**Running title: Formulating Cashew Nut Shell Liquid (CNSL) as a Smart Food Bait for *Iridomyrmex cordatus* Associated with *Phytophthora Pod Rot* Disease (*Phytophthora palmivora*)**

**Ahdin Gassa\*, Muhammad Junaid, Andi Nasruddin and Fatahuddin Fatahuddin**

*Cocoa Research Group, Faculty of Agriculture, Hasanuddin University, Makassar 90245, Indonesia*

\*For correspondence: agasahdin@yahoo.com

**Novelty statement**

The association between dynamic ant population of *Iridomyrmex cordatus* and pod rot disease incidence caused by *Phytophthora palmivora* according to the trails of CNSL formulated into food bait. There was a positive trend of CNSL concentration to reduce ant population of *I. cordatus*. 10% and 20% concentration had a significant sign of limiting ant population until fewer score of *I*. *cordatus* established*.*

**Abstract**

The research aimed to obtain the best concentration of *cashew nut shell oil* (CNSL) formulated as smart food bait to tackle ant population of *Iridomyrmex cordatus* due mainly to a vector of *Phytophthora pod rot*. The research was carried out in cocoa areas in South Sulawesi with randomized block design consisting of six treatments. Feeding trails consisted of food bait formulation was added 1% cashew husk (346.5 g food + 3.5 g flour cashew husk), 5% (332.5 g food + 17.5 g flour cashew husk), 10% (315 g food + 35 g flour cashew husk), 20% (280 g food + 70 g flour cashew husk), Carbaryl 85 SP (dosage recommended), and control. Each of trail was replicated five times and set near to petiole and ant tunnel nest. The research focused on number of ant colony established in the trees until food bait was given. Testing association of ant population and disease incidence was conducted with ANOVA test followed by 5% Turkey test. The results shown that the trail with CNSL concentration had a positive effect to ant population which was the higher concentration given, the lower ant population was obtained. Meanwhile, the population of *I. cordatus* had positive contribution to the increase of disease incidence of Phytophthora pod rot disease*.*Feeding trails with 1% and 5% CNSL concentrationwasless effective to limit ant population and disease incidence according to efficacy test.In contrast, the trails of 10% and 20% were able to control ant population density and disease incidence due to over 51.39% efficacy test.

**Keywords:** Feeding trails; food bait; CNSL; population of *Iridomyrmex cordatus*; *Phytophthora pod rot* disease

**Introduction**

*Iridomyrmex cordatus*, is one of ant-trees, has a considerable influence on food webs in agricultural ecosystem. The presence of *I. cordatus* in number of valuable agricultural commodities rises a controversy. As a successful predator or scavenger, in one hand, ant has a powerful and successful species in hunting and praying numerous animals and insects which are associated with crops and with its real time protection services in the field the farmers take advantages. On the other hand, the existence of ant population in commercial commodities such as cocoa rises numerous issues. One of problematic impacts is as the agent of *Phytophthora pod rot* disease (Gassa *et al*., 2016b). In PNG, *I. cordatus* contributed to fungal spread from crop to crop (Huxley, 1978).

 *Phytophthora* pod rot disease caused by *Phytophthora palmivora* is one of the mostdangerous global cocoa diseases and in Sulawesi the disease is more rampant with much greater impact than any kinds of biological cocoa pests and diseases (Guest, 2007; Marelli *et al*., 2019; Ploetz, 2016). Wet season is one of the main causes behind the disease prevalence since range of ripening time and peak harvest is almost rainy season. A wetter field triggers the cause of pod rot disease, *P*. *palmivora,* conveniently infecting the tree and pods (Pereira, 1992a). The disease incidence in wet season is much higher than dry season (McMahon & Purwantara, 2004; Pereira, 1992b). *P*. *palmivora* is typical soil born pathogen which originally occupies rhizosphere and it can form chlamydospore once extreme condition is faced. In the infection cycle, zoospore motile has an important role of infection process. Zoospore are released from sporangia helped by humidity or favour condition. Sporangia can be carried by wind speed to reach the host prior to infection process commencing. Group of insects is as potential agent to spread the pathogen such as termite and ant. Ant species of *Iridomyrmex cordatus* has convincingly evidenced to associate with pod rot disease and its pathogen in Sulawesi (Junaid *et al*., 2020). Thorold (1975) argued that the disease development caused by humidity level and group of insects underpinning infection process of pathogen using microbial decomposer needs to be considered for cocoa pathogens as well (Kuswinanti *et al*., 2019)

