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Rat Damage Incidences in Lower Perak and Mitigation Measures

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Two incidences of severe rat damage were encountered in a visit to an oil palm estate in Lower Perak recently. Severe rat damage on oil palm fruit bunches and inflorescences was seen in a young mature 6-year-old planting. Rat species identified were Rattus tiomanicus *(*via *cage trapping) and* Rattus argentiventer *(*via *digging the burrow). Furthermore, images of rat chewing inflorescence were taken by an estate personnel during night inspection. Mitigation measures to identify the cause of rat infestation in young mature planting and to reduce risk of damage and crop losses covering various aspects in several headings, namely rat species, rat damage and crop losses, bait shyness, poison baiting, multiple baits application, mass trapping, dog-assisted hunting, worker hunting, and augmentation of barn owl population are discussed. Severe rat damage on immature palms (1 - 2 years old) was seen in a planting of an adjacent estate. It is not possible to comment on the rat infestation in immature planting which was viewed from far. Fast control is required to end the rat infestation before further loss of palms. However mitigation measures are discussed under several headings, namely rat species, rat damage and crop losses, poison baiting, bait shyness, mass trapping, deterrent mixture and rate baiting policy. In conclusion, rats are important pest in mature and immature oil palm plantings and rat management is becoming more challenging due to acute labour shortage and the need for multi-pronged approach in integrated rat management and /or the need to tolerate certain levels of rat damage. To meet these approaching challenges, the training of estate personnel must be emphasised and supported by new findings from on-going R&D works.*

Keywords*: Rats, oil palm, damage, mitigation.*

In a visit to an oil palm estate in Lower Perak in early September 2020, severe rat damage on oil palm fruit bunches and inflorescences was seen in a young mature 6-year-old planting. On the way to view the rat damage in the mature planting, severe rat damage on immature palms (1-2 years old) was seen in a planting of an adjacent estate. In both incidences, the damage was so severe and it was evident that it would be useful to be reported for general information and to create awareness for planters.

Several rat species have been known to be important pests of oil palm in Malaysia. These rats attack and feed on newly planted germinated seeds, bases of lower fronds and apical growing point (palm heart) of seedlings in nursery and immature palms in the fields, unopened and opened inflorescences, developing fruit bunches, unripe black bunches, ripe bunches and the weevil grubs/pupae inside post-anthesis male inflorescence (PAMI). These rat species are listed below:

a) *Rattus exulans* (Pacific rat/Tikus rumah kechil),
b) Rattus tiomanicus (Malayan or Malaysian wood rat/Tikus belukar),
c) *Rattus argentiventer* (Rice field rat/ Tikus sawah),
d) *Rattus rattus diardii* (Malaysian house rat/Tikus rumah),

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e) *Sundamys muelleri* (Swamp giant rat/ Tikus ayer), and
f) *Bandicota indica* (Greater bandicoot rat/Tikus wirok ekor pendek).

In mature palms, rats feed on ripe and unripe oil palm fruits including detached loose fruits on the ground. The dissected stomach content of rat (*R. tiomanicus*) caught in an oil palm field was mainly mesocarp materials. Uncontrolled rat damage can result in 7 - 10 per cent loss of oil production (Liau, 1990). At high rat population (718 rats per ha) of *Rattus rattus diardii*, the potential oil loss is 1300 kg per hectare per year (Balasubramaniam & Chung, 2018). More recently, the oil extraction rate (OER) of severely damaged fresh fruit bunches (FFB) with the outer layer of fruits that had been destroyed was estimated to be 4 - 5 per cent less than normal undamaged FFB's OER (Lee, 2020 -pers. comm.).

The rice field rat, *R. argentiventer,* is normally found in nurseries and young oil palm (Wood, 1976; 1982). Recently the greater bandicoot rat, *Bandicota indica* has been reported to attack immature oil palm and damaged symptoms have been described by Muhammad Idrus *et al*. (2018). In immature plantings, the lower fronds are first chewed by the rat and subsequently repeated attacks lead to feeding on the succulent apical growing point (or palm heart) which usually kill the young palms (Balasubramaniam & Chung, 2018; Chung 2018). The effect of rat damage during the immature phase causes subsequent adverse effect on the early yield of oil palm. Chewing of frond bases by rats caused heavy damage of lower fronds and resulted in yield loss of 20 per cent in the first year of harvesting compared with undamaged palms (Chung *et al*., 1999).

