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Review Article

Performance Comparison of Trunk Injection Mechanisms for *Ganoderma* Control

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Abstract: A severe disease known as *Ganoderma Boninense*, which attacks a group of wood-decaying fungi, causes Basal Stem Rot (BSR) in oil palm trees. One of the treatments introduced to control the spread is injecting a chemical into the palm's trunk. After receiving a hexaconazole treatment for a year, a study on 2008 *Ganoderma*-infected palm trees in an estate revealed that 95.6% of the infected palms were still standing. The injection process facilitates several devices that were used and invented. These machines utilise a pressure-injection technique that injects a chemical through a flexible hose into a healthy palm's tissue to prevent the disease from spreading. Hence, the development of effective trunk injector mechanisms for *Ganoderma* treatment is discussed in this article. The first injection method utilised the Pressure Injection Apparatus (PIA), which can deliver a chemical to the target sites to control BSR. Second, a Mechanical Trunk Injector mainly facilitated chemical injection into the palm trunk using a prime mover. Next, the Tractor Mounted Trunk Injector, comprised of an injection apparatus system, was found to perform effectively and efficiently. The distribution profile of the dye eosin in the stem revealed that it covered more than 80% of the cross-sectional and longitudinal axes of the palm tree's trunk. Instead of the previous injection apparatus control method, this machine could speed up the injection time. Compared to the 20-minute-per-hole completion time of the PIA, the machine only took 3 to 5 minutes to complete an injection, which was 65% faster, and about 100 to 120 palms could be covered in a day. Labour requirements were very minimal as it is a single-operated machine. Utilising the machine would also result in a reduction in the number of workers needed.

Keywords: *Ganoderma*; trunk injection apparatus; trunk injector.

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1. Introduction

Malaysia's oil palm remains the country's primary business, contributing to producing fresh fruit bunches (FFB) of approximately 18 Million tonnes a year (MPOB, 2023). To maintain a reasonable yield throughout oil palm's economic life, producers must apply good agricultural practices (GAP). Nonetheless, the prevalence of pests and diseases can significantly impact FFB production. *Ganoderma boninense*, a wood-decaying fungus, causes the oil palm disease Basal Stem Rot (BSR) (*Figure 1*). It is a severe disease, especially in replanted areas of old oil palm and coconut, and it is still the most severe oil palm disease in Southeast Asia (Gassner *et al.*, 2005; Rakib *et al.*, 2017; Hari *et al.*, 2011). The disease is capable of infecting oil palms at all growth stages. Infected immature palms typically perish within 6 to 24 months of the first foliar symptoms, whereas mature palms can live for two or more years (Turner & Gillbanks, 2003). BSR disease has caused significant economic losses for oil palm plantations (Roslan & Idris, 2012). The incidence of BSR in Malaysia has been increasing annually, with yield losses estimated to reach up to RM 1.5 billion per year (Arif *et al.*, 2011). By the time the palms are halfway through their expected economic life span, the disease has been reported to have killed up to 80% of the stand (Darus *et al.*, 1991).

Figure 1. *Ganoderma Boninense* causes the oil palm disease Basal Stem Rot (BSR)

This fatal disease was considered Malaysia's most severe oil palm disease, with losses reaching up to 80% after repeated planting cycles. Idris *et al.* (2003) confirmed that *Ganoderma* produces enzymes that degrade oil palm tissue, causing severe problems with water and nutrient distribution to the top of the palm tree. Once the disease is established, like most soil-borne diseases, it is challenging to control. The best way to prevent the spread is to avoid it. The sources of infection may be old oil palm and coconut stems and roots, which should be eliminated. Several control measures, such as chemical control using *Hexaconazole* fungicide, soil mounding, sanitation, and stump treatment with *dazomet fumigant*, were proven effective in prolonging the productive life span of the palm (Idris *et al.*, 2016; Naher *et al.*, 2015; Assis *et al.*, 2016). As a short-term control measure, using fungicide as a curative treatment is essential for managing the disease in the fields (Arifurrahman & Idris, 2008).

A pressure-injection apparatus was created to prevent the spread of BSR disease to other oil palm tissues by injecting fungicides. According to Idris *et al.* (2002), this apparatus can inject fungicides quickly and effectively. Idris *et al.* (2004) reported that two types of fungicide, namely *Bromoconazole* and *Hexaconazole*, both belonging to the triazole family, effectively extended the productive life of infected palms. The use of these triazole fungicides as foliar treatments to control apple scabs caused by Venturia inequalis was previously documented (Shahinasi *et al.*, 2017). The incidence of BSR has been on the rise in Malaysia, with yield losses estimated to reach up to RM 1.5 billion per year (Arif *et al.*, 2011). From an economic standpoint, it is crucial to explore various means of controlling the disease's spread so that FFB production, particularly in infected areas, is not severely impacted.

