INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 9, No. 3, p. 129-138, 2016

RESEARCH PAPER OPEN ACCESS

Selection of potato varieties (*Solanum tuberosum* L.) in midlands and the effect of using biological agents

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Key words: Cultivation, Diseases, Growth parameters

http://dx.doi.org/10.12692/ijb/9.3.129-138 Article published on September 22, 2016

Abstract

The study is aimed to produce a potato variety that suits with potato cultivation in midlands as well as to know the effect of using biological agents. The research was conducted from March to July 2015, in Bumiaji and Poncokusumo, two districts in Indonesia. The research was carried out by using Split Plot Design (SPD) consisting of ten treatments and three replications. The treatment was twofold: without and with biological agents (*Trichoderma viride*, *Pseudomonas fluorescents*, *Streptomyces sp.*). Varieties as the subplots are Granola Lembang, Granola Kembang, Desiree, DTO 28, and Nadiya. The results showed that the five different varieties of potatoes with the provision of biological agents showed different responses to the growth parameters and a decline against *Phytophthora infenstan* and *Ralstonia solanacearum* diseases. Nadiya variety treated with biological agents indicates the best growth and the best production in midlands of 18.85 tons/ha-1 in Poncokusumo and 18.80 tons/ha-1 in Bumiaji.

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Introduction

Indonesian potato productivity increases with the consumption of potatoes. In 2009 to 2012, the productivity of the potato according to the land width of 66,531 ha-1, 59,882 ha-1, and 65,989 ha-1 resulted in an average of 15.94 tons ha-1, 15.96 tons ha-1, and 16.58 tons ha-1 (Badan Pusat Statistik dan Direktorat Jenderal Hortikultura, 2013).

The consumption of potato in Indonesia continues to increase with the projected increase of 1.68% per year until 2014, where potato consumption in 2002 was 0.82 million tons to 0.88 million tons in 2006 and to 0.93 million tons in 2007 (FAO, 2012). Potato growing areas in 2013 are 62,900 hectares and the total production of 1,124,282 tons (Badan Pusat Statistik dan Direktorat Jenderal Hortikultura, 2015).

The main factor underlying the planting of potatoes in midlands is the limited agricultural land in the highlands. Exploration effort of potato cultivation land that can be implemented is developing varieties of potato plants adaptive to the environment of midlands. However, farmers tend to be less interested in planting potato in midlands as it has low productivity when compared with the productivity of the potato crop in the highlands, e.g. Granola Kembang in Tosari (highland) to reach 30 tons ha-1. Therefore, the selection of appropriate varieties of potatoes is expected to be able to adapt to the midland from both outcomes and disease resistance (Lehar, 2012; Rosyidah *et al*., 2013; Wulandari, 2014). Selection of the lowland 35 varieties resulted in three superior varieties, namely, Rea Pontiak, Desiree, and DTO 28 (Wardiyati, 1990).

Another problem faced by potato farmers in midlands is the presence of disease which is higher than in highlands. One of the diseases that attack potato crops in midlands is bacterial wilt or brown rot caused by *Ralstonia solanacearum*. In addition, other diseases that attack the potato crops is rotting (blight) leaves caused by pathogenic fungi *Phytophthora infestans* and *Fusarium* wilt caused by the fungus *Fusarium oxysporum*.

Application of biological agents is one technology that can control the disease and optimize the productivity results in midlands. Biological agents applied in this study are *Trichoderma viride*, *Pseudomonas fluorescents*, and *Streptomyces* sp. The three (3) types of biological agents could provide hope for being able to control pathogens on potato and accelerate the process of decomposition of organic matter in the soil. In addition, the biological agents act as Plant Growth Promoting Rhizobacteria (PGPR). PGPR is a compound that serves as a supplier of nutrients, antibiosis, bioactive, such as growth hormone, and stimulates root extension that results in better plant growth that may affect the potato production. Therefore, based on the problem above this study aim was to produce a potato variety that suits with potato cultivation in midlands as well as to know the effect of using biological agents.

Materials and methods

The study was conducted from March to July 2015 in Bumiaji District at Batu City and Poncokusumo District at Malang Regency in Jawa Timur Province, Indonesia. Geographically, they are located in midlands with an altitude of ± 700 m above sea level and the average temperature reaches 26°C.

