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Methods of Land Preparation to Delay *Ganoderma* or Basal Stem Rot (BSR) Disease in Oil Palm Replanting in Inland Mineral Soils – Experiences and Observations

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Three methods of land preparation in oil palm replanting are described, attempted and observations recorded for a period of 11 to 14 years. In method A carried out in 2006 replanting, the land was prepared by excavating only the stumps of Ganoderma *infected fallen and vacant palms through the construction of pits. Here, after 11 and 12 years of replanting resulted in 18 and 21 per cent* of BSR *infections respectively, while, after 14 years the infection increased to 28.5 per cent in the same replants. In method B, comprising of two fields replanted in 2009 and 2008 after clean clearing or 100 per cent removal of boles of living, dead and vacant palm points followed by two rounds of thorough disc ploughing and single rotovating of the soil, showed 5.8 and 8.5 per cent of* Ganoderma *infections after 11 and 12 years, respectively. Although method C was a slow and expensive operation, 100 per cent excavation of living, dead and vacant palm boles followed by deep ploughing or tilting of the soil with the excavator bucket showed 2 per cent* Ganoderma *disease after 11 years of replanting. Among the three modes of land preparation, methods B and C showed a delay in infection of* Ganoderma *in replants compared to method A. The excavator bucket used in method C for deep tilting prompted the search for other tools like Howard ripper and fabricated steel ripper mounted on a bulldozer, of which the latter was found suitable and has been implemented commercially. However, the cost of such operation was 2.6 times (i.e. RM2 030 against RM769 per hectare) higher than the preparation of land by method A in replanting. Another study was conducted to understand the relationship between the visually observed* Ganoderma *palms and normal appearing palms with* Ganoderma *infection at the sub-clinical level. This may be helpful for planters to predict the total* Ganoderma *infected palms present in the field prior to replanting. The relationship appeared to be a cubical expression between the visual and total* Ganoderma *population in a field prior to replanting.*

Keywords*:* Ganoderma *disease, basal stem rot, clean clearing, land preparation, replanting, deep ploughing.*

Ganoderma basal stem rot or BSR is a major disease affecting oil palm plantings of South East Asian countries. The disease is of high economic importance, as it leads to decreased fresh fruit bunch (FFB) production due to the loss of productive palms in the cultivated land area (Turner & Gillbanks, 2003; Corley & Tinker, 2016). The multiple diagnostic symptoms of *Ganoderma* in oil palm consist of lesions at the base of the stem that putrefies

part of the tissues, leading to reduced movement of water and nutrients to the aerial parts of the palms resulting in pale green canopy colour, multiple spear formation and fractured fronds that hang down encircling the trunk. Palms with such symptoms will eventually have basidiocarps or fruiting bodies at the base of the stem and the palm dies eventually in 6 to 12 months after the manifestation of the fruiting bodies (Turner, 1981). There are 15 species of *Ganoderma* that have been reported across the oil palm growing belt that causes BSR disease (Turner, 1981; Corley & Tinker, 2016). However, *Ganoderma boninense* has been identified as one of the pathogenic species that is lethal for the palm's survival (Ariffin *et al.*, 1989; Ariffin *et al.*, 1996). Idris *et al.* (2001) identified three common species in addition to *Ganoderma boninense*, of which, *Ganoderma zonatum* and *Ganoderma miniatocinctum* caused varying degrees of pathogenicity, while *Ganoderma tornatum* was non-pathogenic in nature.

In his past publication, Turner (1965a) indicated that the BSR disease was prevalent in coastal land and that up to 40 to 50 per cent of palms had been lost in the field at 15 years after being replanted from coconut planting. In some cases, even up to 80 per cent palm loss was observed, especially when the coconut logs were buried beneath the soil. The BSR disease was strongly related to the type of replants mainly from coconut cultivation to oil palm followed by oil palm to oil palm. Low incidence was observed from former jungle to oil palm plantings and rubber to oil palm replants (Turner, 1965b). Turner (1965e) cited that the oil palms of that time in Sabah were planted after clearing of the jungle and generally the jungle tree stumps showed the presence of the fruiting body of *Ganoderma*. Such leftover jungle stumps are likely to be colonised by the fungus and the removal of such colonised stumps reduces the potential threat of *Ganoderma* infection in the oil palm planting. Several approaches such as surgery of diseased tissue, trenches etc., were unsuccessfully tried to control *Ganoderma* disease in the oil palm planted fields (Turner, 1965d; Gurmit, 1991). Ho and Hashim (1996) attempted soil mounding to prolong the standing of *Ganoderma* infected palms at its prime age from wind toppling, this support of the infected palms helped in the recovery of operational cost through the harvested crop after 2 to 3 years of implementation. Ultimately, the prevention of *Ganoderma* in the affected replanted field of oil palm from coconut or oil palm appeared to be impossible, nevertheless, excavating the infected stumps and trunk boles at periodic intervals could delay the infection to the neighbouring productive palms (Turner, 1965c; Gurmit, 1991). Turner (1965d) suggested clean clearing by removing stumps and trunks as an essential safe operation of replanting, especially when the former crops are coconut and oil palm. Idris and Ariffin (2005) had demonstrated that the removal of oil palm stumps and roots at the time of replanting to oil palm followed by ploughing and rotavating the soil resulted in reduced and delayed spread of *Ganoderma* disease. The past experience of several authors showed that the excavation of diseased palms in the young replanted fields and clean clearing of land for the replanting delays the advent of *Ganoderma* disease in the fields (Turner, 1965c; Gurmit, 1991; Idris & Ariffin, 2005).

