AGRICULTURE AND NATURAL RESOURCES

Journal homepage: http://anres.kasetsart.org

Research article

Performance and population growth rate of cassava pink mealybug, *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae) under different potassium fertilization regimes

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Article Info

Article history:
Received 25 December 2021
Revised 4 June 2022
Accepted 8 June 2022
Available online 26 August 2022

Keywords:
Cassava,
Cassava pink mealybug,
Life cycle,
Phenacoccus manihoti,
Potassium

Abstract

Importance of the work: The application of potassium fertilizer to improve soil fertility can increase cassava yields and decrease crop damage due to pests.

Objectives: To evaluate the influence of different potassium fertilizer rates on the cassava pink mealybug, *Phenacoccus manihoti* Matile-Ferrero.

Materials & Method: The performance was investigated of *P. manihoti* feeding on potted cassava plants fertilized with three potassium fertilizer rates (0 kg K_2O/ha, 90 kg K_2O/ha and 180 kg K_2O/ha).

Results: *P. manihoti* fed on the cassava plants treated with different potassium fertilizer rates had longer developmental times, shorter longevity and lower fecundity than the mealybugs on the non-potassium fertilization treatment. The mealybugs that fed on the non-fertilized plants had higher adult body size and weight than the mealybug adults in the other treatments. The mealybugs feeding on potassium-treated plants had lower net reproduction, generation time and intrinsic rate of natural increase than those values for mealybugs in the non-potassium fertilization treatment.

Main finding: An appropriate potassium fertilizer rate should be used to minimize the damage by *P. manihoti* to cassava.

Introduction

The cassava pink mealybug, *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae) is a serious insect pest on the cassava plant (*Manihot esculenta* Crantz) in Asia (Wyckhuys et al., 2017). Both nymphs and adults of the mealybug suck the phloem sap from cassava plants. The main symptoms caused by the mealybug are yellowing and curling of the leaves at growing tip, reducing internodes, stunting and weakening of stem, while the leaves of heavy infested plants are dried and completed defoliated (Uwah et al., 2013).

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https://doi.org/10.34044/j.anres.2022.56.4.13

Potassium is an essential nutrient for cassava plants by stimulating net photosynthetic activity of a given leaf area and increase the translocation of photosynthetic to tuberous roots (Howeler, 2002). Potassium plays an important physiological role in the development of resistance to insect pests (Singh and Sood, 2017). However, potassium is generally deficient in soil and therefore, potassium fertilizer application to improve potassium nutrition where there is low inherent soil fertility can increase root yields of cassava (Umeh et al., 2015; Thummanatsakun and Yampracha, 2018) and decrease crop damage due to insect pests.

Waring and Cobb (1992) reported that fertilization and nutrient availability can alter the nutritional quality of a plant and this can influence herbivore growth and reproduction. The rate of potassium added as fertilizer to the host plant can strongly influence the performance of phloem-sap feeding insects such as mealybugs and aphids. For example, Havlickova and Smetankova (1998) indicated that the life span and rate of reproduction of the bird cherry-oat aphid, *Rhopalosiphum padi* (Linnaeus) (Hemiptera: Aphididae), increased when the aphid was fed on potassium-deficient barley. Similar results were also found by Myers and Gratton (2006) that the intrinsic rate of natural increase and net reproduction of the soybean aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae) was significantly greater at low potassium fertilization levels compared to medium and high potassium fertilization levels. An appropriate supply of potassium has been reported to decrease the infestation of mealybugs (Singh and Sood, 2017; Zia-ul-hassan et al., 2021), whereas high potassium fertilizer rates applied to crop plants significantly decrease damage caused by insect pests (Facknath and Lalljee, 2005). The current study investigated the effect of different levels of potassium fertilization on the performance of *P. manihoti* in the laboratory. The objectives were to determine an appropriate potassium fertilizer rate to minimize damage caused by *P. manihoti* on cassava.

Materials and Methods

Cassava planting

Cassava plants were individually grown in plastic pots (30 cm diameter × 20 cm deep) containing around 10 kg of a mixture of soil. The characteristics of the soil mixture were: pH = 5.2; organic carbon = 1.5%; available N = 0.65 mg/100 g; total P_20_5 = 10.5 mg / 100 g; total K_20 = 0.59 mg/100 g. At 14 d after planting, the potted plants were given one of three potassium fertilization levels: 0 kg K_2O/ha (as a control), 90 kg K_2O/ha and 180 kg K_2O/ha. Potassium (as potassium chloride) was dissolved in water and applied in liquid form. All potted plants were maintained in a greenhouse for 6 wk. Then, the plants were transferred to a plant growth room at 60–70% relative humidity, 30±1.0°C temperature and 12 h light: 12 h darkness photoperiod.

