PRE-PLANTING TREATMENTS FOR MANAGEMENT OF BANANA FUSARIUM WILT

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ABSTRACT

Fusarium wilt is one of major constraints of Indonesian banana production. Land management before planting was objected to reduce *Fusarium* inocula in the soil and wilt incidence, and improve banana growth. Research has been conducted from 2005 to 2007 at Aripan experimental farm, which was naturally-heavily infested by tropical race 4 of *F. oxysporum* f.sp. *cubense*. Experiment was arranged in a randomized block design with four replications. Treatments were 1) solarization: plots were covered with transparent polyethylene plastic for 10 months, 2) rotation with maize: plots were planted with two periods of maize, 3) bare: no crop for 10 months, and 4) control: continuous planting of banana. Maize rotation and baring condition reduced Fusarium population in the soil, but could not escape from fusarium wilt of banana. Continuous planting of banana retained the population of fusarium in the soil. Solarization increased soil temperature until 52.35^{o}C, which consequently suppressed Fusarium population in the soil, and reduced fusarium wilt incidence on banana. Fusarium wilt emerged at three months after planting on plot previously rotated with two periods of maize, bare for 10 months, and continuous planting of banana while solarization was able to delay the disease emergence until six months. The first-three treatments resulted in logarithmic trend of disease development and reached peak at six months after planting, while the last treatment performed linier development until the end of observation. Among the treatments, solarization was the only treatment that produced yield.

Keywords: banana, Fusarium wilt, solarization, rotation, bare, *Fusarium oxysporum* f. sp. *cubense*.

INTRODUCTION

Fusarium wilt, which is well known as Panama disease, is caused by *Fusarium oxysporum* f.sp. *cubense* (E.F. Smith) Snyder and Hansen (Stover, 1962; Wardlaw, 1972; Jones, 1997; Ploetz and Pegg, 2000) and having high genetic variability in terms of race and strain, and complexity of infected banana genomes (Stover and Buddenhagen, 1986; Pegg *et al*., 1996; Ploetz and Pegg, 1997; Ploetz and Pegg, 2000), was reported to abandon world banana production (Wardlaw, 1972; Stover and Simmonds, 1987; Pegg *et al*., 1993; Nasir *et al*., 1999; Hermanto *et al*., 2009), and struck all commercial banana varieties (Buddenhagen, 1995; Ploetz and Pegg, 1997; Pittaway *et al*., 1999; Nasir *et al*., 1999; Hermanto and Setyawati, 2002). Nurhadi *et al*. (1994) reported that farmer lost about 2.4 billion Rupiah in Lampung province due to Fusarium wilt and blood disease in harvesting period of 1993/1994. Survey conducted in 15 banana producing provinces in Indonesia showed that fusarium wilt was found in all the surveyed areas, even though endemic cases mainly happened in banana production centers of Sumatera, Java, and Sulawesi (Hermanto *et al*., 2008a; Hermanto *et al*., 2008b; Hermanto *et al*., 2010). Assumed that if a kilo banana worth about one thousand rupiah, with annual production reached 5.03 million tones in 2006, and average wilt incident reached 23.99%, Hermanto *et al.* (2009) calculated annual loss of banana until 1.21 trillion rupiah, equal to 134 million USD. Due to the revealed losses, Simmonds (1960) categorized banana fusarium wilt as one of six lethal diseases of world agriculture.

Since banana fusarium wilt is soil-borne systemic disease; control strategy is mainly addressed to reduce soil inoculums before planting the banana. Disease control through cultural practices (crop rotation and flooding), and solarization were reported in Latin America, Taiwan, India, Malaysia, Australia and Indonesia (Stover, 1962; Price, 1982; Chandra, 1991; Nasir, 1997). The research was objected to study the effect of banana pre-planting through solarization, crop rotation, bare, and continuous banana planting on fusarium wilt propagule in the soil, disease development and plant growth.

