JJBS

Volume 16, Number 2,June 2023
ISSN 1995-6673
Pages 181 – 187
https://doi.org/10.54319/jjbs/160202

Jordan Journal of Biological Sciences

The Response of Some Cassava Clones to Red Mite - *Tetranychus urticae*

Sri Wahyuni Indiati[1,2,*], Kartika Noerwijati[1,2], Sumartini Sumartini[1,2], and Nguyen van Minh[3]

[1]Research Center for Food Crops, BRIN, Jl. Raya Jakarta-Bogor No.Km.46, Cibinong, Cibinong- Bogor 16911, West Java, Indonesia; [2]Indonesian Legumes and Tuber Crops Research Institute, Jl. Raya Kendalpayak No.66,Malang 65162, East Java, Indonesia; .[3]Faculty of Agriculture and Forestry, Tay Nguyen University, 567 Le Duan St. Buon Ma Thuot City, Dak Lak Province, Vietnam, 63100

Received: Feb 2, 2023; Revised: March 25, 2023; Accepted Mar 26, 2023

Abstract

The red spider mite *Tetranychus urticae* (C.L. Koch, 1836) is an essential cassava pest, particularly in dry regions, which may cause a considerable yield loss. To reduce the damage of this pest, chemicals are applied in the field, possibly leading to adverse environmental effects. Therefore, using resistant cultivars is considered an effective and environment-friendly alternative. The study was conducted on 11 cassava clones and four cultivars (as control) during the 2016 planting season to identify the resistant clones to red spider mites in a greenhouse, producing a high yield in the field. The greenhouse experiment was conducted at ILETRI (Indonesian Legumes and Tubers Crop Research Institute). In contrast, the field experiments were explored at the Jambegede research station, Malang district, East Java Province, Indonesia. Both trials were arranged in a randomized block design with three replications. The results showed that there were four clones (CMM 03036-7, CMM 03036-5, CMM 03038-7, and CMM 02040-1), and one cultivar (Adira 4) in cluster 3 were categorized as moderately resistant and resistant groups to mites and had high tuber yields (above the average yield, > 41.12 t ha^{-1}). At a high mite population, all clones or cultivars will be attacked by mite pests; however, the clones (CMM 03036-7, CMM 03036-5, CMM 03038-7, and CMM 02040-1) exhibited the tolerance to red mite attacks. These results indicate that these clones are promising approaches for collecting resistant cassava cultivars against red mites.

Keywords: Environmentally friendly**,** High yielding, *Manihot esculenta* Crantz., Manioc, Pest control, Red spider mites, Resistant cultivar, *Tetranychus urticae* Koch, 1836

1. Introduction

Cassava (*Manihot esculenta* Crantz), one of the most important root crops, is widely grown in Africa, Southeast Asia, and Latin America. Apart from rice, corn, and soybeans, cassava is a priority food-crop commodity and has become the third-largest carbohydrate source. With a total production of 23 900 000 t in Indonesia, 64 % of cassava is used for food while the rest is for starch raw materials, animal feed, and export industries (BBPOPT 2013).

The red mite, *Tetranychus urticae* (Koch, 1836), is always found in cassava plantations around the world, and it is one of the factors causing the low productivity of cassava (Bellotti *et al*., 2012; Graziosi *et al.,* 2016) and decreasing the quality of the yield, such as physical damage, chemical toxins, disease vectors, increased production costs, and social, environmental, and consumer rejection. In Indonesia, red mite infestation usually occurs during the dry season. According to Indiati (2012), yield reduction due to red mite attack can reach 20 % to 53 %, depending on the age of the plant when the attack occurs. At severe levels of damage, yield loss can get 95 % (Santoso and Astuti. 2019). Therefore, comprehensive control efforts are needed to reduce yield loss due to red mite attacks.