 Preliminary study was undertaken to show specific lesion occurrence once the body of *I*. *cordatus* was attached to fresh pod (Gassa *et al*., 2016b). The main reason behind of effectiveness of *Phytophthora pod rot* disease spread was due to tunnel nest of ant built from organic matters which is contaminated by spores, connecting niche and pathogen and providing inoculum sources of *Phytophthora pod rot* disease. The pathogen infects all stages of cocoa pod development and if attacked immature pod leading to *Cherelle* wilt (Acebo Guerrero *et al*., 2012).

 Excessive tunnel nests built in the tree and the presence of active worker ant population during foraging activity lead to ineffective controlled method with pesticide apply and therefore alternative method such as artificial poisonous food bait of ant was proposed to control agent of disease spread. The principle of method was that the colony of ant worker was expected to carry lethal bait to the main nest and then killed the colonies and the queen (Gassa *et al*., 2015a). It was evidenced that population of *I. Cordatus* has greatly contributed to the increase of disease incidence of pod rot disease. Once 200 colonies of ant reached to occupy cocoa tree, 9.3% *Phytophthora pod rot* disease increased per week (Gassa *et al*., 2016b).

 The association between *I. cordatus* and disease and cashew is still unknown and therefore this paper will reveal the significant role of cashew tree in plant protection environmentally friendly. Cashew (*Anacardium occidentale*) generates a shell consisting of outer endocarp, mesocarp and inner epicarp layers. The only inner epicarp layer like testa is necessary for nut industry since it produces nuts while cashew husk (endocarp and mesocarp layer) is generally seen as useless material value as agricultural waste. Shell has mesocarp with tremendous benefits for agricultural products such as natural pesticide (Kardinan, 2001). As spread *Phytophthora pod rot* disease in cocoa orchard this activity was focused to test the best effective concentration to control ant population in cocoa trees.

**Materials and Methods**

**Feeding trails for ant population:** Food baits for ant colonies consisted of shrimp paste. To make shrimp paste, composition of the mixture consisted of 0.25 (50 g shrimp flour): 1.0 (200 g coconut sugar): 0.5 (100 g flour). The mixture was added ± 10 mL condense milk as stimulator and active ingredient for anti-microorganism. Subsequently, all mixtures are poured into one medium and shaped of paste. The paste was separated and respectively added 1% of CNSL (346.5 g paste + 3.5 g cashew husk flour), 5% of CNSL (332.5 g paste + 17.5 g cashew husk flour), 10% of CNSL (315 g paste + 35 g cashew husk flour) and 20% of CNSL (280 g paste + 70 g cashew husk flour). Those paste mixtures was pelleted and incubated 40oC for approximately 30 minutes. However, prior to incubating the pellet, the paste made was some what soft texture.

**Trail design and efficacy test:** The trails were set with randomized block design which were placed into about 900 trees of cocoa surrounding with 1 Ha area. The tree was grouped into 3 plots for every trail with five replications. Testing effective food bait made from different concentration of CNSL and without CNSL (control) and 17.5 g Carbaryl 85 SP as a comparison was conducted. Observation of ant species was commenced once food bait was formulated following method of Gassa *et al.* (2014, 2015b, 2016a). Food bait mixture separately consisted of CNSL in different concentration level (1%; 5%; 10% and 20%), Carbaryl 85 SP (recommended use) and control (without CNSL and Carbaryl 85 SP) respectively. Every mixture was tested in the field and the trails were set to the tree with 5 replications was and mixed (Figure 1a). We focused on ant population density and development tunnel nest before and after trails given (Figure 1b and 1c). Also, Effect of the trails to disease incidence of *Phytophthora pod rot* was tested with ANOVA and post-Hoc test with 5% Turkey test. Finally, the diversity of ant population was estimated with following method of Khoo and Way (Tabel 1).