MATERIALS AND METHODS

Research has been conducted at Aripan experimental farm of Indonesian Tropical Fruit Research Institute, located in 0^{o}43’15.43” - 0^{o}44’21.28” LS and 100^{o}36’35.08” - 100^{o}7’27.06” BT, 430 m asl., soil type latosol, clay soil texture, blocky soil structure, and within 2005-2007. The site was heavily-naturally infested by *Fusarium oxysporum* f. sp. *cubense* VCG 01213/16 of tropical race 4 (Foc TR4). Experiment was arranged in a randomized block design, with four replications. Plots were 5 x 25 m containing 20 cavendish banana plants. A treatment was pre-planting banana management, consisting of **(A). Solarization:** plot was covered by transparent polyethylene plastic for 10 months, **(B). Maize rotation:** plot was planted with two periods of maize cultivation in 40 x 40 cm planting space, **(C). Bare:** plot was let open for one year, **(D). Control:** plot was treated with continuous planting of banana. The treatments were conducted from September 2005 till July 2006, followed by banana planting in August 2006. Observation was

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addressed to: **a)** Soil temperature (20 cm depth) at 07.00 a.m., 12.30 p.m., and 17.00 p.m. every day, **b)** Soil water contents once a month, **c)** Soil macro nutrients (nitrogen, phosphor, potassium) before and after treatments**, d)** Soil microbes once a month, **e)** Fusarium wilt incidence every month, **f)** Agronomic performance of banana (number of leaves, stem girth, plant height, and yield). Parameters a-c was observed during the treatments, while d-f were during banana cultivation. Data were analyzed in variance, descriptive statistic and regression model, and were performed in figures and graphics.

RESULTS AND DISCUSSIONS

Physical, chemical, and biological characters of soil

1. Physical properties

a. Soil temperature

Solarization with transparent polyethylene plastic increased soil temperature until 52.35^{o}C, while it did not happen on maize crop rotation, bare condition, and continuous banana planting, which were only 45.60^{o}C at noon (Figure-1). Krueger and McSorley (2009) explained that transparent plastic sheets allow short-wave radiation from the sun to penetrate the plastic. Once the light passes through the plastic and is reflected from the soil, the wave length becomes longer and cannot escape through the plastic. The trapped light facilitates heating of the soil to temperatures detrimental to most living organisms.

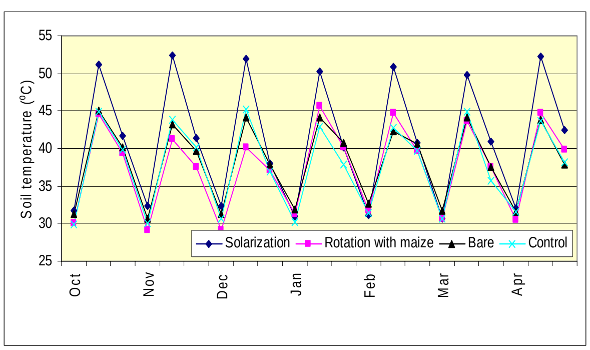

Figure-1. Soil temperature fluctuation in the morning-noon-afternoon during solarization period.

Temperature reached in this work was much higher than that Davis (1991) did that was only reached 40.9^{o}C at 15 cm depth, and 33.3^{o}C at 30 cm on potato land. Mahrer (1991) stated that the effectiveness of solarization was influenced by light radiation, soil type (color and structure), mulch type, soil moisture, air thickness between the plastic cover and the soil, and some activities of soil tillage. It was further stated that the type of plastic cover should absorb short wave-light and reject long wave-light to result in higher temperature, and vice versa.

b. Soil water content

The soil water content was fluctuated in time. Water content in solarization treatment was the lowest (11.43% to 29.35%), while in the other treatments were ranged from 21.15% to 32.10% (Figure-2). It happened because rainfall could not enter into the soil under the plastic cover.

