INTRODUCTION

Indonesia heavily relies on soybeans as a source of food, feed for livestocks, or raw materials for industries. Indonesia’s soybean production has fluctuated in five years between 2013–2018. Although Indonesia’s soybean production has been reported to reach approximately 982,598 ton in 2018, it was still not sufficient for domestic needs which was predicted to reach 2.8 million tonnes per year (Pusat Pengkajian Perdagangan dalam Negeri, 2019). Production fluctuation of soybean is caused by several factors including damage caused by plant pest and disease.

*Aphis glycines* (Hemiptera: Aphididae) is a major pest on soybeans. *A. glycines* damage plant directly and indirectly by sucking leaf and stem fluids and decreasing quality and quantity of soybean productions. In addition, *A. glycines* cause indirect damage by being vectors of Soybean Mosaic Virus (SMV) (Widariyanto, et al., 2017).

Soybean yield loss by *A. glycines* has been reported to reach 58% (Wang et al., 1994); thus, *A. glycines* populations must be managed to stay below economic thresholds. Integrated Pest Management (IPM) is a pest management method based on environmental knowledge and is declared to be the main pest management approach in Indonesia. Good agricultural practice in maintaining plants’ health is the main component in IPM, since healthy crops are more resistant to pest damage. Plant growth promoting rhizobacteria (PGPR) is a method to increase plant resistances, using material that consisted of rhizophere microorganisms with activities that benefit crops (Kafrawi, et al., 2015).

PGPR can induce plant resistances to suppress pest populations (Soesanto, 2008). Resistances is the plant’s ability to harm pest and withstand pest attacks. Induced resistances on vegetative tissues will disturb feeding process and pest’s lives. Disturbed feeding will then affect the growth, development, and reproduction of the pest. Therefore, plant resistance is a limiting factor in the development of pest populations (Hutasoit & Sitanggang, 2018). Latifah et al. (2018) reported lower *Bemisia tabaci* populations in treated plants than in untreated plants.
and leaf spot incidences on tomatoes treated with PGPR compared to the untreated control. Rhizobacteria, component in a PGPR, can affect the interactions between plants and insects. Rhizobacteria are able to increase nutrition uptakes in plants causing an increase of food quality for insects. This is an example of induced tolerance due to rhizobacteria (Rashid & Chung, 2017).

The effects of PGPR on the survivorship and fecundity of A. glycines can be evaluated using life tables. Life tables can provide information on natality, development, reproduction, and mortality of each individual in a population. This study aimed to observe the ability of a commercially available PGPR product, containing Bacillus polymyxa and Pseudomonas fluorescens, in suppressing Aphis glycines Matsumura (Hemiptera: Aphididae) populations.

**MATERIALS AND METHODS**

This study was done at the Department of Plant Protection, Faculty of Agriculture, IPB University, Dramaga between January–April 2013.

**A. glycines Rearing**

Soybean seeds, of Grobogan variety, were used for A. glycines rearing and planted in 15 30× 30 cm polybags filled with soil and compose (2:1) at rates of 4 kg/polybag, compound fertilizer (containing nitrogen, phosphate, and potassium) 16-16-16 at rates of 0.5 g/polybag. Each polybag contained 6 soybean seeds and was watered every day. Initial populations of A. glycines were obtained from soybean fields located in Megamendung, Bogor. A. glycines were infested onto two-weeks-old soybean plants and allowed to reproduce (Figure 1). Soybeans were closed with plastic cylinders and cloth mesh were placed on top. A. glycines were allowed to reproduce until required numbers were reached.

**Effect of PGPR on A. glycines Biology**

All surviving A. glycines were observed everyday to check whether individuals were alive or dead, molted (indicated by exuviae), and a count of the number of nymphs was done. A. glycines life cycles were observed since 1st instar nymphs were infested onto plants until they reach imagoes. A. glycines went through 4 nymph instars before reaching imago. Development between instars were indicated by the existing of exuviae. Pre-oviposition stages were assumed since individuals reached imagoes until the first offspring were produced. Imago life time was counted since individuals reached imagoes until mortality. Fecundity were obtained from the number of nymphs produced by each A. glycines during its lifetime. Observation data were organized into a biological life table of A. glycines. Observations included the length of the 1st, 2nd, 3rd, and 4th nymph instars, life cycle, pre-oviposition, life length, and fecundity on PGPR treated and untreated plants.

