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The role of plant parasitic nematodes on productivity reduction of banana and tomato in East Kalimantan, Indonesia

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Abstract. *Suyadi, Rosfiansyah. 2017. The role of plant parasitic nematodes on productivity reduction of banana and tomato in East Kalimantan, Indonesia. Asian J Agric 1: 40-45.* Plant parasitic nematode is one of the most limiting factor of agricultural ecosystem productivity in East Kalimantan, but their occurrence in agricultural field as a crop's pest generally undistinguished, due to their microscopic size and their existence wrapped in the roots or soil particles. However, plant parasitic nematodes might cause yield loss up to 75%, without showed any disease symptom on crop morphologically. Perennial crop and annual crop under intensive cultivation usually experience high yield loss due to plant parasitic nematodes, if crop protection management was not implemented properly. This research aimed to determine the role of plant parasitic nematodes in reducing crop's productivity in East Kalimantan, in relation to agricultural practices implemented by farmers. A descriptive research and comparative analyses were implemented to determine the role of plant parasitic nematode on yield reduction of banana and tomato as the indicator of productivity. Based on the field observation related to pest management in East Kalimantan, it was determined that plant parasitic nematode existence was neglected by farmers and no significant effort was implemented to control plant parasitic nematodes population. Therefore, low productivity of agricultural ecosystem in East Kalimantan was reported by Statistical Office, and it was not only caused by soil fertility problems, in some crops it was also the impact of population outbreak of plant parasitic nematodes. The first ranking three genera of plant parasite nematodes observed in East Kalimantan were *Meloidogyne*, *Radhopholus*, and *Rotylenchulus*, respectively. *Meloidogyne* and *Rotylenchulus* were major pest on vegetables, and caused yield loss >50% on tomato. While, genus of *Radhopholus* was the major pest on banana, and caused yield loss >75% on banana.

Keywords: Banana, East Kalimantan, nematode, productivity reduction, tomato, yield loss

INTRODUCTION

Plant parasitic nematodes (PPN) were important pest in East Kalimantan Province of Indonesia, compared to other pests, PPN caused highest yield loss on some crops. However, their existence in the field still neglected by farmers, because they could not distinguished the existence of PPN directly in the field, symptomless at early stage of infection, and then no serious efforts were implemented to control their populations. World-wide crops yield loss due to PPN has been estimated at $US 80 billion per year, and this is likely to be a significant underestimate of the true figure, as many growers, particularly in developing nations, are unaware on PPN existence (Jones et al. 2013).

Yield loss due to PPN varied as affected by environmental factors, cropping systems and pest management practices. Reported by Jones et al.(2013) that *Meloidogyne graminicola* caused yield losses up to 87% on rice, cyst nematodes (*Heterodera* and *Globodera* spp.) under specific environmental condition caused yield losses up to 90%, *Pratylenchus* spp. caused yield losses up to 30% on wheat in Australia, reniform nematode (*Rotylenchulus reniformis*) caused yield losses 40%-60%. Furthermore, reported by Singh and Kumar (2015) that yield loss on vegetable crops in Western Uttar Pradesh varied from 4% on bitter gourd (*Momordica charantia*) up to 43% on eggplant (*Solanum melongena*), and *Meloidogyne incognita* was determined as the most important PPN in Uttar Pradesh, this nematode genus involved in the first rank of causal yield losses, on eggplant (43%), tomato (40%), and okra (38%).

Banana yield loss due to burrowing nematode reach more than 50% (Bartholomew et al. 2014) or ranging from 30 to 60% (Brooks 2014). Moreover, reported by Hölscher et al. (2014) that burrowing nematode might cause yield loss up to 75% on banana. Higher banana yield loss commonly occurred in developing countries, because of control efforts for this parasite still limited (Chitamba et al. 2013; Kamira et al. 2013; Srinivasan et al. 2011), and they were some important genera of PPN attacking banana altogether with burrowing nematodes, i.e. *Meloidogyne* (root-knot), *Pratylenchus* (lesion), *Helicotylenchus* (spiral), *Rotylenchulus* (reniform) (Brooks 2014; Kamira et al. 2013; Srinivasan et al. 2011). Whereas, banana yield loss relatively reduced under commercial banana cultivation, where integrated pest management (IPM) technology was implemented (Ricède et al. 2010).