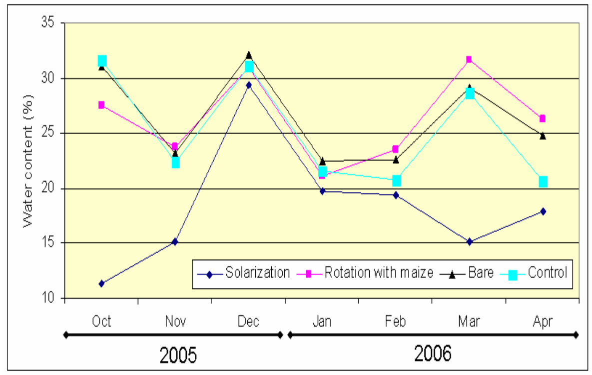

Figure-2. Soil water content fluctuation resulted from treatment of solarization, rotation with maize, bare, and control.

The iincrease of water content in December was caused by run off that touched the soil during heavy rain period of the month.

2. Chemical properties of soil

Solarization did not change nitrogen and potassium content in the soil. Johnson (1919) *in* Chen *et al.* (1991) mentioned that temperature change until 50^{o}C was not enough to change concentration of soil solution. Figure-3 showed that solarization increased phosphate content until 300%. Increase of phosphate after maize planting, and potassium after banana planting happened due to fertilization and nutrient content wasted by the crop.

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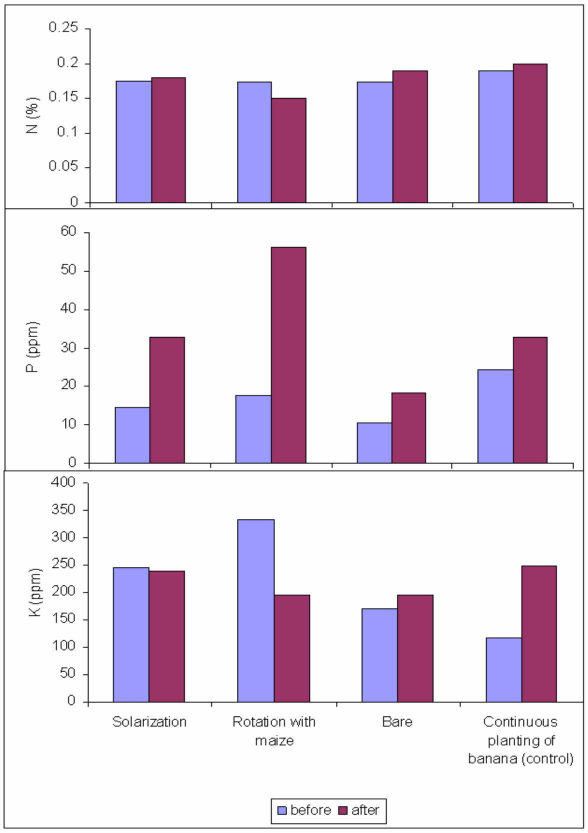

Figure-3. Macro nutrient content of nitrogen, phosphor, and potassium in the soil before and after solarization.

3. Soil microbes

Maize crop resulted in the highest total fungi, while solarization performed the lowest (Figure-4).

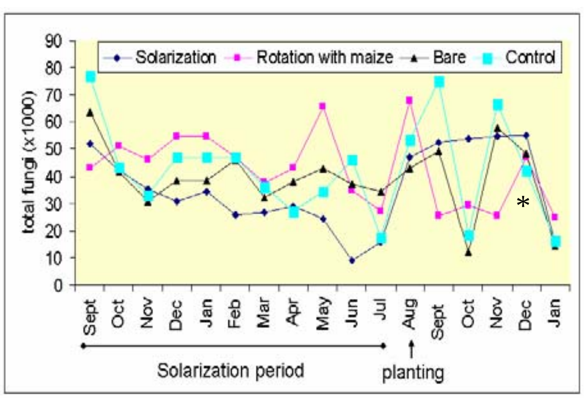

Figure-4. Total fungi per gram soil affected by solarization, crop rotation with maize, bare and continuous banana planting.