**Testing effect of feeding trails to disease incidence of *Phytophthora pod rot*:** The observation of ant colony was undertaken after feeding trail in different concentration including 1%, 5%, 10%and 20% CNSL, 85% of Carbaryl (insecticide) under recommended use and control (without CNSL and Carbaryl 85 SP). Ant colony was weekly observed with a focus on the presence of ant colony and tunnel nest on the tree. The observation also was intended to investigate the association of ant colony and disease incidence in different level disease category. Finally, *Phytophthora pod rot* disease was observed once ripe pods occurred. Mature pods were collected and separated from infected and healthy pods. Weigth of healthy pods was counted to obtain the average of bean weight estimation for every harvesting season. Disease incidence was categorized as follows Table 2.

**For disease incidence, the equation was counted as follows**

**I = ∑ [(n x v) / (N x V)] x 100 %**

**Information:**

**I = Disease incidence (%)**

**n = Number of infected tree to every damage level (pod lesion)**

**v = Score of every damage level**

**N = Number of observed pods**

**V = The highest scoring of pod lesion**

**Efficacy test**

Criteria of efficacy test was followed with disease incidence of *Phytophthora pod rot*. The test of efficacy level aimed to the main trails with different CNSL concentration as following;

TE = (ISK –ISP (ISK)-1 x 100%

Information;

 TE =efficacy level (%)

 ISK=Disease incidence of *Phytophthora pod rot* disease on the control (food bait without CNSL and Carbaryl 85 SP)

 ISP = Disease incidence of pod rot disease on the trails

The trails of food baits were effectively obtained from the test once TE value represented at least 50% and had significant sign to the control.

**Data Analysis**

All trails were examined with a simple and descriptive quantitative and the effect of trails to ant population density and disease incidence was tested separately with ANOVA and Turkey test.

**Results**

 The efficacy test of food bait trails formulated with CNSL and Carbaryl 85 SP in reducing ant population associated with the disease incidence in Luwu district was performed to Table 3. According to Table 3, the results demonstrated that no significant sign of the effect of food bait trails formulated with CNSL and Carbaryl 85 SP against the ant population density in the field at the beginning observation. However, after second to the end observation, the trail of 20% cashew husk shown to have a greatest consistent effect to control the density of ant population. For the trail of 10% cashew husk, the effect commenced to show in the fourth observation. It has evidenced that in the 10% and 20% concentration, the average of ant population with score 1.00-1.75 was much fewer than the trails of 1% and 5% concertation of cashew husk formulated into food bait. The trails of 1% and 5% concentration have had much less effective effect to manage ant population in the cocoa orchard. For instance, the average of ant population to those trails still shown to have abundant population.

 Statistically, a simple linear regression analysis (Table 4) demonstrated that there is an association between the trails of CNSL concentration and dynamic ant population of *I*. *cordatus*. The finding suggested that there is a positive trend obtained from the effect of level concentration of CNSL (X) towards dynamic population of ant (Y). Also, based on association values, the ant population underwent to drop incrementally by the times. The findings suggest that the concentration level of CNSL has significantly affected to control dynamic population of *I*. *cordatus,* which was occupying cocoa orchard, and once it was controlled, it is expected to have impact of reducing *Phytophthora pod rot* disease as well. The association of ant population and cocoa disease incidence is described Table 5. In this Table 5, it can be predicted upcoming incidence of pod rot disease in the cocoa field that *I*. *cordatus* will be undermining population score and then development of pod rot disease incidence will incrementally drop once the observation is still undertaken.

 The association between dynamic ant population of *I. cordatus* and pod rot disease incidence caused by *Phytophthora palmivora* according to the trails of CNSL formulated into food bait and 17.5 g Carbaryl 85 SP is shown in Table 5.