Tomato yield loss due to PPN ranging from 25 up to 100% and the main nematode genus attacking tomato was *Meloidogyne* (Seid et al. 2015). As well as in the banana case, yield loss due to PPN on tomato mostly occurred in developing countries, it because of poor control efforts implemented to the parasite. Whereas, PPN in developed countries relatively well manage and more control

technique alterative were available. The availability of resistant cultivars apparently was the most prospective control technique for PPN on tomato (Rani et al. 2009; Gharabadiyan et al. 2013). However, the most practical control measure applicable in East Kalimanatan was soil amendment of dung manure (Aalders et al. 2009) which prevented tomato yield loss direct and indirectly.

Research activities related to PPN and their management in East Kalimantan are still limited. The most intensive research on PPN which conducted in East Kalimantan was focused on banana and tomato. It because the symptoms of PPN attacking both crops relatively easy to observe, i.e. root galls on tomato and root rot or black head on banana which caused toppling disease. This research was purposed to determine the role of PPN on productivity reduction of banana and tomato, as the indicator of crop yield loss due to PPN in East Kalimantan. Furthermore, to encourage farmers understanding on the existence of PPN as the important pest in the province and hopefully farmers could control them properly.

MATERIALS AND METHODS

Study area

Field observations and surveys to determine the existence of PPN on tomato and banana were conducted at production centers of banana and tomato in East Kalimantan Province, Indonesia. Banana production area were distributed in almost all of districts in East Kalimantan, whereas tomato production area only found in Balikpapan municipal, Kutai Kartanegara and Penajam Paser Utara districts. Production centers of banana commonly located along province main road and along rivers in the province (Figure 1).

