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# FIELD EVALUATION OF OIL PALM GENETIC MATERIALS FOR PARTIAL RESISTANCE IN *Ganoderma* HOTSPOTS OF TROPICAL PEAT SOIL

**MOHD DIN, A[1]*; MARHALIL, M[1]; MOHD MUSTAKIM, M[1]; NORZIHA, A[1]; KUSHAIRI, A[2] and RAJANAIDU, N[3]**

**ABSTRACT**

*The Malaysian Palm Oil Board's (MPOB) oil palm genetic materials were evaluated for* Ganoderma *infection in* Ganoderma *hotspots at the MPOB Research Station in Bagan Datuk, Perak, Malaysia. The objectives of the study were to investigate the development of the disease among oil palm genetic materials [*dura *x* dura *(DxD),* dura *x* pisifera *(DxP) and D-selfed] and subsequently to identify progenies having partial resistance to the basal stem rot (BSR) disease caused by* Ganoderma*. The progenies were planted in 2008 in a completely randomised design in an area formerly cultivated with oil palm but devastated by* Ganoderma*, hence regarded as a* Ganoderma *hotspot. Field census for symptoms of palms with* Ganoderma *infection was conducted for eight years, four years after field planting. The study showed a low infection rate of less than 10%, hence potential partial resistance on 31 (10 DxD, 13 DxP and eight D-selfed) progenies. The partial resistance of the 31 progenies will need to undergo further reconfirmation via screening in the nursery using established techniques prior to being utilised for the production of partial resistance planting materials. Upon confirmation of the partial resistance, utilising parents linked to the DxD, D-selfed and DxP progenies could undergo further breeding and improvement before being utilised as maternal parents for seed production. Individual palms from the DxP progenies could also be directly mass propagated via cloning for immediate utilisation.*

**Keywords:** *Ganoderma* hotspots, oil palm genetic materials, partial resistance, tropical peat soil.

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## INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is an important perennial oil crop for many countries. Malaysia is one of the leading producers and exporters of palm oil in the world. Oil palm breeding plays a key role in the development of the oil palm industry, especially in the production of quality planting materials.

[1] Malaysian Palm Oil Board,
6 Persiaran Institusi, Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia.

[2] No. 2 Jalan TH 1, Tiara Heights,
43900 Sepang, Selangor, Malaysia.

[3] 10-14-3 Danau Permai Condo, Jalan 3/109F
58100 Kuala Lumpur, Malaysia.

* *Corresponding author e-mail: mohddin@mpob.gov.my*

Oil palm breeding populations, exploited for commercial seed production, have an extremely narrow genetic base (Arasu and Rajanaidu, 1975). A bulk of the current planting material is produced using maternal palms that are descendants of the four 'Bogor' palms that were planted at the Bogor Botanical Gardens in 1848. These four palms, which formed the basic breeding stock, were planted at Deli, Sumatra, Indonesia and evolved into the 'Deli *dura*' population in oil palm breeding. There are Deli *dura* sub-populations such as Serdang, Elmina, Ulu Remis, Johor Labis and Dumpy (Kushairi and Rajanaidu, 2000; Yong, 1992).

In view of the narrow genetic base of current oil palm planting materials, oil palm germplasm collection has gained importance to broaden the gene pool of current breeding materials. Germplasm conservation is important to sustain

oil palm genetic variation for future exploitation. MPOB has collected oil palm germplasm from the centres of oil palm origin in Africa and Latin America (Rajanaidu, 1994) since 1973.

The basal stem rot (BSR) disease, which is caused by the fungus *Ganoderma boninense*, is a major destructive disease of the oil palm. Among devastating diseases, the *Ganoderma* disease is the only pathogenic disease, causing serious losses of field palms in Southeast Asia (SEA), especially in Malaysia and Indonesia and also other oil palm growing countries such as Colombia, Cameroon and Papua New Guinea. Flood *et al.* (2002) reported that in severely infected areas in the East Asia, over 50% of palms may be infected by *Ganoderma*. Yield reduction may occur both from the death of palms and from reduced yield in infected but still living palms (Corley and Tinker, 2016). Detection and control of this oil palm disease are therefore of great importance to maintain high productivity.

Today, Integrated *Ganoderma* Management (IGM) is practised at varying degrees in the oil palm industry and smallholdings. Implementation of IGM still faces many challenges and a concerted effort that focuses on policy, research, training and communication approaches, is needed in order to attain the full potential of IGM (Idris *et al.*, 2019). In 2016, MPOB published the standard operating procedure (SOP) guidelines to control *Ganoderma* as part of an awareness campaign to manage and mitigate this disease more effectively (Idris *et al.*, 2016). Some BSR disease control methods in existing plantings and management strategies at replanting have been achieved and are being implemented in several oil palm estates and smallholdings in Malaysia (Idris, 2011; Mohd Shukri *et al.*, 2019). Research to develop advanced technologies and the use of the mobile application, remote sensing and Geographical Information System (GIS) application to facilitate *Ganoderma* census/monitoring, biology/epidemiology/etiology, early detection, control and management are necessary for future improvement of the present IGM practices. The exploitation of modern biotechnology, nanoscience and nanotechnology could lead to new innovations in IGM technologies.

The development of breeding materials for *Ganoderma* tolerant or partial resistant traits has been placed under high priority in Malaysia (Mohd Din *et al.*, 2005; 2014). Plant pathologists and breeders do make a clear distinction between total resistance (specific) and partial resistance (nonspecific) (Durand-Gasselin *et al.*, 2011). Total resistance generally results from a gene for gene interaction between the plant and the pathogen. However, such a specific resistance can be bypassed easily by the pathogen, which is not suitable for oil palm. The appropriate strategy would be to select multiple defense genes involved in partial resistance. This selection will encourage and provide sustainable nonspecific resistance to a larger diversity of isolates of the pathogen, rather than a single gene for gene resistance. Selecting palms for multiple partial disease resistances will not result in the disappearance of sick palms in the field, but it will be more efficient to limit their number.