Samples

This study was used seed of potato from the varieties of Granola Lembang, Granola Kembang, Desiree, DTO 28, and Nadiya. The biological agents used are *Trichoderma viride*, *Pseudomonas fluorescence*, and *Streptomyces* sp., chicken manure as much as 20 tons ha-1, NPK (16 : 16: 16) at a dose of 1 ton ha-1, fungicide with the active ingredient of propinab 70% and metalaxyl 35%, as well as insecticide with the active ingredient of karbofuran 3% and pyridaben.

Research Design

This study uses the Split Plots Design (SPD), which consists of ten (10) treatments and three (3) replications. The main plots are with and without biological agents. Varieties as subplots are Granola Lembang, Granola Kembang, Desiree, DTO 28, and Nadiya.

Based on these two (2) factors, ten (10) combinations of treatments were obtained, each treatment was repeated three (3) times to obtain 30 experimental plots. Biological agents were given two weeks before planting. There were three (3) kinds of biological agents, namely *Trichoderma viride*, *P. fluorescence*, and *Streptomyces* sp. blended, then doused in soils which had been given organic fertilizer. The concentration of each biological agent was the same, which was 20 ml/L of water. Population of biological agents was 109 cfu.mL-1 for *Trichoderma viride* (Lehar, 2012) and 108 mL-1 for *P. fluorescence*, and *Streptomyces* sp. (Rosyidah *et al*., 2014).

Statistical Analysis

Data analysis was conducted using Ms.Excel 2010 version with analysis of variance test (F-test with a standard error of 5%). If there is a significant effect on treatment, then it will be continued by using the Least Significant Difference (LSD) Test at 5% level to determine any differences among treatments.

Results and discussion

Potato plant growth components

Based on the research results in two pilot sites (Poncokusumo District and Bumiaji District), it has been revealed that biological agents given to the five kinds of varieties do not show any effect to plant height, to number of stems, and to stem diameter (Table 1).

Table 1. The height, number of stem, and stem diameter potato plants in two observation locations based on varieties and the effect of biological agents.

Treatment	Poncokusumo			Bumiaji		
	Height	Numb. of Stem	Stem Diameter	Height	Numb. of Stem	Stem Diameter
Without biological agents	44.40 a	2.21 a	7.43 a	42.25 a	1.76 a	7.38 a
With biological agents	45.40 a	2.42 b	8.00 b	49.58 a	2.22 a	7.81 a
LSD 5%	7.16	0.54	0.12	12.94	1.01	1.01
Granola Lembang	33.58 a	2.04 a	7. 62 b	42.96 ab	1.46 a	6.80 a
Granola Kembang	32.04 a	2.08 a	7.51 b	44.02 ab	1.71 a	6.80 a
Desiree	48.46 bcd	1.98 a	6.19 a	33.75 a	1.21 a	6.38 a
DTO 28	55.67 d	2.56 bc	8.62 cd	60.25 c	2.74 bc	8.99 bc
Nadiya	54.75 cd	2.92 c	8.65 d	48.61 b	2.83 c	9.01 c
LSD 5%	7.83	0.54	0.60	10.75	0.76	1.46

Note: Numbers accompanied by the same letters in the same column are not significantly different based on the LSD 5%.

There has been the effect on the number of leaves and leaf area (Table 2) due to the administration of biological agents.

The height of the plant, the number of stems, and the stem diameter are not affected either by biological agents or by varieties of potatoes in Poncokusumo and Bumiaji. In Poncokusumo, plants treated with biological agents show bigger stem diameter and more stem numbers than without the administration of biological agents, whereas in Bumiaji there seems to be no difference among the varieties tested, although DTO 28 and Nadiya has the advantage of plant height, number of stems, and stem diameter.

Varieties of potato plants show different growth responses to the administration of biological agents. It is assumed that not all varieties of potato plants can adapt to midlands, and the response of varieties of potato plants toward biological agents was higher growth compared to without biological agents. Hamdani (2009) states that genetic factors are more dominant on the characters displayed on the crops in midlands as genetic factors contribute greater than the environmental factors.

High genetic diversity will really help a population to adapt to changes in the surrounding environment (Ruchjaniningsih, 2006).

Table 2. The number of leaves and leaf area potato plants in two observation locations based on varieties and the effect of biological agents.

