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Good agronomic practices: Varieties capsicum annuum l. And fertilizer dosages influenced and suppressed aphis gossypii population abundance

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ABSTRACT
A field study was conducted on the population abundance of the pest, Aphis gossypii, on several selected Kulai varieties treated with different fertilizer dosages at Universiti Teknologi MARA Melaka Branch Kampus Jasin, from February to November 2021. Aphis gossypii can cause direct harm to crops. The aim of this study was to assess the influence of different chili varieties (Kulai 1033, Kulai 568, and Kulai 461) and fertilizer dosages low, optimum, high, and control on the population of Aphis gossypii, with five replications each, designed using RCBD. The study found that the least presence of Aphis gossypii was detected in treated chili plants of Kulai 568 with a low fertilizer dosage, while the highest was observed in treated chili plants of Kulai 1033 with a high fertilizer dosage for both cropping periods. In conclusion, the presence of Aphis gossypii was most prominent on plants treated with higher fertilizer levels. Additionally, selecting the optimum fertilizer dosage is a key strategy in pest management, as it plays an important role in mitigating the infestation of aphids.

Contribution/Originality: This study was carried out on the effects of fertilizer dosages on several selected varieties of chili plants against pests, specifically aphids. Based on findings, there are evidently fertilizer dosages that influence aphid populations. From an agronomic perspective, the optimal dosages are crucial for controlling or suppressing aphids at low populations. The findings of this study significantly contribute to formulating sustainable control strategies, particularly in integrated pest management.

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1. INTRODUCTION

Chilli is one of the most significant, affordable, and well-known vegetable crops, grown for both its green fruits as vegetables and its red fruits as flavoring (Sugiyanta & Kartika, 2018). Farmers often cultivate chili as a primary or secondary crop due to its economic value. A previous study indicated that Malaysia produced about 33,000 tons of chili per year, while local production was about 23,000 tonnes per year (Hosnan, 2011). It has been reported that chili varieties Kulai 469, Kulai 461, Kulai 223, Kulai 1033, Kulai 151, and Kulai 568 are most favored by Malaysian growers, and they are commonly cultivated in lowlands for commercial purposes (Rivitra, Thevan, & Norhafizah, 2021). With constant changes in consumer preferences, farmers constantly alter their methods in terms of input production to meet standard preferences (Ansari & Hanief, 2013), which is why the application input like fertilizer played an important role in order to produce better quality and higher production of chilli. However, a higher dosage of fertilizer supplied to the plants than the optimum level could have a negative impact on the plants. This is due to the high preference of insect pests towards plants containing higher nutrients, especially nitrogen.

Fertilizer is known as any substance that is applied to soils or plant tissues (leaves) to supply additional nutrients needed by plants to increase their performance (Koshale, Kurrey, & Banjare, 2018). However, overapplication of fertilizers can also cause damage to the environment, such as residues in food commodities and the deprivation of soil fertility (Rekha, Kaleena, Elumalai, Srikumaran, & Maheswari, 2018) and the invasion of insect pests. One of the main problems is insect pest attacks, particularly *Aphis gossypii*, which is harmful to chilli plants, causing plant damage and significant yield reduction. Subsequently, the trend of insect pest attacks is significantly related to fertilizer dosages, as reported in many studies. According to Eigenbrode and Pimentel (1988), the changes in composition and physiology of plants induced by fertilizer might affect plant resistance and susceptibility towards invasion of insect pests or pest attacks. Consequently, the higher nutrient presence in plant tissue is one of the fundamental attributes that make plants more likely to be selected by insect pests (Varghese & Prabha, 2014), mainly for feeding and infestation. There are several reasons why insect pests often attack or are deterred from the host plant (Walling, 2000). One of the reasons is due to fertilizer application. In general, plants with a high content of nutrients supplied by fertilizers are more likely to attract insect pests and cause infestations (Nevo & Coll, 2001). Most local farmers have little knowledge regarding fertilizer usage in terms of dosage. They are more likely to think that applying more fertilizer will eventually lead to better plant growth and development. Meanwhile, there was an impact of fertilizer usage on the insect pest abundance on the plant. This is because fertilizer practices can influence plant defense, where fertilizer aids in nutrient composition modification (Zaini, 2013). It could also change the resistance and susceptibility of plants to insect pests. Chilli plants exhibit a favorable reaction to the use of inorganic fertilizers during the initial stages of vegetative growth; however, this response diminishes as the plants progress into later stages of development. In contemporary agricultural practices, farmers persist in utilizing inorganic fertilizers for their crops due to their ability to deliver swift and readily available nutrients (Khandaker, Rohani, Dalorima, & Mat, 2017). However, this approach inevitably leads to an escalation in production costs. As crucial as the availability of nutrients for plant growth, it also affects the availability of insect pest populations and their population dynamics. Therefore, this study showed how fertilizer usage at different dosages affected insect pest invasion on different varieties of *Capsicum annuum* L. Farmers were implementing effective nutrient management strategies to ensure the optimal growth and successful completion of the life cycle of the chilli plant (Koshale et al., 2018) and reduce cost production as well. A comprehensive understanding of the dynamic fluctuations in the spatial dispersion of pests is important for enhancing the efficacy of pest management tactics (Park & Obrycki, 2004). Additionally, the insect pest populations and preferences are affected by different varieties of plants. Varieties of plants, in general, have different attributes in terms of physiological, biological, and chemical characteristics. Nowadays, many varieties of plants have been produced to obtain more resistant plants against pests and higher yields. *Capsicum annuum* L. var. Kulai is one of the Solanaceae family, where the name is derived from Nahuatl through the Spanish word chili (Khandaker et al., 2017). Despite chili being a non-native crop in Malaysia, it is, however, the second most well-known fruit and vegetable (Khandaker et al., 2017). Generally, all types (sub-varieties) of Chilli Kulai are the same; only the appearance of those chilies contributes to several differences between each of them. In this study, the focus is on testing the sub-varieties of the Chilli Kulai plant. Previous reviews have noted a lack of information specifically studying the effect of Kulai varieties on insect-pest attacks, particularly on Aphis gossypii, and their impact on insect-pest population abundance and yield. Therefore, this study was conducted to evaluate the effect of different fertilizer dosages and sub-varieties of chili on *A. gossypii* in order to identify effective agricultural practices for maintaining the population of *A. gossypii* at the economic threshold level on chili.