In the longer term, breeding for disease resistance offers the greatest hope for the future control of BSR disease. In Malaysia, efforts are being made to develop more productive planting materials through various breeding programs implemented by MPOB and privately owned oil palm plantations. It was reported that breeding materials collected from Cameroon revealed a high genetic diversity as did those of Nigeria and Sierra Leone (Hayati *et al.*, 2004). Cameroon and the Democratic Republic of the Congo (ex-Zaire) germplasms have shown high tolerance to *Ganoderma* disease in field planting (Rajanaidu, 1994). Field observations in North Sumatra disclosed that *E. guineensis* of Deli origin from Malaysia and Indonesia were more susceptible than African material (Durand-Gasselin *et al.*, 2005), and other trials have revealed differences in susceptibility, indicating possible genetic resistance within host populations (Breton *et al.*, 2006; Idris *et al.*, 2004). The existence of resistant genotypes has also been indicated in trials of 20 *dura* x *pisifera* (DxP) crosses in Indonesia (Purba *et al.*, 1994) and in *E. oleifera* x *E. guineensis* hybrids in Malaysia (Chung *et al.*, 1994). Thus, resistant materials are viewed as an outstanding promise for future management of BSR in oil palm in SEA (Breton *et al.*, 2006; Durand-Gasselin *et al.*, 2005; Idris *et al.*, 2004) and there are ongoing works in Sumatera and Socfindo in Indonesia. At MPOB, 15 oil palm progenies with different crosses [*viz. dura* x *dura* (DxD), DxP, *tenera* x *pisifera* (TxP), and *tenera* x *tenera* (TxT)], were screened for resistance to *G. boninense* using three methods, namely rubber woodblock (RWB) sitting technique on germinated seeds (RWB-GS), RWB sitting technique on 4-months old seedlings (RWB-S) and root inoculation technique (RIT) on 12-months old seedlings (Idris, 1999; Idris *et al.*, 2006; Rahamah *et al.*, 2015). There was found to be no significant difference among the progenies screened for resistance to *G. boninense* infection using RWB-GS but had significant differences using RWB-S and RIT. Based on the dead seedlings, the progeny PK 4493 (DxP, Zaire x Cameroon) with 50.0% dead seedlings using RWB-GS while 42.5% and 15.0% dead seedlings for RWB-S and RIT, respectively. Of these materials, the most susceptible was a Deli (Elmina) x Deli (Elmina) (DxD), whilst the most partial resistant was a Zaire x Cameroon (DxP). The identified genetic materials are being used in MPOB breeding programme to develop oil palm resistance to BSR disease.

Screening of oil palm progenies in the field, particularly in *Ganoderma* hotspots, is gaining importance and results have been reported by various researchers. Akbar *et al.* (1971) observed differences in incidence between West African and Deli materials in the field in Indonesia. de Franqueville *et al*. (2001) from Bangun Bandar, Indonesia discovered sources of oil palm genetic resistance and susceptibility to *Ganoderma* sp. They showed significant differences between DP/DT crosses in *Ganoderma* incidence in eight of 12 breeding trials and between clones in six of seven clonal trials. Durand-Gasselin *et al*. (2005) reported lower incidence among Deli x Yangambi crosses than pure Deli *dura*. Selfed Deli *dura* progenies were also found to be more susceptible to *Ganoderma* infection than inter-crossed Deli *dura* progenies in Kluang, Malaysia (Norziha *et al*., 2012) whereas the Deli material was more susceptible than AVROS, with the crosses being intermediate (Rahmaningsih *et al*., 2013). Nurul Fatiha *et al*. (2019) did a study involving nursery and field screenings. In nursery screening, the artificial *Ganoderma* fungi inoculum using woodblocks from rubber were used. Selected germinated seeds and clonal seedlings were planted with *Ganoderma* artificial inoculum for 12 months, purposely to screen for their tolerance level against BSR. The field study involved 20 progenies of both DxP and clonal planting materials, planted in 12.78 ha (an area previously identified as high BSR incidence hotspot), for field screening and selection of potential BSR tolerant material. Based on the two screening methodologies, they were able to observe the correlation for planting material with high tolerance in both nursery and field study. This article deliberates the results of a field study in *Ganoderma* hotspots at the MPOB Research Station Bagan Datuk, Perak, Malaysia to investigate the development of the BSR disease among different oil palm progenies.

## MATERIALS AND METHODS

The planting materials used in this study involved three breeding trials: Trial 0.501 (21 DxD progenies), Trial 0.502 (23 DxP progenies) and Trial 0.504 (14 D-selfed progenies). The DxD genetic materials in Trial 0.501 (*Table 1*) were grouped into Deli x Deli and Germplasm x Germplasm progenies. The DxP genetic materials in Trial 0.502 (*Table 2*), on the other hand, were grouped into Deli x AVROS, Deli x Yangambi, Deli x Germplasm, Germplasm x Germplasm and Germplasm x AVROS. In Trial 0.504 (*Table 3*), the D-selfed were grouped into Deli selfed and Germplasm selfed. The Deli *duras* were from sub-populations Ulu Remis, Serdang, Johor Labis, Banting and Elmina. The germplasm progenies, on the other hand, were derived from crosses involving germplasm from Tanzania (TZA), Angola (AGO) and Nigeria (NGA).

Intermediate partial resistant standard (Deli *dura* selfed and Deli *dura* x Cameroon *pisifera*) progenies and partial resistant standard (Zaire *dura* x Cameroon *pisifera* and Deli *dura* x AVROS *pisifera*) progenies (Idris *et al*., 2004; Nurazah *et al*., 2013) were also included in the trial.

Historically, the land was planted with oil palm (DxP planting materials), which were devastated by *Ganoderma*. The trials were laid in the *Ganoderma* hotspots with tropical peat soil type in 2008 at the MPOB Research Station Bagan Datuk, Perak, Malaysia in a Completely Randomised Design (CRD) with two to four replications at 16 palms per progeny per replication. A total number of 3952 palms were evaluated in this study. Census on the palms for *Ganoderma* infection was done on a quarterly basis from 2013 to 2019.

Based on field observations, the number of palms that showed BSR symptoms such as mottling of the lower fronds, necrosis, retarded growth, desiccation of fronds, presence of fruiting bodies or sporophores on the stem base, frond bases or roots (Idris *et al*., 2016) were recorded and the data analysed using Statistical Analysis System (SAS version 9.2).

## RESULTS

### DxD (Trial 0.501)

The purpose of this trial was to determine if there were any potential DxD families with a low infection rate (less than 10%) towards *Ganoderma*. Selected agronomic traits as per Malaysian Standard (MS157:2017) would be observed thereafter. For families that fulfil MS157:2017, selected *dura*s from that family may be selfed or cloned. The selfed *dura*s or clonal *dura*s may subsequently be progeny tested with *pisifera*s from the advanced breeding population. The resultant *teneras* from the progeny test may be utilised as ortet for the production of *Ganoderma* partial resistant clones.

The percentage of *Ganoderma* infection in each cross was monitored over seven years (*Figure 1*). The initial infection rate in 2013 was 1.26% for Deli x Deli progenies and 0.40% for the Germplasm x Germplasm progenies. The infection rate (%) of the disease increased over the years. By 2019, the Deli x Deli progenies recorded 40.05% infection whereas a much lower infection of 8.53% was observed in the Germplasm x Germplasm progenies. Overall, the Deli x Deli progenies recorded a higher percentage of *Ganoderma* infection in each year of the evaluation, compared to the Germplasm x Germplasm progenies. The initial infection rate in