**A. glycines Cohort Rearing**

Treatments used in this experiment were a PGPR treated and untreated control with 65 replications for each treatment. As much as 240 soybean seeds, variety Grobogan, were wash using clean water and air-dried on sterile paper for 15 minutes. Half of the seed batch were treated using PGPR and the other half was untreated as a control. The PGPR used in this experiment was Rhizomax®. Its formulation was powdery and contained the active ingredients of B. polymyxa dan P. Fluorescens. PGPR suspension were made form 50 g of PGPR products mixed into 5 L of sterilized water. Soybeans seeds used for the treated treatment were immersed in the PGPR.
suspension for 15 minutes, while untreated seeds were immersed in sterile water. Seeds were then air-dried for 15 minutes. Soybean seeds were planted in 60 × 30 cm polybags. As much as 150 mL of the PGPR suspension remains was watered onto PGPR treated soybean plants, while sterile water was treated on the untreated control. This same watering treatment was done when soybeans reached 2 weeks-old.

Soybean seeds used to feed *A. glycines* imagoes and produce 1st instar nymphs were planted in 25 200 mL plastic cups filled with 200 g of growing media consisting of soil and compose (2:1). Two soybean seeds were planted in each cup. Soybean plant that have reached 7 days old were covered with plastic cylinders with cloth meshes on their top as previously mentioned (Figure 2). The following day after plants were covered, two *A. Glycines* imagoes were placed on plants and newly produced 1st instar nymphs were obtained the next day.

First *A. glycines* nymphs were infested on 3-week-old soybean shoots that have been treated or not treated with PGPR. Plants were covered with plastic cylinders with the top and bottom covered with cloth meshes and polybags were placed on top of black cardboard.

**Life Tables and Demographic Statistics of A. glycines**

Surviving individual were counted every day to obtain survivorship data (l_x) of *A. glycines*. Daily fecundity (m_x) were calculated from the average nymphs produce by each imago at every stage (x). Survivorship and daily fecundity were organized into curves and life tables were obtained. Life table of cohorts are the life tables that records the development of each cohort by recording the survivorship of individuals until mortality of all individuals (Begon *et al.*, 2006). Life table parameters of 1 generation of *A. glycine* were divided into 2-week periods starting from week 1 until week 37 (Price, 1997; Wilson & Bossert, 1971). Insect’s demographic statistics according to Zeng *et al.*, (1983) are quantitative analytic parameters of insect populations regarding to its survivalship, fecundity, and population growth patterns. These parameters include:

1. Gross Reproduction Rate (GRR) = \( \sum m_x \)

2. Net Reproduction Rate (Ro) = \( \sum l_x m_x \)

3. Intrinsic addition rate (r_m) = \( \sum l_x m_x e^{-r_m x} = 1 \)

4. Average Generation Length (T) = \( (\ln Ro) / r_m \)

5. Doubling Time (DT) = \( \ln (2) / r_m \)

Net reproduction rates (Ro) is the average offspring produces by each imago (Begon *et al.*, 2006).

**Data Analysis**

Data variances were processed using Microsoft Excel 2007 and analyzed using a two-sample t test at \( \alpha = 5\% \) using Minitab 16.

**RESULTS AND DISCUSSION**

The Effect of PGPR Treatment on *A. glycines* Biology

Results showed that life cycles of *A. glycines* were significantly different between the two treatments. Life cycles of *A. glycines* were longer on plants treated with PGPR compared to ones reared on untreated plants. This may be explained by the results from a study by Hutasoit & Sitanggang (2018)

![Figure 2. Soybean plants in plastic cages used to supply 1st instar *Aphis glycines* nymphs](image)
which showed that PGPR applications were able to affect the development time of 1st and 2nd instar nymphs, pre-pupa, and T. parvispinus imagoes. According to Tétard-Jones et al. (2012), PGPR application had indirect effects on aphid that caused development times to be longer. Longer life cycles and time required to reach imago stages will directly delay individual to reproduce, which is an important factor for insects to successfully infest plants. Kozlowski (1992) stated that delays of individuals to reach reproduction stages will increase mortality before reproduction, length of reproduction stages, offspring numbers and longer generation length.

