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Preliminary assessment on drought tolerance of oil palm in semi-arid area

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Evaluating oil palm growth performance and their corresponding effect on drought is crucial for proper parental selection. The parent palm that has drought tolerance characteristics has less affect on oil yield production, thus, highly potential as future planting material for dry region areas. A study using split-plot with four replications in a randomized complete block design (RCBD) was conducted. All 19 progenies were evaluated and interaction effects were estimated using split-plots analysis. Among all progenies, PB29 showed the highest average production in terms of vegetative growth and oil yield. This was clearly seen on the first year of harvesting (2017), where fresh fruit bunch (FFB) of PB29 was reaching 12.42 t/ha, while in the second year of harvesting (2018), showed increment of 5 t/ha, with a total annual FFB yield of about 17.94 t/ha. Drought tolerance trait is a major improvement if it can be incorporated into new planting material of oil palm. It can widen the range of suitable land selection for plantation thus increasing the possibility to expend oil palm in marginal regime areas. The new breed must possess two characteristics which are, the ability to tolerate a drought condition as well as excessive water supply (seasonal climate), and produce high oil yield.

1. Introduction

Oil palm (*Elaeis guineensis*) is by far the most efficient oil producing crop in the world. It is grown mainly in South-East Asia, Malaysia and Indonesia. In these growing regions, the annual rainfall varies from a well distributed 2000 mm to a seasonal deficit of less than 1500 mm, which can be compensated with irrigation. However, the uneven rainfall distribution is amongst the major contributing factors affecting high oil palm yields (Goh et al., 2000). For optimum yield, the minimum rainfall required is around 1500 to 1800 mm/ year-1 with an absence of dry season and an evenly distributed sunshine exceeding 2000 h year^{-1} (Bakoume et al., 2013). Meanwhile, the mean maximum temperature range between 29 to 33°C and minimum temperature between 22 to 24°C favour the highest oil palm bunch production (Corley and Tinker, 2003). A study in Southern Thailand indicates that dry seasons occur within four months in a year and have caused oil yield reduction by 25% - 35% (Corley et al., 2018, Duangpan et al., 2018). Periodic dry periods in January-March and June-Augustcommonly occur in the inland areas of the peninsular Malaysia (Hazir et al., 2018). Even in the wet tropics, water availability for the oil palm during dry periods can be limited, which creates stress and a wide range of negative effects on productivity.

As demand for vegetable oil increased globally (Khatiwada et al., 2021), cultivation expansion into regions with a significant annual dry season are inevitable. Thus, introduction of drought tolerant planting material is a way to move forward as the tolerant crosses have higher yield than the susceptible crosses (Nodichao et al., 2011). In Malaysia, the oil palm was introduced to northern Peninsular of Malaysia, a monsoonal-type climate region, with distinct long, dry seasons, where rainfall is less than 1500 mm and poorly distributed throughout the year. These were aggravated by limitation of soil's water holding capacity and relatively shallow roots . Soil type and rainfall form the basis of the site yield potential (Woittiez et al., 2017). Areas with a pronounced drought for three months ormore have an inherent effect to yield potential that limits fresh fruit bunch (FFB) production which exacerbates by excessive rain in the following wet months. Hence, irrigation is crucial in reducing the dry period effects.

Oil palm planting material is produced by crossing thick-shelled dura palms with shell-less pisifera palms, to produce the tenera fruit that has a thin shell but thick oil-bearing mesocarp, which has a higher oil yield than the dura. A single pisifera can yield sufficient pollen to produce several million seeds per year, so it is important to identify the best pisifera by progeny testing (Corley et al., 2018). Therefore, finding the oil palms with different responses under drought conditions must be based on their genetic origin, cross-type, partially independent from its production potential, since genetics is the best alternative to identify high-performing crosses and parents (Méndez et al., 2012). Previously, Suresh et al. (2008) has ranked three dura background with drought tolerant character; Zambia (ZS) > Guinea Bissau (GB) > Tanzania (TS). While Méndez et al. (2012) has indicated 4 crosses, L430T x L404T is tolerant, L2T x D118D moderate tolerant, and meanwhile L10T x D118D and L2T x D10D are susceptible. Interestingly, from FGV trials, the L2T, L404, D10D, D8D, L270D, L404D, UR333/5 and UR295/3 have outstanding performance in Serting Hilir Trial 4 & 5 (a moderate to low rainfall regime). However, FGV, lack in performance data of various oil palm progenies under the drought condition.