2. LITERATURE REVIEW

Capsicum annuum L. or chili is one of the highest-value and most affordable vegetable crops, well-known for its green fruits used as vegetables and red fruits used for flavoring. It is cultivated widely for its economic importance and culinary uses, contributing significantly to local and global markets (Pandey, Singh, Kumar, & Singh, 2013).It originated from Mexico and South America. Chili, or some call hot pepper, is naturally known as *C. annuum* L. for its scientific name. Chili is a part of the Solanaceae family, widely cultivated throughout tropical Asia and Central America for its consumable and pungent qualities (Gireesh, Agrwal, Tamrakar, & Sinha, 2020). Chilli (*C. annum* L.) is mostly known as a popular and one of the most favored vegetable crops by farmers in Malaysia. Farmers usually prefer the fertigation system in commercial plant cultivation. In 2011, Malaysia produced 32,780 metric tons of chillies with a growing area of 2,559 hectares (Salamat, 2013). Malaysian farmers are mostly choosing chilli as their choice for planting as a main crop and cash crop.

Aphis gossypii possesses characteristics such as tiny size, adaptability, high dispersal capacity, rapid reproduction rate, and the potential to induce significant plant damage within confined populations. *Aphis gossypii* is recognized as a highly destructive pest that affects more than twenty-four different crops globally (Ebert & Cartwright, 1997). In Malaysia, the exclusive aphid species that colonizes andcauses substantial crop damage in chili plants (*Capsicum annuum* L.) of the Solanaceaefamily is *Aphis gossypii* Glover (Hemiptera: Aphididae) (Rahman, Roff, & Ghani, 2010). According to Singh and Singh (2015), it has been determined that Aphis gossypii Glover is a widely distributed species with a broad diet, making it polyphagous. This aphid species is known to be a significant pest in local regions, particularly affecting crops such as okra, cucurbits, brinjal, and chilli (Singh & Singh, 2015). The insect has the ability to cause direct harm to crops through the process of sap sucking, leading to the development of leaf deformation and curling (Firdaus et al., 2020).

Interestingly, the preference for inorganic or organic fertilizers among farmers can vary depending on several factors, including the type of crop being grown, the specific needs of the medium, environmental considerations, and economic factors. Regarding chili crops, the exclusive use of organic manure did not result in a significant enhancement of both vegetative and reproductive development of chili plants due to the comparatively delayed release of nutrients (Parani & Nanthini, 2022). The utilization of inorganic fertilizers is frequently used to enhance agricultural productivity by increasing crop yields and preserving soil fertility (Deore, Limaye, Shinde, & Laware, 2010). However, if the dosage of fertilizer is not supplied appropriately, it will cause different pest infestation rates and damage done by insect pests on the plants (Zaini, 2013).

3. MATERIALS AND METHODS

3.1. Background of Study

The study investigated the effect of different chili varieties and fertilizer dosages on the population dynamics of *Aphis gossypii*. This research was conducted at Universiti Teknologi MARA Melaka Branch Kampus Jasin; the study spanned two planting seasons during February–June 2021 and August–November 2021, respectively.

3.2. Site Preparation and Fertigation System

In the greenhouse, chili seeds were germinated in sterilized trays filled with a cocopeat medium and watered daily for 35 days. In the open field, the fertigation system was equipped to supply sufficient waterand nutrients to the plants throughout the duration of this research for both seasons. Seedlings were transplanted into the open field in polybags containing a mixture of cocopeat and rice husks. The open field was prepared by clearing, plowing, and laying a fertigation system comprising PVC pipes, microtubes, and drip emitters. The fertigation system consisted of fundamental requirements, including fertilizing, irrigation, planting medium, and water supplies. The fertigation system used five tanks: one for water and four for fertilizer solutions. A water pump (0.5 HP) connected to a filtration system distributed the solutions through the mainline and sub-lines to individual polybags.

3.3. Seed Selection and Preparation

The study incorporated three distinct seed types, namely Kulai 1033 (V1), Kulai 568 (V2), and Sakata 461 (V3). The implementation of sowing seeds strictly followed standard procedures. Prior to sowing, the chili seeds underwent a soaking process lasting 2 hours and 30 minutes. The seeds were also treated with Captan, a fungicide that helps prevent fungal infection (Ayesha, Suryanarayanan, Nataraja, Prasad, & Shaanker, 2021). For the sowing process, the seed trays were completely filled with peat moss. The seeds were sown one seed per tray hole. With heights of 10 to 20 cm and 7 to 10 leaves, the seedlings were ready to undergo the transplanting process.

3.4. Fertilizer Preparation

Two barrels of nutrient solutions were prepared for both A and B stock. The solution was then stirred until the mixtures were well combined. Later, these two stocks were mixed together into the water tank to formulate a fertilizer that plants readily absorbed, using an Electrical Conductivity meter. Fertilizers were mixed in specific ratios and distributed weekly based on plant growth stages.