Aspergillus and *Trichoderma* dominated the population from 2 until 10 months after solarization. As it was reported by Chen *et al.* (1991), solarization reduced most of the soil pathogens, but not antagonistic fungi such as *Trichoderma*, *Talaromyces* and *Aspergillus*. Total fungi, which were still dominated by those few fungi, increased sharply two months after plastic cover was removed. The low genetic variability, as indicated in Figure-5, caused low competition between and among the microbes, and gave more change to thermophilic fungi to develop. As the microbe variability increased at the following months, the total fungi went down steadily.

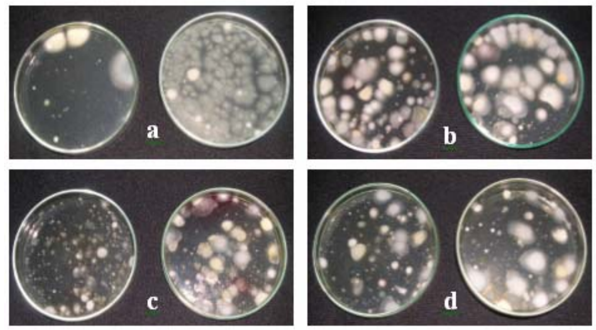

Figure-5. Diversity of soil microbes due to **a.** Solarization, **b.** Rotation with maize, **c.** Bare, and **d.** Control/continuous banana planting.

As it happened on soil microbes, solarization almost nullified *Fusarium* population in the soil. The fungus was not found until 10^{-2} dilution, while it was easily found on other treatments (Figure-6). Maize rotation and 10-month bare could also significantly suppress Fusarium population in the soil. Instead of temperature change, unavailability of the host might influence the suppression. Continuous planting of banana retained the pathogen surviving in the soil. Eliza (2004) reported that pre-planting treatment with gramineous crops like maize (*Zea mays*), sorghum (*Sorghum bicolor*), dry land rice (*Oryza sativa*), and giant grass (*Pennisetum purpureum*) showed ability in disease suppression compared with no rotation treatment, which the best treatment was pre-planting with giant grass as showed by the lowest disease incidence (13.33%) and severity (18.83%) compared with control (60% and 31.67%), respectively). Roots of gramineous colonized by various populations of bacteria promise to be biological control agents to various soil borne pathogens. The result from *in vitro* test showed that 20.90% of 182 tested bacteria isolates had antibiotic activity against *Foc* and more than one third (7.7%) of those were endophytic bacteria from rice roots.

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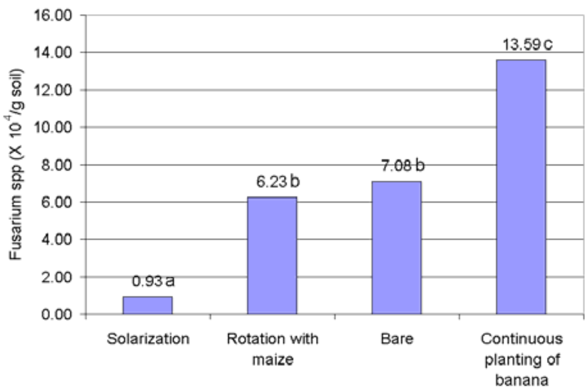

Figure-6. Average population of *Fusarium* spp. in the soil affected by solarization, maize rotation, baring condition, and continuous banana planting.

Note: numbers above the bars followed by the same letter are not significantly different at LSD 0.05.

Figure-7 showed that the effect of solarization on suppressing *Fusarium* spp. population could stand even until one year after the treatment. Fluctuation of the pathogen population on other treatments might be due to fluctuated weather situation on the treatments which were not as stable as solarized soil.