Life time of A. glycines were not significantly different between treatments at all life stages, except 2nd nymph instars (Table 1). A. glycines molt 4 times during its development into imagoes. Development time of 2nd instar A. glycines on untreated plants were significantly lower compared from insects on PGPR treated plants causing individuals taking longer to reach imago stages. PGPR application may inhibit fluid sucking by A. glycines causing nutrient deficiency of individuals and hinder development. Research by Fahimi et al., (2013) demonstrated that PGPR application significantly affected 1st and 3rd instar, but not significantly affect 2nd and 4th instar A. gossypii. Short life time will affect fecundity. Fecundity and the length of pre-oviposition of A. glycines were not significantly different between the two treatments (Figure 3). Food affect growth, development, fertility, mortality, and fecundity of insects (Begon et al., 2006).

Survivorship and mortality of A. glycines were similar between the two treatments used in the experiments (Figure 4). Survivorship of A. glycines from untreated plants reached 37 days, while 25 days on PGPR treated plants. Rhizobacteria possess antagonistic properties that suppress growth of phytopathogens by competing for nutrient and habitat,

Table 1. Aphis glycines biology on untreated and PGPR treated soybean plants

| Stage            | Control (days) | PGPR (days) |
|------------------|----------------|-------------|
| 1st Instar       | 1.2            | 1.3 ns      |
| 2nd Instar       | 1.1            | 1.4 *       |
| 3rd Instar       | 1.1            | 1.4 ns      |
| 4th Instar       | 1.1            | 1.4 ns      |
| Life cycles      | 4.5            | 4.9 *       |
| Pre-oviposition  | 0.4            | 0.7 ns      |
| Life length      | 14.6           | 14.1 ns     |
| Fecundity        | 66.6           | 65.3 ns     |

Information: ns = no significances, *treatments were significantly different based on t-test at α = 5%.

Figure 3. Survivorship and daily fecundity of Aphis glycines on untreated plants (control) (a) and PGPR treated soybeans (b)
supply Fe/iron to plants, produce lytic enzymes, and antibiotic properties (Jing et al., 2007). This shows that PGPR are able to induce plant resistances and accelerate *A. glycines* mortality.

*A. glycines* survival type can be categorized as type I. Many nymphs were produced daily based on the fecundity curves ($m_x$) (Figure 5). In some occasions, there were *A. glycines* nymphs that were reared on both treatments that were able to produce offsprings. Food availability is an extrinsic factor that affect developmental time and reproduction of insects. Fecundity curve ($m_x$) continually increased after *A. glycines* individuals reach imagoes stage.

The highest fecundity reached 8.5 nymphs in one day was from untreated soybean plants and eight nymphs on PGPR treated soybean plants. These daily fecundities occurred peak several times on populations reared on untreated soybean plant, while from populations reared on PGPR treated plants only occurred once. This demonstrated that PGPR treatments were able to reduce the occurrences and level of maximum daily fecundity of *A. glycines*.

### The Effect of PGPR on *A. glycines* Demographic Statistics

The value of *A. glycines* GRR on untreated soybeans was larger than ones treated with PGPR, reaching 104.861 and 71.834 individual/generation respectively (Table 2). The number of female individuals produced by female imagoes (Ro) increased on untreated plants. Ro values from populations reared on untreated plants imply that the next *A. glycines* generation will increased by 63.326 folds from the previous generation and by 57.780 fold on PGPR treated plants. High GRR and Ro values indicate suitability of host for insects (Hidayat et al., 2019).

The value of rm are related to mortality, natality, and developmental time of an organism. On untreated plants, rm value was 0.586 nymphs/day in optimum environmental conditions and unlimited resources and 0.557 on PGPR treated plants. Longer life cycles of *A. glycines* reared on PGPR treated soybean plants causes lower intrinsic growth rate compared to populations reared on untreated plants. Intrinsic growth rate can be used to predict insect
population growth for a certain period and compare reaction of populations to temperature, humidity, nutrient levels, or secondary metabolites from plants (Hutasoit & Sitanggang, 2018; Havlickova, 1987). High rm values indicate that populations may continuously increase (Gill et al., 1989).

Doubling time of *A. glycines* reared on untreated plants was 1.184 days and 1.245 days from populations reared on PGPR treated plants. Low DT values may increase GRR and Ro (Efendi et al., 2018). The value of rm and DT can explain population growth in constant environmental condition and unlimited resources (Price, 1997; Southwood & Henderson, 2000).