3.5. Experimental Design

The study implemented a randomized complete block design (RCBD) with three chili varieties (Kulai 1033, Kulai 568, and Kulai 461) and four fertilizer dosages (F1-F4), including a control (F4). Each treatment combination consisted of 5 replications (blocks), totaling 240 plants with 60 experimental plots. Table 1 indicates that different groups of plants received different regimes of fertilizer supply to a uniform group of healthy chili seedlings. For the F1 groups, all the plants uniformly received 1.0 ppm from week 1 until week 10. However, plants in the F2 group received different dosages of fertilizer, starting from 1.2 ppm in week 1 and increasing by 0.2 ppm each week until week 7 (2.0 ppm), after which a consistent dosage was maintained until week 10. For the F3 group, plants received 2.4 ppm in week 1, with an increase of 0.2 ppm each week until week 7 (2.6 ppm), followed by a consistent dosage until week 10. A similar regime of fertilizer was supplied to the plants in group 4, but the dosages started at 1.8 ppm in week 1 and increased by 0.2 ppm each week (Table 1).

Table 1. The different fertilizer Dosages (mS) according to four group rates.

Fertilizer dosages (mS)	Week fertilizer dosage									
	1	2	3	4	5	6	7	8	9	10
F1 (Part per million)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
F2 (Parts per million)	1.0	1.2	1.4	1.6	1.8	1.8	2.0	2.0	2.0	2.2
F3 (Parts per million)	1.4	1.6	1.8	2.0	2.2	2.2	2.4	2.4	2.4	2.6
F4 (Parts per million - Control)	1.8	2.0	2.2	2.4	2.6	2.6	2.8	2.8	2.8	3.0

3.6. Data Collection

Two sampling approaches were implemented in the experiment. The first approach was destructive sampling by manual collection of leaves through plucking from the middle strata of plants (Mohd Rasdi, Fauziah, Fairuz, & Mohd Saiful, 2021). A total of six leaves, each of equal size, were systematically collected from three chili plants within each plot over all five blocks. The second approach was the utilization of sticky traps measuring 20x25cm. The primary purpose of using sticky traps is to trap adult winged insect pests, as they possess rapid mobility. Observations were made for 10 weeks per season. Weekly manual sampling of leaves was carried out, and sticky traps were placed near the plants. All leaf samples and sticky traps were brought back to the laboratory for sorting and counting the insect pests.

3.7. Data Analysis

All the data were subjected to analysis using SPSS software. Prior to analysis, a normality test was conducted using the Kolmogorov-Smirnov test for normal distribution. As a result, the data were not normally distributed; therefore, a non-parametric test was used. To compare the median number of aphid populations among treatments, Kruskal-Wallis H tests were employed to compare medians across treatments.

4. RESULTS

4.1. Effect of Different Chilli Varieties and Fertilizer Dosages against Aphis gossypii Population for First and Second Cropping Periods

For the first cropping period, Figure 1 provides a total mean number of *Aphis gossypii* for three different chili varieties and four different fertilizer dosages during a ten-week period. A significant difference ($P<0.05$) in mean aphid populations between Kulai 568 (V2) and Kulai 461 (V3) for fertilizer dosage F1. Meanwhile, there was no significant difference ($P>0.05$) detected between Kulai 1033 (V1) and Kulai 568 (V2), as well as between Kulai 1033 (V1) and Kulai 461 (V3), across all four fertilizer dosages. From Figure 2, a significant difference was found among all four fertilizer dosages applied to treated chili varieties. Across all chili varieties treated with different fertilizer dosages, chili plants Kulai 1033 (V1) treated with fertilizer dosage F4 exhibited the highest presence of *A.gossypii* with a mean of 100.74, while chili plants Kulai 568 (V2) treated with F1 had the lowest mean of 38.02. Summing the total mean number of aphids across all three chili varieties and all fertilizer dosages from F1 to F4, the highest total mean was observed on chili plants Kulai 461 with 70.90, followed by Kulai 1033 with 68.97, and the lowest was Kulai 568 with 62.39.

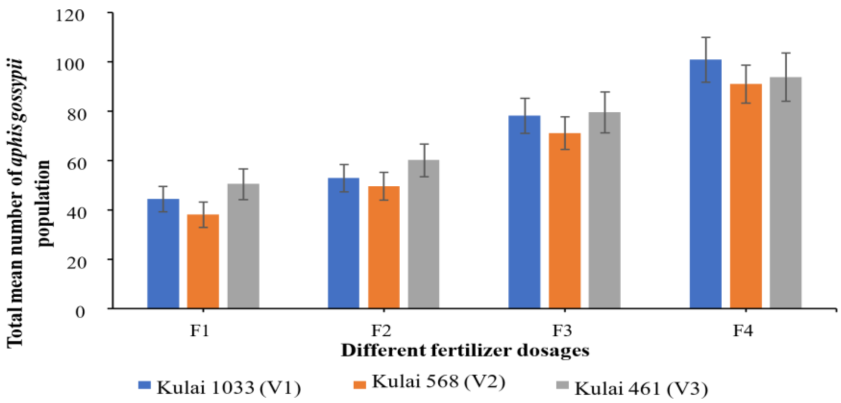

Figure 1. The total mean numbers (±S.E) of *Aphis gossypii* for each different chili variety against different fertilizer dosages for the first cropping period.

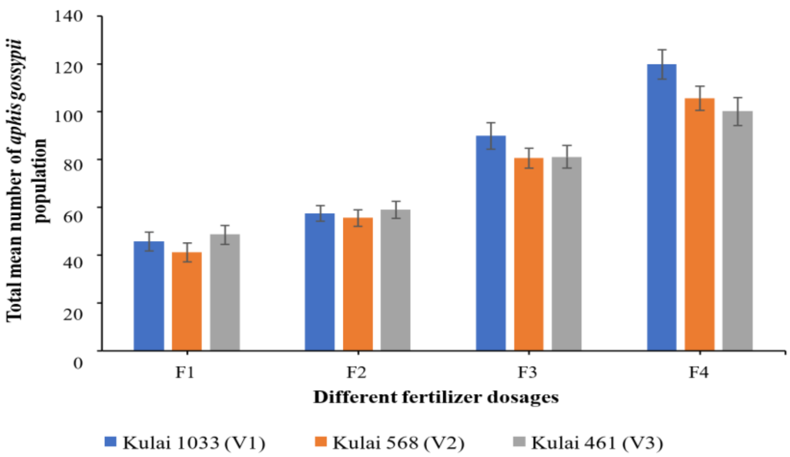

Figure 2. The total mean numbers (±S.E) of *Aphis gossypii* for different fertilizer dosages against each different chili variety for the first cropping period.