Gurmit (1991) indicated *Ganoderma* disease as a scourge of oil palm plantings in coastal areas. This disease is a scourge for inland soils as well, where the land was formerly cultivated with rubber, cocoa and oil palm for over a century (Benjamin & Chee, 1995). Dunlop, a British company initiated their

first planting of rubber trees in 1910 in the inland soils of Negri Sembilan and North Johore. The first oil palm was planted in 1965 in Gomali Estate by Lord Baillieu (Wilson, 1971). Since, the acquisition of Dunlop plantation land by the IOI group in 1990, two generations of oil palm have been cultivated and the third cycle is currently being replanted. Almost all rubber cultivation of that time were eventually changed to oil palm plantings. BSR incidence was observed in all the converted crops, be it rubber to oil palm, cocoa to oil palm or oil palm to oil palm. The estates with high *Ganoderma* disease were all from the ex-Dunlop estates. Prior to 2008, it was a common practice in the group to excavate only boles of fallen diseased and vacant palm points of the previous planting instead of excavating all the planted points. This practice increased the infection rate of *Ganoderma* disease in the subsequent replants. Changes in methods of land preparation during replanting were attempted with the objective of reducing or delaying BSR incidence in the replants. The present paper elaborates on several methods and approaches tried during land preparation during replanting from oil palm to oil palm with the anticipation to reduce or delay the BSR disease in the replanted fields in the inland soils. The long-term results obtained from the observational plots supported the development of ideas for trying out different field tools for land preparation, which are elaborated further in the present paper.

METHODS OF LAND PREPARATION IN REPLANTING TO DELAY *GANODERMA* OR BSR DISEASE IN OIL PALM REPLANTING

The following are the three methods of land preparation tried at replanting with zero-burn approach.

Method A: Land preparation by a selective excavation of diseased stumps and vacant points of fallen palms. This was a common practice in the group prior to 2008,

Method B: Land preparation by complete clean clearing by the excavation of all healthy, diseased standing palms, diseased stumps and vacant points of fallen palms, followed by disc ploughing and rotavating of land prior to replanting, and

Method C: Land preparation by complete clean clearing by the excavation of all healthy, diseased standing palms, diseased stumps and vacant points of fallen palms, followed by deep ploughing or tilting of soil using excavator bucket and rotovating of land prior to replanting.

Apart from Method A, Methods B and C were laid out with the objective and anticipation of reducing and delaying *Ganoderma* infection to palms through initial land preparation at the time of replanting. The results of the Methods B and C were later compared with Method A. The three methods of land preparation are further elaborated below.

Method A. Land preparation by a selective excavation of diseased stumps and vacant points of fallen palms-Field 79A

Method A was the normal and common practice of land preparation for replanting prior to 2008 in the group. In field 79A, 13.7 hectares of land was selected to replant in 2006. The soil type is Tawar of sub recent alluvium in nature. The total number of palms replanted in 2006 was 1980. The palms prior to felling were planted in 1979 originally with a planting density of 136 palms per hectare. The land is

flat to gentle undulating hence, the planting was direct, straight and in an equilateral triangle pattern. The planting distance was confirmed prior to felling by measuring palm to palm base with a planting distance of about 9.2 m and distance between palm rows of 8.0 m apart. The reason for measuring the planting distance in 2006 was to increase the planting density to 148 palms per hectare. Thus, the new planting lines of palms for the 2006 plantings had a planting distance of 8.8 m within the palm row and a distance between palms rows of 7.6 m. There were 218 dead fallen palms or vacant points (constructed pits prior to felling) in 13.7 hectares, leading to 120 standing palms per hectare, which is equivalent to 88 per cent of standing palms prior to felling. All the vacant or dead fallen palm points were excavated with a pit size 1.0 m x 1.0 m x 1.0 m at 6 monthly intervals for a period of 2 years prior to felling. As the days of replanting drew closer the pits were closed by filling with soil from near at hand. In this case, the majority of the vacant points or fallen palms were considered as *Ganoderma* infested, as there was no history of high density planting of palms, followed by thinning or even removal of sterile or *pisifera* palms, which will be the result of poor planting material. Even palms uprooted due to wind was not observed. Here the old standing palms were felled, the stem was shredded with the sharp-edged bucket of the excavator, and the shredded stems were windrowed to new pre-lining at two palm rows interval of future replants. This was the land preparation for the field 79A for 2006 replants from oil palm to oil palm.