Effective rat control in oil palm estates is achieved by maintaining low pest population to prevent severe crop losses (Wood & Nicol, 1973). In the last five decades, rats in oil palm estates are controlled by using anticoagulant wax baits to reduce their populations and to minimise damage. The biological control of rats by providing adequate number of nest boxes in the augmentation of barn owl population was reported to be successful in the 1990s (Duckett, 1991; Duckett & Karrupiah, 1990; Heru *et al.*, 2000). Recently, there have been publications reporting the ineffectiveness of using barn owl to control rat infestation in oil palm estates (Balasubramaniam & Chung, 2018; Saravanan *et al*., 2020). It is prudent to re-visit the use of barn owl amidst the widespread implementation to satisfy certification requirements. The feedback from the planters on severe damage seems to suggest the cause may be poor bait acceptance and/or the presence of bait shy biotype in the rat population. The problem of bait shyness in oil palm estates has been reported previously (Chung, 2019 a & b).

The objective of this paper is mainly to document the two incidences of severe rat damage, one in young mature planting and the other in immature planting encountered in Lower Perak areas. Further deliberation will consider on possible causes of rat infestation and mitigation measures to counter the negative impacts are provided.

RAT DAMAGE INCIDENCE IN MATURE PLANTINGS

The 6-year-old mature oil palm planting on a flat terrain was attacked by rats. It is an excellently maintained young mature planting with clean weeded planting strips, neat individual frond heaps and short inter-row ground cover of soft grasses (*Figure 1*).

Figure 1 An excellently maintained young mature oil palm planting with clean weeded planting strips, neat individual frond heaps and short inter-row ground cover of soft grasses

The fruit bunches on most palms were severely damaged (*Figures 2, 3, 4 & 5*). Unopened and opened inflorescences were also severely damaged (*Figures 6 & 7*). An estate personnel went to the affected field at night and successfully photographed a close-up view of a rat chewing the inflorescence (*Figure 8*).

The rat species trapped by the estate was identified as *Rattus tiomanicus* which was characterised by clean white belly (*Figure 9*). However, looking at the type of severe damage on unripe bunches and inflorescence, it could be caused by *Rattus argentiventer*. This evaluation was confirmed when an estate personnel caught a mature *R. argentiventer* (*Figure 10*).

During the visit, rat baiting was in progress. Poor acceptance was seen on brodifacoum wax baits placed on frond butt. Moreover, fresh damage was still seen on fruit bunches and inflorescences. This poor bait acceptance could be the cause for the failure in rat control which had resulted in such severe damage. Furthermore, the estate in the past had experienced bait shyness incidence. Rat control against bait shy biotype was carried out by a poisoning campaign with rhinoceros beetle grubs in mixture with acute poison. In immature palms, rat damage was prevented by painting the frond bases with a layer of bituminous compound and zinc phosphide mixture.

Mitigation measures to identify the cause of rat infestation in young mature planting and to reduce risk of damage and crop losses are reviewed and discussed below:

a) *Rat species* - It is useful to carry out a study to identify the rat species (listed

Figure 2 A severely damaged fruit bunch with almost 85 per cent fruits chewed up

Figure 3 A freshly damaged fruit bunch with almost 95 per cent fruits chewed up and kernel eaten

Figure 4 A severely damaged fruit bunch with fruits eaten and exposing the fruit stalk

Figure 5 A severely damaged developing fruit bunch with large portion of the middle section eaten and exposing the fruit stalk

Figure 6 A new inflorescence severely chewed up and the debris scattered on adjacent fruit bunches. Note severe old damage on fruit bunch at the bottom right corner

Figure 7 Boring into unopened sheath and chewing up the inflorescence

earlier) and the associated population. Trapping in estate using drop door wire cages has been a successful method to catch several *R. tiomanicus*. However, *R. argentiventer* is relatively trap shy and difficult to catch using cages. Collection using snap traps with an attractive lure is the alternative method. In the well maintained planting with individual frond heap and clean weeded strips, workers hunting by disturbing the frond piles and using bamboo to knock on palm canopy to force out the rats can be effective in catching or killing many rats (*Figure 11*). The collected rats can then be identified and/or dissected to determine stomach content or breeding status of mature female rats.