Treatment	Location: Poncokusumo				Location: Bumiaji			
	Without Biological Agents		With Biological Agents		Without Biological Agents		With Biological Agents	
	Number of Leaves	Leaf Area	Number of Leaves	Leaf Area	Number of Leaves	Leaf Area	Number of Leaves	Leaf Area
Granola Lembang	30.58 a	74.42 bc	37.42 a	265.20 bcde	60.92 ab	173,18 ab	74.42 bc	262,87 bcd
Granola Kembang	27.33 a	86.87 c	19.58 a	273.35 de	80.75 bc	167,15 ab	86.87 c	272,27 cd
Desiree	46.08 a	56.08 ab	56.08 a	266.18 cde	41.25 a	155,67 a	56.08 ab	262,87 bcd
DTO 28	134.42 bc	193.17 fg	149.83 de	480.74 gh	158.17 de	390,80 ef	193.17 fg	474,10 fg
Nadiya	140.42 cd	196.00 g	160.54 e	496.46 h	165.67 e	333,96 de	196.00 g	488,96 g
LSD 5%	41.38	25.38	41.38	25.38	69.35	96.48	69.35	96.48

Note: Numbers accompanied by the same letters in the same column are not significantly different based on the LSD 5%.

Suryanti *et al.* (2003) state that plants treated with biological agents of *T. viride*, *P. fluorescence*, and *Streptomyces* sp., are able to decompose lignin, cellulose, and chitin of organic matter into nutrients ready to be absorbed by plants.

Table 2 shows that the number of leaves of the potato varieties of Lembang Granola, Granola Kembang, and Desiree did not differ between those with biological agents and without biological agents. DTO 28 and Nadiya treated with biological agents had more leaves than those without biological agents; the same thing happened in Bumiaji. Moreover, Table 2 shows that Nadiya administered with biological agents has the biggest leaf width, 496.46 in Poncokusumo and 488.96 in Bumiaji. This is similar for DTO 28 treated with biological agents, as the leaf area in Poncokusumo is 480.74 and Bumiaji are 474.10. Plant leaf area is the lowest for Desiree without biological agents that is 157.00 in Poncokusumo and 155.67 in Bumiaji, but does not differ by no biological agents of Granola Lembang (166.18) and Granola Kembang (170.15).

Table 3. Percentage of plants attacked by *Phytophthora infenstan* disease in two observation locations based on varieties and the effect of biological agents.

Treatment	Plants Attacked (%)			
	Poncokusumo		Bumiaji	
	Without Biological Agents	With Biological Agents	Without Biological Agents	With Biological Agents
Granola Lembang	13.33 d	1.67 b	10,00 c	0,00 a
Granola Kembang	0.00 a	0.00 a	0,00 a	0,00 a
Desiree	5.00 c	0.00 a	18,33 d	3,33 b
DTO 28	0.00 a	0.00 a	0,00 a	0,00 a
Nadiya	0.00 a	0.00 a	0,00 a	0,00 a
LSD 5%	1.11		2.13	

Note: Numbers accompanied by the same letters in the same column are not significantly different based on the LSD 5%.

In Poncokusumo, plants treated with biological agents has leaf area bigger than those without biological agents. DTO 28 and Nadiya have bigger leaf area compared to Granola Lembang, Granola Kembang, and Desiree treated with and without biological agents. In Bumiaji, all varieties treated with biological agents have bigger leaf area than without biological agents.

Biological agents given to organic fertilizer will be able to act as decomposers of organic matter to provide nutrients to support plant growth (Lehar, 2012). The results of the process of decomposition of organic matter are the release of nutrients contained in organic materials. A metabolism that occurs in the plant will run normally when the availability of nutrients is sufficient, thus affecting the process of photosynthesis and respiration (Wulandari, 2014).

Table 4. Percentage of plants attacked by *Ralstonia solanacearum* disease in two observation locations based on varieties and the effect of biological agents.

Treatment	Plants Attacked (%)			
	Poncokusumo		Bumiaji	
	Without Biological Agents	With Biological Agents	Without Biological Agents	With Biological Agents
Granola Lembang	5.00 b	1.67 a	10.67 ef	10.00 def
Granola Kembang	5.00 b	0.00 a	10.00 cdef	0.00 a
Desiree	5.00 b	0.00 a	15.00 f	6.67 bcde
DTO 28	1.67 a	0.00 a	6.67 bcde	0.00 a
Nadiya	0.00 a	0.00 a	0.00 a	0.00 a
LSD 5%	2.13		7.09	
KK_1 (%)	86.24		40.23	
KK_2 (%)	70.42		53.95	

Note: Numbers accompanied by the same letters in the same column are not significantly different based on the LSD 5%.