Method B. Land preparation by complete excavation of standing, fallen and vacant palms boles followed by disc ploughing and rotavating of land - Fields 86A and 85A

The soil type for field 86A is Batu Anam, a poor iron base shale parent material. This field was replanted in 2008 with a total of 395 palms and covers an area of 2.7 hectares. Field 85A is on Medang soil, a recent alluvium parent material, replanted in 2009 with 390 palms and covers an area of 2.6 hectares. The palm stand prior to felling was 72 palms per hectare (53%) in field 86A and 88 palms per hectare (65%) in field 85A. Initially, both 86A and 85A were planted with 136 palms per hectare and the distance was measured with the available palm stand in view of changing to the new palm stand of 148 palms per hectare in replants. The terrain for field 86A was gentle undulating, while field 85A was flat. Here the palm stand was low and vacancy of land was due to BSR. Although both these lands were located in different estates, the method of land preparation was the same. In method B, the palm trunks were felled and shredded using the sharp-edged bucket of the excavator and windrowed along the predetermined linings at an interval of two palm rows meant for future replanting. The palm boles of all living, diseased and stumps were completely excavated with a pit size of 1.0 m x 1.0 m x 0.8 m and refilled with soil near at hand. The land was ploughed twice to the depth of 30 cm to 40 cm using a disc plough and the root materials exposed as the result of ploughing were handpicked and placed over the windrowed shredded material. Later, the windrowed old palm shredded material was pushed to the ploughed section using a bulldozer to facilitate the ploughing along the windrow section. Here too the exposed roots were handpicked. Once two rounds of 100 per cent ploughing were completed, the shredded material was pushed and windrowed to its original position. The rest of the land except the windrowed section was rotavated to break up the large sizes of the ploughed soil material.

Method C. Land preparation by complete excavation of standing, fallen and vacant palms boles followed by deep ploughing or tilting of land with excavator bucket and rotovating of land-Field 90F

Field 90F was replanted by the underplanting method in 1990. The standing palm prior to felling in 2009 was 83 palms per hectare (61%). Here again, the palms were planted with 136 palms per hectare and later changed to 148 at the time of replanting in 2009. Low palm stand was mainly due to BSR brought about by the underplanting system. In method C, the palm trunks were felled, sliced or shredded and windrowed to the predetermined lines. The boles of all the standing, dead and vacant palms were excavated. Since disc plough was not available at that time, the whole land was excavated and the soil was tilted using a 120 PC excavator. The excavator bucket is capable of tilting the soil to a depth of 60 cm to 70 cm (*Figure 1*). The area in between the windrowed shredded materials of the trunk was first tilted and rotavated. Then the windrowed shredded trunk was pushed from its initial position to the ploughed and rotavated section using a bulldozer. Later, the initial windrowed section was tilted using the same excavator bucket. After tilting, the shredded trunk was repositioned back to the initial windrowed area without rotavating the soil in that section. Thus, every inch of the land was tilted using the excavator bucket. By excavation of the whole land, the boles of the former underplanting were also removed. Only the planting points and future harvesting rows were rotavated to break up large chunks of Durian (Red) type soil series. The primary roots exposed as the result of excavation and rotavating of soil were removed using hand forked hoe and placed over windrowed debris. Here an area covering 1.7 hectares was replanted with 250 palms.

Figure 1 Excavator bucket tilting the soil

THE OUTCOME OF THE THREE METHODS OF LAND PREPARATIONS

The results of *Ganoderma* incidences in the three types of land preparation methods are summarised in *Table 1*. The cumulative annual trend of fallen disease palms in the three methods in four fields are shown in *Figure 2*.

In field 79A before land preparation by method A, the palm stand was 120 per hectare, which was about 88 per cent standing palms. At 11 and 12 years after replanting in method A, the percentage of BSR diseased fallen palms was 18 and 21 per cent, respectively. After 14 years of replanting in method A, the *Ganoderma* infection in the 2006 replants, increased to 28.5 per cent which is equivalent to 106 standing palms per hectare or 42 dead palms per hectare, and was higher than the infection rate observed prior to replanting (*Figure 2*). The incomplete removal of boles

TABLE 1
SUMMARY OF THE DIFFERENT METHODS OF LAND PREPARATION FOR REPLANTING AND NUMBER OF PALMS AFFECTED BY *GANODERMA* AS PER ANNUAL CENSUS TILL 2020

Field number and hectares of former oil palm planting	*Palm stand per hectare prior to replanting*	*Method of land preparation prior to replanting*	*Replanted year*	*Total number of palms planted according to the method of replanting (stand per ha)*	*Total number of palms cumulatively fallen due to* Ganoderma *by 2020* [1/]
79A/13.7 ha	120 (88.0)	Method A	2006	1 980 (148/ha)	564 (28.5%)
86A/2.7 ha	72 (53.0)	Method B	2008	395 (148/ha)	34 (8.5%)
85A/2.6 ha	88 (65.0)	Method B	2009	390 (148/ha)	23 (5.8%)
90F/1.7 ha	83 (61.0)	Method C	2009	250 (148/ha)	5 (2.0%)

Notes:

Method A - Land prepared by selectively excavating the boles of *Ganoderma* fallen palms and vacant points two years prior to felling at 6 monthly intervals.