Hence, this article will discuss several effective chemical injection mechanism methods developed for *Ganoderma* control.

2. Injection of Chemical Control

Effective delivery of the fungicide to the advancing fungal *mycelium* within the lesion is critical for successful disease control, based on a report by Idris *et al.*, 2009. During the procedure, a drill was used to create a hole in the tree. Once the drilling process was complete, the nozzle was precisely pushed into the drilled hole and the chemical was injected into the oil palm tissues in a precise amount. During the injection, the fluid (chemical mixture of *Hexaconazole* and water) was pumped from the tank through the hose and into the nozzle (Idris *et al.*, 2004). The volume meter measures the amount of fluid passing through, while the pressure gauge measures the system's operating pressure. The volume of 4.4 g *Hexaconazole* diluted in 7 litres of water has been suggested. The injection volume of *Hexaconazole* was 90 ml per palm, as recommended by Abdul *et al.* (2018), Idris *et al.* (2002), Razak *et al.* (2004), and Idris *et al.* (2009). Three methods were available among several technologies used to control the BSR disease.

2.1 Pressured Injection Apparatus (PIA)

The Pressured Injection Apparatus (PIA) comprised an injector, a hose, a stop cork, a connector, a pressure pump engine, and a chemical tank (Figure 2). In the treatment operation for the palm, an injection hole was drilled into the palm trunk at a slight downward angle using an engine drill with a drill bit. The stainless-steel injector was inserted into the drilled hole, and the injector connected the high-pressure supply hose to the stop cork and the chemical tank (Idris *et al.*, 2002). The drill is used to create the hole, and the injector is used to inject fungicide into the oil palm trunk. Tests conducted by Idris *et al.* (2002) revealed that the machine's performance for the PIA method was 7 to 8 palms per hour; therefore, it was estimated that the machine's daily output would be 50 to 60 palms.

Figure 2. Trunk Injection Apparatus (TIA) complete set

2.2 Mechanical Trunk Injector

The Mechanical Trunk Injector was developed by Razak *et al.* (2004), which consisted of a prime mover, a chemical tank, a pressure-regulated reciprocal pump, a long flexible hose, and a power unit (Figure 3). The power unit was furnished with a stainless-steel injecting nozzle, and a drill bit embedded in a cast-nylon holder was attached to the injecting nozzle. The power unit and injector equipment are distinct units. The injecting nozzle was placed into a drilled hole, and the chemical was pressure-injected from the tank by a tractor-mounted pump. During the injection operation, the nozzle was larger than the drill to provide a tight fit between the nozzle and the drilled hole.

Razak *et al.* (2004) reported that, on average, 1.5 to 3 minutes per injection hole were required to complete the operation, and the volume inserted was 3 to 5 litres respectively. Injections took a short period compared to the 20-minute-per-hole completion time of using PIA. About 60 to 80 palms were estimated to be covered per day. Using this machine, an operator will no longer complain of back strain, as he will no longer be required to carry a water tank on his back, as in the previous method.

Figure 3. The Mechanical Trunk Injector

2.3 Tractor Mounted Trunk Injector

Earlier technologies consisted primarily of hand-held equipment and were only partially mechanised, thus requiring the user to bring additional tools during an operation and limiting output. The mounted Trunk Injector system, where the operator controls the device while seated atop the primary mover, is more practical. It has the same concept as the Mechanical Trunk Injector, which combines a drill with an injector. The apparatus (injecting set) would be mounted to the front of the prime mover, and the driver would control its operation from the driver's seat (Figure 4). The apparatus would be moved by a mechanical and hydraulic system that requires only an operator (Abdul *et al.*, 2018).