In general, mite control can be done in several ways, such as using resistant cultivars, biological control by relying on natural enemies in the field, mechanical control by spraying water on the underside of leaves so that mites are washed away with the water flow, planting cassava at the beginning of the rainy season, and chemical control. In Indonesia, the control of red mites on cassava plants has yet to be carried out optimally by farmers. This is closely related to cassava's relatively low economic value, so applying insecticides to control red mites needs to be properly applied to cassava plants. Using 2 mL L^{-1} dicofol in the field did not affect the intensity of mite attacks. However, the tuber yield in the plots controlled by dicofol 2 mL L^{-1} was 14 % higher than in the plots without control (Indiati, 2012). Chemical control should be applied only in emergencies because of the increased control cost and the negative environmental effect. To overcome this problem, it is necessary to look for alternative control methods, for example, by using resistant cultivars to pest attack (Wani *et al*., 2022), organic pesticides (Ekawati and Purwanto, 2013; Ikhwan *et al*., 2021; Roeswitawati *et al*., 2021), and pests' natural enemies in the form of insect pathogens (Jones *et al*., 2022). Radhakrishnan *et al*. (2015)

* Corresponding author. e-mail: tika_iletri@yahoo.com; kart012@brin.go.id.

stated that low-input or chemical-free pest control is particularly suitable for cassava, as it is grown by smallholders throughout resource-poor tropical developing countries on small plots or degraded land.

Planting resistant cultivars is a solution to long-term problems in pest and disease control because it is economical, easy to use, can be combined with other control methods, and does not pollute the environment (Douglas, 2018). Using resistant crops with other control components in pest management suits agricultural agroecosystems. Planting resistant cultivars is a cheap, easy control technique and does not pollute the environment. Eight cassava cultivars are somewhat resistant to red mite attacks such as Adira 1, Adira 2, Adira 4, Malang 1, Malang 4, Malang 6, LITBANG UK-2, UK-1 Agritan have been released by the Ministry of Agriculture (Balitkabi, 2016). Planting resistant cassava cultivars can inhibit the development rate of mite populations, reduce the intensity of mite attacks, and reduce cassava yield losses. A series of selection activities have been carried out to obtain promising cassava clones with high yield and starch content, but the response to the red mite attack has yet to be discovered. Therefore, this study aimed to identify the resistant clones of red spider mites in a greenhouse, producing a high yield in the field.

2. Materials and Methods

2.1. Study area

The greenhouse experiment was carried out at ILETRI. The coordinates are -8° 2' 51" S and 112° 37' 30" E, with an altitude of 436 m above sea level. The field experiment was done at the Jambegede research station in Malang district, East Java province, Indonesia. It is located at the coordinates -8° 10' 20" S and 112° 33' 43" E, at 335 m above sea level. The Jambegede research station has a climate type of C3, with rainfall of 1 600 mm to 2 600 mm yr^{-1}, and the soil type Alfisols is associated with Inceptisols.

2.2. Procedures

The greenhouse experiment was conducted from June to October 2016. The study used a randomized block design with 11 cassava clones and four cultivars as treatments and was repeated three times. The materials used were cassava cuttings, red mite imago, soil as a medium, and NPK fertilizer. Cassava cuttings consisted of 11 clones (CMM 03025-43, CMM 03036-7, CMM 03036-5, CMM 03038-7, CMM 03094-12, CMM 03094-4, CMM 03095-5, CMM 02040-1, CMM 02033-1, CMM 02035-3, and CMM 02048-6) and four cultivars as control (UJ 5, Malang 6, Malang 4, and Adira 4), UJ5 as the negative control, and Adira 4 as the positive control. Cassava cuttings of 25 cm in length were planted in pots (one cutting per pot) with a diameter of 30 cm (volume 5 kg of soil). Fertilization is applied at the time of planting, with up to 10 g of NPK fertilizer per pot mixed with soil. Watering occurs three times a week, while weeding is done as needed.

The intensity of the mite attack was observed on each plant aged 1 wk after infestation (WAI), 2 WAI, 3 WAI, 4 WAI, 5 WAI, 6 WAI, 7 WAI, and 8 WAI. The intensity of the mite attack was calculated based on Equation (1)

$$I = \sum \frac{nxv}{NxV} x\,100\ \% \qquad (1)$$

Note:

I = intensity of the attack
N = number of leaves in 1 plant
V = the highest score (in this case, 5)
n = number of leaves in each category score
v = category score (0 to 5)

Leaf damage scores due to mite attacks are categorized in Table 1.