Potato plants treated by *T.viride* and combined with *P. fluorescens* and *Streptomyces* sp. show higher number of leaves and bigger leaf area as *T.viride* stimulates plant growth by secreting growth hormones, such as auxin and cytokinins (Glick, 1995).

Furthermore, organic matters decomposed by *T. viride* biological agent and in combination with *P. fluorescens* and *Streptomyces* sp. are able to stimulate height, the number of stem, number of leaves, and leaf area of potato plants (Nurbaya *et al*., 2011; Lehar, 2012; Mezaache-Aichour *et al*., 2013; Rosyidah *et al*., 2013). This is also evidenced by Haryuni (2013) that the stevania plant treated with biological agents shows an increase in the number of leaves than without biological agents.

Table 5. Weight per potato plant in two observation locations based on varieties and the effect of biological agents.

Treatment	Weight per Potato Plant (gr)			
	Poncokusumo		Bumiaji	
	Without Biological Agents	With Biological Agents	Without Biological Agents	With Biological Agents
Granola Lembang	116.64 ab	188.01 abc	104,50 a	181,67 ab
Granola Kembang	88.94 ab	186.92 abc	74,17a	232,50 a
Desiree	44.90 a	83.56 ab	44,23a	80,67 a
DTO 28	367.65 bc	864.02 de	358,33 bc	835,58 de
Nadiya	507.43 c	882.77 e	459,75 c	859,17 e
LSD 5%	320.65		194.47	

Note: Numbers accompanied by the same letters in the same column are not significantly different based on the LSD 5%.

Phythoptora infestan and Ralstonia solanacearum attack

There is an interaction between varieties of potatoes and biological agents towards the attack of diseases in two locations observation. Varieties treated with biological agents and without biological agents show different levels of effect toward attack of diseases caused by *Phythoptora infestan* (Table 3) and *Ralstonia solanacearum*, as shown in Table 4.

Table 3 shows that in two locations, the variety of potato plants appeared to be most vulnerable to *Phytophthora infenstan* disease (high percentage of attack) is on Granola Lembang without biological agents (13.33%) in Poncokusumo, and Desiree variety without biological agents (18.33%) in Bumiaji. Treatment for Granola with biological agents in Poncokusumo is 1.67% and for Desiree with biological agents in Bumiaji is 3.33%. Nadiya and DTO 28 without biological agents and with biological agents are not affected by *Phytophthora infenstan* disease. Table 4 shows that in the two locations, the variety of potato plants appeared to be most vulnerable to *Ralstonia solanacearum* disease (high percentage of attack) is on Granola Lembang, Granola Kembang, and Desiree without biological agents, reaching 5.00% in Poncokusumo. Only one variety, with biological agents, attacked by *Ralstonia solanacearum*, that was Granola Lembang (1.67%).

Table 6. Weight of potato plant per plot in two observation locations based on varieties and the effect of biological agents.

Treatment	Weight of Potato Plant per per Plot (Kg)			
	Poncokusumo		Bumiaji	
	Without Biological Agents	With Biological Agents	Without Biological Agents	With Biological Agents
Granola Lembang	2.67 a	2.83 c	0.50 a	1.10 d
Granola Kembang	2.80 a	2.97 d	0.90 c	2.00 e
Desiree	3.52 ef	2.70 ab	0.50 a	0.67 b
DTO 28	3.62 f	4.53 h	6.40 fg	6.63 h
Nadiya	4.45 gh	7.13 i	6.43 g	7.99 i
LSD 5%	0.16		0.07	

Note: Numbers accompanied by the same letters in the same column are not significantly different based on the LSD 5%.

The highest percentage of variety affected by *Ralstonia solanacearum* in Bumiaji is Desiree without biological agents (15.00%), and there is no significant effect on Granola Lembang and Granola Kembang. The use of biological agents tends to decrease the number of attack by *Phytophthora infenstan* and *Ralstonia solanacearum* disease in Poncokusumo and in Bumiaji.

