Integrated Crop Management to Minimize Scab Disease and Tuber Borer on Sweet Potato in Tidal land

Sumartini* and Yusmani Prayogo

Indonesian Legumes and Tuber Crops Research Institute, Jalan Raya Kendalpayak KM 8, Pakisaji Distric, Malang, East Java, Indonesia.

*Corresponding author: sumartiniputut@yahoo.co.id

Abstract. Tidal land in South Kalimantan is quite extensive and very suitable for development of sweet potato commodity. The main obstacle to increase the production of sweetpotato in tidal land is the presence of scab disease (Sphaceloma batatas) and tuber borer (Cylas formicarius). The aim of research was to integrate crop management to decreased scab disease and the tuber borer in tidal land. The research was conducted in Rohan Raya Village, Wanaraya Distric, Barito Koala, South Kalimantan, from March to July 2019. The treatments were plowed and harrowed land, dolomite and organic fertilizer, wedding frequency, mulch width, application of Beauveria bassiana entomopathogenic fungi, and shallot extract. The result showed that the tidal land was endemic to scab disease and tuber borer. By using crop management was able to suppress scab disease and tuber borer compared to conventional systems. Conventional technology was unable to prevent both. Besides, local variety was more susceptible to them than superior variety, Sari in addition, it had high productivity. The yield of Sari with crop management can reached up to 24,15 t ha⁻¹. When sweet potato priced was Rp 3,500 kg⁻¹, the income Rp 84,525,000 ha⁻¹, and the production cost was Rp 23,950,000. So, the B/C ratio was 2.5. Therefore, crop management can be used as an innovation technology. This technology was feasible to be developed and recommended to overcome the constrain of major pest and disease of sweet potato in tidal land South Kalimantan and in other tidal land in Indonesia.

1. Introduction

In Indonesia, the tidal land is large enough, it was reached up to 33 million ha. The wide swamp area is around 13.2 million hectares spread across Sumatera (2.77 million ha), Kalimantan (3.5 million ha), Sulawesi (0.61 million ha) and Papua (6.3 million ha), only about 5% of this area is used intensively cultivated for agriculture, especially food crops [1,2]. Swamp land in South Kalimantan is about 208,893 ha which is divided into three groups, namely organic soil (peat), river sediment mineral soil (embankment), and marin sediment mineral soil, and around 37% of this area has been utilized for agriculture [3,4,5,6]. which is potential land for the development of cassava and sweet potatoes. However, the use of these land was various obstacles, namely in the form of physico-chemical land. According to [7] these obstacles are in the form of water puddle, physical condition of the land, high soil acidity, the presence of toxic substances (Al, Fe and H₂S), saltwater intrusion and low soil fertility.

Cassava and sweet potato are widely cultivated in tidal land of South Kalimantan, is which widely used for farming is type C and D. According to [8], the productivity of cassava and sweet potato in tidal land is still low so it can be improved through land management, both physically, biologically and chemically. Sweet potatoes developed by the local community are local variety having superior taste. However, the tuber is highly susceptible to the bore attacked by Cylas formicarius and scab disease caused by the fungus, Sphaceloma batatas. Tubers that have been bored by C. formicarius are unfit for consumption since the insect pests change the taste of the tubers becomes bitter. The yield
loss reaches up to 100% [9,10]. Meanwhile, the damage caused by scab is also utterly large because all plant organs have spots, especially the shoots of the plants resulting disruption of the photosynthesis process and the tuber formation process [11,12, 13, 14].

The main pest management technologies available for sweet potatoes rely solely on the application of chemical pesticides, but the attack of tuber borer pests and scab disease in the field continues to increase and difficult to control. [15] indicated that the addition of mulch could reduce the yield loss of sweet potatoes caused by *C. formicarius* tuber pests. During the dry season when many tubers are exposed due to ground surface breaks, making it easier for *C. formicarius* laying eggs on the surface of the tuber. By adding mulch to the beds, widening and heighten the beds, and soaking the soil, the tubers that are formed will be protected from *C. formicarius* imago [16,17, 18, 19]. In addition, tuber borer can also be controlled using entomopathogenic fungus *Beauveria bassiana* [20]. The efficacy of *B. bassiana* fungus is characterized by the ability of the fungus to kill at all stages of insect pests [21,22].