For the second cropping period, based on the data presented in Figure 3, there was a significant difference (P<0.05) in the mean number of *A. gossypii* between chili cultivars Kulai 1033 (V1) and Kulai 461 (V3) when treated with fertilizer dosage F4. Statistically, there was no significant difference (P>0.05) in the mean population of aphids observed across all sub-varieties of chili Kulai that were treated with fertilizer dosages F1, F2, and F3. In Figure 4, it was observed that there is a significant difference (P<0.05) in the population of *A. gossypii* among the different chili varieties that were treated with each dosage of fertilizer. In the second cropping period, all three chili varieties subjected to differing fertilizer dosages revealed that Kulai 1033 (V1), when treated with the F4 fertilizer dosage, exhibited the highest incidence of *A. gossypii*, with a mean of 119.82. Conversely, Kulai 568 (V2), upon receiving the F1 fertilizer dosage, demonstrated the lowest mean presence, recorded at 41.12. Upon aggregating the invasion metrics of *A. gossypii* across all fertilizer treatments (F1 through F4) for each of the three chili varieties, it was observed that Kulai 1033 (V1) had the highest cumulative mean number of *A. gossypii*, totaling 78.21. This was followed by Kulai 461 (V3) with a total mean of 72.13, and Kulai 568 (V2) presented the lowest cumulative mean, at 70.72.

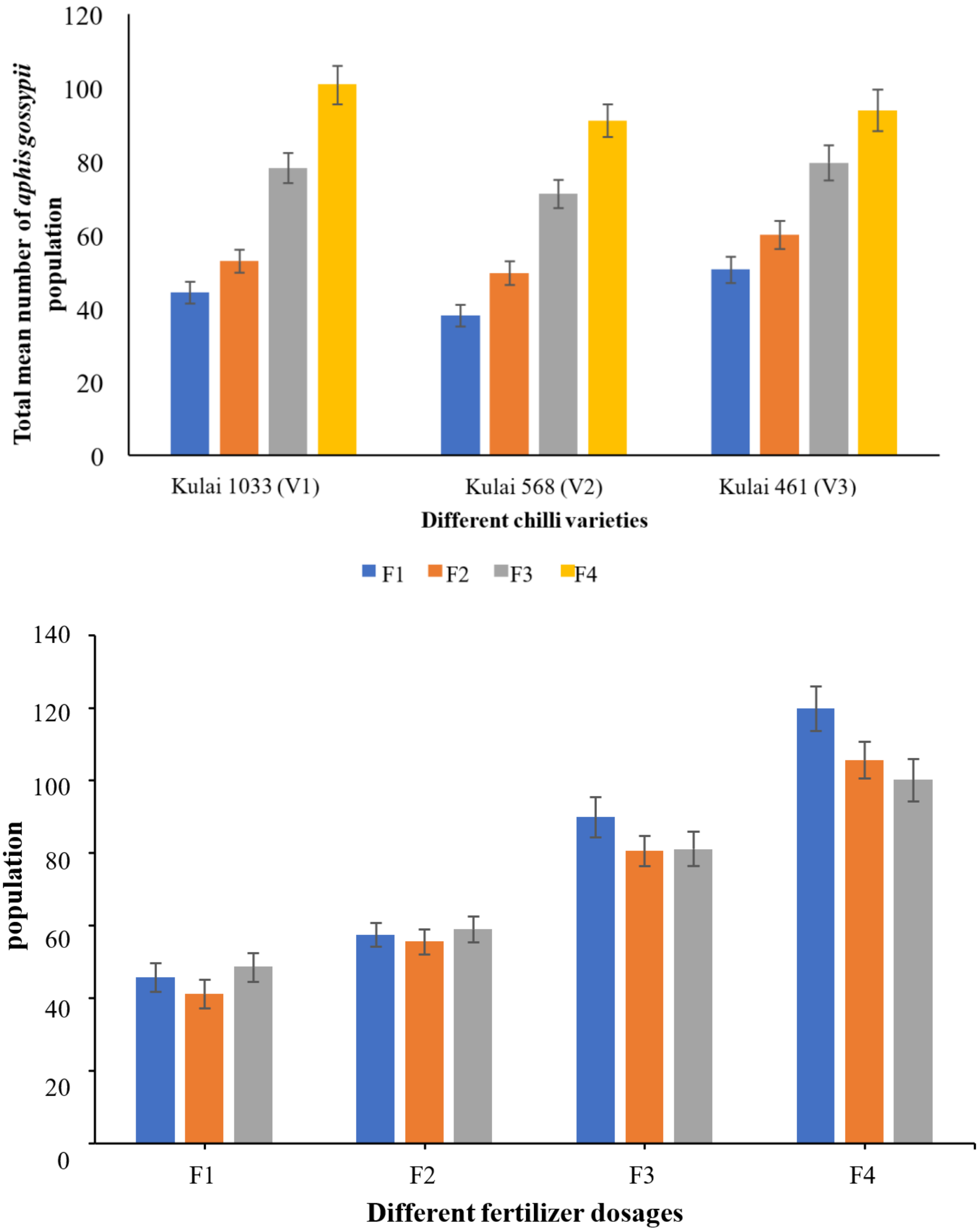

Figure 3. The total mean numbers (±S.E) of A*phis gossypii* for each different chili variety against different fertilizer dosages for the second cropping period.