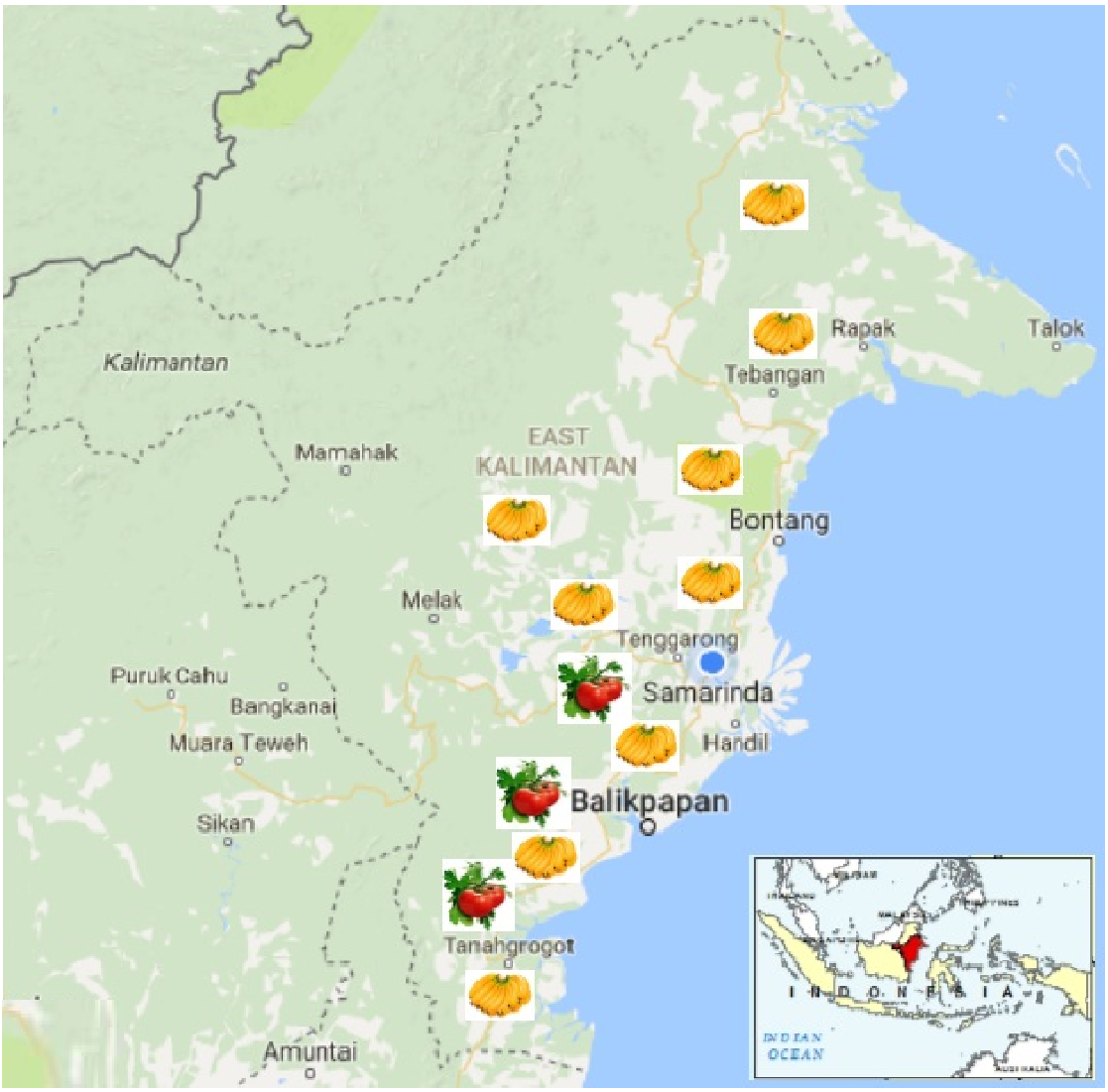

Figure 1. The production center sites of banana and tomato in East Kalimantan Province, Indonesia. The banana and tomato centers are indicated by the banana and tomato symbols

Procedures

This research was a combination of field and desk research. Field research were focused on the determination of the existence of PPN attacking the crops, and their impact on crop productivity reduction. The primary data were gathered from field research, i.e.: PPN genera attacking tomato and banana, population densities of each PPN genus, and the actual yield of banana and tomato under traditional cultivation system implemented by farmers. While, the time series of secondary data about productivity, production, and harvested or cultivated area of banana and tomato will be gathered from the formal data reported by the Statistic Center Bureau of East Kalimantan Province.

Field research

Field surveys and observations were carried out to gather primary data, to determine the existence of PPN attacking tomato and banana at the sites of production center, as well as actual or attainable yield of both crops at each farmer field. Crops yield and productivity were directly observed and measured or counted in the field. While, PPN genera and their population densities were gathered from soil and roots samples. Then, nematodes extractions were conducted at the laboratory, soil samples were processed by Baermann Funnel Method and root samples were processed through Direct Maceration Method.

Desk research

The main purposed of desk research was to gather a time series secondary data which available and reported formally by the Statistic Center Bureau of East Kalimantan Province. Secondary data required were crop production (yield), productivity, and harvested area of banana and tomato in East Kalimantan. The secondary data used in this research will cover at least five years period, to elaborate the dynamic of banana and tomato production in the province.

Data analysis

The comparative data analysis was implemented in this research to describe the role of PPN on banana and tomato productivity reduction. Data analysis was conducted base on the secondary data and justified by the primary field data comparatively. Therefore, the description of time series secondary data of banana and tomato production in the province was elaborate to explain the relationship occurrences between the existence of PPN and productivity reduction on banana and tomato.

RESULTS AND DISCUSSION

The productivity of tomato

Tomato farmers in East Kalimantan always cultivated their crop under intensive management, especially in term of fertilizer application and above ground pest control, but plant parasitic nematodes control efforts were still neglected. Consequently, they were harvest only limited yield of tomato, and the average annual productivity was still very far from the potential and attainable yield of the crop.

Based on the field observation and experiment in Samarinda was determined that the average attainable yield of tomato *Ratna* variety was 20 ton.ha^{-1}, and the occurrence of PPN (*Meloidogyne* spp.) at population density of 2-3 juveniles.g^{-1} soil at harvest time reduced tomato productivity about 57-77% (Table 1). The experiment was conducted at the field where previously planted by tomato, and unknown initial population density of *Meloidogyne* spp. but evenly distributed through soil tillage management. While, the population density development of plant parasitic nematodes was prevented by applying chicken dung as a soil amendment treatment.

The potential productivity of tomato commercial varieties which are available in East Kalimantan was always above 40 ton.ha^{-1} (Purwati 2009). However, the annual average productivity of tomato reached in the East Kalimantan province was considered very low compared to the potential productivity, only ranging from 14.88% (2012) and up to 30.83% (2014) (Figure 1).

The highest attainable productivity of tomato was occurred in Penajam Paser Utara District, about 24.44 ton.ha^{-1} (Table 2), but the productivity of tomato in other districts and cities was lower, therefore the annual average productivity of tomato in the province was still low. Based on the standard of the highest attainable productivity (24.44 ton.ha^{-1}), the annual average productivity of tomato in the province was ranging from 24.39% (2012) up to 50.45% (2014).