Figure 4. The Tractor Mounted Trunk Injector

All the components, including the drill, injecting nozzle, and hydraulic system, were placed on a mini-tractor-mounted table. The table is permanently mounted in front of the tractor. One worker would operate the machine using automated drilling and injection operations. Injecting oil palm trunks should be both effective and efficient. To prevent waste, there should be no leakage on the hose during high-pressure injection. The machine should be simple to operate, capable of increasing worker productivity, and cost-effective (Abdul *et al.*, 2018). The machine's performance was studied by injecting different volumes of 0.1% eosin dye solution into healthy oil palms. The injection pressure was set at approximately 20 bars to ensure the pressure was within the limit while preventing the dye solution from gushing. The three different volumes were evaluated from previous research, i.e. 3, 4, and 5 litres of dye solution on three different palms. Immediately after the injection, the palm was felled and cut into two halves, i.e. along its longitudinal and cross-section X-Y axes (Figure 5). The distribution profile of the dye in the palm trunk on each axe was recorded in Table 1 (Abdul *et al.*, 2018; Razak *et al.*, 2004).

From the study, Abdul *et al.* (2018) found that injecting 10 litres of chemical into a palm trunk by using this technology can treat the healthy tissue of the palm trunk affected by basal stem root disease.

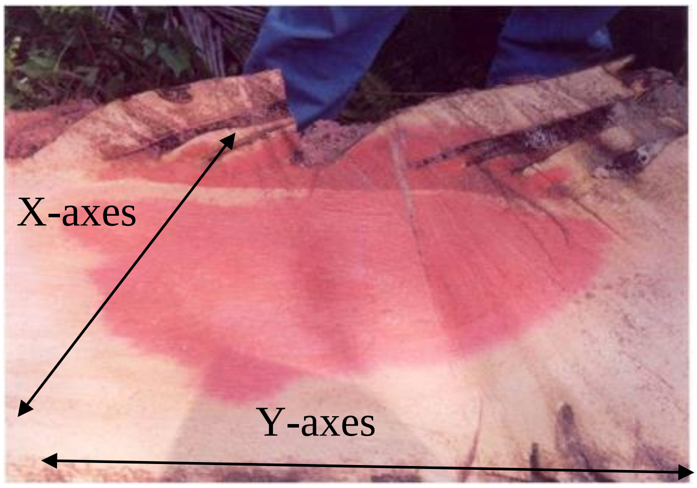

Figure 5. Dye distribution profile in the stem

Table 1. Result of Injection Effectiveness Test

	Injection Volume					
	3-litre		4-litre		5-litre	
Trunk Diameter	64		65		64	
Axis	Distance (mm)	% coverage	Distance (mm)	% coverage	Distance (mm)	% coverage
X (cross-section)	400	62	300	47	300	47
Y (cross-section)	420	66	440	69	440	69

Source: (Abdul *et al.*, 2018; Razak *et al.*, 2004)

Function tests revealed that the machine could inject a 10-litre dilution in only 2.5 minutes per palm. As reported by Abdul ***et al.***, 2018 with this output, it is presumed that the daily production will range between 100 and 120 palms. The results revealed that the machine could perform 8.32 palms per hour, or 37 palms per day while consuming 0.97 litres of diesel per hour. Therefore, this prototype was more than 100 per cent faster than the PIA (performance of PIA was 15 to 20 min palm^{-1} or about 7 to 8 palms hr^{-1}) (Abdul *et al.*, 2018).

3. Performance Comparison

Table 2 shows a comparison of technological methods to control *Ganoderma*.

Table 2. Comparison of technologies to control BSR by using an injection method

	Pressured Injection Apparatus (PIA)	**Mechanical Trunk Injector**	**Tractor Mounted Trunk Injector**
Technology Specification	Manual operation	Semi-Automated Suitable Prime Mover	Automated 27 hp hydrostatic mini tractor
	15-litre Tank Capacity 14.7 bars pressure	Tank 200-litre capacity 20 bars pressure	Tank 200-litre capacity 20 bars pressure

	Pressured Injection Apparatus (PIA)	Mechanical Trunk Injector	Tractor Mounted Trunk Injector
	Two units of 1.2 hp petrol engine (drilling and injection)	1.2 hp petrol engine (drilling)	Hydraulic control (Drilling and injection)
	Separated unit (drill and Injector)	1 unit of drill tools for Drilling Flexible Hose: 50 m	The drill bit and Injector are attached
	Drill bit: 400 mm length, 10.1 mm diameter	Drill bit: 300 mm length, 5 mm diameter	Drill bit*: 240 mm length, 11 mm diameter
	Injector nozzle *: 500 mm length, 10.2 mm diameter	Injector nozzle *: 700 mm length, 7 mm diameter	Injector nozzle *: 372.25 mm length, 12 mm diameter
Method	Required three injection points	Required two injection points	Required one injection point
	Drill the hole with a unit drilling machine and inject it with other unit apparatus (knapsack)	Drill the hole with a unit drilling machine and inject the nozzle with a flexible hose.	The apparatus (drilling and injecting set) is mounted to the prime mover.
	Inject the chemical from the tank (knapsack) through the apparatus	The chemical was pressure-injected from the tank by the tractor-mounted pump	The driver control operation (drilling and injection)
Productivity/coverage	50–60 palms per day	60–80 palms per day	100–120 palms per day
	8 minutes per injection (3 litre per hole)	3 minutes per injection per palm (5 litre)	2.5 minutes per injection per palm (10 litre)
Cost (operation)	RM 15–20/palm	RM 15–25/palm	RM 11.90/palm