In order to continue searching for new genotypes that aretolerant to water deficit, it is crucial to establish a new trial by incorporating various genetic backgrounds in areas where conditions are less favourable for palm growth. The aim of this study is to assess the best crossing palm with drought tolerant progenies in which the effect of yield reduction is minimised.

2. Materials and Methods

2.1. Materials and study area

Selection of planting materials is based on four criterias: (1) Origins ie. AVROS, La Me, and Yangambi; (2) Potential tolerance lineage from previous reports; (3) FGV Advanced materials; and (4) tenera clone materials. A total of 19 progenies were selected including three standard crosses namely SC11, SC12 and SC7b (Table 1). The trial received the standard fertiliser dressings. The study was conducted at FGVAS Chuping, Perlis station that had prolonged dry weather and lower rainfall. This area was categorised as one of the driest places in Malaysia with annual rainfall lower than 1500 mm.

2.2. Experimental Design

Split plot with four replications in a randomized complete block design (RCBD) was done by assigning two levels of irrigation with and without as main block. While in subplot, nineteen progenies were evaluated and their interaction effects with and without irrigation were analysed. The trial site is generally a flat terrain that was previously planted with sugarcane. The field management are following the standard estate and fertilizer practices. Rainfall data was collected in the plot area using rain gauge for four consecutive years from 2015 until 2018. The other information of trial plot has been summarised in Table 2.

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Table 1. The list of nineteen progenies involved with the respective parents

Progeny Code	**Female**		**Male**
FC5337	ARK (IRHO)	x	ML (Yangambi)
FC5576	ARK (IRHO)	x	1931 (NPM)
FC5579	CEB (IRHO)	x	CKP (AVROS)
FC5635	GKN (Banting-NPM)	x	TT3 (Yangambi)
PB 6	GKN (Banting-NPM)	x	ML (Yangambi)
PB14	EN13 (IRHO-NPM)	x	GEL (AVROS)
PB15	C2 (IRHO-NPM)	x	ML (Yangambi)
PB16	J4 (IRHO-NPM)	x	GMH (Yangambi)
PB21	N1 (IRHO-NPM)	x	GMH (Yangambi
PB22	C6 (Banting-NPM)	x	GMH (Yangambi)
PB29	FOP (Banting-FGV)	x	ML (Yangambi)
PB36	FQG (IRHO)	x	TT38 (Yangambi)
PB38	FGO (IRHO)	x	TT38 (Yangambi)
PB80	FGV clone 1 (FGV)	x	ML (Yangambi)
PB88	FGV clone 2 (FGV)	x	ML (Yangambi)
PB91	FGV clone 3 (FGV)	x	GMH (Yangambi)
SC 7b	FD1 (Kulai)	x	ML (Yangambi)
SC11	J2 (IRHO)	x	BAE (La Me)
SC12	J2 (IRHO)	x	TT3 (Yangambi)

*parentheses show the origin of the parent palm used in the breeding program

Table 2. The general information of trial plot that has been using in the experiment

Location	FGV Chuping , Perlis, Malaysia
Area available	23.0 ha
Terrain	Flat – Moderately Undulating
Previous crop	Sugar cane
Soil type	Chuping and Dampar Soil Series
Planting material	19 Progenies
Experimental design	Split plot design irrigation as main plots and progenies as subplots
Plot size	4x4 center recording palms (without border palm)
No. of replication	4
Irrigation technique	Drip irrigation, 250 L/palm/day
Planting density	148 / ha

2.3. Vegetative measurement

The vegetative growth was measured for every individual palm for all replicates. The vegetative data collected includes girth size, palm height, leaf width and length, petiole cross section, frond length and canopy length, by using measuring tape. The data was collected for every sixth months after three years of planting.

2.4. Fresh fruit bunch yield

The FFB yield census were conducted four times a year for each palm after three years of planting. The bunch weight measurement was performed thrice (three FFB for every palm) to obtain the mean of bunch weight and FFB yield (t/ha). Data for bunch number for each palm was measured four times a year.

2.5. Performance Index (PI)

Performance index contains several parameters including; fresh fruit bunch (FFB), bunch number (BNO), average bunch weight (ABW), rachis length (RL), leaflet number (LNO), petiole cross section (PCS), leaf area (LA), leaf dry weight (LDW) and frond dry weight (FDW).

2.6. Statistical analysis

All collected data were subjected to one-way analysis of variance (ANOVA) using SPSS (Version 20). A Tukey HSD of all pairwise comparisons for individual mean values by plots was performed to determine which plot means were significantly different from oneanother. All statistical analysis and differences were evaluated at 5% probability level.