 The results demonstrated that, similar the control, the only trail of 1% CNSL concentration was insignificant effect of limiting *Phytophthora pod rot* disease for entire observation. From first to fourth observation, almost all trails shown to have similar effect of the control, but after fifth week observation, the significant sign of almost all trails was contrast to the control. The trails of 10% and 20% CNSL concentration demonstrated to have much more consistent to decrease *Phytophthora pod rot* disease than any other trails. In general, progressive pod disease incidence was much slower development from 3% to 6% in the trail 20% CNSL and from 4% to 8% of disease incidence development in the trail 10% CNSL respectively. The highest disease incidence was in control behind the trail of 1% CNSL concentration. Likewise, association of ant population and disease incidence is clear. The trend shows that the increase of ant population subsequently affects to rise disease incidence (Table 6).

 In terms of efficacy test of food bait formulated with CNSL consisting of anacardate acid towards *I. cordatus* as a vector for *Phytophthora pod rot* disease was performed Table 7. Table 7 shows that the only 10% and 20% CNSL trails performed over 50% efficacy test level which is effective concentration to limit ant colony in the field. Meanwhile, 1% and 5% CNSL, 17.5 g carbaryl 85 SP and control are alike to show less effective for ant colony limitation according to statistical efficacy test which is shown to have much fewer level.

**Discussion**

The results demonstrated to have significant sign of CNSL trails (food bait with CNSL formulation) especially 10% and 20% concentration of CNSL against ant population and cocoa pod disease incidence. A successfulness to control the agent and the cause of *Phytophthora pod rot* disease is because of robust phenolic compounds contained from the husk of cashew. 30% of mesocarp of cashew husk is *Cashew Nut Shell Liquid* (Lilia *et al*., 1991). Cashew liquid, is one of many sources of robust natural phenolic compounds, has a potential natural pesticide to be developed. Ohler (1966), Kubo and Kim (1987) suggested that due mainly to 80% anacardate acid, CNSL can be used as insect repellent. Not just insect repellent as a role, antibacterial and antifungal are another role of the substances of *Cashew Nut Shell Liquid* since it consists of anacardate acid aiming to break pathway of *prostaglandin synthetase* (Kardinan, 2001). This enzyme has a vital role for prostaglandin development to support physiological and reproductive systems of insects.

 Likewise, the trail of 17.5 g Carbaryl 85 SP also performed a significant sign with fewer ant population than concentration 1% of CNSL and the control. The score average of ant population density was about 2.25 but it seemed to have a much higher than trials of 10% and 20% concentration. In this trail, the ant population was found to have somewhat density with about 200 ant population density by commencing development of tunnel nest. The finding indicated that the trail of 7.5 g Carbaryl 85 SP seemed to have less effective to reduceant population. It is assumed that the strong smelly odor may lead to repellent of the colonies.

 The cause of *Phytophthora pod rot* disease can survive in the rhizosphere and mixed with organic matters so that with foraging activity of ant colony the inoculum is accidently taken leading to risk a high infectious cycle. Pereira (1992a) stated that root and organic matters are a primary infective inoculum when initial rain occurs and then infected pod on the canopy are seconder inoculum which is directly impact to loss of yield. It is statistically seen that there is a greatest correlation of foraging activity to carry pathogen of *Phytophthora pod rot* disease. The score of ant colony tends to increase to the maximum population while disease incidence of *Phytophthora pod rot* is subsequently high by the times of observation from 0.05 to 3.86 with near 1.00 value of coefficient correlation.

**Conclusion**

There was a positive trend of CNSL concentration to reduce ant population of *I. cordatus*. 10% and 20% concentration had a significant sign of limiting ant population until fewer score of *I*. *cordatus* established*.* There was the greatest association between the increase of ant population density and the increase of disease incidence of *Phytophthora pod rot.* Due to testing efficacy fewer than 50%, feeding trails of 1% and 5% CNSL concentration and 17.5 g Carbaryl 58 SP were ineffective to limit disease incidence. In contrast, feeding trails of 10 % and 20% concentration shown to have over 50% of efficacy test.