**Stainless-Steel*

Source: (Abdul *et al.*, 2018; Idris *et al.*, 2002; Ikmal *et al.*, 2014; Razak *et al.*, 2004; Nur-Rashyeda *et al.*, 2022)

Based on the findings from the three methods, the Tractor Mounted Trunk Injector was highly effective and practical for trunk injection. The machine took only 2.5 minutes to complete a 10-litre injection dilution instead of 20 minutes per hole when using the PIA, a time savings of approximately 65 per cent. Compared to the Mechanical Trunk Injector, the workloads are less, causing the job task (drilling and injection) to be done with operators controlling both tasks. It is estimated that around 100 to 120 palms can be covered daily depending on field topography and distances between infected palms (Abdul *et al.*, 2018; Ikmal *et al.*, 2014). The injection process required less physical effort, allowing the operator to extend his working hours, increasing his productivity and daily income.

Labour requirements were deficient, as only a single worker was required to operate the machine. The operational cost was quite reasonable, at RM 3.15 per palm (without fungicide) and RM 11.90 per palm (with fungicide), with a cost-effectiveness of RM 1.02 per palm over an expected five-year economic life span (Arif *et al.*, 2011; Ariffin & Idris, 2002; Assis *et al.*, 2016; Idris, 2007; Idris *et al.*, 2004).

Therefore, it is suggested that the industry utilise the Tractor Mounted Trunk Injector to control the spread of BSR disease in oil palm plantations by injecting *Hexaconazole* into the trunks. This will provide benefits by increasing worker productivity and decreasing the required number of workers, accelerating plantation operations and reducing the time wasted transporting numerous tools for palm treatment. A change from the Hydraulic Lever Control to the Automated Electronic Control could be implemented concurrently with IR 4.0 to increase the machine's operation efficiency. This will increase the benefits to the plantation and its operators.

4. Conclusions

It was found that the Tractor Mounted Trunk Injector could effectively inject chemicals into the targeted tissues. Using a dye solution, this machine was shown to be capable of producing a profile of the oil palm stem's extensive distribution. In addition, using this machine could reduce injection time compared to an alternative injection apparatus. Using this machine, the operator will no longer complain of back strain, as he will no longer be required to carry a water tank on his back, as in the current method. As a single-operator machine, the labour requirement is shallow. Additionally, the machine will reduce the number of workers needed. Therefore, it is highly suggested that the industry use this tractor-mounted trunk injector compared to other methods to control the spread of BSR disease in oil palm plantations by injecting *Hexaconazole* into the trunks.

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References

Abdul, R. J., Mohd, I., Aminulrashid, M., *et al.* (2018). Development and field evaluation of a tractor mounted oil palm trunk injector. *Journal of Oil Palm Research*, *30*(1): 101–110.

Arif, M. S., Roslan, A., Idris, A. S., *et al.* (2011). Economics of oil palm pests and Ganoderma disease and yield losses. In *Third International Seminar Integrated Oil Palm Pests and Management*., MPOB Bangi, Selangor, Malaysia, pp. 83–98.

Ariffin, D., Idris, A. S. (2002). Progress and research on Ganoderma basal stem rot of oil palm. In *Seminar Recent Progress in Management of Peat and Ganoderma*, Bangi, Selangor: MPOB, p. 50 pp.

Arifurrahman, R., Idris, A. S. (2008). In vitro evaluation of an effective fungicide against Ganoderma boninense, the causal agent of basal stem rot (BS). In *Oil Palm 7th International Conference on Plant Protection in the Tropic-Update on GAP in IPM*. Kuala Lumpur. p.1–4.

Assis, K., Chong, K. P., Idris, A. S., *et al.* (2016). Economic loss due to Ganoderma disease in oil palm. In *Proceeding of Indonesia Conference on Mathematics, Statistics and Scientific Computing*, Kuala Lumpur, p. 12.