PGPR is a soil rhizosphere microbes, which may increase plant growth and its resistances against pest and disease. Application of PGPR will directly affect plants by increasing the availability and mobilization or facilitate nutrients absorption, synthesize and alternate concentrations of various phytohormones that induce growth, and indirectly affect plants by suppressing activities of pest and disease by producing compounds and metabolites, such as antibiotics and siderophore, and systemically induce plant resistances (Zainudin et al., 2014; Walida et al., 2018).

The PGPR bacterial group *Bacillus* sp. and *Pseudomonas* sp. are the most studied genus due to their potential as biocontrol agents (Manik et al., 2018). Antibiosis is a suppressing mechanism used by the *Bacillus* sp. and *Pseudomonas* sp. Antibiosis is a PGPR mediated resistance mechanism against insect on plants that produces allelochemicals, such as chitinase enzymes, hydrogen cyanide (HCN), and siderophore. These allelochemicals have been reported to suppress reproduction, modify physiology, delay maturity, and induce physical behavior or abnormality on insects that eventually inhibit abundances of insect pest (Tuhuteru et al., 2019; Disi et al., 2019).

### Table 2. *Aphis glycines* demographic statistics on untreated and PGPR treated soybean plants

| No. | Parameter                          | Treatment            | Control | PGPR   |
|-----|------------------------------------|----------------------|---------|--------|
| 1.  | Gross reproduction rates (GRR)     | 104.861              | 71.834  |        |
| 2.  | Net reproduction rates (Ro)        | 63.326               | 57.780  |        |
| 3.  | Intrinsic growth rates (rm)        | 0.586                | 0.557   |        |
| 4.  | Average generation length (T)      | 7.084                | 7.287   |        |
| 5.  | Doubling time (DT)                 | 1.184                | 1.245   |        |

**CONCLUSION**

PGPR containing *B. polymyxa* and *P. fluorescens* were able to suppress *A. glycinus* populations. Applications of PGPR caused longer development of 2nd instar nymphs and eventually causing longer life cycles. This caused populations to grow slower than the untreated control.

**LITERATURE CITED**

Begon, M., C.R. Townsend, & J.L. Herper. 2006. *Ecology: From Individuals to Ecosystems*. 4th edition. Blackwell Publishing, Oxford. 659 p.

Disi, J., J. Simmons, & S. Zebelo. 2019. Plant Growth-Promoting Rhizobacteria-induced Defense against Insect Herbivores, p. 385–410. In D.K. Maheshwari & S. Dheeman (eds.), *Field Crops: Sustainable Management by PGPR*. Botany Department, Mohanlal Sukhadia University, Udaipur, India.

Efendi, S., Yaherwandi, & N. Nelly. 2018. Biologi dan Statistik Demografi *Coccinella transversalis* Thunberg (Coleoptera: Coccinellidae), Predator *Aphis gossypii* Glover (Homoptera: Aphididae). *Jurnal Perlindungan Tanaman Indonesia* 22: 91–97.

Fahimi, A., A. Ashouri, M. Ahmadzadeh, V.H. Naveh, A. Asgharzadeh, F. Maleki, & G.W. Felton. 2013. Effect of PGPR on Population Growth Parameters of Cotton Aphid. *Archives of Phytopathology and Plant Protection* 47: 1274–1285.

Gill, J.S., A.S. Sidhu, & J. Sigh. 1989. A Study to Determine Innate Capacity for Increase in Numbers of *Earias insulana* (Boisd) on Cotton. *Journal of Insect Science* 2: 289–295.

Havlickova, H. 1987. Behaviour and Reproduction of Cereal Aphids in Relation to Changes in the Content of Water and Free Amino Acids in Wheat during the Growing Seasons. *Journal of Applied Entomology* 103: 142–147.

Hidayat, P., Harleni, Y. Maharani, & H. Triwidodo. 2019. Biologi dan Statistik Demografi *Rhopalosiphum rufiabdominale* (Sasaki) dan *Tetraneura nigriabdominalis* (Sasaki) (Hemiptera: Aphididae) di Akar Padi. *Jurnal Entomologi Indonesia* 16: 180–186.

Hutasoit, R.T. & K.D. Sitanggang. 2018. Pengaruh *Plant Growth Promoting Rhizobacteria* terhadap Biologi dan Statistik Demografi *Thrips parvispinus* (Thysanoptera: Thripidae) pada Cabai. *Jurnal Agroplasma* 5: 26–34.