The productivity of banana

Banana palced the number one of fruit produced in East Kalimantan. its production reached 72,114 ton in 2015 (BPS, 2015) or about 30% of total fruit production in the province which composed of about 20 kind of fruits. Banana farmers commonly cultivated their crop traditionally, and production inputs relatively were not implemented to the crop. The risk of PPN infection at new banana plantation was come from the planting materials. Because, banana farmers commonly used suckers as planting material, where small amount of soil and root were carried PPN in it. Afterward, the population of PPN will be increased and caused significant yield loss and productivity reduction.

Based on the field survey and observation of PPN population density and banana yield in Kutai Kartanegara district, it was determined the relationships between PPN population density and productivity reduction on banana. The dominance of PPN genera at the observation area were *Radopholus, Meloidogyne,* and *Pratylenchus.* They are all together caused the productivity reduction on banana of Saba variety at the upland area about 41.67% and about 33.33% at the watershed area (Table 3). Those productivity reduction on banana was the impact of PPN at the population density of about 5891 and 4919 nematodes per 100 g of root, which generated the average root lesion at

level of 55.9% and 39.8%, respectively (Table 3). In the older banana plantation, without PPN control activities, the root lesion incident generally reach up to 90% - it was the precondition for toppling disease and productivity reduction more than 75%.

Table 1. The relationships between plant parasitic nematode (*Meloidogyne* spp.) population densities and productivity reduction of tomato in East Kalimantan Province, Indonesia

Chicken dung application (ton.ha^{-1})	Nematode population (juvenile per 50g soil)	Tomato productivity (ton.ha^{-1})	Produtivity reduction (%) based on attainable tomato yield (20 ton.ha^{-1})
0 (Po)	170	4.55	77.25
5 (P_1)	140	5.34	73.30
10 (P_2)	134	6.76	66.20
15 (P_3)	122	7.91	60.45
20 (P_4)	120	7.98	60.10
25 (P_5)	110	8.59	57.05

Table 2. Harvested area, productivity, and production of tomato at districts and cities of East Kalimantan province, Indonesia.

Districts/cities	Harvested area (ha)	Productivity (ton.ha^{-1})	Production (ton)
Berau	98	1.77	174
Kutai Barat	23	2.34	54
Kutai Kartanegara	467	12.47	5,823
Kutai Timur	68	1.88	128
Mahakam Ulu	-	-	-
Paser	22	5.30	117
Penajam Paser Utara	103	24.44	2,517
Balikpapan	191	17.66	3,374
Bontang	15	3.89	58
Samarinda	14	7.34	103

Source: BPS (2015)

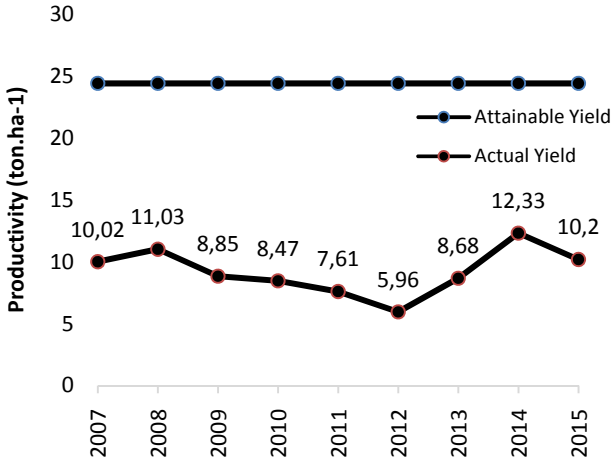

Figure 1. Tomato productivity trend in East Kalimantan (Sources: BPS, 2012 and 2015)

Table 3. The Relationships between plant parasitic nematodes population density and productivity reduction on banana of Saba variety in Kutai Kartanegara distict of East Kalimantan proince, Indonesia

PPN genera	PPN genera population density (individu per 100 g root)	Total of PPN population density (individu 100 g root)	Average root lesion (%)	Productivity reduction (%)
Watershed (periodically flooded area)				
Radopholus	9106			
Meloidogyne	4070	14756	39.8	33.33
Pratylenchus	1580			
Upland area				
Radopholus	9967			
Meloidogyne	4610	17672	55.9	41.67
Pratylenchus	3095			