**Suggestion**

Prior to being disseminated feeding trails of food bait formulated with CNSL in farmer level in order to manage ant population carrying inoculum source of *Phytophthora pod rot* disease caused by *P*. *palmivora*, the need of continue this research is highly recommended. Once complete dataset obtained from the intensive research, the knowledge of farmers to control *Phytophthora pod rot* disease carried by specific ant is expectedly high.

**Acknowledgements**

We would like to thank the Ministry of Research and Technology and Higher Education (Kemenristekdikti) of Indonesia for the research funding in the fiscal year of 2019 under the skim **Unggulan Perguruan Tinggi.**

**References**

Acebo-Guerrero Y., A. Hernandez-Rodriguez, M. Heydrich-Perez, M. El Jaziri, AN. Hernandez- Lauzardo, 2012. Management of black pod rot in cacao (*Theobroma cacao* L.). A Review Fruits, 67:41–48. DOI: http:// dx.doi.org/10.1051/fruits/2011065.

Gassa, A., T. Abdullah, Fatahuddin, M. Junaid, 2014. Formulation of artificial diet to increase population distribution and aggressive behavior of Weaver Ant (*Oecophylla Smaragdina* F.) for controlling Cocoa Pod Borer (*Conopomorpha Cramerella* Sn. Journal Academic Research International (ARInt), Vol.5 No.1: 1-10

Gassa, A. And M. Junaid, 2015a. Coconut ant control *(Iridomyrmex spp.)(Hymenoptera: Formicidae)* as vector Fungus Rotten Fruit Cocoa *(phytophthora spp.)* with some type insecticide is provided in the form feed. Journal of Chemical and Pharmeceutical Research, 7(4): 30-34

Gassa, A., T. Abdullah, Fatahuddin, M. Junaid, 2015b. The use of several types of artificial diet to increase population and aggressive behavior of Weaver Ants (*Oecophylla Smaragdina F*.) in reducing Cocoa Pod Borer infestation (*Conopomorpha Cramerella* Sn.). Journal Academic Research International (ARInt), Vol.6 No.1: 63-72

Gassa, A., Fatahuddin, T. Abdullah, M. Junaid, 2016a. Black Ant (*Dolichoderus thoracicus*): Artificial diet and nest prospects in controlling Cocoa Pod Borer (*Conopomorpha cramerella* Sn.). Research Journal of Pharmaceutical, Biological and Chemical Sciences, Vol. 7(4): 3185-3191

Gassa, A., S. Mulia, Yumarto, M. Junaid, 2016b. Phythophthora black pod disease of cocoa caused by *Phytophthora palmivora*: Development of bio-fungicidal package in controlling the disease and the vector by food bait. Journal of Chemical and Pharmaceutical Research, Publisher Elsevier, Vol. 8(6): 129-135

Guest, D., 2007. Black pod: Diverse pathogens with a global impact on cocoa yield. *Phytopathology, 97*(12), 1650-1653. DOI:10.1094/PHYTO-97-12-1650

Huxley, C. R., 1978. The ant-plants myrmecodia and hydnophytum (rubiaceae), and the relationships between their morphology, ant occupants, physiology and ecology. *New Phytologist, 80*(1), 231-268. DOI:10.1111/j.1469-8137.1978.tb02285.x

Junaid, M., Gassa, A., Rosmana, A., Baker, S., 2020. First report of Phytophthora black pod disease of cocoa spread by *Iridomyrmex cordatus* in Sulawesi: A dilemma about predatory insect for cocoa pest control. IOP Food Security and Sustainable Agriculture and in the Tropics, Makassar 2019. (*In Press*)

Kardianan, A., 2001. Pestisida Nabati Ramuan dan Aplikasi, PT Penebar Swadaya. Jakarta.