**TABLE 1. PEDIGREE OF DXD PROGENIES IN TRIAL 0.501**

| No. | Progeny code | | Pedigree no. | Material | Cross type | No. of palms | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | ECP HP | 429 | 0.338/209 x 0.338/89 | Deli Ulu Remis x Deli Ulu Remis | DxD | 32 | Deli x Deli |
| 2 | ECP HP | 551 | 0.338/332 x 0.281/44 | Deli Ulu Remis x Deli Serdang | DxD | 64 | Deli x Deli |
| 3 | ECP HP | 578 | 0.338/63 x 0.278/318 | Deli Ulu Remis x Deli Johor Labis | DxD | 64 | Deli x Deli |
| 4 | ECP HP | 590 | 0.338/373 x 0.281/44 | Deli Ulu Remis x Deli Serdang | DxD | 64 | Deli x Deli |
| 5 | ECP HP | 592 | 0.338/422 x 0.278/318 | Deli Ulu Remis x Deli Johor Labis | DxD | 64 | Deli x Deli |
| 6 | ECP HP | 607 | 0.338/63 x 0.281/57 | Deli Ulu Remis x Deli Serdang | DxD | 48 | Deli x Deli |
| 7 | ECP HP | 629 | 0.338/422 x 0.281/64 | Deli Ulu Remis x Deli Serdang | DxD | 64 | Deli x Deli |
| 8 | PK | 4638 | 0.256/650 x 0.256/1030 | TZA x TZA | DxD | 64 | Germplasm x Germplasm |
| 9 | PK | 4263 | 0.256/2995 x 0.312/99 | TZA x AGO | DxD | 64 | Germplasm x Germplasm |
| 10 | PK | 4271 | 0.256/1926 x 0.312/99 | TZA x AGO | DxD | 48 | Germplasm x Germplasm |
| 11 | PK | 4288 | 0.256/2995 x 0.312/941 | TZA x AGO | DxD | 64 | Germplasm x Germplasm |
| 12 | PK | 4294 | 0.256/1926 x 0.312/941 | TZA x AGO | DxD | 64 | Germplasm x Germplasm |
| 13 | PK | 4349 | 0.312/99 x 0.256/2995 | AGO x TZA | DxD | 32 | Germplasm x Germplasm |
| 14 | PK | 4352 | 0.312/941 x 0.256/2995 | AGO x TZA | DxD | 32 | Germplasm x Germplasm |
| 15 | PK | 4375 | 0.256/2995 x 0.256/1926 | TZA x TZA | DxD | 64 | Germplasm x Germplasm |
| 16 | PK | 4384 | 0.312/99 x 0.256/1926 | AGO x TZA | DxD | 48 | Germplasm x Germplasm |
| 17 | PK | 4429 | 0.312/36 x 0.311/405 | AGO x AGO | DxD | 64 | Germplasm x Germplasm |
| 18 | PK | 4442 | 0.312/941 x 0.256/1926 | AGO x TZA | DxD | 64 | Germplasm x Germplasm |
| 19 | PK | 4525 | 0.256/984 x 0.256/1030 | TZA x TZA | DxD | 48 | Germplasm x Germplasm |
| 20 | PK | 4526 | 0.256/1926 x 0.256 /2995 | TZA x TZA | DxD | 64 | Germplasm x Germplasm |
| 21 | PK | 4580 | 0.311/1 x 0.311/262 | AGO x AGO | DxD | 48 | Germplasm x Germplasm |
| 22 | PK | 4009 | 0.212/438 x 0.212/438 | Deli Banting self | DxD | 64 | Deli self (intermediate std) |
| 23 | PK | 4841 | 0.212/6 x 0.219/1371 | Deli Elmina x CMR | DxP | 64 | Deli x Cameroon (intermediate std) |
| 24 | PK | 4454 | 0.212/203 x 0.174/480 | Deli Ulu Remis x AVROS | DxP | 64 | *Deli x AVROS (partial resistant std) |
| | | | Total number of seedlings | | | 1 360 | |

Note: Shaded grey are intermediate and partial resistant standards.
*DxP standard cross; TZA - Tanzania; AGO - Angola.

**TABLE 2. PEDIGREE OF DXP PROGENIES IN TRIAL 0.502**

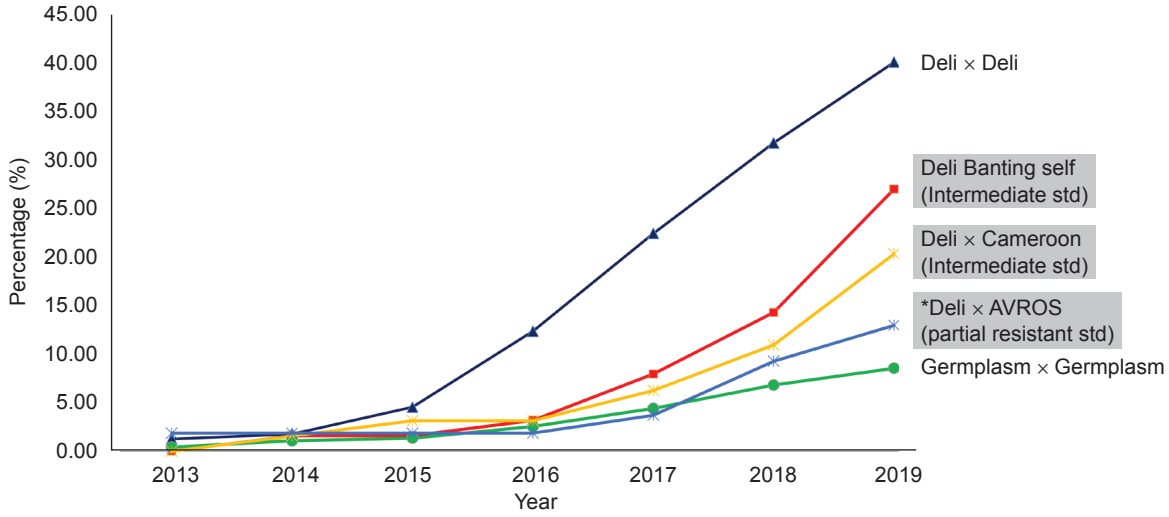
| No. | Progeny code | | Pedigree no. | Material | Cross type | No. of palms | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | ECP HP | 415 | 0.279/24x0.394/456 | Deli Banting x Avros | DxP | 64 | Deli x Avros |
| 2 | ECP HP | 550 | 0.279/24 x 0.394/234 | Deli Banting x Avros | DxP | 64 | Deli x Avros |
| 3 | ECP HP | 618 | 0.281/44 x 0.394/234 | Deli Johor Labis x Avros | DxP | 64 | Deli x Avros |
| 4 | PK | 4118 | 0.254/191 x 0.174/480 | Deli Ulu Remis x Avros | DxP | 64 | Deli x Avros |
| 5 | PK | 4535 | 0.332/100 x 0.394/24 | Deli Ulu Remis x Avros | DxP | 64 | Deli x Avros |
| 6 | PK | 4550 | 0.332/278 x 0.395/419 | Deli Ulu Remis x Avros | DxP | 64 | Deli x Avros |
| 7 | PK | 4591 | 0.332/340 x 0.395/419 | Deli Ulu Remis x Avros | DxP | 48 | Deli x Avros |
| 8 | PK | 4674 | 0.332/116 x 0.395/372 | Deli Ulu Remis x Avros | DxP | 32 | Deli x Avros |
| 9 | PK | 4529 | 0.332/451 x 0.395/204 | Deli Ulu Remis x Yangambi | DxP | 64 | Deli x Yangambi |
| 10 | PK | 4548 | 0.332/45 x 0.395/204 | Deli Ulu Remis x Yangambi | DxP | 48 | Deli x Yangambi |
| 11 | ECP HP | 500 | 0.338/361 x 0.337/552 | Deli Ulu Remis x NGA | DxP | 64 | Deli x Germplasm |
| 12 | PK | 4540 | 0.332/218 x 0.337/1092 | Deli Ulu Remis x NGA | DxP | 64 | Deli x Germplasm |
| 13 | PK | 4621 | 0.332/220 x 0.337/554 | Deli Ulu Remis x NGA | DxP | 64 | Deli x Germplasm |
| 14 | PK | 4648 | 0.332/116 x 0.337/291 | Deli Ulu Remis x NGA | DxP | 64 | Deli x Germplasm |
| 15 | PK | 4679 | 0.312/1241 x 0.337/291 | AGO x NGA | DxP | 64 | Germplasm x Germplasm |
| 16 | PK | 4474 | 0.256/2058 x 0.337/1092 | TZA x NGA | DxP | 48 | Germplasm x Germplasm |
| 17 | PK | 4539 | 0.312/682 x 0.337/1092 | AGO x NGA | DxP | 64 | Germplasm x Germplasm |
| 18 | PK | 4651 | 0.256/2425 x 0.337/1092 | TZA x NGA | DxP | 64 | Germplasm x Germplasm |
| 19 | PK | 4465 | 0.311/405 x 0.174/480 | AGO x Avros | DxP | 48 | Germplasm x Avros |
| 20 | PK | 4482 | 0.311/405 x 0.394/24 | AGO x Avros | DxP | 32 | Germplasm x Avros |
| 21 | PK | 4504 | 0.312/99 x 0.174/247 | AGO x Avros | DxP | 64 | Germplasm x Avros |
| 22 | PK | 4505 | 0.311/269 x 0.174/211 | AGO x Avros | DxP | 48 | Germplasm x Avros |
| 23 | PK | 4570 | 0.256/2313 x 0.394/24 | TZA x Avros | DxP | 64 | Germplasm x Avros |
| 24 | PK | 4009 | 0.212/438 x 0.212/438 | Deli Banting self | DxD | 64 | Deli self (intermediate std) |
| 25 | PK | 4841 | 0.212/6 x 0.219/1371 | Deli Elmina x CMR | DxP | 64 | Deli x Cameroon (intermediate std) |
| 26 | PK | 4454 | 0.212/203 x 0.174/480 | Deli Ulu Remis x AVROS | DxP | 64 | *Deli x AVROS (partial resistant std) |
| | | | Total number of seedlings | | | 1 520 | |