3. Results

The trial was planted on 2014 with plot density at 148 palms/ha. Precipitation data around the plot was recorded from 2015 until 2018 at 1363.58, 1147.70, 1434.8 and 1318.3 mm/year, respectively (Table 3). This rainfall data in the plot area indicated lower precipitation compared to other locations of peninsular Malaysia at 2000 mm to 3000 mm/year (Saimi et al., 2020). Three progenies have higher PI values compared to standard cross (SC7) which are PB16, FC5579 and PB29 with values of 74%, 76% and 89%, respectively (Figure 1). Among these three progenies, PB29 has the highest in vegetative growth and yield. The majority of progenies showed lower PI compared to SC7, with the lowest PI is PB14 at 18%.

Table 3. The rain gauge data has been recorded for four consecutive year from 2015-2018 in the study plot area

	Rain gauge (mm)			
Month/Year	**2015**	**2016**	**2017**	**2018**
Jan	2.40	24.00	170.5	185.6
Feb	0.0	7.1	4.1	0
Mac	12.4	0	150.2	1.8
April	100.4	86.6	210.7	38.6
May	136.6	206.7	142.4	156.7
Jun	67.0	58	123.0	121.6
Jul	168.7	92	67.2	205.5
Aug	169.2	84	124.0	50.7
Sept	212.6	175.5	124.0	182.5
Oct	129.4	180.6	124.0	174.6
Nov	238.3	147.2	124.0	58.1
Dec	126.6	86	70.7	142.6
Sum	1363.58	1147.70	1434.8	1318.3

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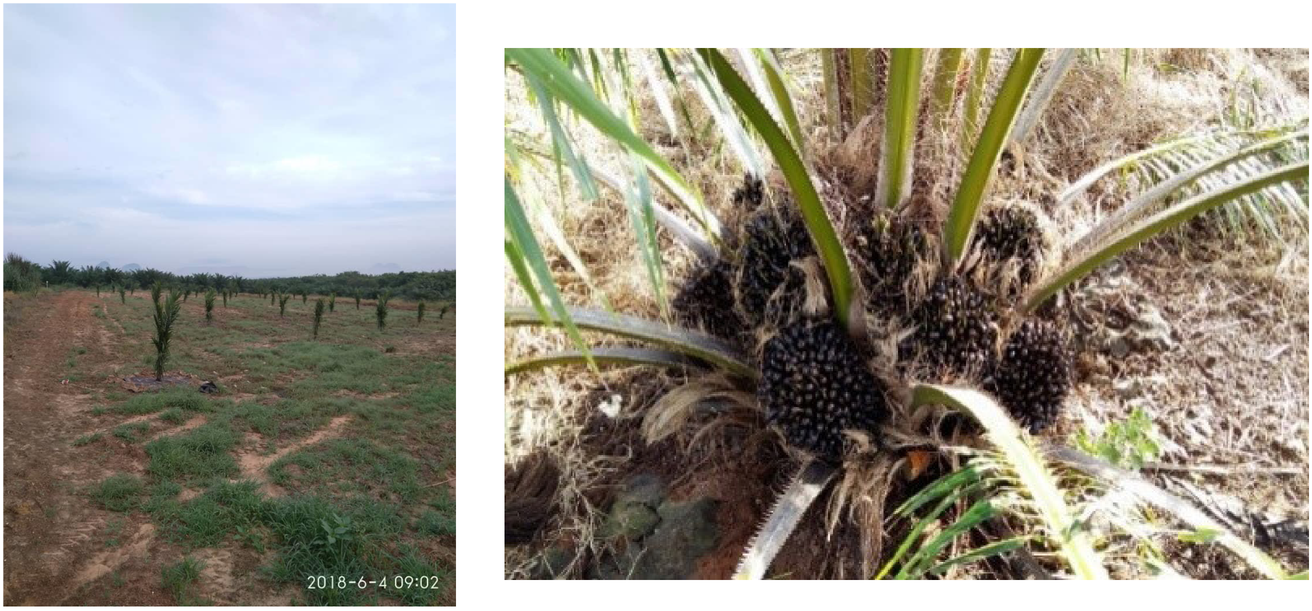
The plot area was well managed to reduce environmental effects such as weed competition for fertilizer, bare soil cropping, antitranspirants, cropping with other palms and diseases (Figure 2A). As shown in Figure 2B, PB29 is no doubt the best performer for FFB yield even in a drought area. These progenies have high potential to exploit further to produce a more susceptible drought plant material in the near future.