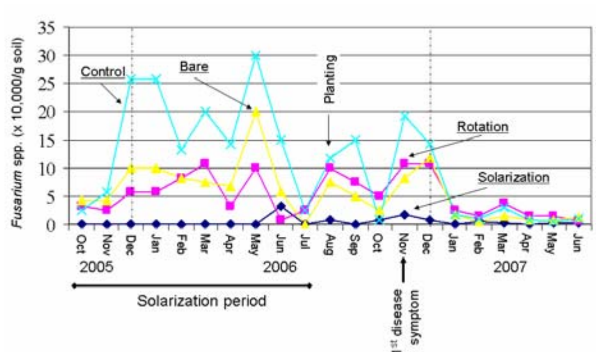

Figure-7. Number of *Fusarium* spp. propagule in the soil affected by solarization, rotation with maize, bare, and control.

Chen *et al.* (1991) reported that reduction of soil borne fungi by 90% due to solarization. Furthermore, DeVay and Katan (1991) stated that the effectiveness of solarization in killing pathogen was a function of temperature and exposure time of the temperature. Ninety per cent of pathogen mortality (ED_{90}) was gained at 37°C for 2-4 weeks exposure or 47°C for 1-6 hours.

Pathological characters

Planting banana after the treatments showed that pre-panting solarization significantly reduced Fusarium wilt incidence. On the other hand, even though Fusarium population in the soil decreased, maize rotation and 10-month baring still resulted in Fusarium wilt. It indicated that the two treatments still leave the pathogen at the level of inoculums potential. Fusarium wilt has started to appear at three months after planting on maize rotation, bare condition, continuous banana cultivation, while solarization delayed the appearance until six months after planting. Fusarium wilt on the first three treatments developed logarithmically and reached the peak at the sixth month, while solarization retained the wilt developed liniarly with low coefficient regression until 14 months after planting (Figure-8).

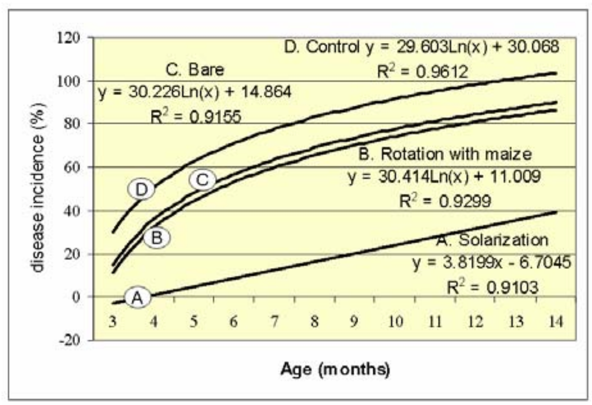

Figure-8. Fusarium wilt incidence affected by solarization, rotation with maize, bare, and control.

Notes: disease symptom firstly appeared at three months after planting on maize rotation, bare condition, and continuous banana planting (control).

The graph implied that the increase of temperature resulted by solarization suppressed Fusarium population in the soil, and consequently, decreased Fusarium wilt incidence on banana. Davis (1991) reported that temperature escalation until 44°C resulted by solarization reduced wilt diseases caused by *Verticillium dahliae* and *Prathylenchus* on clone NDA 8694-3, Ruset Burbank and A68113-4 of potato. It was further mentioned that solarization was potentially able to be combined with several other components of disease control.

Agronomic characters of the banana

a. Plant height, stem girth, and number of actual leave

Due to heavy incidences of Fusarium wilt, agronomic performances of the banana were observed for only eight months. The treatments did not affect banana growth. Average plant height, stem girth, and number of actual leaves of the four treatments were consecutively ranged from 142.09-187.38 cm, 44.83-47.83 cm and 8.12-9.74 leaves per plant, following similar growing pattern (Figure-9).