Method B - Complete removal of boles of healthy and fallen diseased, and vacant palms, followed by two rounds of disc ploughing and one round of rotavating the land between two windrows.

Method C - Excavator method, complete clean clearing land preparation by single excavation or tilting of soil using excavator bucket followed by a round of rotavating the land between two windrows

Parenthesis given is the standing palms or dead palms expressed in percentage

[1/] Recorded the *Ganoderma* infected fallen dead palms during each harvesting round.

at the time of replanting could be the main reason for the high incidence of disease. The boles of *Ganoderma* infected palms under sub clinical level (see discussion on "Census relationship between visually observed symptoms of *Ganoderma* infection before and after felling at the time of replanting" of this paper) were not identified or completely excavated at the time of replanting in field 79A. In this replant field the BSR was observed from the second year after replanting in 2008. As the diseased or dead palm boles were not excavated in replants, cumulatively in 14 years the inoculum developed from the fallen diseased palms could have aggravated the situation for the rapid spread of infection in 2006 replants. This situation was similar to the findings by Turner (1965c), as indicated it was the usual estate management practice to keep the diseased palms even after the formation of fruiting bodies at the stem base. Bunches continued to be harvested from these infected palms until the palm was dead. By that time, the disease from the infected palms may spread to the neighbouring healthy palms. The removal of the infected palms and excavation of the stumps as soon as the fruiting body is formed on the trunk would be a desirable approach. For that, frequent inspection of palms, movement of heavy machinery to infected palms and removal of palms at an early infected stage by digging a pit 0.9 m x 0.9 m x 0.9 m may delay the spread of infection and prolong the survival of the healthy neighbouring palms (Turner, 1965c).

In fields 86A and 85A in method B, the standing palms of 53 and 65 per cent, respectively were low before land preparation

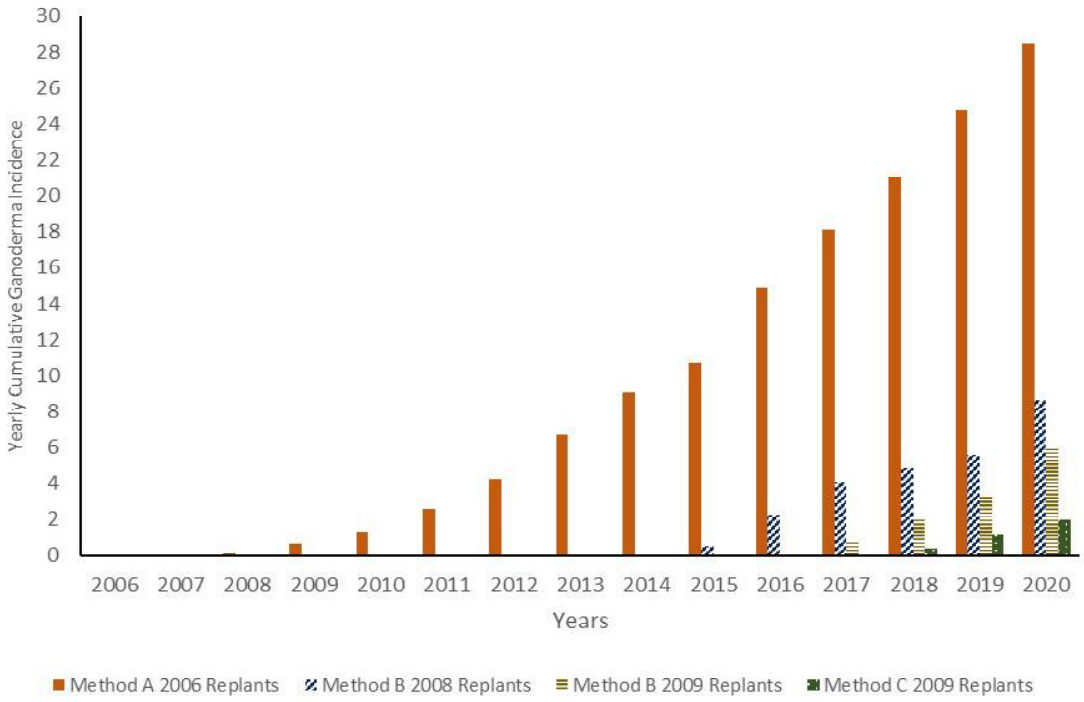

Figure 2 Annual cumulative Ganoderma *infected fallen palms in the three methods*

