47***
SJ0097TP	AVROS TxP	O.174/288	O.174/480	0.41	12.17	4.47	7.18	64.50
SJ0099TP	AVROS TxP	O.174/307	O.174/656	0.43	12.46	4.96	9.31	61.60
SJ0100TP	AVROS TxP	O.182/103	O.174/655	0.51	11.30	4.67	7.83	53.20
Mean(3 AVROS TP Families)				***0.45***	***11.98***	***4.70***	***8.11***	***59.77***
SJ0006DP	MPOB Std DP	O.212/272	O.174/655	0.45	13.88	5.28	9.33	65.22
SJ0007DP	MPOB Std DP	O.212/270	O.159/149	0.53	15.60	5.55	9.98	62.21
SJ0008DP	MPOB Std DP	O.212/203	O.174/480	0.44	13.73	5.59	9.57	66.03
Mean (3 MPOB Std DP)				***0.47***	***14.40***	***5.47***	***9.63***	***64.49***
SJ0027DP	Deli Dx AVROS Test Cross	O.212/738	O.174/480	0.42	15.72	5.57	9.10	64.26
	Mean	Total Progeny						
	Nig DxT	5		0.36	11.08	5.16	8.31	54.69
	Nig T x T	1		0.38	14.26	5.69	9.10	55.40
	Nig TS	4		0.30	9.96	4.71	7.22	55.58
	AVROS TxP	4		0.52	12.46	4.91	8.11	59.09
	MPOB Std DP	4		0.48	14.87	5.53	9.53	62.53
	Deli Dx AVROS Test Cross	1		0.42	15.72	5.57	9.10	64.26

Table 3.2: Vegetative Measurement Nig Dura of GB1 & GB2

Trial IJM	Cross	Female	Male	Hgt Incr	PCS	RL	LA	GRT
GB1								
SJ 0122 DD	Nig D x Deli D	O.149/5616	O.212/694	0.60	12.43	5.57	8.93	61.73
SJ 0123 DD	Nig D x Deli D	O.152/83	O.212/179	0.55	12.37	5.33	8.54	57.99
Mean (Nig Dx Deli D)				***0.58***	***12.40***	***5.45***	***8.74***	***59.86***
SJ 0115 DD	Nig D x D	O.149/13130	O.150/5375	0.34	9.91	4.71	7.27	48.45
SJ 0116 DD	Nig D x D	O.150/1968	O.150/1908	0.24	7.74	4.74	6.04	44.93
SJ 0117 DD	Nig D x D	O.149/14674	O.150/2036	0.46	11.94	5.45	7.86	55.07
SJ 0118 DD	Nig D x D	O.150/2356	O.149/13130	0.33	9.18	4.84	7.07	51.97
Mean (NIg DxD)				***0.34***	***9.69***	***4.94***	***7.06***	***50.10***
SJ 0104 DS	Nig DS	O.149/13252		0.32	11.28	4.89	7.68	55.26
SJ 0105 DS	Nig DS	O.150/5375		0.23	7.97	4.28	6.00	44.06
Mean (Nig DS)				***0.28***	***9.63***	***4.59***	***6.84***	***49.66***
GB2								
SJ 0103 DS	Nig DS	O.151/146		0.29	13.53	5.44	8.90	66.18
SJ 0106 DS	Nig DS	O.150/5278		0.31	13.96	5.29	8.91	65.19
SJ 0107 DS	Nig DS	O.150/5112		0.18	8.80	4.60	7.44	55.81
SJ 0114 DS	Nig DS	O.150/498		0.17	7.39	4.27	6.49	50.00
SJ 0119 DD	Nig D x D	O.149/14674	O.150/5375	0.22	10.29	5.05	7.62	54.88
Mean (Nig DS)				***0.22***	***10.11***	***4.80***	***7.62***	***56.47***
	Mean	Total Progeny						
	Nig Dx Deli D	2		0.58	12.40	5.45	8.74	59.86
	Nig D x D	5		0.32	9.81	4.96	7.17	51.06
	Nig DS	6		0.25	10.49	4.80	7.57	56.08
	Deli DxD	26		0.47	15.05	5.41	8.92	59.76
	Deli DS	20		0.50	11.97	4.90	7.09	52.21