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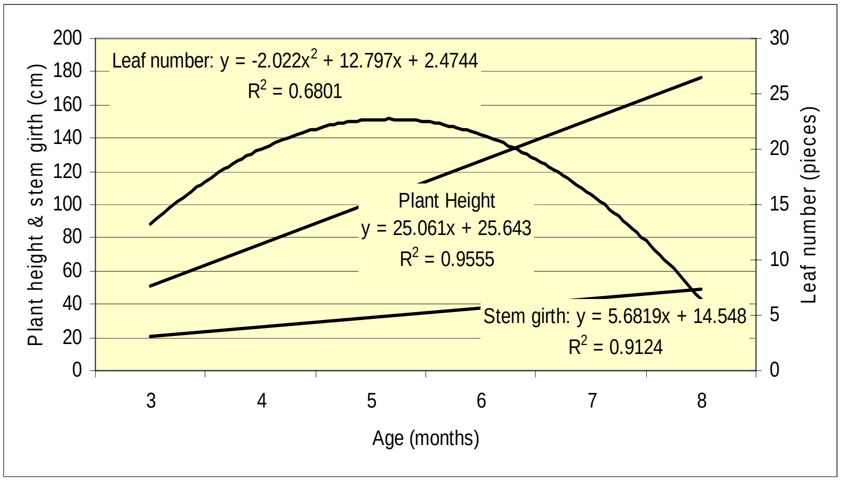

Figure-9. Growth rate of plant height, stem girth, number of actual leaves affected by solarization, rotation with maize, bare, and control.

Note: analysis was done based on data collected from 3-8 months after planting.

Until 8-month old, banana plant height and stem girth grew linearly, consecutively with the following equation: $Y = 25.061X + 25.643$, $R^2 = 0.96$ and $Y = 5.681X + 14.548$, $R^2 = 0.91$, while number of actual leaves developed quadratic ally, where $Y = -2.022X^2 + 12.797X + 2.4744$, $R^2 = 0.68$. Reduction of the number of actual leaves was caused by Fusarium wilt incidence started from three months after planting.

b. Yield

Due to fusarium wilt incidence, yield data could only be collected from the plot treated with solarization. Average data at generative stage were 186.80 ± 24.74 cm, 50.58 ± 4.96 cm, 11.08 ± 1.73 sheets, respectively for plant height, stem girth, and number of actual leaves (Figure-10).

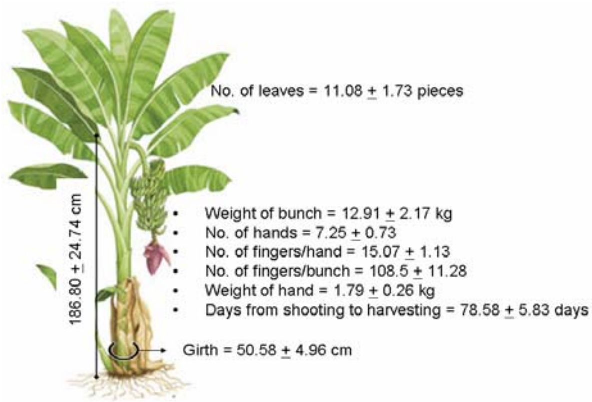

Figure-10. Agronomical performance of 'Ambon Hijau' (AAA, Cavendish type) planted on solarized soil of *Fusarium oxysporum* f.sp. *cubense* TR4 naturally-heavily infested land.

Fruit was harvested at 78.58 ± 5.83 days from shooting with 12.91 ± 2.17 kg/bunch, 7.25 ± 0.73 hands/bunch, 15.07 ± 1.13 fingers/hand, 108 ± 11.28 fingers/bunch, 1.79 ± 0.26 kg/hand. The yield was much lower than the potency of Ambon Hijau (Cavendish) did, due to chemical, physical, and biological stresses. Gasoni *et al.* (2008) reported that solarization increased plant stand by 25-95% in *Rhizoctonia solani*-infested soils and fresh weight by 32-41% of table beet.

CONCLUSIONS

a) Maize rotation and baring condition reduced Fusarium population in the soil, but could not escape from Fusarium wilt of banana.
b) Continuous planting of banana retained the population of Fusarium in the soil.
c) Solarization increased soil temperature until 52.35°C, which consequently suppressed Fusarium population in the soil, and reduced Fusarium wilt incidence on banana.

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