Khoo, K.C. and M.J. Way, 1991. Colony dispersion and nesting habits of the ants, *Dolichoderusthoracicus*and *Oecophylla smaragdina* in relation to their success as biological control agents on cocoa. Bulletin of Entomological Research, 81: 341 – 350

Kubo, I. and M. Kim. 1987. Prostaglandin Synthetase Inhibitors. Anew Approach for Insect Control. In Biologically Active Natural Product.Eds. Hostettman and P.J. Lea. Clarendron Press. Oxford: 185-194

Kuswinanti, T., M. Junaid, Melina, U. Surapati and Ratnawaty, 2019. A promising microbial use on cocoa: decomposing cocoa waste and controlling *Lasiodiplodia theobromae* in-vitro. *IOP Conference Series: Earth and Environmental Science, 343*, 012256. doi:10.1088/1755-1315/343/1/012256

Lilia, S.P.M., R.O. Quimaldo, M.E. Flaveier and M.S. Villau, 1991. Studies on Cashew (*Anacardium occidentale*) Nut Oil. The Philipine Agriculturist, 74(4), Oct-Dec: 511

Marelli, J.-P., D.I. Guest, B.A. Bailey, H.C. Evans, J.K. Brown, M. Junaid, A.S. Puig, 2019. Chocolate under threat from old and new cacao diseases. Phytopathology,109(8): 1331-1343. doi:10.1094/phyto-12-18-0477-rvw

McMahon, P. and Purwantara, A. (2004). Major crops affected by Phytophthora: Phytophthora on Cocoa. In A. Drenth & D. Guest (Eds.), *Diversity and management of Phytophthora in Southeast Asia* (pp. 104-114). Australian Centre for International Agricultural Research, Canberra: BPA Print Group Pty Ltd, Melbourne, Australia.

Pereira, J. L. (1992a). Cocoa and Its pathogens in the Region of Origin: A Continued Risk. Paper presented at the FAO Plant Production and Protection, Rome.

Pereira, J. L., 1992b. Cocoa and its pathogens in the region of origin: A Continued Risk. Paper presented at the Cocoa Pest and Disease Management in Southeast Asia and Australasia, Rome.

Ploetz, R., 2016. The impact of diseases on cacao production: Aglobal Overview. In A. B. Bailey & W. L. Meinhardt (Eds.), Cacao Diseases: A History of Old Enemies and New Encounter*s* (pp. 307-335). Cham: Springer International Publishing.

Rosmana, A., C. Waniada, M. Junaid, and A. Gassa, 2010. Peranan semut *Iridomyrmex cordatus* dalam menularkan pathogen busuk buah *Phytophthora palmivora.* Pelita Perkebunan, Vol.6 No.3: 169-176

Thorold, C. A. 1975. Disease of Cocoa. Clarendon Press, Oxford. 423 p.



**Figure 1**. (Red arrowhead) (a) Trail of food bait formulated with CNSL was placed to near pod petiole occupied by *I*. *cordatus* colony, (b) tunnel nest of *I*. *cordatus* established in infected pod and (c) tunnel nest was empty and damaged.

**Tabel 1**. Scoring ant population density (Khoo and Way, 1991)

|  |  |  |
| --- | --- | --- |
| Scoring | Category | Ant population on the cocoa tree |
| 1 | Fewer | < 50 ant population seen occupied in the branch, stem but no tunnel nest development |
| 2 | Mild | Up to 200 ant population density and commencing development of tunnel nest |
| 3 | Many | 200-500 ant population density in the stem and branch and tunnel nest built |
| 4 | Abundant | >500 ant population density occupied the tree and numerous tunnel nest linkage built |

**Table 2**. Score of pod damage

|  |  |  |
| --- | --- | --- |
| **Score** | **Damage level** | **Lesion percentage on pod (%)** |
| **0** | **No lesion** | **0** |
| **1** | **Pod lesion** | **>0-25** |
| **2** | **Pod lesion** | **>25-50** |
| **3** | **Pod lesion** | **>50-75** |
| **4** | **Pod lesion**  | **>75** |