Insect rearing

The cassava pink mealybugs were collected from open fields in Hai Lang district, Quang Tri province, Vietnam (16°60'56.91"N 107°31'56.21"E). The collected mealybugs were reared on the potted cassava plants fertilized with different levels of potassium fertilizer inside cages (60 cm × 160 cm × 180 cm). A sub-colony of the cassava pink mealybug was reared on the potted plants supplied with each potassium fertilization rate in a plant growth chamber (SANYO MIR-553; Japan) at 30±1.0 °C temperature, 60–70% relative humidity and 12 h light:12 h darkness photoperiod.

Insect developmental time

The developmental time was recorded for the *P. manihoti* reared on the potted plants fertilized with different potassium fertilizer rates. A new ovisac from the sub-colony of the cassava pink mealybug was exposed to a plastic clip-cage (5 cm × 10 cm × 20 cm) on the 3rd youngest leaf of \cassava plant cultured with the similar potassium fertilized rate to the sub colony. As soon as they hatched, 1st instar nymphs were removed from the clip-cage, and only 10 nymphs were left in each clip-cage. Ten clip-cages were investigated for each potassium fertilization level. All attached clip-cages with cassava plants were maintained in the plant growth room at 60–70% relative humidity, 30±1.0° C temperature and 12 h light: 12 h darkness photoperiod. The molting of nymphs was observed daily and used to calculate the developmental time.

Size and weight of adults

Immediately after emergence, a batch of 10 adults was weighted. Five replications with 50 adults for each fertilization level were weighted. There were 50 adults for each fertilizer level measured for their length and width to indicate the size of mealybug adults.

Longevity and fecundity

Ten newly emerged adults from each sub-colony were transferred into a clip-cage attached on the 3rd youngest leaf of potted cassava plants with the similar fertilizer level to the sub-colony. Ten clip-cages were investigated for each potassium fertilization level. The clip-cages attached with cassava plants were maintained in the plant growth room at 30±1.0 ° C temperature, 60–70% relative humidity and 12 h light: 12 h darkness photoperiod until all adults had died. Daily, the oviposition and survival of adults were observed. Egg numbers of new ovisacs laid by adults from the clip-cage were counted daily under a stereomicroscope to determine the adult fecundity rate.

Population increase

The net reproduction rate (R_0), generation time (T) and intrinsic rate of natural increase (r_m) were estimated using the equations of Birch (1948), $Ro = \Sigma l_x m_x$; $T = \Sigma x l_x m_x / \Sigma l_x m_x$; $\Sigma(\exp(-r_m x) l_x m_x) = 1$; where, x is the adult age, lx is the proportion of adults surviving to age x and m_x is the number of daughters produced per adult alive at age x.

Data analysis

Data were analyzed using the STATISTICA 10.0 software (Tulsa, USA). To compare the differences in developmental time, adult size and weight, the fecundity and longevity of the mealybug, one-way analysis of variance and Tukey's honestly significant different test was conducted and the tests were considered significant at $p < 0.05$.

Results

Immature development

The developmental time of the cassava pink mealybug was significantly influenced by the level of potassium fertilization. The developmental times of the 1st, 2nd and 3rd instars reared on non-potassium fertilized plants (0 kg K_2O/ha) was the shortest. There was no significant difference in the developmental times of the 2nd and 3rd instar stages on plants treated with 90 kg K_2O/ha and 180 kg K_2O/ha. The total developmental time for the 1st instar to emerge as adult mealybugs reared on high potassium fertilized plants (180 kg K_2O/ha) was the longest (17.9 days; F = 38.97; df = 2,249; $p < 0.0001$), as shown in Table 1.

Weigh, size, longevity and fecundity of adult

The potassium fertilizer rate impacted the weight and size of *P. manihoti* adults. The cassava pink mealybugs reared on non-potassium fertilized plants were heaviest (F = 10.26; degrees of freedom (df) = 2,147; $p < 0.001$), and widest (F = 5.22; df = 2, 147; $p < 0.01$). There were no significant differences in the weight or size of the adults observed between the 90 kg K_2O/ha and 180 kg K_2O/ha treatments. There were no significant differences in adult longevity of the mealybugs reared on plants given the different levels of potassium fertilizer. Longevity was 24.5 d, 22.5 d and 23.1 d for the potassium treatments of 0 kg K_2O/ha, 90 kg K_2O/ha and 180 kg K_2O/ha, respectively (Table 3). The potassium fertilizer level significantly influenced the fecundity of the cassava pink mealybug. The mealybugs reared on plants that had no added potassium fertilizer had the shortest oviposition time (F = 5.50; df = 2, 134; $p < 0.01$) and the highest number of laid eggs (F = 14.53; df = 2,134; $p < 0.0001$).