and replanting. After 11 and 12 years the *Ganoderma* infection in the 2009 and 2008 re-plantings were 5.8 and 8.5 per cent, respectively. For 2008 replants, BSR fallen palms were first sighted in 2015, 7 years after replanting. In 2009 replants, the BSR fallen palm was reported in 2017, 8 years after replanting. This indicates that a clean clearing of land at the time of replanting is an essential operation for land preparation to delay the infection in the replants by removing the disease inoculum in the old stand. However, the reverse was the situation in replants of 2006 under method A, with selective removal of boles, the BSR showed disease manifestations from the second year after replanting (*Figure 2*). The infected BSR palms in the observation plots of method B were bordered with 1999 and 2000 plantings. Here the fields of 1999 and 2000 were replanted at that time without excavation of all the boles. The infection was most likely spread from the neighbouring older replants, which was observed to have high *Ganoderma* infections in the boundaries of 2008 and 2009 replants with method B.

In field 90F, the land was tilted using an excavator bucket following method C and this was a time-consuming operation. The excavator bucket can plough deeper to about 60 cm to 70 cm than the disc ploughing tool of about 30 cm depth. Deep ploughing of up to 60 cm supports the removal of primary roots beneath the soil. In the land prepared by method C, BSR fallen palms were observed in 2018, 9 years after replanting. After 11 years, the total *Ganoderma* infected fallen palms was 2 per cent in method C. The *Ganoderma* infected fallen palms were along the boundary

of the method C plot with the neighbouring field of 2004 plantings. There was a possibility that the infection in method C plots could have been spread from the neighbouring 2004 plantings, where dead palms were observed. Overall, again it was a clear indication that in the clean land preparation with deep tilting of soil the incidence of *Ganoderma* was delayed further when compared to the partial direct land clearing observed in field 79A of method A (*Figure 2*). The deep excavation or tilting of land with the excavator lead to the need for searching and developing new tools and machinery to carry out land preparation faster than the excavator.

OTHER TOOLS TRIED FOR DEEP PLOUGHING BASED ON THE ABOVE STUDY

The ploughing or tilting of soil using an excavator was a slow operation, hence alternative tools and machines were sought and tried to speed up the operation of land preparation. The other tools and machines tried are detailed below.

Howard ripper

The Howard ripper (*Figure 3*), imported from India, has a long hoe of length 1 m and was mounted onto tractors of 80 and 100 horsepower (HP). However, the tractors used for ripping soil were under powered due to the depth of soil ripping and dragging of large quantities of primary roots and volume of soil. To ease this the ploughing had to be conducted twice. The first ploughing or ripping at 30 cm to 40 cm depth, followed by a second ripping to a depth of 50 cm to 60 cm. The double ploughing was time-consuming. In laterite soil the deep ripping of soil was not possible, only the surface of up to 10 cm to 15 cm was ploughed.

Figure 3 Howard ripper

Fabricated steel ripper mounted on D6 bulldozer

The ripper was fabricated, mounted on D6 bulldozer and used for deep ripping of the soil in *Ganoderma* infected fields (*Figures 4* & *5*). This appeared to be more effective than the tractor driven Howard ripper due to the higher engine horsepower in D6 bulldozer. The area covered by the D6 bulldozer was twice that of the Howard ripper mounted on 80 to 100 HP tractors.

Deep ploughing of up to 60 cm supports the removal of primary roots underneath the soil. The Howard ripper needs high horse-powered tractors. Difficulties were encountered in high silty shale like Batu Anam series soil to the extent that the ripper was broken. Deep ploughing with a fabricated ripper mounted on a bulldozer is a practical approach, which not only removes the primary roots (*Figure 5*), but also any tissues accidentally buried under the soil at the time of excavation and filling of soil into the pit. Based on the practicality of work, the fabricated steel ripper mounted on D6 bulldozer appeared to be the most suitable machinery for commercial

Figure 4 Fabricated ripper on D6 bulldozer ripping the soil

Figure 5 Amount of primary roots removed from the soil

implementation of clean clearing of replanting fields.

COST OF VARIOUS LAND PREPARATION METHODS

The cost of land preparation on a per hectare basis for a partial cleaning (only *Ganoderma*) as in method A, disc ploughing (method B) and ripping of soil with Howard ripper or ripper fabricated on D6 bulldozer and excavator bucket method of tilting of soil (method C) are given in *Table 2*. All costs are calculated and expressed in Ringgit Malaysia (RM).