[23] reported that scab disease caused by *S. batatas* can be controlled using various types of natural pesticides including shallot or onion extract. The metabolite compounds produced by shallot are fungicidal so that they can kill fungus spores which eventually the development of the disease can be inhibited [24,25]. Judging from the efficacy of the various components of the technology mentioned above, there is a great opportunity to reduce the occurrence of pests and diseases to prevent the sweet potatoes yield loss in tidal land. The purpose of this research was to study crop management in suppressing the occurrence of tuber borer and scab disease in sweet potatoes on tidal land.

2. Methodology

Research was conducted in Rohan Raya Village, Wanaraya Subdistrict, Barito Kuala Regency, South Kalimantan, in March to July 2019. This study compared two technologies namely innovation technology and existing technology, with consist of various components. Innovation technology is crop management that consists of technology components that are assembled based on the results of research activities four years previously. Assembled components of crop management technology include; the use of superior varieties, dolomite, land cover using straw mulch, addition of the width and height of the beds, increasing the dose of organic and inorganic fertilizers, and controlling tuber borer using entomopathogenic fungus *Beauveria bassiana* and scab disease using natural pesticides from shallots extract (Table 1). Existing technology consists of various components which are almost the same as innovation technology components. A striking difference in existing technology is that land is not covered by mulch, pest and disease control does not use chemical pesticides, in addition to increasing doses of fertilizer and dolomite. Each technology uses 0.1 ha of land and five times replication, so the total land used is 1 ha.

2.1. Research implementation

Tidal land used is C type which was planted with oil palm aged three years previously. The sweet potatoes were planted between oil palm. At first, land was cultivated by plowing twice (existing) and then it was harrowed until became loose (innovation). Land was given dolomite 1 t ha$^{-1}$ (existing) and 2 t ha$^{-1}$ (innovation) mixed with organic fertilizer (manure) respectively 2 t ha$^{-1}$ (existing) and 3 t ha$^{-1}$ (innovation). Inorganic fertilizers as much as 200 kg ha$^{-1}$ (existing) and 400 kg (innovation) are given in accordance with a predetermined time. Raised bed formed with a height of 40 cm and a width of 100 cm (existing), for technological innovation 60 cm high bed and 150 cm wide bed. In technological innovation, the bed then covered with mulch straw as much as 2 t ha$^{-1}$ which spread throughout the entire beds.

The sweet potato varieties used were local and Sari (national variety). Local variety was obtained from Barito Kuala while Sari varieties were obtained from Indonesian of Legumes and Tuber Crops Institute (ILETRI). Each stem cuttings from the two varieties before planting were immersed in a chemical insecticide carbofuran (existing) and a suspension of conidia *B. bassiana* (innovation) for one hour. Application of the chemical insecticide deltamethrin and *B. bassiana* was continued at 30, 45, 60 and 75 days after planting (dap). Meanwhile, disease control using benomyl chemical fungicide (existing) and shallot extract (innovation) was carried out at the age of 35, 42, 49 and 53 dap. Weeding on existing technology and innovation is carried out twice at the age of 15 and 45 dap, at the
time of the second weeding is also carried out the reversal of the stem so that the bulbs formed are large.

| No. | Technology Component | Crop management | Innovation |
|-----|----------------------|----------------|------------|
| 1.  | Land                 | Plow 2x        | Plow 2x, harrow 2x |
| 2.  | Variety              | Local & Sari   | Local & Sari |
| 3.  | Dolomite             | 1 t/ha         | 2 t/ha (mixing with compost) |
| 4.  | Mulch                | -              | 2 t/ha |
| 5.  | Bed                  | L 100 cm, H 40 cm | L 150 cm, H 60 cm |
| 6.  | Organic fertilizer   | 2 t/ha         | 3 t/ha (mixing with Dolomite) |
| 7.  | An organic fertilizer| Phonska 200 kg (plant hole) | Phonska 400 kg (rows) |
| 8.  | Weeding              | 2x (15 and 45dap) | 2x (15 and 45 dap) |
| 9.  | Pest management      | Insecticide:   | *Pest |
|     |                      | * Carbofuran (at planting time) | B. bassiana (Bb) |
|     |                      | * Deltametrin (30, 45, 60, 75 dap) | Soaking of stem cutting into Bb |
|     |                      |                | suspension before planting |
|     |                      |                | followed by application at. 30, 45, 60, 75 dap |
|     |                      | *Disease       | Boenomy: (35, 42, 49, 53 dap) |
|     |                      |                | Soaking the stem cutting into SE |
|     |                      |                | (35, 42, 49, 53 dap) |
| 10. | Harvest time         | 120 dap        | 120 dap |

dap = days after planting, SE = shallot extract

Table 1: Sweet potato production in tidal land with existing and innovation technology component