Table 4.1: Growth Index Tenera of PA1

IJM	Cross	Female	Male	FP	V	BI	LAR
SJ0128DT	Nig D x T	O.150/2356	O.149/2704	25.58	47.43	0.63	5.03
SJ0129DT	Nig D x T	O.150/498	O.150/501	25.50	43.46	0.64	5.07
SJ0130DT	Nig D x T	O.150/498	O.150/665	23.42	41.04	0.69	4.62
SJ0131DT	Nig D x T	O.150/2194	O.150/665	24.27	42.35	0.69	4.76
SJ0145TT	Nig T x T	O.150/5974	O.149/11526	24.31	52.82	0.66	4.22
SJ0136TS	Nig TS	O.150/5060		25.28	35.04	0.66	4.32
SJ0096TP	AVROS TxP	O.174/773	O.174/4211	30.60	71.99	0.53	3.30
SJ0001DP	MPOB Std DP	O.212/270	O.159/149	26.55	66.13	0.57	3.75
	DxP			26.45	70.74	0.58	3.70
	Mean	Total Progeny					
	Nig DxT	4		24.69	43.57	0.66	4.87
	Nig TxT	1		24.31	52.82	0.66	4.22
	Nig TS	1		25.28	35.04	0.66	4.32
	AVROS TxP	1		30.60	71.99	0.53	3.30
	MPOB Std DP	1		26.55	66.13	0.57	3.75

Table 4.2: Growth Index Nig Dura of GB1

IJM	Cross	Female	Male	FP	V	BI	LAR
SJ 0122 DD	Nig D x Deli D	O.149/5616	O.212/694	27.90	66.34	0.56	3.86
SJ 0123 DD	Nig D x Deli D	O.152/83	O.212/179	29.10	63.1	0.56	4.02
SJ 0115 DD	Nig D x D	O.149/13130	O.150/5375	27.90	42.82	0.62	4.78
SJ 0116 DD	Nig D x D	O.150/1968	O.150/1908	28.60	33.03	0.64	5.02
SJ 0117 DD	Nig D x D	O.149/14674	O.150/2036	28.70	55.9	0.57	4.13
SJ 0118 DD	Nig D x D	O.150/2356	O.149/13130	28.20	41.59	0.62	4.72
SJ 0104 DS	Nig DS	O.149/13252		27.60	47.42	0.56	4.51
SJ 0105 DS	Nig DS	O.150/5375		28.60	32.47	0.63	4.95
	Mean	Total Progeny					
	Nig D x Deli D	2		28.50	64.72	0.56	3.94
	Nig D x D	4		28.35	43.34	0.61	4.66
	Nig DS	2		28.10	39.95	0.60	4.73
	Deli DxD	12		29.78	70.18	0.51	3.58
	Deli DS	15		30.93	59.27	0.48	3.67

Table 5.0: Yield Comparison between Meliau and Sijas

Progeny Code	Cross	Female	Male	PT1 Meliau (3-6 YAP)			Sijas (3-6 YAP)		
				FFB	Bno	Bwt	FFB	Bno	Bwt
SJ 0128 DT	Nig D x T	O.150/2356	O.149/2704	91.84	11.32	8.11	173.02	27.80	6.22
SJ 0129 DT	Nig D x T	O.150/498	O.150/501	90.31	10.13	8.92	165.00	21.20	7.78
SJ 0130 DT	Nig D x T	O.150/498	O.150/665	73.40	8.31	8.84	191.61	22.51	8.51
SJ 0131 DT	Nig D x T	O.150/2194	O.150/665	90.72	9.47	9.58	193.35	25.46	7.59
Mean (Nig DxT)				***86.57***	***9.81***	***8.86***	***180.75***	***24.24***	***7.53***
SJ 0104 DS	Nig D self	O.149/13252		79.37	9.28	8.55	126.34	25.05	5.04
SJ 0001 DP	MPOB Std DP	O.212/270	O.159/149	105.06	8.39	12.52	191.51	15.60	12.28