Method A of land preparation by felling, shredding palm trunk, windrowing shredded trunk and stump and bole excavation of fallen diseased and vacant palms has the lowest cost for land preparation of about RM769 per hectare. However, this method of planting had an early infection of *Ganoderma* disease as shown in *Figure 2*. The cost of land preparation using disc ploughing in method B, Howard ripper, and fabricated ripper on bulldozer was almost similar and was about RM2 030.00 per hectare. Here the highly infected fields when cleaned up during land preparation had a low number of *Ganoderma* infected palms after 10 to 11 years (*Table 1* & *Figure 2*). The extra costs between method A and the intensified land preparation by clean clearing, disc ploughing (method B) or deep ripped ploughing was about RM1 261.00 per hectare, which is equivalent to about 1.8 tonnes FFB per hectare [@calculated at crude palm oil (CPO) price of RM3 500 per tonne at oil extraction ratio of 20%], such extra costs can be recovered through early scout harvesting yields. The excavator ploughing was a slow method and the most expensive. The total cost for land preparation prior to replanting was RM2 892.00 per hectare. However, this method was one of the effective methods for delaying the *Ganoderma* infection, perhaps due to tilting of soil to 60 cm depth. Based on this deep ploughing using an excavator, the concept of deep ploughing using a ripper came into effect and the steel ripper fabricated and mounted on a bulldozer was the most practical to be implemented in the field.

CENSUS RELATIONSHIP BETWEEN VISUALLY OBSERVED SYMPTOMS OF *GANODERMA* INFECTION BEFORE AND AFTER FELLING AT THE TIME OF REPLANTING

The census was conducted in replanting fields at the time of felling to understand the number of BSR palms at the subclinical level. It re-

TABLE 2
COST (RM) OF DIFFERENT METHODS OF LAND PREPARATION FOR REPLANTING

Cost of different methods of land preparation for replanting	*Cost (RM) per hectare*
A. Land preparation by removing *Ganoderma* palms only field 79A (Method A) ▪ Lining for windrowing the shredded trunk material. ▪ Felling of old palm stand, trunk shredding and windrowing (@120 palms per hectare) ▪ Excavation of fallen diseased palms' stumps only by construction of pit (1mx 1m x 1m) and refilling the pit.	769
B. Clean clearing, disc ploughing[1/] and rotavating (Method B) or deep ploughing using Howard ripper[2/] or fabricated ripper on D6 bulldozer[3/] ▪ Initial lining for windrowing the shredded trunk material. ▪ Felling of old palm, shredding and initial shredded material windrowing ▪ 100% excavation of stumps and boles of living and dead old palms by pit 1m x 1m x 0.8m construction and refill of pits and refilling soil in the pit. ▪ Re-windrowing of shredded trunk for 100% ploughing using bulldozer and repositioning to initial windrow. ▪ Disc ploughing or deep ripping of soil @2 rounds 100% ▪ Rotavating of ploughed land @1 round ▪ Additional round of re-lining for re-windrowing	2030
C. Clean clearing excavator tilting of soil (Method C) [4/] ▪ Lining for windrowing ▪ Excavator for felling, excavation of boles shredding, windrowing and 100% deep ploughing using excavator bucket ▪ Rotavating plus root collection ▪ Additional round of re-lining of windrowing	2892

Note:
[1/] Output of tractor (80 Hp) mounted with disc ploughing= 3.0 hectares per day
[2/] Output of tractor (100 Hp) mounted with Howard ripper= 1.5 hectares per day
[3/] Output of fabricated ripper on D6 bulldozer (215 Hp) for deep ploughing= 2 hectares per day
[4/] Output of clean clearing by excavator (PC120) (method C) = 0.2 hectare per day.

emphasises the need for clean clearing or removal of boles of all the palms during replanting. An attempt to derive a mathematical model, which may be helpful to planters to evaluate the fields prior to replanting has been tried. Prior to felling, the palms that visually exhibited the symptoms of *Ganoderma* were counted in a random manner for 14 locations covering a total of 1 768 palms. One or more combinations of the recognised visible symptoms of the disease are the presence of multiple spear formation in the upper canopy, pale green canopy, skirting of fractured middle and lower green fronds, presence of *Ganoderma* fruiting bodies, rotted basal stem, vacant points and collapsed palms. These palms were grouped under the census as the number of visually observed *Ganoderma* infected palms prior to felling or land preparation operation. After the infected palms are felled, there were standing palms that looked normal and yielding fresh fruit bunches showing no

symptoms of *Ganoderma*. However, when such palms were pushed with an excavator, the base of the trunk broke leaving the bole fully or partially in the soil. It was observed that the inner part of the trunk core was rotten and affected by the fungal infection. This group of palms were classified as *Ganoderma* infected palms under the sub-clinical stage. The census of *Ganoderma* affected palms in 14 sections of replanting areas prior to felling and after felling at the sub-clinical level are given in *Table 3*.

In *Table 3*, the census based on visually observed *Ganoderma* symptoms prior to felling (column A) and after felling at sub-clinical level (column C) is considered as the sum of total *Ganoderma* infected palms of the 14 locations or replicates. The mean ratio observed was 1: 0.6 between the visually identified infected palms before felling and the normal looking palms which were sub-clinically infected with *Ganoderma*. As given in *Table 2*, the percentage of palms with *Ganoderma* symptoms prior to felling (column B) and the total percentage of infected palms including sub-clinically infected palms (B+D) in all the replicates were plotted on the graph in *Figure 6*.