Table 1 Effects of potassium fertilization on developmental times (days) of *Phenacoccus manihoti*

Growth stage	Potassium (kg K_2O/ha)			Analysis of variance parameters		
	0	90	180	F	df	p
1st instar	5.5±0.06^c	5.9±0.07^b	6.1±0.08^a	16,73	2,249	< 0.0001
2nd instar	5.4±0.06^b	5.7±0.08^a	5.7±0.06^a	6.64	2,249	0.0016
3rd instar	5.4±0.09^b	5.8±0.08^a	6.0±0.07^a	12.51	2,249	< 0.0001
1rst instar - adult	16.4±0.13^c	17.4±0.13^b	17.9±0.10^a	38.97	2,249	< 0.0001
n	80	89	83			

Values (mean ± SD) in the same row superscripted with different lowercase letters are significantly ($p < 0.05$) different.

n = number of tested mealybugs

The laid egg numbers of adults were 361.7, 271.6 and 291.2 on the plants fertilized with potassium at the rates of 0 kg K_2O/ha, 90 kg K_2O/ha and 180 kg K_2O/ha, respectively. There was no significant difference in oviposition times, numbers of laid eggs and oviposition rates of *P. manihoti* reared on plants fertilized with 90 kg K_2O/ha and 180 kg K_2O/ha. *P. manihoti* reared on plants given no potassium fertilizer had the shortest pre-oviposition period (F = 5.71; df = 2,134; p = 0.0042), as shown in Table 3.

The population increase in *P. manihoti* was influenced by the potassium fertilizer levels. There was a difference in the values of R_0, (T) and r_m of *P. manihoti* reared on potted cassava plants fertilized with different potassium levels. The net reproduction rates were 319.80, 283.43 and 263.23 for the potassium fertilizer levels of 0 kg K_2O/ha, 90 kg K_2O/ha and 180 kg K_2O/ha, respectively. The generation times were 14.25 d, 13.62 d and 13.28 d for the potassium fertilizer rates of 0 kg K_2O/ha, 90 kg K_2O/ha and 180 kg K_2O/ha, respectively. The intrinsic rate of natural increase was 0.59 female per female per day (♀/♀/ day), 0.55 ♀/♀/ day and 0.55 ♀/♀/ day for the potassium fertilizer rates of 0 kg K_2O/ha, 90 kg K_2O/ha and 180 kg K_2O/ha, respectively (Table 4).

Discussion

The nutritional content of a host plant has an important impact on herbivore development and reproduction (Dixon, 1977). Potassium is a key component of plant nutrition that significantly influences some insect pests (Shah, 2017). Potassium nutrition has an effect on the profile and distribution of primary metabolites in plant tissues, which in turn could affect the attractiveness of a plant to insects and their subsequent growth and development (Amtmann et al., 2008). Shah (2017) stated that potassium deficiency resulted in reduced synthesis of proteins, starch and cellulose, as well as an increased accumulation of lower molecular weight compounds, such as amino acids, nitrate, soluble sugars and organic acids. These lower weight molecular compounds are more easily utilized as nutrient sources by sucking insects (Shah, 2017). Therefore, potassium deficiency has been reported to increase the life span and reproduction rate of many sucking insect pests, including *Bropalosiphum padi* L. (Havlickova and Smetankova 1998), *Macrosiphum euphorbiae* (Thomas) (Jansson and Ekbom, 2002) and *Aphis glycines* Matsumura (Myers and Gratton, 2006; Walter and Difonzo, 2007). In addition, the current results provide confirmation that increasing the potassium fertilizer rate for cassava plants had a negative impact on the development and fecundity of the cassava pink mealybug. The results were similar to other investigations of other sucking insects, such as *M. euphorbiae* (Jansson and Ekbom, 2002) and *A. glycines* (Myers et al., 2005) in which the insects feeding on plants with no added potassium fertilizer developed more rapidly and laid more eggs compared to those on potassium-fertilized plants.