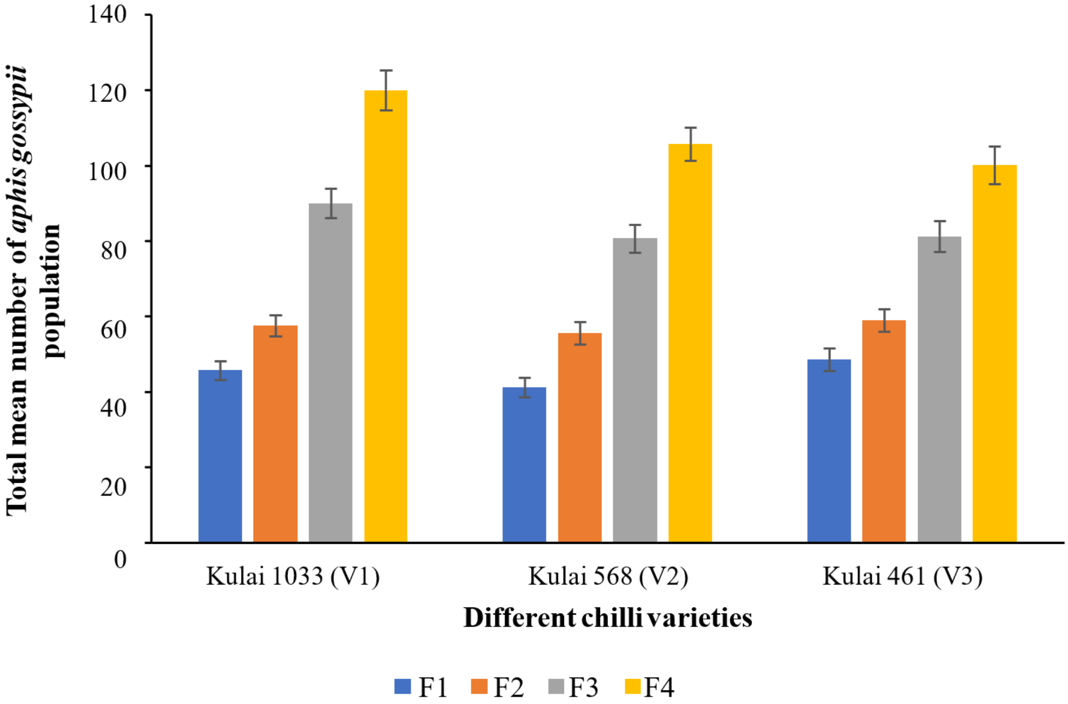

Figure 4. The total mean numbers (±S.E) of A*phis gossypii* for different fertilizer dosages against each different chili variety for the second cropping period.

4.2. Comparison of Mean Number of Aphis gossypii Between First and Second Cropping Periods in the Treated Chilli Plants

Table 2 shows the comparison of the mean number of *Aphis gossypii* in treated chili varieties between the first and second cropping periods. The aphid infestation significantly increased in most treated chili plants from the first to the second cropping period. However, some treated chili plants showed a moderate increase in the mean number of *A. gossypii*, while others experienced a decrease in *A. gossypii* infestation between the two cropping periods. The overall mean number of *A. gossypii* generally trended upwards from the first to the second cropping period across most treated chili plants. Exceptions were observed in the treated chili plants V3F1 (FC = 50.38 > SC = 48.52) and V3F2 (FC = 59.96 > SC = 58.88), where a decline in *A. gossypii* population was recorded, contrasting with the general pattern of increase observed in other treated chili plants. This analysis highlights the complexity and variability inherent in *A. gossypii* population dynamics in response to chili varieties and fertilizer dosages over cropping periods.

Table 2. Comparison mean number of *Aphis gossypii* in three different chili varieties (Kulai 1033 (V1), Kulai 568 (V2), Kulai 461 (V3)) treated with four different fertilizer dosages (F1, F2, F3, F4) between the first and second cropping periods.