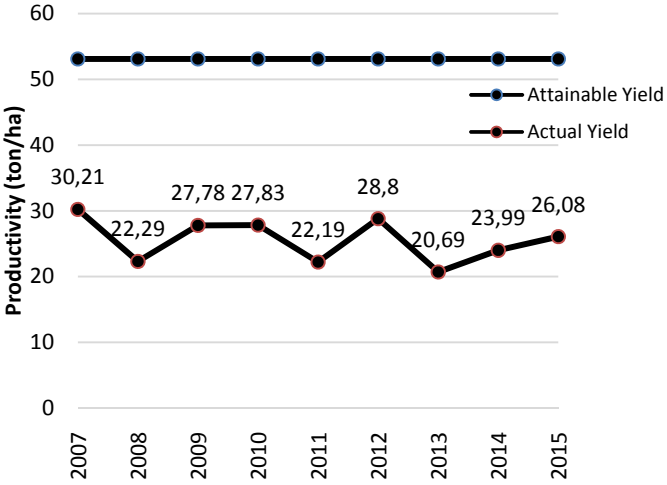

Figure 2. The banana productivity trend in East Kalimantan (Sources: BPS 2012 and 2015)

Table 4. Harvested area, productivity, and production of banana at districts and cities of East Kalimantan Province, Indonesia

District/City	Harvested area (ha)	Productivity (ton/ha)	Production (ton)
Paser	500.77	18.48	9252
Kutai Barat	14.85	16.90	251
Kutai Kartanegara	717.27	22.12	15868
Kutai Timur	694.12	30.37	21081
Berau	200.45	12.89	2584
Penajam Paser Utara	264.94	11.34	3004
Mahakam Ulu	-	-	-
Balikpapan	306.77	53.11	16292
Samarinda	188.28	20.10	3784
Bontang	5.28	12.12	64

Source: BPS (2015)

The average annual productivity of banana in the province (Figure 2) was ranging from 20.69 ton.ha^{-1} (2013) up to 30.21 ton.ha^{-1} (2007) (BPS 2015). Based on the highest attainable productivity (53.11 ton.ha^{-1}) as the standard of determination (Table 4). It means that the average annual productivity of banana in the province were only reached 38.96% up to 56.88%. The banana productivity will be lower if it considered the well manage banana plantation, including integrated management of PPN.

Discussion

Plant parasitic nematodes was a serious pest of agricultural ecosystem in East Kalimantan, but their existence still neglected by farmers as well as Agricultural Government Officers. A special effort of extension and technologies dissemination for controlling this pest in provincial and districts level was still limited. However, research and field observation conducted by lectures and students of Mulawarman University since 1990 proved that PPN was one of the important (silent) pest in East Kalimantan (Hambarwati 2004; Nur 2004; Nurmina 2006; Zulaichan 2007; Ngaini 2008; Sanjaya 2008; Sartono 2008; Septian 2011; Hidayat 2015, *unpublished data*). Population densities of plant parasitic nematodes in agricultural ecosystem of East Kalimantan under intensive cultivation were always above of the economic injury level. It was justified that plant parasitic nematodes were causal pest which contributing to agricultural ecosystem productivity reduction.

East Kalimantan situated in tropical rain forest climatic zone considered as a zone of flora and fauna diversity center, including plant parasitic nematodes. Therefore, various genera of plant parasitic and free leaving nematodes were observed in East Kalimantan, major plant parasitic nematodes genera which frequently determined in agricultural ecosystem were *Meloidogyne*, *Radhopholus*, *Rotylenchulus*, *Helicotylenchus, Pratylenchus,* and *Tylenchorhynchus.*

Meloidogyne was the most distributed nematode genus in East Kalimantan, this genus was the major pest on vegetable crops, and also attacking food crops and fruit crops. Genus of *Radhopholus* was the major pest of banana causing toppling disease in over all of banana development area in the province. Genus of *Rotylenchulus* are mostly attacking vegetables and food crops, especially on the family member of *Solanaceae* and *Leguminoceae*. Genera of *Helicotylenchus* and *Pratylenchus* are mostly attacking food crops of grasses family, and together with *Radhopholus* attacking banana. While, *Tylenchorhynchus* are adapted to perennial crops and cause serious damage on oil palm seedling in Paser District of East Kalimantan (Suyadi 2010, *unpublished data*).