Table 1. The red mite *T. urticae* damage index classification on the cassava leaf surface score

Score	Description
0	Healthy leaves (no spotting)
1	There is yellowish spots (about 10 %) on some lower leaves and or middle leaves
2	Yellowish spots (11 % to 20 %) on the lower and middle leaf.
3	Clear damage; lots of yellow spots (21 % to 50 %), few areas have necrotic (< 20 %), especially the lower and middle leaves are slightly shrunken; a number of leaves become yellow and fall out.
4	Severe damage (51 % to 75 %) at the lower and middle leaves, abundant population of mites and found white threads such as spider webs
5	Total leaf loss; plant shoots shrink; more white threads; plant death.

Source: Wahyuningsih *et al.* (2021).

The field experiment was conducted in the 2016 rainy season at the Jambegede research station, Malang district, East Java Province, Indonesia. The experiment used a randomized block design, repeated three times. The research materials consisted of 15 genotypes of cassava, consisting of 11 promising clones, namely CMM 03025-43, CMM 03036-7, CMM 03036-5, CMM 03038-7, CMM 03094-12, CMM 03094-4, CMM 03095-5, CMM 02040-1, CMM 02033-1, CMM 02035-3, and CMM 02048-6, and four superior cultivars as controls, namely Adira 4, UJ 5, Malang 4, and Malang 4 and Malang 6.

Cassava stem cuttings about 25 cm in length were planted vertically on plots measuring 5 m × 6 m with a spacing of 100 cm × 80 cm. Fertilization and weeding are performed 1 mo to 3 mo after planting. The first fertilization was (46 kg N, 36 kg P2O5, and 60 kg K2O) ha^{-1}, and the second was 46 kg N ha^{-1}. The repair of the mounds is carried out at the same time as fertilization. Cassava shoots should be removed by leaving two shoots at 2 mo after planting. Harvesting is done at the age of 10 mo. Observations were made on small tuber weight, big tuber weight, small tuber number, big tuber number, and fresh tuber yield.

The data obtained were analyzed using analysis of variance; if there was a significant difference, it was continued with the 5 % DMRT test (Adinurani, 2016, 2022). In addition, cluster analysis among the observed variables was also carried out.

2.3. Mass rearing of red mite

The test insect in the greenhouse experiment was the adult red mite *T. urticae* obtained from the Muneng research station, Probolinggo, East Java field. The mites obtained are maintained and propagated in screen houses on peanut leaves or cassava plants. Peanut and cassava plants used for mite propagation are made by planting peanut seeds of the Kancil varieties or UJ5 cassava cuttings in pots with a diameter of 30 cm (volume 5 kg of soil). Fertilization is applied at the time of planting, with up to 10 g of NPK fertilizer per pot. Watering is done as needed. After the cassava plants tested were 1 mo old, each plant was infested with 15 adult red mites from mite propagation in the greenhouse.

2.4. Mite infestation

A red mite infestation was carried out artificially by infesting 15 adult red mites per pot on the 1-month-old test plant. The infestation was carried out by attaching peanut leaves containing 15 adult red mites to each fourth or fifth lower surface of the cassava leaf from the shoot.

2.5. Data analysis

The severity of the damage caused by the red mite attack on the cassava plant was then used to determine the cassava clones' resistance level. The level of resistance to mites was determined based on the mean and the Standard Deviation (SD) method developed by Sholihin *et al.* (2022) as follows: **HR** (high resistance): I < (R–2SD); **R** (resistance): (R–2SD) < I < (R-SD); **MR** (moderate resistance): (R-SD) < I < (R+SD); **S** (susceptible): I > (R+SD). Note: R = average mite infestation intensity; I = intensity of red mite attack; SD = standard deviation