Note: Shaded grey are intermediate and partial resistant standards.
*DxP standard cross; TZA - Tanzania; AGO Angola; NGA - Nigeria.

**TABLE 3. PEDIGREE OF D-SELFED PROGENIES IN TRIAL 0.504**

| No. | Progeny code | | Pedigree no. | Material | Cross type | No. of palms | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | ECP HP | 594 | 0.281/57 x 0.281/57 | Deli Serdang x Deli Serdang | DxD | 64 | Deli self |
| 2 | ECP HP | 609 | 0.338/460 x 0.338/460 | Deli Ulu Remis x Deli Ulu Remis | DxD | 64 | Deli self |
| 3 | PK | 4074 | 0.212/306 x 0.212/306 | Deli Elmina x Deli Elmina | DxD | 64 | Deli self |
| 4 | ECP HP | 401 | 0.282/978 x 0.282/978 | NGA x NGA | DxD | 64 | Germplasm self |
| 5 | ECP HP | 411 | 0.282/1065 x 0.282/1065 | NGA x NGA | DxD | 64 | Germplasm self |
| 6 | ECP HP | 413 | 0.282/935 x 0.282/935 | NGA x NGA | DxD | 64 | Germplasm self |
| 7 | PK | 4233 | 0.311/1022 x 0.311/1022 | AGO x AGO | DxD | 48 | Germplasm self |
| 8 | PK | 4364 | 0.256/2995 x 0.256/2995 | TZA x TZA | DxD | 48 | Germplasm self |
| 9 | PK | 4410 | 0.312/36 x 0.312/36 | AGO x AGO | DxD | 64 | Germplasm self |
| 10 | PK | 4414 | 0.311/405 x 0.311/405 | AGO x AGO | DxD | 64 | Germplasm self |
| 11 | PK | 4481 | 0.256/1926 x 0.256/1926 | TZA x TZA | DxD | 64 | Germplasm self |
| 12 | PK | 4485 | 0.256/2058 x 0.256/2058 | TZA x TZA | DxD | 64 | Germplasm self |
| 13 | PK | 4532 | 0.256/2125 x 0.256/2125 | TZA x TZA | DxD | 64 | Germplasm self |
| 14 | PK | 4542 | 0.311/1 x 0.311/1 | AGO x AGO | DxD | 32 | Germplasm self |
| 15 | PK | 4009 | 0.212/438 x 0.212/438 | Deli Banting x Deli Banting | DxD | 48 | Deli self (intermediate std) |
| 16 | PK | 4841 | 0.212/6 x 0.219/1371 | Deli Elmina x CMR | DxP | 64 | Deli x Cameroon (intermediate std) |
| 17 | PK | 4493 | 0.221/1340 x 0.219/1371 | ZRE x CMR | DxP | 64 | Zaire x Cameroon (partial resistant std) |
| 18 | PK | 4427 | 0.212/3 x 0.174/211 | Deli Elmina x AVROS (S.C) | DxP | 64 | *Deli x AVROS (partial resistant std) |
| | | | Total number of seedlings | | | 1 072 | |

Note: Shaded grey are intermediate and partial resistant standards.
*DxP standard cross; TZA - Tanzania; AGO - Angola; NGA - Nigeria.




Note: Shaded grey is intermediate and partial resistant standards.
*DxP standard cross.

*Figure 1.* Ganoderma *infection rate (%) of DxD progenies in Trial 0.501 from 2013 to 2019.*

2013 for both intermediate standards was 0.00% but eventually rose to more than 20.00% by 2019. According to Mior *et al.* (2009), the development of disease incidence is not a function of time but rather a sign of the individual palm responding to the *Ganoderma* infection. The higher response of the Deli x Deli progenies to *Ganoderma* infection as compared to Germplasm x Germplasm progenies in this study supported the above testimony.

ANOVA showed significant differences ($p \leq 0.01$) in the infection rate among the five types of crosses. There were significant differences between Deli x Deli and Germplasm x Germplasm progenies. The infection rate on the Deli x Deli was significantly higher than both intermediate infection standards. On the other hand, the infection rate on the Germplasm x Germplasm was significantly lower than both intermediate standards. The infection rate on the partial resistant standard (Deli x AVROS) was significantly lower than the Deli x Deli but was not significantly different from the infection rate on Germplasm x Germplasm.