Rainfall in Sijas Estate from 2000 till 2010

Year	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010	
Month	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**
Jan	14	440.0	15	365.0	19	531.0	16	709.0	21	981.0	7	156.0	15	393.0	25	767.0	16	290.5	23	503.0	16	551.0
Feb	11	158.0	13	532.0	12	271.0	8	139.0	9	243.0	6	64.0	20	1070.0	12	108.1	21	519.5	17	714.0	5	32.5
Mar	8	190.0	17	509.0	6	97.0	11	424.0	3	239.0	11	425.0	15	107.0	7	75.6	18	554.0	12	191.0	10	175.0
Apr	12	357.0	5	37.5	4	93.0	1	11.0	7	66.0	3	20.0	9	75.0	8	102.1	16	197.0	16	245.0	12	173.0
May	3	142.0	10	203.5	7	214.0	12	303.0	13	217.0	13	314.0	11	179.0	16	168.2	10	241.0	11	270.5	14	189.0
Jun	12	307.0	9	111.0	13	238.0	17	132.0	13	377.0	14	352.0	14	313.0	18	152.0	19	436.0	16	247.5	9	51.0
Jul	13	290.0	14	235.0	10	192.0	16	222.0	20	323.0	9	233.0	19	525.0	17	298.5	14	256.0	13	188.0	18	182.5
Aug	11	189.0	11	145.3	9	167.0	18	325.0	8	88.0	7	247.0	17	315.0	18	159.0	15	183.0	7	98.0	15	283.5
Sep	17	185.0	16	278.5	17	352.0	20	515.0	15	176.0	9	144.0	10	254.0	11	163.0	18	248.0	10	286.0	14	265.5
Oct	16	445.0	12	190.0	15	385.0	18	245.0	14	154.0	17	432.0	12	348.0	18	359.0	18	225.0	12	177.5	13	216.0
Nov	20	204.0	17	340.0	14	349.0	13	111.0	9	91.0	16	166.0	12	243.0	15	203.0	16	291.0	20	329.0	15	303.5
Dec	12	167.0	16	587.0	10	130.0	27	1135.0	21	840.0	14	151.0	16	583.0	22	662.5	19	336.0	19	364.0	22	259.5
Total	149	3074.0	155	3533.8	136	3019.0	177	4271.0	153	3795.0	126	2704.0	170	4405.0	187	3217.9	200	3777.0	176	3613.5	163	2682.0

Rainfall in Meliau Estate from 2000 till 2010

Year	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010	
Month	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**	**Days**	**mm**
Jan	19	952.0	10	177.5	10	196.0	22	353.0	16	155.0	14	350.0	19	304.5	25	718.5	23	367.0	22	491.0	14	531.0
Feb	19	317.0	14	496.0	10	297.0	14	191.0	14	108.0	10	125.5	23	757.5	16	148.0	21	511.0	17	486.5	6	34.0
Mar	16	341.5	21	335.0	6	154.0	19	525.0	10	213.6	14	290.5	18	398.5	8	103.5	22	498.0	16	271.0	6	22.0
Apr	16	311.0	7	76.0	9	79.0	5	14.0	14	95.0	6	63.5	16	154.5	12	139.5	18	308.0	19	305.0	10	191.0
May	9	232.5	18	194.5	17	353.0	11	174.0	21	347.5	24	417.5	17	324.5	20	447.0	10	271.0	16	259.5	21	212.0
Jun	16	434.0	5	84.0	16	234.0	17	327.0	17	152.0	20	626.0	20	539.0	23	401.0	22	462.0	19	413.0	12	192.0
Jul	18	381.0	18	284.0	12	205.0	18	312.0	20	317.0	12	211.5	21	359.5	16	323.5	11	352.0	16	233.0	15	433.0
Aug	13	226.0	9	167.0	11	314.0	17	519.0	10	270.5	10	222.5	20	216.5	18	242.5	20	404.0	14	153.0	13	357.0
Sep	17	273.0	17	419.0	13	287.5	17	273.0	18	345.5	18	400.5	16	186.5	16	282.5	15	346.0	6	84.0	17	267.0
Oct	19	280.0	15	236.0	16	304.5	19	345.0	8	102.5	17	311.0	21	223.0	24	439.0	19	262.0	21	375.0	15	386.0
Nov	16	234.0	15	288.0	15	294.0	19	276.0	13	172.5	20	268.5	16	281.0	16	212.5	25	361.0	18	205.0	18	325.0
Dec	10	196.0	20	511.0	18	320.0	16	214.0	24	502.0	23	363.5	20	461.0	25	454.0	17	234.0	22	463.0	18	373.0
Total	188	4178.0	169	3268.0	153	3038	194	3523.0	185	2781.1	188	3650.5	227	4206.0	219	3911.5	223	4376.0	206	3739.0	165	3323.0