3. Results and Discussion

3.1. The greenhouse experiment

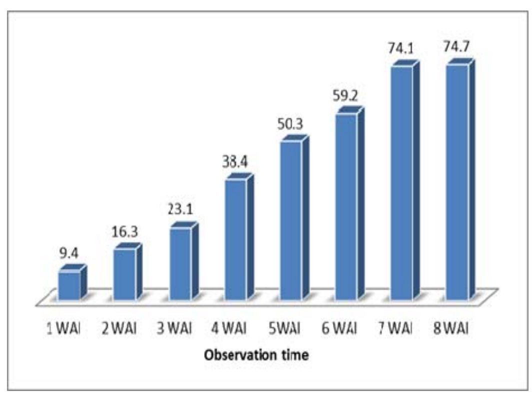
The symptoms of a red mite attack on cassava begin with the appearance of yellow spots along the leaf bones. Symptoms of a mite attack will be seen in two weeks. The symptoms then spread, and brown necrosis occurs on the affected leaves. Severe infestations cause the leaves to dry and fall off. The initial attack of the red mite occurs on the plant's lower leaves, then spreads to the upper part of the plant. Mite-infected leaves turn reddish brown or dark brown, then dry and eventually fall off.

Red mites attack plants by destroying mesophyll cells and sucking cell contents, including chlorophyll. As a result, the rate of photosynthesis decreases, transpiration increases, and the chlorophyll content is low (Rioja *et al*., 2017; Silva *et al*., 2016). Damage to plants due to mite attacks causes the photosynthetic ability of plants to decrease; nutrient production decreases; tuber size decreases; and yields also decrease (Indiati, 2012; Sobha, 2017). Severe mite attacks can cause the death of cassava plants (Indiati, 2012; Pramudianto and Sari, 2016).

3.1.1. Intensity of mite attack on cassava

Attacks by red mites on cassava begin in 1 WAI and increase until 8 WAI (Table 2). All cassava cultivars and clones were not significantly different at 1 WAI; the leaf damage intensity was still relatively low (3.88 % to 14.58 %). However, the intensity of red mite attacks on 2 WAI and 3 WAI significantly differed between clones/cultivars. At 2 WAI, the attack intensity started to creep up from 9 % to 24 %, and CMM02035-3 showed the lowest intensity equivalent to the positive control cultivar (Adira 4). On CMM02035-3 and Adira-4, all the leaves still looked green, and yellowish spots were found (about 10 %) on some of the lower and middle leaves, while the remaining clones and cultivars showed yellowish spots around 11 % to 20 % on the lower and middle leaves. Even CMM 02048-6 showed apparent damage, characterized by many yellow spots and few necrotic areas (< 20 %), especially on the lower leaves. At 3 WAI, the damage intensity increases to 40 % (Table 2). The most down attack occurred on CMM 03038-7 and was not significantly different from Adira 4 (positive control). Besides CMM 03038-7, there are one cultivar and three clones with lower damage intensity than Adira 4 as positive controls. All the leaves on these clones and cultivars still looked green; only yellowish spots (about 10 %) were found on some of the lower and middle leaves.

From 4 WAI to 7 WAI, crop damage continued to increase, averaging 38.44 % in 4 WAI, 50.75 % in 5 WAI, 59.18 % in 6 WAI, and 74.12 % in 7 WAI (Figure 1). The differences among the tested clones were not significantly different. At 5 WAI, 6 WAI, and 7 WAI, the lowest plant damage occurred at CMM 02033-1, while the most significant damage occurred at CMM 03094-12. Both clones were stable at the lowest and highest damage intensities. At 8 WAI, the intensity of plant damage decreased by an average of 74.66 %, which was caused by most of the test clones experiencing severe leaf loss. In these observations, there were seven clones with increasing attack intensity (leaf fall has not yet occurred), including Malang 6, CMM 03025-43, CMM 03036-7, CMM 02040-1, CMM 02033-1, CMM 02035-3, and CMM 02048-6, with the lowest attack occurring at CMM 02035-3 (69.8 %). A severe mite infestation in the greenhouse will cause high leaf loss in some cassava clones. Resistant cassava clones were characterized by low leaf loss over some time (Indiati, 2012). According to Poovizhiraja *et al.* (2018), host plants' morphological and chemical components, especially plant nutrients, cause severe crop damage and yield losses.