b) *Bait shyness* - Bait shyness refers to the general poor bait acceptance or bait avoidance by a given rat population or

Figure 8 Close-up view of a rat chewing the inflorescence at night (photo credit Tan Kay Nan)

Figure 9 Rat trapped by estate was identified as Rattus tiomanicus *– white belly*

Figure 10 Rat caught by estate worker digging into burrow was identified as Rattus argentiventer *– pale grey or silver belly (left) and tawny or orange-brown back (right) (photo credit Tan Kay Nan)*

Figure 11 A team of workers hunting for rats by opening up frond heap in a rat population study

certain bait shy biotype. It can be further divided into poison shyness (the rodenticide is the cause) and base shyness (the food material is the cause). Past experiences indicate that bait shyness in local rat species is caused by the food materials used in bait formulation, namely a mixture of broken maize, fish or prawn dust, saw dust, wax and crude palm oil. In the present round of baiting, bait shyness was suspected to be the reason of poor bait acceptance with minimum or no replacement needed in the second or third round of baiting.

Bait acceptance trials both in laboratory and in the field are required to identify the most accepted rat bait for rat baiting and at the same time to determine and confirm the presence of bait shy biotype. From experience, acceptance of oil palm loose fruits or rhinoceros beetle grubs were high (80-100 per cent) by bait shy biotype.

One plantation put up a video recording at night and found that the rats in the affected estate preferred taking loose fruits to commercial baits. Several commercial wax baits had failed to attract the rats.

c) *Rat damage and crop losses* - Rat baits which were attractive and well accepted by field rats in oil palm estates have given good and effective large scale rat control in the past five decades or more. Failure in rat baiting lead to build up of rat population and widespread severe damage to fruit bunches, inflorescences and PAMI will be common in the affected fields. Crop

losses can be higher than 7 - 10 per cent oil yield when male and female inflorescences and developing fruit bunches are seriously damaged at high rat infestation situations. Much lower OER loss of 4 - 5 per cent has been estimated for FFB when the outer layer of fruits had been destroyed by rats (Lee, 2020 - pers. comm.). Oil palm estates with bait shy biotype do not achieve good rat control and estate management should not be blamed for the higher level of rat damage until an effective solution is found.

It is important for an estate encountering bait shyness to monitor rat damage, especially with more accurate assessment in young mature plantings. Old damage on fruit bunches will stay until the ripe fruit bunches are harvested. To monitor existing rat infestation, the percentage of palm with fresh damage (any sign of damage; green colour for unripe fruits; yellow to orange colour for ripe fruit) is useful. In general, higher percentage of fresh damage may indicate high rat population in the field. However, there was no direct correlation of percentage fresh damage to rat population and a summary is reproduced in *Table 1* for information (Wood, 1969).

For taller and older mature plantings (for example, 10 years old and above), rat damage assessment becomes much less accurate and the data obtained may not give a good reflection of existing rat population. There appears to be a need to review fresh rat damage assessment methodology and the 5 per cent fresh damage action threshold for commencing rat baiting. At the same time, it is useful to investigate the possibility of monitoring rat damage for tall palm planting by assessing harvested FFB.

d) *Poison baiting* - Rat baiting in oil palm estates has given good and effective large scale rat control in the past five decades or more. Inadequate baiting and poor implementation will lead to ineffective control resulting in

TABLE 1
POPULATION SIZES OF *R. TIOMANICUS* AND PERCENT FRESH DAMAGE IN EIGHT OIL PALM PLANTINGS IN ULU REMIS, JOHORE (1967/68)

Age of oil palm plantings (years)	*Rat population*		*Percent palm with fresh damage (%)*
	per acre	*per hectare*	
17	205	506*	9
12	80	197	12
10	92	227	22
10	110	271	46*
10	105	259	22
10	75	185	24
4	122	301	10
4	97	239	14

Source: adapted from *Table 1*, Wood (1969). * highest value.

continuous damage to inflorescences and fruit bunches. Moreover, it will lead to build up of rat population to a level that may need more than 10 rounds of baiting. Rat baiting is carried out by placing one bait per palm (usually on or inside the front butt) and replacing baits taken by rats at 4 days interval (first generation anticoagulant baits) and 7 days interval (second generation anticoagulant baits). The baiting is continued until acceptance level falls to 20 per cent or less. The estate baiting campaign is required to be completed within 2 months and repeated in 6-monthly intervals. Very low fresh damage of 0 - 1 per cent was recorded immediately after effective rat baiting and it will give a low rat population period of up to 6 months.