First cropping period											**Total mean (FC)**	**Second cropping period**										**Total mean (SC)**	**Total mean (FC + SC)**
Week	1wat	2wats	3wat	4wat	5wat	6wat	7wat	8wat	9wat	10wat		1wat	2wat	3wat	4wat	5wat	6wat	7wat	8wat	9wat	10wat		
Mean ± SE	1.55± 0.3	7.22± 1.08	18.42± 1.94	44.3± 3.28	68.65± 4. 09	88.97± 5. 21	98.38± 6. 38	108.15 ±4.34	115.35 ±4.38	123.23 ±3.77	67.42	4.03 ±0.48	9.45 ±1.14	23.33 ±2.26	48.4 ±3.23	74.83 ±4.41	95.22± 5.45	103.53 ±6.34	117.22 ±5.33	126.32 ±5.26	134.55 ±5.54	73.69	141.11
V1F1	0.2± 0.19	1.6± 0.98	7.8± 2.69	29.8± 7.23	33± 6.63	64.2± 11.47	57.4± 9.24	73.6± 7.68	80.2± 9.60	95± 4.97	44.28	0.4± 0.25	2.4± 1.36	8.6± 2.93	30.6 ±7.03	34.8± 6.4	63± 10.6	64.8 ±6.85	74.2 ±7.81	80.8 ±9.08	97± 5.13	45.66	89.94
V1F2	0.8± 0.37	4.2 ±1.43	14. 4±1.29	29.6± 9.19	48.4± 4.33	69.4± 5.71	70.2± 4.49	90.4± 2.58	96.2± 8.19	104.4± 4.06	52.80	1.4± 0.6	6.8± 1.32	21± 2.35	33.4 ±8.38	50.4± 3.98	72.2± 4.48	85.2± 4.03	93.6± 2.94	103.4± 9.84	107.2± 3.73	57.46	110.26
V1F3	3.4 ±0.87	11.6± 1.86	23.8± 1.71	72.2± 9.53	84.6± 4.58	103.8± 13.83	92.8± 10.22	124± 10.95	128± 6.88	136.6± 6.55	78.08	7.4± 1.12	14.6± 2.04	31.6± 2.69	71± 8.89	94± 3.03	114.8± 9.25	131.6± 12.64	138.8± 11.55	148.8± 10.66	146.4± 6.36	89.9	167.98
V1F4	7± 0.55	18.8 ±3.14	39.4± 3.83	59.6± 2.04	105.6± 8.04	128.8± 17.54	177.2± 12.54	148.4± 12.19	152.8± 8.87	169.8± 9.47	100.74	9± 0.89	24.4± 3.64	53.2± 1.71	67.6± 5.47	117.2± 5.83	152± 9.42	180.4± 11.77	191.6± 9.41	187.4± 16.08	215.4± 12.03	119.82	220.56
V2F1	0	3.2± 2.27	0.6± 0.6	6.6± 4.19	25.8± 11.75	44± 2.68	58.6± 8.61	73.2± 8.29	83.8± 10.38	84.4± 6.27	38.02	0.4± 0.25	3.2± 2.27	3.0± 1.99	11.8± 3.46	30.2± 11.79	46± 1.09	63± 7.42	75.6± 6.98	88.4± 3.53	89.6± 5.57	41.12	79.14
V2F2	0.2 ±0.2	6.2 ±3.93	5.8 ±3.01	17.8 ±5	43.6 ±5.6	61.4 ±2.8	72.2 ±7.1	91± 3.02	95± 4.16	102 ±4.92	49.52	1.6 ±0.68	6.6± 3.79	8.4± 3.66	26± 1.14	52.6± 8.0	66± 2.66	76.4± 7.55	97.8± 2.75	106.8 ±2.52	113.2± 5.68	55.54	105.06
V2F3	1.6± 0.75	10.2± 4.21	28.6± 5.58	50.2± 7.19	66± 7.44	98.8± 3.57	94.2± 10.65	109.2± 4.47	122.6± 3.75	129.4± 7.18	71.08	6.2± 0.2	11± 3.62	31.6± 5.24	56.4 ±5.41	78.2± 9.5	108.2± 3.09	107.2± 13.9	125.4± 3.49	135.6± 4.07	146.2± 7.7	80.6	151.68
Table 2. Continue.																							
V2F4	3± 0.99	17.4 ± 5.16	43.6± 9.66	77.2 ± 17.22	104.6± 23.04	111.6 ± 24.15	121.6± 28.05	126.6 ± 27.93	145± 31.73	159 ±35	90.96	9.2± 0.73	20.2± 5.27	50.6± 3.61	85± 4.99	121.4± 8.69	126± 4.98	133.4± 17.51	154.2 ± 7.51	168.2 ±4.79	188± 8.49	105.62	197.56
V3F1	0	0.6± 0.25	2.2± 1.43	27.2 ± 8.92	62.8± 6.83	52.6 ±8.62	67.4 ±10.2	104.2 ± 19.12	86.6± 15.68	100.2 ± 2.35	50.38	1± 0.45	1.4± 0.25	5.6± 0.51	28± 8.67	63.2± 6.76	49.4± 9.12	61.4± 7.05	101.4 ± 20.65	86.8± 15.78	87± 4.6	48.52	98.9
V3F2	0	1.2± 0.37	7.2± 2.73	41± 3.66	62.2± 9.92	71.8 ±9.37	85.8 ±5.59	105.4 ± 16.23	101.2± 13.26	123.8 ± 7.82	59.96	1.4± 0.6	3± 0.32	11± 1.34	41.8± 3.61	63.6±10 .04	76.2± 5.49	80.2± 4.69	103± 16.94	102.2±1 3.62	106.4 ±6.33	58.88	118.84
V3F3	0	4± 0.55	19.4± 1.03	58.4 ± 3.08	96.8± 14.38	118 ±24.3 3	105. 8±9.99	125.6 ± 24.25	138± 13.15	128.6 ± 6.29	79.46	3.8± 1.24	8.2± 0.8	21.6± 1.44	59.4± 2.96	96.6± 14.73	123.2± 23.22	94.4± 3.97	123± 25.14	138.4±1 2.3	142.4 ±6.7	81.1	160.56
V3F4	2.4 ± 0.25	7.6± 0.75	28.2± 2.71	62± 7.83	90.4± 7.55	143. 2±19. 9	177.4± 36.06	126.2 ± 11.45	154.8± 13.04	145.6 ± 9.56	93.78	6.6± 1.44	11.6± 0.51	33.8± 3.17	69.8± 4.89	95.8± 7.32	145.6± 20.18	164.4± 39.78	128± 11.72	169± 7.11	175.8 ± 10.82	100.04	193.82
Cropping Period Kruskal-Wallis	Variety (Kruskal-Wallis H = 1.989; df = 2; P > 0.05)											Variety (Kruskal-Wallis H = 1.296; df = 2; P > 0.05)											
	Fertilizer (Kruskal-Wallis H = 78.916; df = 3; P < 0.05)											Fertilizer (Kruskal-Wallis H = 98.999; df = 3; P < 0.05)											
	Week (Kruskal-Wallis H = 446.783; df = 9; P < 0.05)											Week (Kruskal-Wallis H = 440.106; df = 9; P < 0.05)											
	Block (Kruskal-Wallis H = 0.676; df = 4; P > 0.05)											Block (Kruskal-Wallis H = 0.81; df = 4; P > 0.05)											

Note: WAT = Week after transplanting. V = Variety. F = Fertilizer. FC =First cropping. SC = Second cropping

4.2.1. Population Trends of Aphids in Different Chilli Varieties at Different Fertilizer Dosages

In the first cropping period, Kulai 1033 (V1) exhibited the highest mean *A. gossypii* population at Week 10 (126.45), followed closely by Kulai 461 (V3) (125.55) and Kulai 568 (V2) (118.7). In the second cropping period, Kulai 1033 (V1) again showed the highest infestation (134.55), but Kulai 568 (V2) surpassed Kulai 461 (V3) during Weeks 9–10.