PB29 was selected for further statistical analysis by comparing with control progeny, SC7. As a result, FFB yield (t/ha) between PB29 and SC7 shows an increase in oil yield up to 20% than control during the first year after planting at 2.14 t/ha and higher increment recorded on the second year of drought up to +38% at 17.94 t/ha of FFB (Table 4).

4. Discussion

High PI of the three progenies (PB16, FC5579 and PB29) are contributed to high bunch number production as showen in Figure 2B for the PB29 that has high number of bunch formation at three years



(A) (B)

Figure 2. Plot of progeny PB29. (A) Plot setup for individual replicate for the initial year of planting (0 year after planting); (B) individual palm (3 years after planting)

Table 4. The preliminary comparison of FFB yield between PB29 and SC7 in drought area.

	Progeny	
Years of harvesting	PB29	SC7
First (2017)	12.42 (+20%)	10.28
Second (2018)	17.94 (+38%)	12.90

*Parentheses show the percentage increase compared to SC7 after planting. Generally, in the event of water scarcity, the formation of female inflorescence is reduced and replaced with formation of male inflorescence. However, for PB29, its' ability to produce high number fertile female inflorescence, indicates strong evidence that this progeny might have one of the potential drought tolerance traits. According to Corley et al. (2018), drought reduced oil palm yield through a vegetative part including the fruit bunch number, by changes in the ratio of female to male inflorescences. Meanwhile, for other progenies, they show reduction of bunch number by producing lower PI. Since water is the critical factor for optimum oil palm growth, deficiency will act as a signal to repress the female sex expression, while an increase in the production of male flowers coupled with slow growth leads to poor productivity (Cha-um et al., 2013).

Progenies that are tolerant to drought may have a better root formation system indicated by a good vegetative growth even under water deficit conditions and vice versa to the susceptible progenies. These was reported previously that tolerant oil palm genotype had higher Total Root Length (TRL), Total Root Surface Area (TRSA) and Potential Root Water Extraction Ratio (PRER) than susceptible genotypes based on half distances between roots, and the distance of water migration from soil to root (Cha-um et al., 2013; Murugesan et al., 2017). Palms fibrous root system is capable of observing water quicker and commonly found at irrigated soil (0.7 m in depth), while deep roots systems (1.1 m) are mainly developed by palms that grow in rain-fed areas (Cha-um et al., 2013).

Even when the plant was still in the early growth stage, the progeny PB29 had showed an impressive performance by producing FFB yield at 17.94 t/ha. Meanwhile, others reported that trial on dry area produced FFB yield at 16-18 t/ha for palm age 8-10 years old, with Angola, Tanzania, La Me and some Deli lines are promising population, with the best crosses being Angola × Tanzania and Angola × La Me, which had better appearances, higher water potentials at dawn and higher leaf specific weights (Suresh & Mathur, 2009). Bayona-Rodriguez & Romero (2019) reported that IRHO parent palm is an outstanding cultivar which is a good response to dry periods. Interestingly, in this study the Banting-FGV × Yangambi progeny is the most drought tolerant compared to La Me line (SC11) and IRHO (Bayona-Rodriguez & Romero, 2019). Different drought tolerant background reports might be due to genetic differences of cultivars that were able to reduce photosynthesis rates up to 25% to 40% during water deficit (Bayona-Rodriguez & Romero, 2019). Therefore, selecting a right parent palm with a drought tolerance trait is important to produce progeny with the right genes in response to water deficit conditions to minimize oil yield loss.

Drought periods has an effect on male and female inflorescence ratio and decreased in bunch number. Water deficit has a direct impact on FFB and oil yield, up to 20% reduction. The water problem for oil palms is the result of climate changes that reduce precipitation and increase drought seasons. Furthermore, it is difficult to utilize irrigation systems in large areas to avoid water deficit or to reduce sessional dry impacts because of economical, technical and agricultural limitations (Jazayeri et al., 2015).

5. Conclusions

Drought is a major constraint for oil palm plantation, and we are highly depending on rainfall in most of cultivation regions. In this preliminary study, we found a potential progeny from cross-pollination palm that has tolerance to drought without a yield depression.

As the oil palm cultivation expands into drought-prone regions, drought tolerant planting material is urgently needed. As a result from this study, we have identified some potential parents of progenies PB29, PB16 and FC5579 that appear to transmit drought tolerance to their offspring. These potential parents will also be valuable for commercial seed production and oil palm breeding programmes in the future.

These results also can be used for omics studies, to find the likely genes, pathways, processes and mechanisms involved in oil palm response to drought which will lead to molecular assisted selection plant breeding programs.

Conflict of interest

The authors declare no conflict of interest.

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