Ten (PKs 4638, 4271, 4294, 4375, 4384, 4429, 4442, 4525, 4526 and 4580) of the 14 Germplasm

x Germplasm progenies gave low infection rate (less than 10.00%), ranging from 0.00% to 9.68%. However, all of the seven Deli x Deli progenies gave high infection rates (more than 10.00%), ranging from 18.75% to 53.97% (*Table 4*). Both intermediate standards and the partial resistant standard gave a high infection rate (more than 10.00%). Only one progeny (PK 4442) fulfilled the Malaysian Standard (MS157:2017) used as a benchmark for agronomic performance to be eligible for utilisation as a maternal parent. For the other progenies, further introgression to *dura*s from the advanced breeding population may be required to improve the agronomic performance.

**DxP (Trial 0.502)**

The purpose of this trial was to determine if there were any potential DxP families with a low infection rate (less than 10.00%) towards *Ganoderma*. Selected agronomic traits as per Malaysian Standard (MS157:2017) would be observed thereafter. The resultant *tenera*s from the progeny test may be utilised as ortet for the production of *Ganoderma* partial resistant clones.

The initial infection in 2013 was 0.23% for Deli x AVROS progenies, 0.00% for both Deli x Yangambi and Germplasm x Germplasm progenies (*Figure 2*). Similar to trial 0.501, the infection rate (%) of the disease increased over the years. In 2019, the Deli x AVROS progenies recorded 22.43% infection while the Deli x Yangambi progenies recorded 12.73% infection. The lowest infection rate was observed in the Germplasm x Germplasm progenies with 4.41%. Meanwhile, infection rates for the Deli x Germplasm progenies were similar to Deli x Yangambi progenies, increasing from 0.00% in 2013 to 13.62% in 2019. Germplasm x AVROS progenies, on the other hand, displayed infection rates close to Germplasm x Germplasm progenies, increasing from 0.00% in 2013 to 4.46% in 2019.

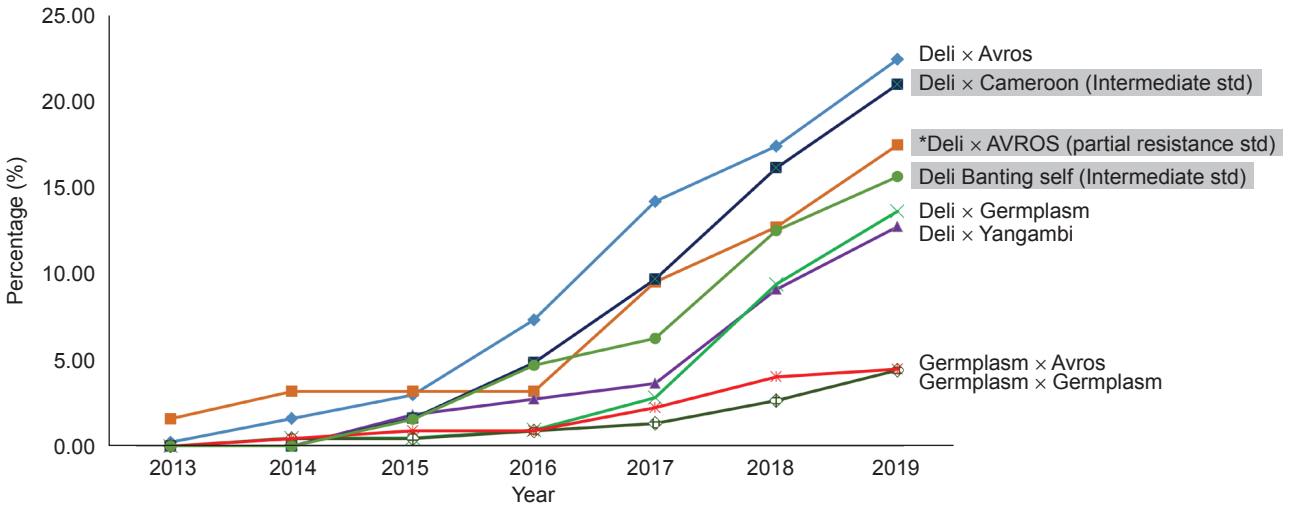
ANOVA showed significant differences ($p \leq 0.01$) between the eight groups of progenies. By Duncan New Multiple Range Test, significant differences were observed in the infection rates between Deli x AVROS and Deli x Yangambi progenies. However, there was no significant difference in the infection rates between Germplasm x Germplasm and Germplasm x AVROS.

Thirteen progenies, two Deli x AVROS (PKs 4550 and 4591), two Deli x Germplasm (ECH HP 500 and PK 4621), four Germplasm x Germplasm (PKs 4679, 4474, 4539 and 4651) and five Germplasm x AVROS (PKs 4465, 4482, 4504, 4505 and 4570) gave low infection rates (less than 10.00%) (*Table 5*). Both intermediate standards