Note: WAI = week after infestation

Fig. 1. Development of mite attack intensity on cassava from 1 WAI to 8 WAI. ILETRI greenhouse, dry season 2016.

Table 2. The intensity of red mite attack on several cassava clones/cultivars in greenhouse conditions.

Clones/cultivars	Observation schedule (WAI) (%)									
	1	2		3		4	5	6	7	8
UJ 5	6.62	13.97	abc	26.49	ab	31.45	45.35	61.67	78.46	78.67
Malang 6	10.17	19.14	cdef	22.48	ab	45.03	60.98	65.86	77.98	80.74
Malang 4	8.29	15.66	abcd	18.54	ab	32.91	55.28	63.68	79.69	76.57
Adira 4	3.88	9.98	a	19.02	ab	31.44	46.89	56.25	72.88	67.11
CMM 03025-43	10.26	21.68	def	26.01	ab	44.51	49.28	63.35	77.84	80.25
CMM 03036-7	9.30	17.52	bcde	21.74	ab	33.31	41.62	53.71	66.41	74.95
CMM 03036-5	7.80	10.54	a	17.72	ab	34.22	48.75	56.93	76.02	74.47
CMM 03038-7	9.65	11.35	ab	14.87	a	34.41	50.76	54.60	75.22	74.36
CMM 03094-12	11.34	20.49	def	30.40	bc	53.37	61.97	67.70	80.75	67.73
CMM 03094-4	12.69	22.67	ef	25.63	ab	49.09	56.67	62.29	78.54	69.63
CMM 03095-5	13.48	18.70	cdef	26.63	ab	46.69	52.07	60.49	75.35	73.46
CMM 02040-1	8.72	15.57	abcd	18.20	ab	32.88	45.63	55.97	73.18	79.39
CMM 02033-1	9.21	13.19	abc	17.82	ab	22.75	38.34	49.03	58.79	72.65
CMM 02035-3	4.30	9.94	a	20.96	ab	31.28	46.50	52.30	62.96	69.85
CMM 02048-6	14.58	24.36	f	39.62	c	52.69	55.05	63.93	77.71	80.00
Mean	9.35	16.32		23.08		38.44	50.75	59.18	74.12	74.66
Sd	3.0	4.8		6.3		9.3	6.7	5.5	6.5	4.6
DMRT	ns	5.64		11.46		ns	ns	ns	ns	ns
CV (%)	22.33	19.37		17.36		24.16	13.38	9.26	8.71	6.18

Note: WAI = weeks after infestation; ns = not significant

Numbers in the same column followed by the same letter are not significantly different based on the DMRT test at 5 %.

3.1.2. Category of resistance of cassava to red mites

Table 3. Resistance criteria of 15 cassava clones/cultivars to the red mite. ILETRI greenhouse, dry season 2016.

Clones/Cultivars	Observation Schedule (WAI)						
	1	2	3	4	5	6	7
UJ 5	MR	MR	MR	MR	MR	MR	MR
Malang 6	MR	MR	MR	MR	S	S	MR
Malang 4	MR	MR	MR	MR	MR	MR	MR
Adira 4	R	R	MR	MR	MR	MR	MR
CMM 03025-43	MR	S	MR	MR	MR	MR	MR
CMM 03036-7	MR	MR	MR	MR	R	MR	R
CMM 03036-5	MR	R	MR	MR	MR	MR	MR
CMM 03038-7	MR	R	R	MR	MR	MR	MR
CMM 03094-12	MR	MR	S	S	S	S	S
CMM 03094-4	S	S	MR	S	MR	MR	MR
CMM 03095-5	S	MR	MR	MR	MR	MR	MR
CMM 02040-1	MR	MR	MR	MR	MR	MR	MR
CMM 02033-1	MR	MR	MR	R	R	R	HR
CMM 02035-3	R	R	MR	MR	MR	R	R
CMM 02048-6	S	S	S	S	MR	MR	MR