**Tabel 3**. Performance of population of *I. cordatus* in different CNSL concentration level

|  |  |
| --- | --- |
| Trails | Scoring average of *I.Cordatus* / Observation (week) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Cashew husk 1 % | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 3.50 ab |
| Cashew husk 5 % | 4.00 a | 3.75 ab | 3.75 a | 3.75 ab | 3.75 a | 3.75 a | 3.75 a | 3.75 a | 3.25 ab | 3.00 ab | 2.75 bc |
| Cashew husk10 % | 3.75 a | 3.50 ab | 3.25 ab | 3.25 b | 2.75 b | 2.75 b | 2.50 b | 2.25 bc | 2.25 c | 2.00 bc | 1.75 cd |
| Cashew husk 20 % | 3.75 a | 3.00 b | 2.50 b | 2.25 c | 2.00 c | 2.00 c | 1.50 c | 1.50 c | 1.25 d | 1.25 c | 1.00 d |
| Carbaryl 17.5 g | 3.75 a | 3.50 ab | 3.50 a | 3.25 b | 3.00 b | 3.00 b | 2.75 b | 2.75 b | 2.75 bc | 2.5 b | 2.25 c |
| Control | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a | 4.00 a |
| BNJ Value | 0,799 | 0,889 | 0,93897 | 0,72732 | 0,899 | 0,68573 | 0,96977 | 0,86569 | 0,93897 | 102,142 | 120,613 |

Information: numbers in the same column followed by same alphabets indicates insignificant according to DMRT test(p > 0.05).

**Table 4**. A simple regression analysis explained the association between the trails and dynamic population of *I*. *cordatus* by the times

|  |  |  |  |
| --- | --- | --- | --- |
| Observation (week) | Linear equation  | r = correlation coefficient  | Trend of Y value  |
| 1 | *Y* = 4.0008 - 0.0146*X* | r = -0.3559 | 3.99 |
| 2 | *Y* = 4.0179 - 0.0511*X* | r = -0.7835 | 3.92 |
| 3 | *Y* = 4.2094 - 0.0777*X* | r = -0.8469 | 3.98 |
| 4 | *Y* = 4.0958 - 0.0897*X* | r = -0.8862 | 3.73 |
| 5 | *Y* = 4.1010 - 0.1043*X* | r = -0.8940 | 3.58 |
| 6 | *Y* = 4.0704 - 0.1070*X* | r = -0.9277 | 3.43 |
| 7 | *Y* = 4.1119 - 0.1336*X* | r = -0.9192 | 3.18 |
| 8 | *Y* = 4.0806 - 0.1362*X* | r = -0.9123 | 2.99 |
| 9 | *Y* = 3.9875 - 0.1441*X* | r = -0.9425 | 2.68 |
| 10 | *Y*  = 3.8875 - 0.1446*X* | r = -0.9173 | 2.43 |
| 11 | *Y* = 3.6375 - 0.1456*X* | r = -0.8864 | 1.99 |

Information: Trend of Y value is resulted from linier equation and observation time (X) indicating the higher value of ant colony, the higher disease incidence of *Phytophthora pod rot* disease.

**Table 5.** The association between ant population of*I.cordatus* and pod rot disease incidence caused by *P. palmivora* regarding the trails of different CNSL concentration and Carbaryl 85 SP

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Perlakuan | 6 | 7 | 8 | 9 | 10 | 11 |
| Kulit Mete 1 % | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a | 3.50ab |
| Kulit Mete 5 % | 3.75a | 3.75a | 3.75a | 3.25ab | 3.00ab | 2.75bc |
| Kulit Mete 10 % | 2.75b | 2.50b | 2.25bc | 2.25c | 2.00bc | 1.75cd |
| Kulit Mete 20 % | 2.00c | 1.50c | 1.50c | 1.25d | 1.25c | 1.00d |
| Karbaril 17,5g | 3.00b | 2.75b | 2.75b | 2.75bc | 2.5b | 2.25c |
| Kontrol | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a |