**TABLE 4. AGRONOMIC PERFORMANCE OF DxD PROGENIES WITH LOW INFECTION RATE (< 10%) TO *Ganoderma* IN TRIAL 0.501**

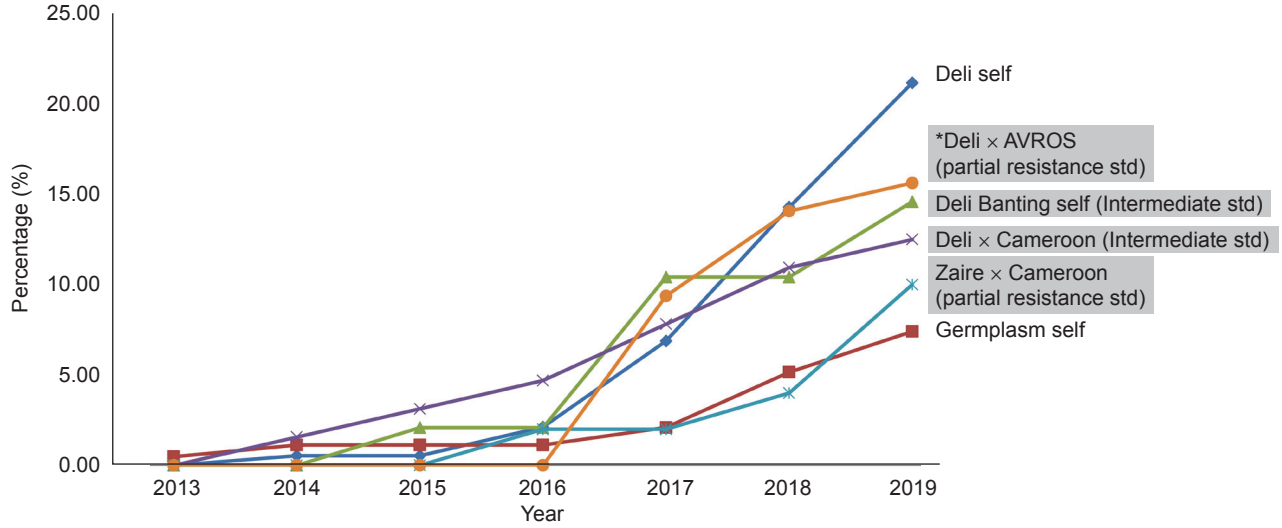
| No. | Crosses | Progeny code | Pedigree no. | Material | n | Cross | Infection % (2019) | MFFB | M/F | K/F | S/F | O/DM | O/B | K/B | OY | TEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Germplasm x Germplasm | PK4638 | 0.256/650x0.256/1030 | TZA x TZA | 61 | DxD | 1.64 | 124.70 | 60.13 | 14.81 | 25.06 | 75.80 | 14.72 | 7.54 | 23.95 | 31.72 |
| 2 | Germplasm x Germplasm | PK4271 | 0.256/1926x0.312/99 | TZA x AGO | 48 | DxD | 8.33 | 174.41 | 50.61 | 16.23 | 33.16 | 77.70 | 14.01 | 9.10 | 25.35 | 35.66 |
| 3 | Germplasm x Germplasm | PK4294 | 0.256/1926x0.312/941 | TZA x AGO | 62 | DxD | 8.06 | 155.29 | 50.48 | 15.81 | 33.70 | 78.81 | 14.26 | 9.15 | 23.89 | 33.10 |
| 4 | Germplasm x Germplasm | PK4375 | 0.256/2995x0.256/1926 | TZA x TZA | 62 | DxD | 9.68 | 161.40 | 46.82 | 17.08 | 36.11 | 76.22 | 10.62 | 8.53 | 18.58 | 27.48 |
| 5 | Germplasm x Germplasm | PK4384 | 0.312/99x0.256/1926 | AGO x TZA | 48 | DxD | 8.33 | 167.48 | 45.05 | 18.36 | 36.59 | 78.18 | 13.71 | 11.47 | 27.16 | 40.78 |
| 6 | Germplasm x Germplasm | PK4429 | 0.312/36x0.311/405 | AGO x AGO | 60 | DxD | 1.67 | 117.44 | 55.07 | 9.32 | 35.61 | 78.93 | 16.75 | 5.92 | 23.41 | 28.31 |
| 7 | Germplasm x Germplasm | PK4442 | 0.312/941x0.256/1926 | AGO x TZA | 63 | DxD | 4.76 | 163.03 | 58.13 | 17.90 | 23.98 | 77.27 | 13.86 | 9.11 | 23.54 | 32.60 |
| 8 | Germplasm x Germplasm | PK4525 | 0.256/984x0.256/1030 | TZA x TZA | 48 | DxD | 0.00 | 127.82 | 54.21 | 16.45 | 29.34 | 71.97 | 11.85 | 8.60 | 20.47 | 29.32 |
| 9 | Germplasm x Germplasm | PK4526 | 0.256/1926x0.256/2995 | TZA x TZA | 64 | DxD | 4.69 | 151.11 | 50.04 | 16.83 | 33.14 | 77.00 | 12.69 | 9.48 | 25.13 | 36.36 |
| 10 | Germplasm x Germplasm | PK4580 | 0.311/1x0.311/262 | AGO x AGO | 47 | DxD | 4.26 | 134.06 | 49.70 | 12.52 | 37.79 | 79.32 | 13.54 | 6.71 | 18.56 | 24.01 |
| | Partial resistant std | PK4454 | 0.212/203x0.174/480 | *Deli x AVROS | 54 | DxP | 12.96 | 152.57 | 71.39 | 11.72 | 16.89 | 79.47 | 22.05 | 7.34 | 35.64 | 42.97 |
| | MS157:2017 | | | | | | | 150.00 | 57.00 | 5.00 | 33.00 | 75.00 | 19.00 | | | |

Note: Shaded yellow are traits which fulfilled MS157:2017.
Shaded grey is partial resistant standard cum DxP standard cross.
FFB - fresh fruit bunch (kg palm$^{-1}$ yr$^{-1}$); M/F - mesocarp to fruit (%); K/F - kernel to fruit (%); S/F - shell to fruit (%); O/DM - oil to dry mesocarp (%); O/B - oil to bunch (%); K/B - kernel to bunch (%); OY - oil yield (kg palm$^{-1}$ yr$^{-1}$); TEP - total economic product (kg palm$^{-1}$ yr$^{-1}$).




Note: Shaded grey is intermediate and partial resistant standards.
*DxP standard cross.

*Figure 2.* Ganoderma *infection rate (%) of DxP progenies in Trial 0.502 from 2013 to 2019.*




Note: Shaded grey is intermediate and partial resistant standards.
*DxP standard cross.

*Figure 3.* Ganoderma *infection rate (%) of D-selfed progenies in Trial 0.504 from 2013 to 2019.*

and the partial resistant standard displayed high infection rates (more than 10.00%). Benchmarking the agronomic performance of the 13 selected progenies (with low infection rate) against MS157:2017, none of the DxP or *tenera* progenies fulfilled all the four traits in order to be eligible for immediate selection and utilisation as planting materials.

Since none of the 13 DxP families fulfilled MS157:2017, no *teneras* can be selected for cloning and utilised as *Ganoderma* partial resistant clonal planting material. Selected agronomic traits as per Malaysian Standard (MS157:2017) would be observed thereafter.

**D-selfed (Trial 0.504)**

The purpose of this trial was to determine if there were any potential D-selfed families with a low infection rate (less than 10.00%) towards *Ganoderma*. The next step after that would be to look at selected agronomic traits as per Malaysian Standard (MS157:2017). For families that fulfil MS157:2017, selected *duras* from that family may be selfed or cloned. The selfed *duras* or clonal *duras* may subsequently be progeny tested with *pisiferas* from the advanced breeding population. The resultant *teneras* are potential candidates for *Ganoderma* partial resistant clones.