Many conventional wax baits are not attractive to bait shy biotype. These baits are not suitable for poison baiting. Rhinoceros beetle grubs coated with acute rodenticide or liquid anti-coagulant rodenticide have proven to be highly attractive and palatable to bait shy rats in cage feeding trials and recorded good percentage of mortality. These types of baits should be explored and evaluated in field trials to gauge their effectiveness for the control of bait shy biotype and the reduction in rat damage. Other non wax-based baits should be tested for their attractiveness and effectiveness against bait shy rats both in the laboratory and oil palm field. One such example is described by Turner and Gillbanks (2003), *viz.* a mixture of zinc phosphide (3 parts), dried fish or chicken meal (6 parts), and broken rice (100 parts) wrapped in waterproof paper and treated with coconut oil. The use of acute rodenticide is likely to be prohibited by certain certification scheme. Some adjustment is required if anticoagulant rodenticide is to be used in place of acute poison (to achieve the desired dosage rate).

e) *Multiple baits application* - An estate facing acute labour shortage may not be able to implement rat baiting smoothly and properly. Published trial results have reported applying multiple baits per palm can reduce labour requirement (Chung & Bala-subramaniam, 2000). Applying five baits per palm required three rounds of baiting compared with one bait per palm at eight rounds of baiting. Applying 300 g block bait (20 baits x 15 g) needed only one application with no replacement. However, the costings were much higher. These measures can be used to bring down the high rat population subsequently reverting to normal cost-effective baiting practice of one bait per palm.

f) *Mass trapping* - Mass trapping using drop door wire cages are being carried out to remove bait shy rats in some oil palm estates (Chung, 2019b). This approach has been reported recently, but not much detail is available. Perhaps mass trapping can be evaluated in small blocks to assess the cost-effectiveness and logistical aspects.

g) *Dog-assisted hunting* - Dog-assisted hunting of bait shy rats has been reported to be successful in controlling the rat population in a consolidated area of 364 hectares of 11- year-old oil palm

in the 2009 planting (Saravanan *et al.*, 2020). A team of two workers with dogs covered 2.25 hectares per day. Four rounds of hunting in a year managed to cause a very significant reduction in the percentage of fresh damage from more than 37 per cent to 5.5 per cent. The costing was reported as RM165.73 per hectare per year.

The 6-year-old planting in Lower Perak with individual frond heaps and clean ground conditions is a suitable location to try out dog-assisted hunting. However, the sourcing and training of hunting dogs may take sometime.

h) *Hunting by workers* - A team of six to eight specially trained workers is required for this job. Three to four workers are to be assigned to open up the frond heaps using rakes fitted to long handles and using bamboo to knock on the palm canopy. Three to four workers are to be stationed at strategic positions to collect escaping rats using sweep net or killing them using a stick made from cut rachis (*Figure 11*). This type of hunting can be a start off measure until sourcing and training of hunting dogs can be completed.

i) *Augmentation of barn owl population* - For long-term biological control, setting up nest boxes at one unit per 10 ha to augment barn owl population has been carried out in many oil palm estates. It is essential to carefully monitor the barn owl population by regular assessment on nest box occupancy rates. It normally takes 2 to 3 years to achieve good rat control (indicated by low % fresh damage) (Duckett, 1991). Estate personnel must be vigilant to assess their effectiveness and one requirement is high occupancy rate (80-100%).

The establishment of barn owl boxes at a ratio of one unit for every 4 hectares of oil palm planting with 57 per cent of occupancy rate was unable to control the high rat population (Saravanan *et al.*, 2020). This finding concurs with the observation of severe rat damage in several oil palm estates and the sub-optimum occupancy rates of nest boxes, in spite of being put up near optimum density (i.e. 1 unit : 10 ha).

Notwithstanding these recent reports or observations, rats remain the main diet of the barn owls in oil palm estates. In estates encountering bait shyness, putting up barn owl nest boxes to augment barn owl population could be a long-term preventive control and a temporary stop gap measure to remove bait shy rats. It is important to note that rat baiting with chemical poison is not compatible due to risks of secondary poisoning (Lee, 1994). It is apt to include mass trapping or hunting in integrated rat management because these measures do not harm the barn owls, except in removing some of their food source (the rats). Further evaluation is needed.