Plants treated with biological agents in proper organic fertilizer can enhance microbial activity in organic fertilizers and can stimulate plant growth as expected. Biological agents added to the organic fertilizer also boost biodiversity in the soil (Arinal and Nurrahma, 2013), so that giving *T. viride* combined with *P. fluorescens* and *Streptomyces* sp. is expected to increase the number of beneficial bacteria. This way the pathogens can be controlled.

The results of the research in the two locations show that the percentage of infected potato plants by *Phytophthora infenstan* (Table 3) and *Ralstonia solanacearum* (Table 4) can be reduced by the provision of biological agents. This is presumable because of the administration of biological agents *T. viride* and combined with *P. fluorescens* and Streptomyces sp. on chicken manure and cow dung as organic fertilizer, so that plants easily colonize the biological agents that are antagonistic against pathogens that can cause a resistant response in plants.

Further, plants not given biological agents of *T. viride* in combination with *P. fluorescens* and Streptomyces sp. will be dominated by the pathogen.

Plants that colonize with biological agents that are antagonistic to pathogens can cause resistance response in plants. Biological agents generally have the effect of system resilience in the plant because it can produce some phenols which can be used to produce an antibiotic that provide immune (Rosyidah *et al*., 2013).

This is consistent with the results of studies by Soesanto *et al*., (2012), Chamzurni *et al*., (2011), and Sari *et al*., (2012) which state that the biological agents capable of suppressing the pathogen, so that plants can grow and develop without the attack of pathogens. They will also act as a producer of growth hormone, known as Plant Growth Promoting Rhizobacteria (PGPR), which can stimulate plant growth.

Table 7. Weight of potato plant per hectare in two observation locations based on varieties and the effect of biological agents.

Treatment	Weight of Potato Plant per Hectare (ton/Ha^{-1})			
	Poncokusumo		Bumiaji	
	Without Biological Agents	With Biological Agents	Without Biological Agents	With Biological Agents
Granola Lembang	0.79 a	1.61 b	0.87 a	1.59 b
Granola Kembang	1.47 b	1.62 b	2.14 d	4.76 f
Desiree	1.90 b	1.99 b	1.81 c	2.62 e
DTO 28	16.15 cd	18.22 e	16.11 gh	18.21 i
Nadiya	16.25 d	18.85 f	16.20 h	18.80 j
LSD 5%	0.42		0.15	

Note: Numbers accompanied by the same letters in the same column are not significantly different based on the LSD 5%.

According to Wachjadi *et al*., (2013), the phenolic compounds in plants are directly related to the level of plant resistance to infectious disease. Treatment using *T. viride* biological agents and in combination with *P. fluorescens* and *Streptomyces* sp. is able to control diseases caused by the attack of *Phytophthora infenstan* and *Ralstonia solanacearum*; this is supported by the opinion of Marwoto and Muharam (2013) and Suprapta (2012) which state that biological agent of *P. fluorescens* is able to control the diseases caused by control *Ralstonia solanacearum* and other pathogenic fungi in potato plants.

Production of potato plants

There has been a relationship between varieties of potatoes and the use of biological agents on the weight of potato tuber, per plot and per hectare, both in Poncokusumo and in Bumiaji. The following data show the weight per plant (Table 5), weight per plot (Table 6) and weight per hectare (Table 7) of potato.

Table 5 shows that the highest weight per plant is for Nadiya variety with biological agents (882.7 g) in Poncokusumo and in Bumiaji (859.17 g). The lowest weight is for Desiree variety without biological agents (44.90 g) in Poncokusumo and (44.23 g) in Bumiaji. Nadiya variety with biological agents shows the highest value but is not significantly different from DTO 28 variety. It also shows the highest value with biological agents in Poncokusumo and Bumiaji but is significantly different from other treatments.

Table 6 shows that Nadiya variety with biological agents has the highest weight per plot (7.13 kg) in Poncokusumo and in Bumiaji (7.99 kg). The weight of Nadiya variety per plot with biological agents is significantly different from other treatments. The lowest weight of tuber per plot is for Granola Lembang without a biological agent (2.67 kg) in Poncokusumo. The lowest weight of tuber per plot is for Granola Lembang without a biological agent (0.50 kg) and Desiree (0.50 kg) in Bumiaji.