Note: HR: high resistance, R: resistance, MR: moderate resistance, S: susceptibility

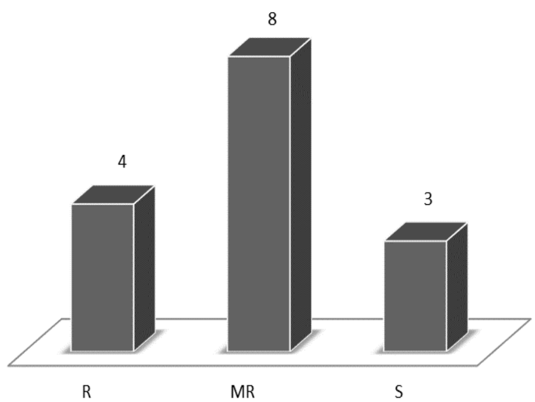
The resistance level of cassava was determined based on the standard deviation method, which was calculated based on the intensity of mite attacks per observation. The resistance response of each cassava clone or cultivar to a red mite attack is different, depending on genetics and the environment. Therefore, in each compliance, the resistance response of each clone depended on the mean severity of the attack and the value of the standard deviation of the set of tested cassava clones.

Overall, from 1 WAI to 7 WAI, there was one clone, CMM 02035-3, which consistently had better resistance than the Adira 4 (resistant check cultivar) (Table 3). In addition, this clone has the characteristics of dense leaves that do not fall off easily, so it is resistant to red mite attacks.

In high mite populations, all cultivars with different levels of resistance will be attacked by mites. Still, the period from the appearance of initial symptoms to severe symptoms is other. Resistance and susceptible cultivars take longer (Indiati, 2012). Based on the description above, the classification of the resistance of cassava clones to mite attack will be based on the intensity of plant damage at 2 WAI, with the following category: Eight clones/cultivars (UJ 5, Malang 6, Malang 3; CMM 03036-7, CMM 03094-12, CMM 03095-5, CMM 02040-1, CMM 02033-1) were tested including the MR category, four clones including the R category (Adira 4, CMM 03036-5, CMM 03038-7, CMM 02035-3); and three clones (CMM 03025-43, CMM 03094-4, and CMM 02048-6) including susceptible (S); UJ-5 as a sensitive check was included in the moderately resistant (MR) category, and Adira 4 was included in the resistant (R) category (Figure 2) against the red mite.

The presence of severe mite attacks will cause plants to grow less optimally. In heavily infected plants, fine cobweb-like threads between the cassava leaves serve as a bridge for transferring mites from one leaf to another or from one plant to another. The line also helps to protect mites from predators (Iwasa and Osakabe, 2015; Sato *et al*., 2016).

The response of different cassava cultivars to mite attack can be influenced by various factors, including leaf morphology (leaf shape, leaf color, leaf thickness, and cuticle thickness) (Radhakrishnan *et al*., 2015). In addition to differences in leaf morphology, the content of chemical compounds or nutrients in cassava leaves can also affect the level of mite attack on leaves (Poovizhiraja *et al*., 2018). Santoso and Astuti (2019) reported that every cultivar showed different resistance against *T. kanzawai*. The Manggu cultivar showed the lowest damage, while the Mentega cultivar showed the highest. On the Manggu cultivar, *T. kanzawai* had the most extended life cycle and lowest fecundity. The Manggu cultivar was more resistant to the attack of the red mite *T. kanzawai* than other cultivars.



Note: R = resistance, MR = moderately resistant, S = susceptible.

Figure 2. Distribution of resistance groupings of 15 cassava clones to red mite attack. ILETRI greenhouse, dry season 2016.