In *Figure 6*, the percentage of visually selected infected *Ganoderma* palms prior to felling (column B) were plotted on X-axis and the total infected palms visually observed before and after felling (column B+D) were plotted on Y-axis. There was a clear relationship

TABLE 3
GANODERMA PALMS BEFORE AND AFTER FELLING DURING LAND PREPARATION

Replicates	*Total palms observed*	Ganoderma *palms observed*				*Total* Ganoderma *palms observed before and after felling (%)*
		Before felling		*After felling*		
		no.	*(%)*	*no.*	*(%)*	
		A	*B*	*C* [1/]	*D*	*B+D*
1	173	72	42	64	37	79
2	169	107	63	50	30	93
3	138	73	53	47	34	87
4	183	163	89	12	7	96
5	188	145	77	22	12	89
6	109	34	31	41	38	69
7	111	29	26	53	48	74
8	152	65	43	43	28	71
9	75	21	28	31	41	69
10	81	29	36	24	30	65
11	174	15	9	36	21	29
12	122	5	4	28	23	27
13	93	34	37	18	19	56
14	100	26	26	25	25	51
Total	1768	792		469		
Mean			45		27	71

Note: [1]/ Sub-clinical stage

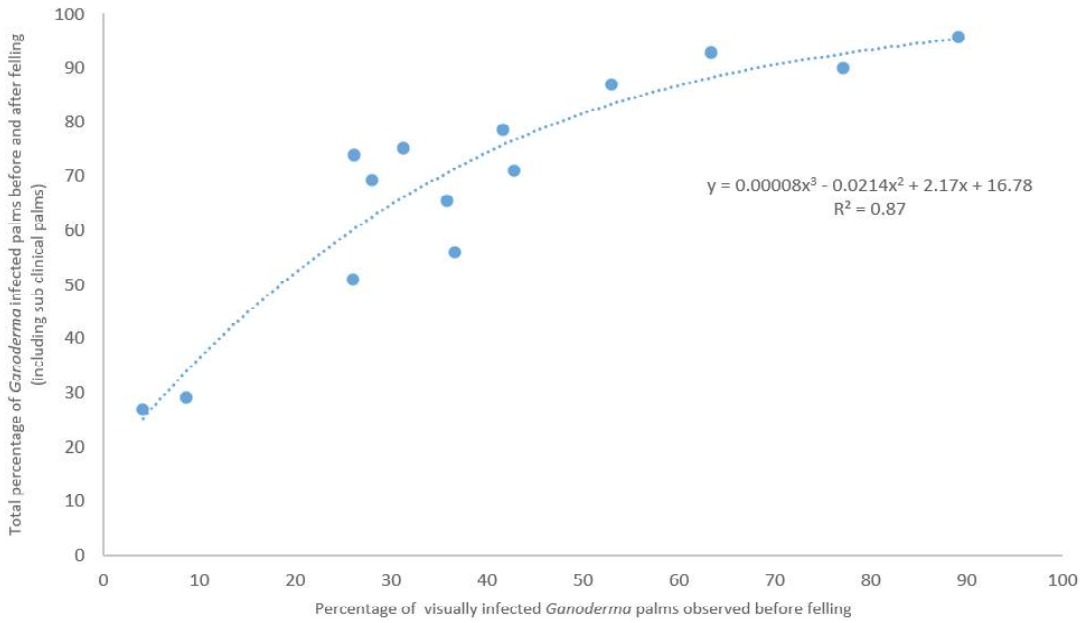

Figure 6 Relationship of the percentage of visually observed infected Ganoderma *palms prior to felling and total infected palms visually observed before and after felling (inclusive of sub clinical) during land preparation in an oil palm to oil palm replanting*

between the infected palms observed visually prior to felling and the total observed infected palms before and after felling in a field. The trend line appears to be cubical with an R^2 value of 0.87 indicating a strong relationship of observations. This indicates that in addition to the visually observed standing infected palms before felling, there are normal-looking palms that are thought to be healthy but are infected with *Ganoderma* at the sub-clinical level. From *Figure 2*, one could predict the total infected palms of a field if there is a census of the visually selected infected standing palms prior to felling. If there are 30 per cent of visually observed infected standing palms in the field, the predicted total infected palms including the sub-clinical infected palms are about 65 per cent. This again stresses the importance of 100 per cent clean clearing of the old standing palms before replanting including the sub-clinically infected and the normal healthy palms. This could be the reason that in the 2006 replanting (*Table 1*) by not removing the sub-clinically infected *Ganoderma* palms of the previous palm stand (field 79A) resulted in a high incidence of *Ganoderma* after 14 years.