Darus, A., Seman, I. A., Hassan, A. H. (1991). Histopathological studies on colonization of oil palm root by Ganoderma boninense. *Elaeis*, *3*(1): 289–293.

Gassner, A., Wong, W. C., Hong, H. W., *et al.* (2005). Assessment of the spatial and temporal proliferation of upper stem rot in oil palm plantation (*Elaeis guineensis*) in the Kudat Region, Sabah. In *Proceeding of the PIPOC 2005 International Palm Oil Congress Agriculture, Biotechnology and Sustainability Conference*. MPOB, Bangi. p. 1–4.

Hari, P., Susanto, A., Surianto. (2011). Physical barrier on the oil palm trunk: An approach to prevent upper stem rot disease caused by Ganoderma boninense. In *Proceeding of the PIPOC 2011 International Palm Oil Congress - Agriculture, Biotechnology and Sustainability Conference*. MPOB, Bangi. p. 79–83.

Idris, A. S. (2007). Managing the ganoderma basal stem rot in oil palm plantation through sanitation and fungicidal treatment. In *2007 Conference on Plantation Commodities*, Putra World Trade Centre, Kuala Lumpur (Malaysia), 3–4 Jul 2007, Malaysian Cocoa Board, p.

Idris, A. S., Ahmad, H., Ariffin, D., *et al.* (2002). Control of Ganoderma-infected palm development of pressure injection and field applications. *MPOB Information Series N131*.

Idris, A. S., Ariffin, D., Basri, M. W., *et al.* (2003). PCR Technique for detection of Ganoderma. *MPOB Information Series No. 188*.

Idris, A. S., Ahmad, H., Ariffin, D., *et al.* (2004). Prolonging the productive life of Ganoderma-infected palms with hexaconazole. *MPOB Information Series No. 214*.

Idris, A. S., Arifurrahman, R., Kushairi, A. (2009). An evaluation of hexaconazole for controlling Ganoderma basal stem rot of oil palm in the field as a preventive treatment. In *Proceeding of the PIPOC 2009 International Palm Oil Congress - Agriculture, Biotechnology and Sustainability Conference*. MPOB, Bangi. p. 1292–1300.

Idris, A. S., Nur Rashyeda, R., Mohd Hefni, R., *et al.* (2016). Standard operating procedures (SOP) guidelines for managing Ganoderma disease in oil palm. *Malaysian Palm Oil Board, Malaysia*, 1–7.

Ikmal, H., Razak, J., Rahim, S., *et al.* (2014). Tractor mounted trunk injector for control of basal stem rot (BSR) disease. *MPOB Information Series*, (546).

Malaysian Palm Oil Board (MPOB). (2023). The Malaysian Palm Oil Industry Performance 2022 and Prospects for 2023. In *Palm Oil Economic Review and Outlook Seminar 2023*, pp. 1–53.

Naher, L., Siddiquee, S., Yusuf, U. K., *et al.* (2015). Issues of Ganoderma spp. and basal stem rot disease management in oil palm. *American Journal of Agricultural Science, 2*(3): 103–107.

Nur-Rashyeda, R., Idris, A. S., Sundram, S., *et al.* (2022). A field evaluation on fungicides application o control upper stem rot (usr) disease in oil palm caused by *Ganoderma* spp. *Journal of Oil Palm Research*. https://doi.org/10.21894/jopr.2022.0037

Razak, J., Ahmad, H., Ramdhan, K., *et al.* (2004). Mechanical trunk injection for Ganoderma control. *MPOB Inf. Ser.*, (215).

Rakib, M., Bong, C., Khairulmazmi, A., *et al.* (2017). Ganoderma species of basal and upper stem rots in oil palm (Elaeis guineensis) in Sarawak, Malaysia. *Journal of Academia UiTM Negeri Sembilan*, 5(1): 27–35.

Roslan, A., Idris, A. S. (2012). Economic impact of Ganoderma incidence on Malaysian oil palm plantation–a case study in Johor. *Oil Palm Industry Economic Journal*, 12(1): 24–30.s

Shahinasi, E., Brahushi, F., Devolli, A., *et al.* (2017). The ecotoxicology of pesticides group of triazole and their use to control apple scab (Venturia inaequalis). *Journal of Hygienic Engineering and Design*, *634*(11): 36–42.

Turner, P. D., Gillbanks, R. A. (2003). Oil Palm Cultivation and Management.,(The Incorporated Society of Planters: Kuala Lumpur.).