Plants not fertilized with added potassium led to increased body size and adult weight of *P. manihoti* (Table 2). The size of the adult is a popular indicator used to measure the fitness of an insect. For example, other studies indicated that the fitness of an insect female increased with body size; bigger female laid more eggs and had greater longevity (Alois, 1993; Tran et al., 2007). The results from the current study indicated that *P. manihoti* feeding on potassium-deficient plants had a significant positive effect on the adult fecundity. Potassium fertilization was disadvantageous to the fecundity of the cassava pink mealybug being 1.2-fold and 1.3-fold increase in non potassium vs. potassium fertilized plants. This was in accordance with Wyckhuys et al. (2017) on the fecundity of *P. manihoti* adults, while many studies reported that the fecundity of insect adults had a high correlation with the adult weight and body size (Alois, 1993; Ellers et al., 1998; Tran et al., 2007). The current results showed that the cassava pink mealybug that had fed on potassium- deficient plants were significantly larger and heavier and were both positively correlated with fecundity.

Table 2 Effects of potassium fertilization on weight and size of *Phenacoccus manihoti* adults

Growth stage		Potassium (kg K_2O/ha)			Analysis of variance parameters		
		0	90	180	F	df	p
Weight (mg/10 adults)		6.0±0.03[a]	5.4±0.11[b]	5.5±0.12[b]	10.26	2,147	0.0001
Size (mm)	Length	2.1±0.04[a]	2.0±0.04[b]	2.0±0.06[b]	3.37	2,147	0.370
	Width	1.2±0.03[a]	1.1±0.02[b]	1.1±0.04[b]	5.22	2,147	0.0065

Values (mean ± SD) in the same row superscripted with different lowercase letters are significantly (p < 0.05) different.

Table 3 Effects of potassium fertilization on longevity and fecundity of *Phenacoccus manihoti*

Growth stage	Potassium (kg K_2O/ha)			Analysis of variance parameter		
	0	90	180	F	df	p
Longevity (d)	24.5±0.66[a]	22.5±0.30[b]	23.1±0.53[ab]	3.53	2,134	0.32101
Pre-oviposition time (d)	6.6±0.11[b]	7.1±0.13[a]	7.0±0.09[a]	5.71	2,134	0.0042
Oviposition time (d)	17.9±0.65[a]	15.4±0.36[b]	16.1±0.53[b]	5.50	2,134	0.0051
Fecundity (No. eggs)	361.7±16.09[a]	271.6±6.92[b]	291.1±10.81[b]	14.53	2,134	< 0.0001
Oviposition rate (No. eggs/d)	20.1±0.45[a]	17.7±0.33[b]	18.2±0.40[b]	9.35	2,134	0.0023
Post-oviposition (d)	0.0	0.0	0.0	-	-	-
n	48	39	50			

Values (mean ± SD) in the same row superscripted with different lowercase letters are significantly ($p < 0.05$) different.
n = number of tested mealybugs

Table 4 Effects of potassium fertilization on net reproduction (*Ro*), generation time (*T*) and intrinsic rate of natural increase (r_m) of *Phenacoccus manihoti*

Potassium (kg K_2O/ha)	Ro	T	r_m
0	319.80	14.25	0.59
90	283.43	13.62	0.55
180	263.23	13.28	0.55

The intrinsic rate of natural increase (r_m) is an indicator to measure how an insect population increase occurs. Dixon (1977) indicated that there were three main factors influencing the intrinsic rate of natural increase: developmental rate, fecundity and longevity. Lower potassium fertilizer rates resulted in an increase in occurrence, population level, population increase and net reproduction rate of the soybean aphid, *A. glycines* (Myers et al., 2005). The r_m value of the cassava pink mealybug was significantly influenced by the potassium fertilizer rate and decreased as the application rate increased (Table 4). The current study demonstrated that non potassium fertilized plants had an increased development rate, fecundity and longevity, as a result of the increasing r_m value of *P. manihoti*. A similar influence on the intrinsic rate of natural increase has been reported for other sucking insects like the soybean aphid, *A. glycines*, Myers and Gratton (2006) indicated a significantly greater r_m value for a low potassium treatment (0 kg K_2O/ha) compared to the medium and high levesl of potassium treatment.

Ezui et al. (2016) indicated that potassium had a positive effect on the growth and yield of cassava as these were both significantly enhanced. Adequate potassium nutrition was also found to play positive roles in lowering disease incidence and infestation, thereby increasing crop yield (Amtmann et al., 2008; Zia-ul-hassan et al., 2021). Thus, an appropriate potassium fertilizer rate should be used to minimize the damage by *P. manihoti* to cassava plants because increasing the rate of potassium fertilization can cause a decrease in the population of *P. manihoti*. Therefore, applying potassium fertilizer can be an essential measure in an integrated pest management system to control the cassava pink mealybug in cassava production.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgements

Dr. Kris A.G. Wyckhuys provided useful consultancy advice on the laboratory bioassays. This work was partially supported by Hue University under the Core Research Program, Grant No. NCM.DHH.2020.14

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