DISCUSSION

Turner (1965c) and Turner (1965d) strongly emphasised clean clearing for the entire infected fields. If replanting is carried out, then every palm must be removed. The healthy palms must also be included as they may be infected at the sub-clinical levels and their non-removal will result in renewed disease outbreaks in subsequent replants. Gurmit (1991) proved their two methods of clean clearing in replantings staggered the infection at 3.4 per cent to 3.5 per cent after 9 years. In the first

clean clearing method, the palms were poisoned, root pruned, felled trunks were cut into three sections and stacked and burnt. This is followed by root raking to remove roots and boles tissues. The second method mentioned by Gurmit (1991) was felling of palms by excavator, shredding the trunk into smaller pieces and windrowing and complete extraction of bole with larger size of pit 1.5 m x 1.5 m x 1.0 m. Here again, the tissues were burnt during the dry season. The non-burning of felled palms started in the early 1990s, hence the burning method adopted in 1976 and 1980 by Gurmit (1991) is not relevant for the current time. However, the staggering of the disease may not be the effect of burning, but could be due to the clean clearing during replanting. Idris and Ariffin (2005) reported a high incidence of 30 per cent basal stem rot after 10 years in replants without excavation of stumps, while in the treatment with complete stump excavation with pit size of 1 m x 1 m x 1 m followed by ploughing and rotovating of soil showed a staggered and lower incidence of *Ganoderma* (11%) after 10 years of replanting.

The present observational study confirms that the land preparation as in methods B and C, by clean clearing the field and exposing roots through ploughing delays the *Ganoderma* infection in the replants. Complete excavation of old palm stumps of live including sub-clinical, dead and vacant palms became an integral part of the land preparation. Here the size of the pit constructed was 1.0 m x 1.0 m x 0.8 m, which was smaller than the dimensions indicated by Gurmit (1991) and Idris and Ariffin (2005). Deep ploughing supports the removal of primary roots of the old palm stand and any accidental burial of remnants of shredded palm stems. The deep ploughing using excavator in method C showed a delay in *Ganoderma* infection compared to method B. Due to the high cost and longer time taken for operation with the excavator, a new tool was searched for deep ploughing and eventually the ripper was fabricated using steel, mounted onto a D6 bulldozer was developed. The deep ploughing by ripper fabricated on D6 bulldozer is being commercially implemented within the group as a measure to delay BSR for land preparation during replanting, which is equivalent to clean clearing of land of method C.

These observational studies also showed the importance of neighbouring productive fields of different planting ages to be cleaned as well. The disease formed from the neighbouring older fields could spread to the clean clearing replants. Proper timely excavation of neighbouring infected palms and diseased stumps through excavation may further delay the spread of disease to replants. When the land is prepared by methods B and C, a buffer perhaps about two palm rows of the neighbouring infected field palms (fields not under replanting) can be excavated for a further delay of the spread of disease to the replants. The current observational trials although delay in having the disease in the plots, but the neighbouring older fields with BSR had spread the disease to replants of land prepared by methods B and C. Once the disease is spread to replants and if no excavation of disease palms continued, a faster spread of disease can be expected from the boundaries of neighbouring fields and within replanted fields. The excavation of infected palms on time in the intra and inter fields may possibly help to delay the disease in the fields replanted with good practices of land preparation.

It appears that the inland soils of IOI estates with more than a century of cultivating different perennial crops such as rubber, cocoa and oil palm had the highest incidences of *Ganoderma* irrespective of the types of inland

soil. The main reason could be during the process of replanting and land preparation, the tissues of the previous cultivated crop may not have been completely cleared from the soil. From oil palm to oil palm replants, where *Ganoderma* is much prevalent, the boles of the previous replanting are still visible on the ground. The present study showed most of the fundamental findings made by Turner (1965c, 1965d), Gurmit (1991), Idris and Ariffin (2005) and proved that the clean clearing of land preparation prior to replanting is a necessity in the replanting programme. Although the cost of land preparation is higher when stumps and boles of the dead and living standing palms are completely removed, it could be recovered from scout harvesting of bunches in replants from 24 to 35 months with yields of 7 to 8 tonnes FFB per hectare. An additional benefit of ploughing and rotavating the land is the aeration of soil from compaction of previous cultivation, enabling faster growth of palms for early yields.

CONCLUSION

Oil palm replanted in inland soils after several cycles of cultivation of perennial crops like rubber, cocoa and oil palm for many years showed severe *Ganoderma* incidence. The clean clearing of stumps and boles of oil palm during land preparation for replanting with complete shallow or deep ploughing staggers and reduces the *Ganoderma* incidence in the replant field. This shows the importance of complete clean clearing of the land prior to replanting although the cost is higher in such operation. Deep ploughing using ripper mounted on bulldozer appeared to be most suitable to do a clean clearing of land and commercially is much more feasible to implement. For a better understanding of BSR diseases in replanting fields, it is appropriate to predict and understand the total *Ganoderma* infected palms including the sub-clinical level infection in a field through the census of the visibly obvious infected palms in the field.

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