|  |  |
| --- | --- |
| Trails | Scoring average of disease incidence / Observation (week) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Cashew husk 1 % | 0.75 a | 1.75 a | 2.25 a | 3.75 a | 6.50 ab | 9.50 ab | 13.25 ab | 14.25 ab | 14.75 ab | 15.75 ab | 16.75 ab |
| Cashew husk 5 % | 1.50 a | 2.25 a | 2.75 a | 4.00 a | 5.25 abc | 7.75 bc | 11.00 abc | 12.00 bc | 12.25 bc | 12.75 b | 13.75 b |
| Cashew husk10 % | 1.25 a | 2.50 a | 2.75 a | 3.50 a | 4.00 bc | 5.75 cd | 6.75 cd | 7.50 de | 8.00 cd | 8.25 c | 8.75 c |
|  Cashew husk 20% | 1.00 a | 1.00 a | 1.75 a | 2.50 a | 3.00 c | 4.00 d | 4.50 d | 5.25 e | 5.50 e | 5.75 c | 6.00 c |
| Carbaryl 17.5 g | 1.00 a | 2.00 a | 3.00 a | 3.75 a | 5.25 abc | 7.00b cd | 8.25b cd | 10.75 cd | 11.00 bc | 12.50 b | 13.25 b |
| Control | 0.75 a | 1.25 a | 2.25 a | 4.50 a | 7.50 a | 11.50 a | 15.50 a | 17.00 a | 17.50 a | 17.50 a | 18.00 a |
| BNJ Value | 1,88964 | 2,20542 | 3,17728 | 2,91938 | 3,0666 | 3,17959 | 4,14816 | 4,44402 | 4,86697 | 4,17816 | 3,91676 |

Information: numbers in the same column followed by same alphabet indicates insignificant according to DMRT test(p > 0.05).

**Table 6**. A simple regression analysis explains the association between dynamic ant population by the times and pod rot disease incidence caused by *P*. *palmivora*

|  |  |  |  |
| --- | --- | --- | --- |
| Observation (week) | Linear equation  | r = correlation coefficient  |  Trend of Y value |
| 1 | Y = 0.8316 + 0.056X | r = 0.0191 | 0.89 |
| 2 | Y = 0.7473 + 0.2747X | r = 0.1076 | 1.29 |
| 3 | Y = 0.6 + 0.5X | r = 0.2299 | 2.10 |
| 4 | Y = 0.7672 + 0.8356X | r = 0.4999 | 4.12 |
| 5 | Y = -0.5636 + 1.7354X | r = 0.7414 | 8.12 |
| 6 | Y = -1.7816 + 2.8732X | r = 0.8349 | 15.44 |
| 7 | Y = -1.4456 + 3.7605X | r = 0.8768 | 24.88 |
| 8 | Y = -0.7939 + 3.8529X | r = 0.9101 | 30.01 |
| 9 | Y = 0.3707 + 3.7896X | r = 0.8973 | 34.39 |
| 10 | Y = 1.0169 + 3.8362X | r = 0.9329 | 39.01 |
| 11 | Y = 2.4931 + 3.8681X | r = 0.9220 | 44.95 |

Information: Trend ofY value is resulted from linier equation and observation time (X) indicating the higher value of ant colony, the higher disease incidence of *Phytophthora pod rot* disease.

Table 7**.** Efficacy test level of cashew husk (CNSL) toward*I. cordatus*and disease incidence of *Phytophthora pod rot* disease

|  |  |  |
| --- | --- | --- |
| No. | Trail | Efficacy Test Level (%) |
| 1. | Control | 0.00\* |
| 2. | CNSL 1 % | 6.94\* |
| 3. | CNSL 5 % | 23.61\* |
| 4. | CNSL 10% | 51.39 |
| 5. | CNSL 20% | 66.67 |
| 6. | Carbaryl 17.5 g | 26.39\* |

Information: \*) ineffective level efficacy of trails if fewer than 50% efficacy test level