RAT DAMAGE INCIDENCE IN IMMATURE PLANTINGS

Unlike in the case of walk-in inspection in the 6-year-old mature planting (described earlier), the immature planting (1 - 2-year-old) of the adjacent estate was viewed from the boundary of the road. The immature palms attacked by

rats and the newly planted seedlings were those in a belt of several palms from the boundary drain. In general, it is a fairly uniform planting of healthy immature oil palms with dark green foliage and good number of fronds as expected in a normal palm configuration (*Figure 12*). The inter-row vegetations are a mixture of legume covers and soft grasses in a relatively thin even sheet growth.

Individual palm or pocket of immature palms were severely damaged by rat attack with most of the middle and lower fronds damaged (caused by rat chewing on the frond bases) and all lying flat on the ground. The affected palms were only left with a few upper fronds (about 4 to 6 fronds) which had not been attacked standing in near vertical and vertical position (*Figure 13*). If no action is taken soonest, the rat will continue to chew and bore in order to feed on the succulent apical growing point (or palm heart). As a result, the immature palms will be killed. This may explain the number of newly planted seedlings seen in the boundary belt and each covered at the base by a fabric collar (looking like empty fertiliser bags) (*Figure 14*). It may be better to plant new seedlings (to replace severely damaged or dead seedlings) after the rat infestation is effectively controlled.

All the three common rat species, namely *R. tiomanicus, R. argentiventer* and *R. r. diardii* do chew on frond bases of immature palms and cause damage to the lower fronds. However from past experience it can be deduced that the very severe damage seen in this case may point to *R. argentiventer* being

Figure 12 A fairly uniform and healthy immature oil palm planting

Figure 13 A severely damaged immature palm with most of the middle and lower fronds damaged (caused by rat chewing on the frond bases)

Figure 14 Newly planted seedling at a vacant point with fabric collar (probably used to deter rat attack)

the culprit. This rat species is known to have a preference to feed on vegetative materials and also feed more voraciously on unripe fruit bunches and inflorescences. Anyway, this can only be known if rat trapping or rat hunting is carried out in affected immature planting of the adjacent estate. This is beyond our current deliberation.

Quite a number of nest boxes (*Figure 15*) have been installed in this immature planting, probably a step towards long-term preventive rat control through augmentation of barn owl population. However, it certainly had not prevented the severe rat damage. It is also not possible to probe further in our discussion on the other possible causes leading to the current serious rat infestation. It suffices here to take note that rat infestation resulting in severe frond damage in immature palms can occur if the estate personnel is not vigilant and implement timely control to counter the negative impacts.

Mitigation measures to identify the cause of rat infestation in immature planting and to reduce risk of damage and crop losses are discussed below:

a) *Rat species* - It is useful to carry out a study to identify the rat species and the associated population. Both drop door cages and snap traps should be used with attractive lure (e.g. rhinoceros beetle grubs). Digging into the burrows may be useful.

b) *Rat damage and crop losses* - Chewing of frond bases by rats caused heavy damage of lower fronds and resulted in yield loss of 20 per cent in the first year of harvesting compared with undamaged palms (Chung *et al*., 1999). Delay in control will even lead to death of immature palms when the rat has fed on the apical growing point. Oil palm estates normally adopt zero damage policy in immature planting.

c) *Poison baiting* - Trapping studies have shown that rats do not leave the replanting field practicing zero-burning

Figure 15 A barn owl nest box erected in immature planting (probably aiming for biological control of rats)

technique. For replanting areas, rat baiting is required as soon as the planting of oil palm seedling has been completed. Second generation baits which are more potent are recommended to deal with rat infestation in immature planting. The rat baiting is carried out by placing one bait per palm (usually at the palm base) and baits taken by rats are replaced at 7 days interval (second generation anticoagulant baits). The baiting continues until acceptance level falls to 20 per cent or less. The number of baiting rounds is dependent on the existing rat population. Further baiting of immature planting will take place at 6-monthly campaigns at the same time with other estate plantings. This is required to keep rat population low and also effectively prevent rat damage. In special case, multiple baits application may be considered to alleviate the labour shortage in some estates.