In other host plants, several different resistance mechanisms are responses to the red mites' attacks. In citrus plants, the mechanism of host plant resistance to red mites is associated with flavonoid content (Agut *et al*., 2014), leaf trichoma (Olbricht *et al*., 2014), increased peroxidase and polyphenol oxidase activities in melon—*Cucumis melo* L. (Shoorooei *et al.,* 2013), and antibiosis and antixenosis in lima beans— *Phaseolus lunatus* L. (França *et al.,* 2018). De Oliveira *et al.* (2018) reported that tomato (*Solanum lycopersicum* L.) genotypes with high zingiberene (ZGB) content are a potential gene source for resistance to the mite *T. urticae* and possibly other pests in tomato breeding programs.

The phytochemical content of plants influences the red pest mites, But, the mechanism of cassava resistance to red mites is not yet known with certainty. Indiati (2012) stated that trichomes on cassava shoots are not the only factor determining cassava's resistance to mites. The cassava leaf buds of M4-p, OMM 0915-11, and UJ5d50-207-3, which were attacked by mites with the lowest intensity, did not have trichomes (Indiati, 2012; Sholihin *et al*., 2022). However, low mite infestation was found in clones and cultivars with leaves with more than 70 % moisture content. In addition, the HCN content in leaves was also not significantly correlated with mite attacks (Indiati, 2012). Yang *et al*. (2020) reported that the mite-resistant cassava genotype (XX048) had thicker abaxial epidermis and palisade tissue than the susceptible genotype (GR4). The mite damage index of XX048 was lower than GR4. XX048 had synthesized more secondary metabolites in the leaves than GR4. XX048 accumulated higher levels of secondary metabolites, potentially contributing to its higher mite resistance.

3.2. The field experiment

The results of the analysis of variance for yield variables and components showed that all variables showed significant differences except for the number of small tubers. The weight of small tubers ranged from (0.51 kg to 1.41 kg) plant^{-1}, with an average of 0.91 kg plant^{-1}. The weight of large tubers ranged from (2.37 kg to 7.29 kg) plant^{-1}, with an average of 4.32 kg plant^{-1}. The one with the highest significant tuber weight was clone CMM 03094-4. Small tubers range from 2.53 to 6 tuber plant^{-1}, with an average of 3.9 small tuber plant^{-1}. The number of large tubers ranged from 2.67 to 7.47 plant^{-1}. The tuber yield per ha ranged from 21.26 t ha^{-1} to 62.41 t ha^{-1} (average 41.12 t ha^{-1}). Six promising clones had tuber yields above the average: CMM 03036-7, CMM 03036-5, CMM 03038-7, CMM 03094-4, CMM 02040-1, and CMM 02048-6 (Table 4).

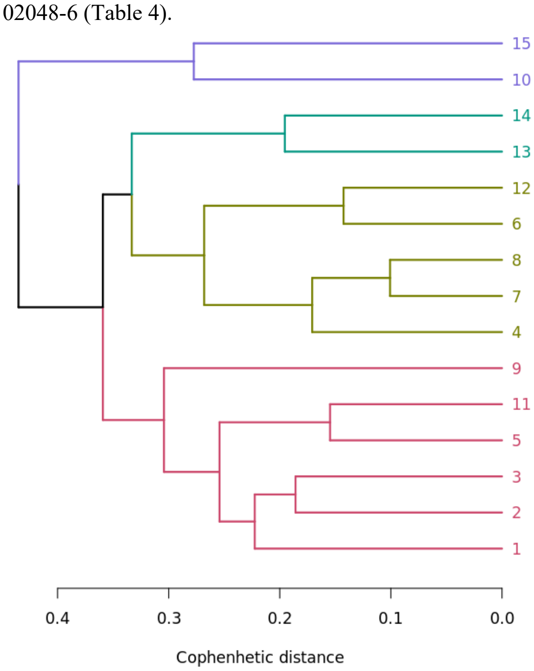


Figure 3. Cluster analysis using tuber yield, yield components, and intensity of mite infestation variable