For the first cropping period, fertilizer dosage F4 consistently resulted in the highest *A. gossypii* populations, peaking at 158.73 (Week 7). F1 had the lowest infestation, with a mean of 93.2 at Week 10. For the second cropping period, F4 again showed the highest *A. gossypii* presence (193.07 at Week 10), with a significant increase from Week 8. F1 maintained the lowest population, with a mean of 91.2 at Week 10.

In the first cropping period, there was a rapid population increase of *A. gossypii* from Weeks 4 to 7, slowing down in Weeks 8 to 10. The second cropping period exhibited a more gradual increase, with peak populations occurring later, from Weeks 9 to 10. Table 3 shows the weekly aphid population growth rate for both cropping periods.

Table 3. Weekly aphid population growth rate for the first and second cropping periods.

Week Range	First cropping period	Second cropping period
Weeks 1-3	Moderate	Slow
Weeks 4-7	Rapid	Gradual
Weeks 8-10	Slowing	Rapid

Kulai 1033 (V1) consistently showed an increase in aphid populations in the second cropping period compared to the first, with the largest differences observed during Weeks 6 and 10. Kulai 568 (V2) showed slight differences, with a notable increase in Weeks 1–3 and Week 9. Kulai 461 (V3) exhibited a decrease in the second cropping period compared to the first from Week 7 onward, suggesting a decline in aphid attraction over time. Table 4 shows the weekly mean aphid population by variety for the first and second cropping periods. Meanwhile, Table 5 shows the weekly differences in the mean aphid population by variety X fertilizer for the first and second cropping periods.

Table 4. Weekly mean aphid population by variety for first and second cropping periods.

Week	Kulai 1033 (V1) - First	Kulai 1033 (V1) - Second	Difference (Second - First)	Kulai 568 (V2) - First	Kulai 568 (V2) - Second	Difference (Second - First)	Kulai 461 (V3) - First	Kulai 461 (V3) - Second	Difference (Second - First)
1	2.85	4.03	+1.18	0.60	3.25	+2.65	0.60	2.05	+1.45
2	8.15	9.45	+1.30	3.15	6.45	+3.30	2.85	5.75	+2.90
3	21.35	23.33	+1.98	14.25	15.35	+1.10	10.55	12.25	+1.70
4	38.67	44.30	+5.63	30.15	30.55	+0.40	25.55	25.25	-0.30
5	60.25	65.55	+5.30	50.25	50.15	-0.10	45.85	45.35	-0.50
6	80.33	95.22	+14.89	70.55	70.45	-0.10	65.25	65.25	0.00
7	95.45	103.53	+8.08	90.15	90.25	+0.10	90.55	85.15	-5.40
8	110.35	115.20	+4.85	105.25	105.35	+0.10	115.35	105.25	-10.10
9	120.45	125.30	+4.85	115.15	120.35	+5.20	120.25	115.25	-5.00
10	126.45	134.55	+8.10	118.70	125.30	+6.60	125.55	120.25	-5.30

Table 5. Weekly differences in mean aphid population by variety × fertilizer for first and second cropping periods.

Week	Kulai 1033 (V1) F1	Kulai 1033 (V1) F2	Kulai 1033 (V1) F3	Kulai 1033 (V1) F4	Kulai 568 (V2) F1	Kulai 568 (V2) F2	Kulai 568 (V2) F3	Kulai 568 (V2) F4	Kulai 461 (V3) F1	Kulai 461 (V3) F2	Kulai 461 (V3) F3	Kulai 461 (V3) F4
1	+0.30	+0.40	+1.00	+1.20	+0.50	+0.60	+1.10	+1.50	+0.20	+0.40	+0.80	+1.00
2	+0.50	+0.70	+1.30	+1.50	+0.60	+0.80	+1.50	+2.00	+0.30	+0.70	+1.20	+1.50
3	+1.00	+1.50	+2.00	+2.50	+0.80	+1.20	+1.70	+2.30	+0.50	+1.00	+1.50	+2.00
4	+2.00	+3.00	+4.00	+5.00	+1.20	+2.00	+3.50	+4.50	+1.00	+2.00	+3.00	+4.00
5	+3.00	+4.50	+5.50	+6.50	+2.50	+3.50	+5.00	+6.00	+2.00	+3.00	+4.00	+5.00
6	+5.00	+6.50	+7.50	+8.50	+3.50	+5.00	+6.50	+8.00	+3.00	+4.50	+6.00	+7.00
7	+6.00	+8.00	+9.50	+10.50	+4.00	+5.50	+8.00	+9.50	+4.00	+5.50	+7.50	+8.50
8	+7.50	+9.50	+10.50	+12.00	+4.50	+6.00	+9.00	+11.00	+4.50	+6.00	+8.00	+9.00
9	+8.50	+10.50	+11.50	+13.00	+5.50	+7.00	+10.00	+12.50	+5.00	+7.00	+9.50	+10.50
10	+9.00	+11.50	+13.00	+14.50	+6.00	+7.50	+11.00	+13.50	+5.50	+7.50	+10.00	+11.00

Note: Columns: Each corresponds to a specific chili variety and fertilizer dosage combination (e.g., Kulai 1033 (V1) with F1 fertilizer).
Values: Each cell contains the difference in mean aphid population between the second and first cropping periods for the respective week. Positive values indicate higher populations in the second cropping, while negative values indicate a decrease

5. DISCUSSION

5.1. Effect of Different Chilli Varieties and Fertilizer Dosages against Aphis Gossypii Population for First and Second Cropping Periods

A. gossypii's population in the first cropping period showed a steady weekly increase, with the highest densities observed around Weeks 8–10. Plants treated with F4 fertilizer consistently attracted the highest *A. gossypii* populations, with an average peak density of 126.45 *A. gossypii* on Kulai 1033 (V1) by Week 10. The lowest aphid populations were found on F1-treated plants, particularly on Kulai 568 (V2), which averaged around 93.2 aphids by Week 10. These trends suggest a clear correlation between nutrient availability and aphid reproduction rates.