**TABLE 5. AGRONOMIC PERFORMANCE OF DxP PROGENIES WITH LOW INFECTION RATE (< 10%) TO *Ganoderma* IN TRIAL 0.502**

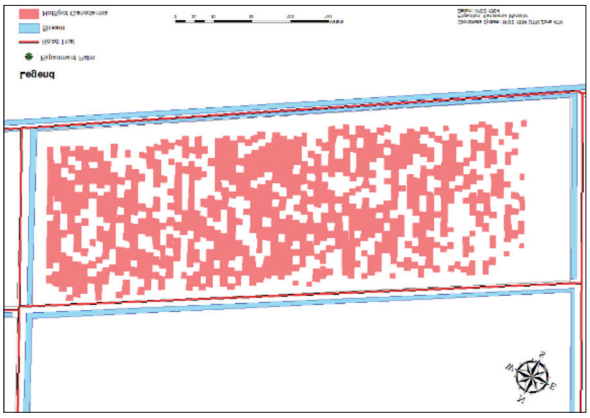
| No. | Crosses | Progeny code | Pedigree no. | Material | Cross | n | Infection % (2019) | MFFB | M/F | K/F | S/F | O/DM | O/B | K/B | OY | TEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Deli x AVROS | PK4550 | 0.332/278 x 0.395/419 | Deli Ulu Remis x AVROS | DxP | 58 | 5.17 | 157.01 | 80.53 | 8.66 | 10.81 | 81.96 | 23.79 | 4.71 | 42.72 | 47.70 |
| 2 | Deli x AVROS | PK4591 | 0.332/340 x 0.395/419 | Deli Ulu Remis x AVROS | DxP | 47 | 6.38 | 179.57 | 79.80 | 7.60 | 12.60 | 79.73 | 23.18 | 3.92 | 44.92 | 49.52 |
| 3 | Deli x Germplasm | ECP HP500 | 0.338/361 x 0.337/552 | Deli Ulu Remis x NGA | DxP | 53 | 7.55 | 184.71 | 80.01 | 4.56 | 15.43 | 79.43 | 26.21 | 2.75 | 48.50 | 51.55 |
| 4 | Deli x Germplasm | PK4621 | 0.332/220 x 0.337/554 | Deli Ulu Remis x NGA | DxP | 32 | 6.25 | 93.49 | 75.48 | 11.52 | 13.01 | 79.55 | 21.74 | 6.80 | 30.68 | 36.43 |
| 5 | Germplasm x Germplasm | PK4679 | 0.312/1241 x 0.337/291 | AGO x NGA | DxP | 64 | 0.00 | 159.39 | 71.27 | 9.78 | 18.96 | 77.88 | 19.32 | 4.70 | 34.88 | 39.99 |
| 6 | Germplasm x Germplasm | PK4474 | 0.256/2058 x 0.337/1092 | TZA x NGA | DxP | 48 | 4.17 | 137.60 | 76.74 | 10.77 | 12.49 | 80.45 | 21.54 | 5.66 | 41.01 | 47.64 |
| 7 | Germplasm x Germplasm | PK4539 | 0.312/682 x 0.337/1092 | AGO x NGA | DxP | 53 | 7.55 | 146.27 | 79.38 | 8.24 | 12.37 | 80.15 | 24.59 | 4.58 | 39.23 | 43.63 |
| 8 | Germplasm x Germplasm | PK4651 | 0.256/2425 x 0.337/1092 | TZA x NGA | DxP | 62 | 6.45 | 137.46 | 71.48 | 12.44 | 16.09 | 76.91 | 17.78 | 6.68 | 28.40 | 34.71 |
| 9 | Germplasm x AVROS | PK4465 | 0.311/405 x 0.174/480 | AGO x AVROS | DxP | 46 | 8.70 | 133.93 | 76.35 | 11.44 | 12.22 | 81.50 | 26.67 | 6.89 | 40.20 | 46.47 |
| 10 | Germplasm x AVROS | PK4482 | 0.311/405 x 0.394/24 | AGO x AVROS | DxP | 29 | 3.45 | 89.22 | 74.90 | 11.91 | 13.20 | 78.41 | 23.23 | 7.26 | 37.74 | 44.98 |
| 11 | Germplasm x AVROS | PK4504 | 0.312/99 x 0.174/247 | AGO x AVROS | DxP | 54 | 0.00 | 155.93 | 77.75 | 11.71 | 10.53 | 80.91 | 20.53 | 5.65 | 46.41 | 54.01 |
| 12 | Germplasm x AVROS | PK4505 | 0.311/269 x 0.174/211 | AGO x AVROS | DxP | 46 | 4.35 | 173.98 | 74.02 | 11.87 | 14.11 | 80.41 | 20.41 | 5.80 | 33.82 | 39.56 |
| 13 | Germplasm x AVROS | PK4570 | 0.256/2313 x 0.394/24 | TZA x AVROS | DxP | 49 | 6.12 | 114.97 | 70.57 | 12.91 | 16.52 | 80.57 | 16.29 | 5.07 | 23.61 | 28.23 |
| | Partial resistant std | PK4454 | 0.212/203 x 0.174/480 | *Deli x AVROS | DxP | 63 | 17.46 | 151.50 | 78.55 | 8.73 | 12.72 | 81.37 | 24.14 | 4.67 | 42.87 | 47.82 |
| | MS157:2017 | | | | | | | 170.00 | | | | | 25.00 | 3.00 | 42.50 | |

Note: Shaded yellow is traits which fulfilled MS157:2017.
Shaded grey is partial resistant standard cum DxP standard cross.
FFB - fresh fruit bunch (kg palm$^{-1}$ yr$^{-1}$); M/F - mesocarp to fruit (%); K/F - kernel to fruit (%); S/F - shell to fruit (%); O/DM - oil to dry mesocarp (%); O/B - oil to bunch (%); K/B - kernel to bunch (%); OY - oil yield (kg palm$^{-1}$ yr$^{-1}$); TEP - total economic product (kg palm$^{-1}$ yr$^{-1}$).

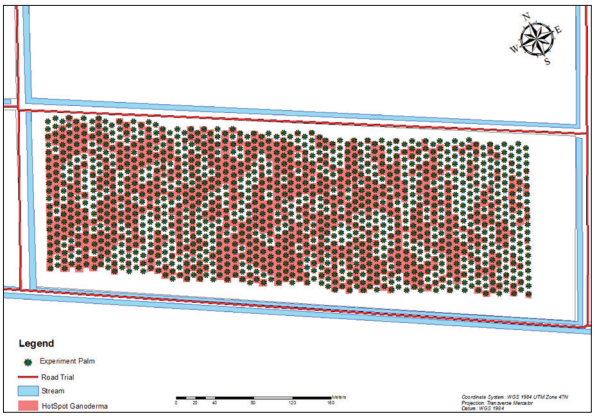
**TABLE 6. AGRONOMIC PERFORMANCE OF D-SELFED PROGENIES WITH LOW INFECTION RATE (< 10%) TO *Ganoderma* IN TRIAL 0.504**

| No. | Crossing programme | Progeny code | Pedigree no. | Material | Cross type | n | Infection % (2019) | MFFB | M/F | K/F | S/F | O/DM | O/B | K/B | OY | TEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Germplasm selfed | PK4233 | 0.311/1022 x 0.311/1022 | AGO x AGO | DxD | 48 | 6.25 | 122.69 | 56.62 | 10.51 | 32.88 | 79.19 | 14.85 | 5.39 | 20.73 | 25.19 |
| 2 | Germplasm selfed | PK4364 | 0.256/2995 x 0.256/2995 | TZA x TZA | DxD | 48 | 6.25 | 91.70 | 64.16 | 10.46 | 25.38 | 76.74 | 14.48 | 5.07 | 10.56 | 13.20 |
| 3 | Germplasm selfed | PK4410 | 0.312/36 x 0.312/36 | AGO x AGO | DxD | 56 | 1.79 | 74.60 | 61.05 | 9.79 | 29.17 | 80.44 | 15.67 | 5.19 | 14.26 | 16.98 |
| 4 | Germplasm selfed | PK4414 | 0.311/405 x 0.311/405 | AGO x AGO | DxD | 64 | 6.25 | 55.75 | 53.06 | 11.94 | 35.00 | 79.05 | 14.67 | 6.05 | 13.64 | 17.02 |
| 5 | Germplasm selfed | PK4481 | 0.256/1926 x 0.256/1926 | TZA x TZA | DxD | 62 | 0.00 | 88.76 | 54.87 | 15.00 | 30.13 | 75.51 | 15.23 | 8.64 | 20.47 | 27.34 |
| 6 | Germplasm selfed | PK4485 | 0.256/2058 x 0.256/2058 | TZA x TZA | DxD | 59 | 8.47 | 63.72 | 61.92 | 6.77 | 31.32 | 77.30 | 18.76 | 4.31 | 21.52 | 24.48 |
| 7 | Germplasm selfed | PK4532 | 0.256/2125 x 0.256/2125 | TZA x TZA | DxD | 63 | 3.17 | 77.93 | 49.09 | 12.12 | 38.78 | 77.12 | 14.25 | 7.21 | 20.37 | 26.72 |
| 8 | Germplasm selfed | PK4542 | 0.311/1 x 0.311/1 | AGO x AGO | DxD | 32 | 3.13 | 88.46 | 60.14 | 12.49 | 27.38 | 77.57 | 17.67 | 7.85 | 20.28 | 25.69 |
| | Partial resistant std | PK4493 | 0.221/1340 x 0.219/1371 | Zaire x Cameroon | DxP | 50 | 10.00 | 66.01 | 59.09 | 15.21 | 25.71 | 75.50 | 14.31 | 7.74 | 19.31 | 25.60 |
| | Partial resistant std | PK4427 | 0.212/3 x 0.174/211 | *Deli x AVROS | DxP | 64 | 15.63 | 148.77 | 79.66 | 8.77 | 11.56 | 80.00 | 22.94 | 4.94 | 34.75 | 39.20 |
| | MS157:2017 | | | | | | | 150.00 | 57.00 | 5.00 | 33.00 | 75.00 | 19.00 | | | |