2.2. Observation

Observed parameters such as (1) The intensity of the scab disease measured by the severity of the disease (disease severity) is by observing the area of the plant that affected by scab at the terminal end of the plant along the 50 cm. Scoring observations were carried out at 60 and 90 dap plant age. Scoring severity of disease by using categories 0-5 as developed by [11], which is as follows; 0 = symptom-free plant, 1 = <5 scab patches every 10 cm of stems and leaf stems (no change in leaf shape), 2 = 5-50 scab spots per 10 cm of stems and leaf stems (patches on leaf bones caused slight changes in the shape of the leaves), 3 = there are >50 scab patches every 10 cm of stems and leaf stems (the leaves undergo a deformation), 4 = scab spots fill almost most of the stems and leaf stems (leaves change shape), and 5 = dead leaves (the tip of the plant changes shape and the meristem tissue dies). (2) The number of eggs of *C. formicarius* pest was observed by counting the eggs placed by the *C. formicarius* imago at the base of the tuber using stereo microscope. The number of tubers observed was 20 from 20 sample plants. (3) The number of *C. formicarius* larvae found in the tubers by splitting the tubers which are crushed by *C. formicarius* larvae from every 20 tubers in 20 sample plants. (4) Intensity of tuber borer attacked was taken from 20 sample plants, each tuber infected by *C. formicarius* sample is measured the level of tuber damage. (5) Tuber weight (t ha⁻¹) is tuber yield on 20 m² area.

3. RESULTS AND DISCUSSION

3.1. The intensity of scab disease

Scab disease caused by *S. batatas* is classified as endemic pathogens that develop in local variety planted by farmers throughout the season. The results showed that the intensity of scab disease ranged from 0.70 to 33.20% (Figure 1).
The lowest intensity of scab disease occurred in Sari variety that was applied using chemical fungicides (0.70%), while the highest intensity of scab disease occurred in local variety that was controlled using chemical fungicides which reached 33.20% (existing). The intensity of scab disease in local variety on technological innovation by soaking of stem cuttings in shallot extract before planting continued application in plants aged 35, 42, 49, and 53 dap appeared to be lower at around 14.70% and the intensity of scab disease in Sari variety only 1.70%. Local variety is indicated to be more susceptible to scab despite control measures using chemical fungicides containing active benomyl (existing) at ages 35, 42, 49, and 53 (dap).

Sari variety appeared to be more tolerant to \textit{S. batatas} fungal infections than local variety. This condition was significant from the consistency of symptoms of scab attack only ranging from 0.70 to 1.70% which occurred in all plots that use Sari varieties. Meanwhile, symptoms of damage to scab disease in local variety, both those applied using chemical fungicides (existing) and through crop management (innovation) appeared to be higher ranging from 14.70 to 33.20%. The results of this study indicate that the control of scab disease in endemic land on tidal land can be done through crop management and the application of natural pesticides such as shallot extract (SE). The SE application started from soaking the cuttings for one hour before planted followed by the application on the plant surface at the age of 35, 42, 49, and 53 dap.

The efficacy of natural fungicides SE (innovation) was higher in controlling scab disease in local variety compared to chemical fungicides with active benomyl (existing). However, the control of scab by using SE with Sari variety found to be better, although not significantly different. [26]'s results indicate that plant-based pesticides from SE were quite effective in suppressing the development of scab disease caused by \textit{S. batatas} fungi. The efficacy of SE as a natural pesticide because it contains various metabolites in the form of flavonoids, quercetin, ascalin, furostanol, and saponin which are toxic in inhibiting the growth of hyphae of various types of fungi that cause plant diseases [27]. Furthermore, [27] explained that saponins from SE contain spirostanol and furostanol which play an important role in killing fungal hyphae.

### 3.2. Intensity of \textit{C. formicarius} pests

The intensity of tuber borer infestation was observed from the percentage of tubers \textit{C. formicarius} larvae at harvest time. The intensity of tuber damage ranged from 0.70-27.60% (Figure 2). The level of damage to the tuber from the host area due to \textit{C. formicarius} larvae in the Sari variety appeared to be lower, both controlled using chemical insecticides (existing) and technological innovation.
Meanwhile, the symptoms of tuber damage in local varieties appear to be much higher when compared to Sari varieties, both chemical control and technological innovation. The results of this study indicated that differences in planted varieties and control technology had a significant effect in overcoming endemic land conditions of *C. formicarius*. The success of tuber borer control was in having a superior variety, Sari. While the control in innovation technology consisted of land manipulation including; addition of the width and height of the beds, closing the beds using mulch in the form of straw and application of entomopathogenic fungus *B. bassiana*.