d) *Bait shy rats* - In estates facing bait shy biotype, poison baiting using rhinoceros beetle grubs plus acute rodenticide/rhinoceros beetle grubs plus anticoagulant rodenticide may be used. However, the use of acute rodenticide is likely to be prohibited by certain certification scheme. Other non wax-based baits should be tested to secure a good and quick kill.

e) *Mass trapping* - Many conventional wax baits are not attractive to bait shy biotype. Mass trapping using drop door cages and snap traps may be used as stop gap measure. It is probably useful as a treatment for acute infestation occurring in small areas or isolated pocket of few palms.

f) *Deterrent mixture* - Talking to senior planters, many will remember the old days when painting mixture of bituminous compound and acute rodenticide (zinc phosphide at 5%) to frond bases (10 - 20 cm band above ground) as a deterrent measure against rat damage in immature planting was carried out. It was carried out not only to prevent damage from rats, but also used to deter chewing by larger vertebrate pests, namely porcupines and wild pigs. Zinc phosphide paste form has been reported for use as deterrent in young planting, but not suitable for newly planted palms due to phytotoxic effects (Turner & Gillbanks, 2003). The paste can be made of lime, tapioca flour or starch and zinc phosphide in a 5:5:1 ratio with small quantity of both sticking and wetting agents.

g) *Rat baiting policy* - In an estate with past history of rat infestation, the company's rat baiting policy must clearly emphasise baiting before felling palm in fields scheduled for replanting, baiting after completion of planting seedlings, increased surveillance by estate personnel on symptoms of rat damage to lower frond and good and timely circle weeding for ease of monitoring.

DISCUSSION AND CONCLUSION

The current inspection on rat infestation in mature planting points to the existence of high rat population causing severe damage to inflorescences, fruit bunches and PAMI. Although rat species trapped was only *R. tiomanicus*, the severity of the damage

indicates the culprit may include *R. argentiventer*. A big *R. argentiventer* was collected by an estate personnel when digging into the burrow. Good images of the rat attack were successfully documented by an estate personnel during his inspection at night.

The build-up of rat population could have been due to the poor acceptance of rat bait by bait shy biotype. Baiting with conventional wax bait will not solve the current rat infestation and thus prevent further damage. Estate management has to consider the application of rhinoceros beetle grubs plus anticoagulant rodenticide to control the rat problem.

It is not possible to comment on the rat infestation in immature planting of the adjacent estate. Fast control is required to end the rat infestation before further loss of palms. The nest boxes erected most likely had not helped to increase barn owl population to the level that can give effective rat control. It may be because the nest boxes were put up quite recently and it normally requires 2 to 3 years to build-up the barn owl population.

In fields facing severe rat damage, both mature and immature plantings should be inspected more often and corrective measures applied soonest. Assessment on control measures are also required in order to make the necessary changes to further ensure success in rat control or at least to minimise damage/crop losses.

In an estate facing labour shortage and does not have bait shyness problem, multiple baits application may be considered. However, the costing can be much higher. Small scale testing is recommended to gauge the bait acceptance first before moving ahead with large areas of commercial application.

When bait shyness is detected and confirmed, it is clear that conventional rat baits are not effective. Rat poisoning can be carried out using rhinoceros beetle grubs plus anticoagulant rodenticide. Other non wax-based baits should also be tested. Small scale testing is recommended to gauge effectiveness first before moving ahead with large areas for commercial application.

An estate must implement company policy of rat management to achieve good control of rats. The benefit is the prevention of 7 per cent to 10 per cent loss in oil crops. If the rats have damaged the inflorescences and developing fruit bunches, the losses are much higher. In an estate with bait shy rats, the existing company policy of rat management using anticoagulant wax bait is no longer effective. These estates with bait shy biotype do not achieve good rat control and estate management should not be blamed on higher level of rat damage until an effective solution is found. In the long-term, integrated rat management (IRM) using several compatible methods is recommended. Whether this IRM package can contribute the same good rat control equal to rat baiting, remains to be assessed after putting into practice. The success of IRM would require the continued support of research and development inputs.

Finally, it suffice to conclude that rats are important pest in mature and immature oil palm plantings. Rat management is becoming more challenging due to acute labour shortage and the need for multi-pronged approach in IRM and/or the need to tolerate certain levels of rat damage. To meet these approaching challenges, the training of estate personnel must be emphasised and support from new findings of on-going R&D works are needed.

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