The role of plant parasitic nematodes on the tomato productivity reduction

In relation to the role of plant parasitic nematodes as the causal agent of tomato productivity reduction, it could be elaborated by the fact that the higher tomato yield were reached at the area of tomato production centers, such as Balikpapan city, Penajam Paser Utara and Kutai Kartanegara districts (Table 2). It was due to the impact of the organic soil amendment which commonly applied by farmers at the area of tomato production centers. Organic soil amendment, especially animal dung aside beneficial for the soil fertility improvement. Tt was also played a role as nutrient source for natural enemies of plant parasitic nematodes. Therefore, those natural enemies will suppress population of plant parasitic nematodes and more effective than that of performed by synthetic nematicides (Aalders et al. 2009).

Tomato is one of the important vegetable crop in East Kalimantan, and tomato farmers always manage their crop intensively, including pest control activities. So, the major pest of tomato was successfully solved, except for PPN - because the existence of PPN was undistinguished due to their microscopic size and wrapped in the soil particles or plant roots. However, farmers in the province were mostly still applying inorganic fertilizers and pesticides as the component of production inputs for their tomato crop. Consequently, the population of PPN was always above the economic injury level and caused a significant yield loss.

The impact of inorganic fertilizers and pesticides application will be reduced the diversity of soil micro-flora and fauna, including those natural enemies of PPN. Whereas, the survivor and adaptive PPN of tomato will be free from their enemies, and their population will increased rapidly to reach the economic injury level. Therefore, the productivity reduction caused by the PPN cannot be rejected, and the average annual productivity of tomato in the province considered low, only ranging from 24.39% (2012) up to 50.45% (2014) compared to the attainable yield (Figure 1 and Table 2). It means that the productivity reduction of tomato caused by PPN in East Kalimantan was occurred at about 49.55% up to 75.61%. Furthermore, the productivity reduction will be higher, if the potential yield (40 ton.ha.$^{-1}$) considered as the comparison standard, so the productivity reduction of tomato caused by PPN in East Kalimantan will be about 69.17% up to 85.12%.

The role of plant parasitic nematodes on the banana productivity reduction

The opposite crop management of tomato was implemented on banana, most banana farmers managed their crop traditionally, they never provide any production input to their crop. They just planted the banana suckers and sometimes implementing weed control, and then left them up to harvest time. Fortunately, banana in East Kalimantan relatively was not faced to the serious pest attack, except the outbreak of bacterial wilt disease at early 2000 (Suyadi 2007). However, the impact of bacterial wilt disease could be easily differentiated from the PPN in the banana productivity reduction. Because, eradication treatment was implemented to banana infected by bacterial wilt.

Plant parasitic nematodes distributed simultaneously with the distribution of planting material, because together with the suckers were carried a small amount of soil and/or banana roots which contained PPN in it. Then, those PPN will reproduce rapidly on suitable host. As we knew that

the life cycle of plant parasitic nematodes just only about one month under suitable environment condition. It means, the population density of plant parasitic nematodes in a year will almost reached the economic injury level, if natural enemies were not functioning effectively to reduce the population of PPN. Consequently, banana yield will drastically reduce at third or fourth harvest and afterward, but farmers never pay any attention to control the PPN and they just expect that yield reduction was due to nutrients shortage and soil fertility reduction.

In relation to the role of PPN in the reduction of banana productivity, field observations determined that PPN was the causal agent of drastic yield reduction on saba cultivar banana (the most common banana cultivar planted by farmer in East Kalimantan). At first harvest of the new planted banana, farmer will harvest a bunches of banana with >10 combs which composed of 18 fingers each comb in average, but at fourth harvest and afterward farmers will only get a banana bunches with five or less combs and smaller fingers, if proper management of plant parasitic nematodes were not implemented (Swandono et al. 2009; Suyadi 2013). Based on the explanations stated above, and determination of the average annual productivity based on the attainable yield (Figure 2 and Table 4) experiencing yield loss on banana of about 61% was common in the province, because quantitatively the number of comb was reduced and qualitatively the size of fingers become smaller. The highest productivity reduction of banana in the province could reached 78.65% (Table 4).

Just like on tomato management case, farmers controlling PPN on banana only indirectly, it was the impact of organic manure application as soil amendment. Then, the organic manure will supply a nutrient to the crop as well as provide a "food" for natural enemies of PPN. That case could easily distinguished on the banana planted around the farmers housing, where banana plant always received organic material from the household waste.

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