Figure 2: The sweet potato tubers damage due to *C. formicarius* in local and Sari varieties with existing and innovation management.

Beds as a medium for the formation of tubers is quite influential on the safety of tubers from *C. formicarius* larvae. The higher and wider the ridge the tuber formed will be more hidden in the beds so it will make it difficult for *C. formicarius* imago to lay their eggs at the base of the stem near the formation of the tuber. Therefore, some researchers advised for the base of the stem with the aim of the tubers being covered by soil so that the adult insect will find it difficult to lay eggs [28,29,30]. Meanwhile, the activity of the cultivation in the practice of sweet potato cultivation is highly expected because it aims to increase the height and width of the beds in order to protect the tubers that are formed so that it will hinder the process of laying eggs of *C. formicarius* tubers adult [31].

The technique to protect tubers from *C. formicarius* pests can also be done by covering the soil surface, especially at the base of the stem forming the tuber. This cultivation practice can be done by applying mulch to coat the base of the stem near the formation of the tubers. The function of this cultivation practice will make it difficult for oagopositor adult of *C. formicarius* in the process of laying their eggs due to obstruction from mulch exposure. [30] indicated that applying mulch to the base of the stem can save the tubers from the larvae of *C. formicarius*. Meanwhile, [32] explained that mulching at the age of 60 dap was able to save tubers suitable for consumption up to 80%.

The efficacy of controlling tuber borer, *C. formicarius* on innovation technology is also largely determined by the efficacy of *B. bassiana* entomopathogenic fungus applied to sweet potato cuttings by immersion before planting. In addition, the efficacy of *B. bassiana* fungus was applied at the age of 30, 45, 60, and 75 dap through the base of the stem near the location of the tuber formation. Furthermore, the structure of the insect population in the base of the trunk has a high chance of being infected by the fungus *B. bassiana*. This condition can occur because the fungus *B. bassiana* can kill all *C. formicarius* stages ranging from eggs, larvae, adult and various other types of pests [18,24,33,34]. *Beauveria bassiana* toxicity is caused by the content of the toxin produced, such as bassiacridin which functions to block the insect DNA system and beaucericin function can cause
integument paralysis so that the fungus is potentially used as a biological agent for controlling various types of pests [35,36,37].

3.3. The number of eggs and larvae of C. formicarius

The number of C. formicarius eggs found in each tuber was different in each variety, the number of eggs in the local variety applied using chemical insecticides (existing) up to 21 eggs, while in Sari variety it was 14 (Table 2). The number of eggs in innovation technology was lower, both in the local and Sari varieties, each with only 11 eggs and 4 eggs. The average number of eggs in technological innovation was much lower when compared to existing technology. The results of this study indicated that the use of varieties was very influential on the interest of imago to lay their eggs on tubers. Local varieties of sweet potato were preferred by imago C. formicarius as a place for laying eggs when compared to Sari varieties.

Control technology also had a significant effect on the number of eggs laid by imago. Technology innovation with crop management and application of B. bassiana fungus, so C. formicarius imago was less interested in laying their eggs on the bulbs. This condition maybe caused by the fungus B. bassiana produces metabolites and toxins such as basiacridin, basianolid, beauvericin, and tenellin which function as poisons. [38] and [22] reported that B. bassiana fungi had very high efficacy, because besides being able to kill mites, pests also had a significant effect on the number of eggs laid on plants. Furthermore, the negative impact of B. bassiana application is the ability of ovicidal fungi to cause eggs to not hatch [39,40,41].

| Variety | The number of eggs and larvae of C. formicarius * |  |
|---------|-----------------------------------------------|---|
|         | Eggs (item)                                   | Larvae (tail) |
|         | Existing                                      | Innovation | Existing | Innovation |
| Local   | 21,50 a                                       | 11,25 a     | 20,25 a  | 6,25 a     |
| Sari    | 14,75 b                                       | 4,50 b      | 10,50 b  | 1,50 b     |
| DMRT (0.05) | 9,97                                          | 5,03        | 8,75     | 4,85       |

* Data transformation to arc sin √x before analyses. Data followed by the same word in the same column is not significant different at DMRT, α = 0.05.