Nadiya variety with biological agents has the highest weight per hectare (18.85 tons/ha-1 in Poncokusumo and 18.80 tons/ha-1 in Bumiaji) as shown in Table 7; this is significantly different from other treatments. The lowest weight of tuber per hectare is for Granola Lembang without a biological agent (1.47 tons/ha-1) in Poncokusumo and Desiree (1.81 tons/ha-1) in Bumiaji. All varieties treated with biological agents are higher than those without, except for Granola Kembang and Desiree in Poncokusumo.

Such interactions show that the administration of biological agents *T. viride*, *P. fluorescens*, and *Streptomyces* sp. is able to increase crop weights, per plant, per plot, and per hectare when compared to the treatment without biological agents. Biological agents of *T. viride*, *P. fluorescens*, and *Streptomyces* sp. act as growth stimulants known as PGPR. PGPR is known as a compound that serves as a supplier of food substances, antibiosis, or as a growth hormone to increase the growth of potato plants which is characterized by an increase in the number of leaves, leaf width, the weight of tubers per plant, per plot, and per hectare. It is in line with the research by Mugiastuti *et al*., (2010) finding that *Pseudomonas fluorescens* is able to stimulate the growth of tomato plants under PGPR working mechanism, to produce more growth hormone.

Biological agents of *T. viride*, *P. fluorescens*, and *Streptomyces* sp. act as growth stimulants known as PGPR. PGPR is known as a compound that serves as a supplier of food substances, antibiosis, or as a growth hormone to increase the growth of potato plants which is characterized by an increase in the number of leaves, leaf width, the weight of tubers per plant, per plot, and per hectare. It is in line with the research by Mugiastuti *et al*., (2010) finding that *Pseudomonas fluorescens* is able to stimulate the growth of tomato plants under PGPR working mechanism, to produce more growth hormone.

Total tuber production is closely related to the number of leaves and leaf area produced. The more the number of leaves on plants with sufficient light intensity, the greater the accumulation of starch in the tuber so the weight becomes greater.

It is also consistent with research by Baihaqi *et al*., (2013) which states that the more number of leaves and leaf area, the higher production of potato tubers will be.

Production of potato tubers is due to high intensity of sunlight absorbed and used to split water molecules into oxygen and hydrogen. Oxygen and hydrogen will be released by plants along with carbon dioxide from the air made into sugars or glucose. Glucose formed is stored in the form of starch. This result of photosynthesis is translocated to tubers (Ferliati *et al*., 2014). The same thing is also delivered by Chliyeh *et al*., (2014) that administration of biological agents can increase the weight of dry stover on green plants and chili.

Based on the research that has been conducted, it shows that based on varieties and biological agents, optimal results per hectare for potato plants is for Nadiya variety treated with biological agents of 18.85 tons/ha-1 in Poncokusumo and 18.80 tons/ha-1 in Bumiaji and is significantly different with other treatments. This proves that each variety of potato gives different responses to biological agents. According to Wulandari (2014), different varieties of potato plants yield in different production results.

T. viride biological agent in combination with *P. fluorescens* and *Streptomyces* sp. will get the highest growth hormones that stimulate plant growth and production. This is consistent with research findings by Rosyidah *et al*., (2014) that administration of biological agents of *P. fluorescens* + *Streptomyces* sp. + *T. viride* tends to increase growth, fresh weight of tuber per hectare, the percentage of tuber dry weight, and tuber density, and decreases sugar reduction than other treatments. The same is reported by Soesanto *et al*., (2013) stating that the administration of biological agents of *T. viride* combined with *P. fluorescens* and *Streptomyces* sp. produce growth hormone or PGPR which is a compound that serves as a supplier of nutrients, antibiosis, bioactive, such as growth hormone. It also stimulates root extension that results in better plant growth as well as increases production.

Conclusion

Based on the research, it can conclude that the five different varieties of potatoes with the provision of biological agents in Poncokusumo and Bumiaji demonstrate different responses to the growth parameters as well as a decline against diseases caused by *Phytophthora infenstan* and *Ralstonia solanacearum* on all varieties. Nadiya variety treated with biological agents demonstrates the best growth and the best production in midlands in Poncokusumo (8,85g tons/ha-1) and in Bumiaji 18.80 tons/ha-1).

Acknowledgement

The author thanks to Mr. Abd. Fatah and Mr. Rumboko for their willingness to grant permission for to use their land for my study.

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