In the second cropping period, *A. gossypii* aphid densities were significantly higher than in the first cropping period, with peaks occurring earlier (Weeks 7–9) and sustaining higher populations through Week 10. The cumulative nutrient enrichment in the soil and favorable environmental conditions, such as stable temperatures and humidity, likely contributed to this increase. Kulai 1033 (V1) with F4 treatment recorded the highest *A. gossypii* population of 141.5 by Week 10.

In order for herbivores to achieve optimal growth, development, and reproductive performance, they must consume sufficient nutrients from a host plant. According to Lu, Yu, Heong, and Hu (2007), a higher application rate of nitrogen fertilizer significantly increases the number of egg masses laid by the Asian corn borer on maize leaves. Similarly, the data from this study suggest that a high concentration of fertilizer can stimulate a significant increase in the population of aphids. Zaini, Rawi, and Hassan (2013) stated that the growth of plants, the concentration of nutrients, and the early infestation by whiteflies on brinjal plants can affect the whitefly population due to the observation that whitefly populations tend to be higher in non-pre-infested plants as nutrient levels increase. The manipulation of crop nutrient composition through fertilizer application can significantly affect plant defense mechanisms against pests. High nitrogen content in F4 fertilizer increased plant succulence, which provided an optimal feeding environment for aphids. Excess nitrogen weakens plant cell walls, making it easier for aphids to extract nutrients and reproduce rapidly. F2 and F3 fertilizers achieved a balance between plant growth and defense mechanisms. These treatments resulted in moderate aphid populations while supporting healthy plant development. F1-treated plants, which received the least nutrients, exhibited the lowest aphid infestations, suggesting that nutrient limitation can reduce plant attractiveness to pests.

However, there are instances where the application of fertilizer may have adverse effects on insect performance, resulting in reduced growth and survival rates. These exceptions may be attributed to a variety of factors: an increase in the number of natural predators or natural enemies, unfavorable weather conditions, and the development of chemical defenses in plants that react to insects' feeding (Inbar, Doostdar, Leibee, & Mayer, 1999). Zurina, Roff, and Idris (2010) reported a similar trend, where the population of whiteflies was higher during early stages of the season and gradually decreased as the crop growth progressed. The environmental conditions, such as temperature and humidity, can directly affect the survival and reproduction of aphids.

According to recent research conducted by Kirana, Karyadi, Faizal, and Syamsudin (2019), it has been found that distinct varieties of chilli exhibit varying levels of chemical compounds that can significantly impact their attractiveness to insect pests. For instance, certain varieties of chili are known to contain higher levels of capsaicin, a compound known for its pungency. This compound serves as a natural defence strategy against insect pests like aphids, which effectively deter them from feeding on the plants. Conversely, there are other chili varieties that exhibit lower levels of capsaicin and may, therefore, be more susceptible to aphid infestations. The presence of particular volatile organic compounds emitted by various types of chili varieties can also significantly impact their susceptibility to insect pests, as demonstrated by Alonso-Villegas, González-Amaro, Figueroa-Hernández, and Rodríguez-Buenfil (2023). These volatile organic compounds can act as chemical signals that either attract or repel specific insect species, by Hildebrand, Brown, Jackson, and Hamilton-Kemp (1993). However, in general, this study showed that there are no significant effects of sub-varieties among Chilli Kulai on the population of A. gossypii in this study..

6. CONCLUSIONS AND RECOMMENDATIONS

In this study, there are three sub-varieties of the Chili Kulai variety and three different levels of fertilizer were tested to determine the *Aphis gossypii* infestation rate. Throughout the study, it can be concluded that the infestation of aphids in all treated chili plants mostly increased every week. However, the numbers of *A. gossypii* were significantly higher in the mean numbers in the chili varieties treated with high fertilizer dosage compared to the middle and lower dosages. Subsequently, the sub-varieties of Chilli Kulai did not influence pest infestation on chili. Therefore, optimum and balanced fertilization dosages can mitigate infestations or suppress pest infestation at the economic injury level. Additional pest control measures, the findings of this study could contribute to a body of knowledge, especially in Integrated Pest Management (IPM).

This study recommended that the determinant of fertilizer dosage supplied to the crop is highly needed, but the sub-variety of the plant did not have a significant impact on insect-pest infestation. Thus, the findings can be considered and practiced to achieve sustainable cultivation and reduce aphid-induced damage.

Further study is suggested to be carried out regarding the interaction between *A. gossypii* and the fertilizer absorption rate by the plant performance, competition with other pests, and the plant chemical defense system (secondary metabolites).

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Institutional Review Board Statement: The Ethical Committee of the Universiti Teknologi Mara, Malaysia has granted approval for this study (Ref. No.:600-UITMKJ (FPA.23/1).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all research ethics.
Data Availability Statement: Data collections are highly reliable and valid due to a thoroughly designed and planned research methodology and recent data taken within three years.
Competing Interests: Research area focuses on agronomic practices, particularly on selected chili varieties and fertilizer dosage; however, chemical plant defense should be carried out in the future to enhance and confirm that the strategy of good agronomic practices can be implemented effectively in the future.
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