Note: Shaded yellow is traits that fulfilled MS157:2017.
Shaded grey is partial resistant standards. * DxP standard cross.
FFB - fresh fruit bunch (kg palm$^{-1}$ yr$^{-1}$); M/F - mesocarp to fruit (%); K/F - kernel to fruit (%); S/F - shell to fruit (%); O/DM - oil to dry mesocarp (%); O/B - oil to bunch (%); K/B - kernel to bunch (%); OY - oil yield (kg palm$^{-1}$ yr$^{-1}$); TEP - total economic product (kg palm$^{-1}$ yr$^{-1}$).

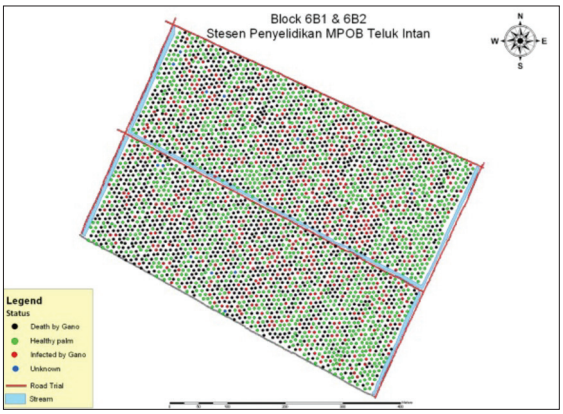


Hotspot (points of infected palms from the previous planting)




Existing palms overlaid on hotspots


Census on *Ganoderma* infection in Blocks 6A1 and 6A2




Census on *Ganoderma* infection in Blocks 6B1 and 6B2

*Figure 4. Establishment and development of trial plots in the* Ganoderma *hotspot of Bagan Datuk, Perak, Malaysia.*

The initial infection in 2013 was 0.47% for Germplasm selfed and 0.00% for Deli selfed progenies (*Figure 3*). The infection (%) of the disease increased over the years. In 2019, the Deli selfed progenies recorded a 21.16% infection rate whereas the Germplasm selfed progenies recorded a lower infection rate at 7.41%.

ANOVA showed significant differences ($p \leq 0.01$) in infection rates among the six groups of progenies. By Duncan New Multiple Range Test the infection rate on Deli selfed palms was significantly higher than Germplasm selfed progenies.

Eight germplasm selfed progenies involving four Angola selfed and four Tanzania selfed had low infection rates ranging from 0.00% to 8.47%. However, all the three Nigerian selfed progenies gave high infection rates ranging from 11.11% to 16.13%. Both intermediate standards and one partial resistant standard showed high infection rates (more than 10.00%). However, the other partial resistant standard (Zaire x Cameroon) had an infection rate of 10.00% (*Table 6*). Benchmarking agronomic performance, none of the D-selfed progenies from the eight selected Germplasm selfed progenies (with low infection rate) fulfilled the required six traits to be eligible for immediate selection as potential maternal parents. This is expected since these progenies are still rather wild genetic materials, being derived from selfed germplasm palms. Furthermore, selfing may also have led to inbreeding depression among the agronomic traits as can be seen from the inferior FFB yield performance among the selfed progenies. Nevertheless, selfing did not appear to have any negative influence on the bunch quality traits, especially for K/F and O/DM. Hence, further introgression to *dura*s from the advanced breeding population would be the way to move forward to improve the agronomic performance. The establishment and development of trial plots in this study are shown in *Figure 4*.

## DISCUSSION

Breeding for disease resistance may provide a long term solution for future control of BSR disease. In Malaysia, efforts on this are being pursued by oil palm breeders from MPOB and the industry, usually jointly with plant pathologists. Results from the three trials (DxD, DxP and D-selfed) on the susceptibility of the Deli *dura* and Deli-based crosses as reported in this study appeared to support earlier field observations. For instance, in North Sumatra *E. guineensis* of Deli origin from

Malaysia and Indonesia was found to be more susceptible than African material (Durand-Gasselin *et al*., 2005). The performance of germplasm and germplasm-based crosses in the three trials also supported earlier field observations for partial resistance. It was reported that oil palm germplasm collected from Cameroon, Nigeria and Sierra Leone revealed high genetic diversity (Hayati *et al*., 2004). Germplasm from Cameroon and Zaire also showed partial resistance to *Ganoderma* (Rajanaidu, 1994). Other trials have also revealed differences in susceptibility, indicating possible genetic resistance within host populations (Breton *et al*., 2006; Idris *et al*., 2004). The existence of resistant genotypes has also been indicated in trials of 20 DxP crosses in Indonesia (Purba *et al*., 1994) and in *E. oleifera* x *E. guineensis* hybrids in Malaysia (Chung *et al*., 1994). Thus, resistant materials view as an outstanding promise for future management of BSR in oil palm in SEA (Breton *et al*., 2006; Durand-Gasselin *et al*., 2005; Idris *et al*., 2004). There was some work on this with Socfindo in Sumatera, Indonesia.

## CONCLUSION

The study showed low infection rate of less than 10%, hence potential partial resistance to *Ganoderma* for 10 DxD (Germplasm x Germplasm) progenies in Trial 0.501, 13 DxP (two Deli x AVROS, two Deli x Germplasm, four Germplasm x Germplasm and five Germplasm x AVROS) progenies in Trial 0.502 and eight D-selfed (Germplasm selfed) progenies in Trial 0.504. The partial resistance of the 31 progenies may need to be reconfirmed in the nursery using established screening techniques. Upon confirmation of the partial resistance, parents linked to the DxD, D-selfed and DxP progenies could be utilised for further breeding and improvement before being utilised as a maternal parent for production of partial resistant planting material. Individual palms from the DxP progenies, on the other hand, could also be directly mass propagated via cloning for immediate utilisation as partial resistant planting material.

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