Jing, Y.D., Z.L. He, & X.E. Yang. 2007. Role of Soil Rhizobacteria in Phytoremediation of Heavy
Metal Contaminated Soils. *Journal of Zhejiang University SCIENCE* B 8: 192–207.

Kafrawi, Z. Kumalawati, & S. Muliani. 2015. Skrining Isolat *Plant Growth Promoting Rhizobacteria* (PGPR) dari Pertanaman Bawang Merah (*Allium ascalonium*) di Gorontalo, p. 132–139, In Prosiding Seminar Nasional Mikrobiologi Kesehatan dan Lingkungan. Makassar, January 29, 2015.

Kozlowski, J. 1992. Optimal Allocation of Resources to Growth and Reproduction Implications for Age and Size at Maturity. *Trends in Ecology & Evolution* 7: 15–19.

Latifah, E., H.A. Dewi, P.B. Daroini, A.Z. Zakaria, J. Mariyono, & A.L. Hakim. 2018. Uji Teknis dan Ekonomis Komponen Pengendalian Hama Penyakit Terpadu pada Usaha Tani Tomat. *Agrovigor: Jurnal Agroekoteknologi* 11: 1–8.

Manik, W.H., E.K. Kristalisasi, & E. Firmansyah. 2018. Pengaruh Komposisi Media Tanam dan Lama Peredaman PGPR (*Plant Growth Promoting Rhizobacteria*) terhadap Pertumbuhan dan Produksi Tanaman Cabai (*Capsicum annum* L). *Jurnal Agromast* 3: 1–10.

Pusat Pengkajian Perdagangan dalam Negeri. 2019. *Analisis Perkembangan Harga Bahan Pokok di Pasar Domestik dan Internasional*. Kementerian Perdagangan Republik Indonesia, Jakarta. 112 p.

Price, P.W. 1997. *Insect Ecology*. 3rd ed. John Wiley & Sons, New York. 764 p.

Rashid, M.H.O. & Y.R. Chung. 2017. Induction of Systemic Resistance against Insect Herbivores in Plants by Beneficial Soil Microbes. *Frontiers in Plant Science* 8: 1816.

Soesanto, L. 2008. *Pengantar Pengendalian Hayati Penyakit Tanaman*. PT Rajagrafindo Persada, Jakarta. 574 p.

Southwood, T.R.E. & P.A. Henderson. 2000. *Ecological Method*. 3rd ed. Blackwell Science, Oxford. 565 p.

Tétard-Jones, C., M.A. Kertesz, & R.F. Preziosi. 2012. Identification of Plant Quantitative Trait Loci Modulating a Rhizobacteria-Aphid Indirect Effect. *PLoS One* 7: e41524.

Tuhuteru, S., E. Sulistyaningsih, & A. Wibowo. 2019. Aplikasi *Plant Growth Promoting Rhizobacteria* dalam Meningkatkan Produktivitas Bawang Merah di Lahan Pasir Pantai. *Jurnal Agronomi Indonesia* 47: 53–60.

Walida, H., A.A. Siregar, & A. Prawanda. 2018. Isolasi Bakteri dari Rendaman Akar Bambu dan Respon Pemberiannya terhadap Pertumbuhan dan Produksi Tanaman Terung Ungu (*Solanum melongena* L.). *Jurnal Agroplasma* 5: 1–9.

Wang, X.B., Y.H. Fang, S.Z. Lin, L.R. Zhang, & H.D. Wang. 1994. A Study on the Damage and Economic Threshold of the Soybean Aphid at the Seedling Stage. *Plant Protection* 20: 12–13.

Zainudin, A.L. Abadi, & L.Q. Aini. 2014. Pengaruh Pemberian *Plant Growth Promoting Rhizobacteria* (*Bacillus subtilis* dan *Pseudomonas fluorescens*) terhadap Penyakit Bulai pada Tanaman Jagung (*Ze a mays* L.). *Jurnal HPT (Hama Penyakit Tumbuhan)* 2: 11–18.

Zeng, F., G. Pederson, M. Ellsbury, & F. D. Davis. 1983. Demographic Statistic for Pea Aphids (*Homoptera: Aphididae*) on Resistant and Susceptible Red Clovers. *Journal of Economic Entomology* 86: 1852–1856.