Table 2: The number of eggs and larvae of C. formicarius in the tuber on local and Sari varieties by application of insecticide (existing) and biological agent (innovation)

The results of observations on the number of larvae found in each tuber were also significantly different between the local and Sari varieties. In table 2 it appeared that the number of larvae found in local varieties is higher when compared to Sari varieties. The number of larvae in local varieties with the application of chemical insecticides (existing) found in each tuber were up to 20 heads tuber⁻¹. Furthermore, the number of larvae found in each tuber controlled by chemical insecticides in Sari varieties was only 10 heads tuber⁻¹. The number of larvae in local varieties with the application of innovation technology was found to be less, namely only 6 heads tubers⁻¹, whereas in Sari varieties were much lower only 1 tail. The greater the number of larvae found in each tuber, the greater level of damage that occurred in the local variety (Figure 3). Therefore, tubers are not suitable for consumption because tubers that have been crushed by C. formicarius larvae become bitter due to the terpene compounds that accumulate in the tubers. The results of this study inform that the success of C. formicarius tuber pest control depends on the technology applied and the variety used.
Figure 3: The tubers damage caused by *C. formicarius* larvae (A), compared to healthy tubers of local variety (B) and healthy tubers of Sari variety (C).

3.4. Healthy tuber yield

The results showed that the results of healthy tubers or those free of *C. formicarius* larvae differed between the varieties and technologies tested. The yield of tubers in local varieties is lower, both those are controlled using chemical insecticides (existing) and using land management technology (innovation), namely 12.27 and 15.14 t ha\(^{-1}\) (Figure 4). Meanwhile, tuber yields for Sari varieties appear to be higher both those controlled using chemical insecticides and innovation technologies respectively 18.25 and 24.15 t ha\(^{-1}\). The results of this study indicated that Sari varieties were more tolerant of *C. formicarius* and scab disease and higher productivity when compared to local varieties (Figure 5). This fact can be seen from the number of eggs placed by the imago in each tuber, the number of larvae that attack each tuber, and the level of tuber damage due to *C. formicarius* larvae and the intensity of scab disease. [42] found that the application of *B. bassiana* without combination with mulch administration had been able to obtain a tuber yield of around 20 t ha\(^{-1}\), while the treatment of adding mulch without the combination of *B. bassiana* obtains a tuber yield of around 18 t ha\(^{-1}\) in tidal land.

Figure 4. The healthy sweet potato tubers (t ha\(^{-1}\)) on local and Sari varieties with existing and innovation management.

3.5. Economic feasibility analysis

The tuber yield obtained from Sari varieties on technological innovation reached 24.15 t ha\(^{-1}\), while for local varieties was only 15.14 t ha\(^{-1}\). The selling price of sweet potatoes in the harvest season was around Rp 3,500 kg\(^{-1}\) so that the cash yielded was Rp 84,525,000. Total yields minus production costs
by Rp 23,950,000. So that the B/C ratio of innovation technology in Sari varieties reached 2.5 while the B/C ratio for local varieties was only 1.2. Judging from the value of the B/C ratio, innovation technology through land management was feasible to be applied and developed in tidal areas with identical suboptimal land, endemic tuber borer and scab disease. The advantage of technological innovation was that it can protect tubers from major disease pests (C. formicarius and S. batatas), tuber yields were relatively more organic so that they can provide healthy food sources and much higher selling prices, leaving no exposure to chemical pesticide residues in the environment thus supporting a sustainable agriculture system.

Figure 5: The sweetpotato tubers of Sari variety, Innovation (A), and existing (B) local variety, existing (C), Innovation (D)

4. Conclusion
The innovation technology through integrated crop management (increasing the dosage of organic and inorganic fertilizers, increasing dolomite dosage, increasing the width and height of mulching, application of entomopathogenic fungus B. bassiana and natural pesticides (shallot extract) reduced the occurrence of pest C. formicarius and S. batatas disease.

The B/C ratio of innovation technology reaches 2.5 and existing was only 1.2 mean that innovation technology was feasible to be developed to increase sweet potato productivity and farmer's income in tidal land in South Kalimantan which was endemic with C. formicarius and S. batatas or tidal diseases.

The innovative technology can reduce the use of chemical pesticides, produce more organic planting system and had a higher selling price, environmentally friendly and supporting sustainable farming systems.
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