Cluster analysis formed four groups (Figure 3). Cluster 1 consisted of two clones, namely clones 10 and 15 (CMM 03094-4 and CMM 02048-6), cluster 2 also consisted of two clones, namely clones 13 and 14 (CMM 02033-1 and CMM 02035-3), cluster 3 consisted of five clones/cultivars, namely clones 4, 6, 7, 8, and 12 (Adira 4, CMM 03036-7, CMM 03036-5, CMM 03038-7, and CMM 02040-1), while cluster 4 consisted of six clones, namely clones 1, 2, 3, 5, 9, and 11 (UJ 5, Malang 6, Malang 4, CMM 03025-43, CMM 03094-12, CMM 03095-5, CMM 030) (Figure 3). The CMM 03094-4 and CMM 02048-6 clones in cluster 1 were high-yielding clones (62.41 t ha^{-1} and 50.94 t ha^{-1}, respectively), but based on the greenhouse test, the two clones were classified as sensitive to red mites. It is suspected that during the field experiment, the red mite attack was not too severe, so it did not affect the decrease in yield. In the glass house experiment, five clones in cluster 3 were categorized as moderately and highly resistant to mites and had high tuber yields (above the average yield) in the field experiment. These clones (CMM 03036-7, CMM 03036-5, CMM 03038-7, and CMM 02040-1) had a high chance of being released as high-yielding cassava cultivars that were resistant to red mites.

Table 4. Yield and yield components of 15 cassava genotypes. Jambegede Research Station, 2016.

No.	Genotypes	Small tuber weight (kg)	Big tuber weight (kg)	Small tuber number	Big tuber number	Tuber yield (t ha^{-1})
1	UJ5	0.74 d	3.45 defg	4.53 abcd	4.67 bcde	34.25 e
2	Malang 6	0.81 d	4.39 cde	3.53 bcd	4.80 bcde	42.70 d
3	Malang 4	0.67 d	4.61bcde	2.53 d	4.60 bcde	50.20 cd
4	Adira 4	0.80 d	4.86 bcde	3.27 cd	5.13 bcd	45.81 bc
5	CMM 03025-43	0.86 bcd	3.13 fg	3.87 abcd	3.33 bcde	24.07 fg
6	CMM 03036-7	1.41 a	5.39 bc	5.60 abc	5.40 abc	46.97 cd
7	CMM 03036-5	0.77 d	6.23 ab	2.80 d	5.47 ab	58.63 a
8	CMM 03038-7	0.93 a-d	4.90 bcd	3.40 cd	5.27 bc	56.64 ab
9	CMM 03094-12	0.51 e	3.19 efg	2.40 d	3.27 cde	29.59 ef
10	CMM 03094-4	1.33 abc	7.29 a	6.00 a	7.47 a	62.41 a
11	CMM 03095-5	0.83 cd	2.37 g	4.47 abcd	2.67 e	22.71 g
12	CMM 02040-1	1.35 ab	4.41 cde	5.87 ab	4.40 bcde	45.60 cd
13	CMM 02033-1	0,67 e	2.49 g	3.07 d	4.07 bcde	25.07 fg
14	CMM 02035-3	0.87 bcd	2.55 g	3.07 d	3.07 de	21.26 g
15	CMM 02048-6	1.15 abcd	5.61 bc	4.53 abcd	5.33 abc	50.94 bc
	Average	0.91	4.32	3.90	4.59	41.12
	F test	*	**	ns	*	**
	CV (%)	33.74	23.14	37.64	27.76	9.99
	LSD (5%)	0.51	1.67	2.45	2.13	6.87

Note: the number of columns followed by the same letter is not significantly different in the 5 % DMRT test. ns = non-significant

4. Conclusion

In the greenhouse experiment, eight clones/cultivars tested belonged to the moderately resistant (MR) category (UJ 5, Malang 6, Malang 4, CMM 03036-7, CMM 03094-12, CMM 03095-5, CMM 02040-1, and CMM 02033-), four clones/cultivar were categorized as resistant (R) (Adira 4, CMM 03036-5, CMM 03038-7, and CMM 02035-3), and three clones (CMM 03025-43, CMM 03094-4, and CMM 02048-6) as susceptible (S).

Four clones (CMM 03036-7, CMM 03036-5, CMM 03038-7, and CMM 02040-1) and one cultivars (Adira 4) in cluster 3 had high tuber yields (above the average yield, > 41.12 t ha^{-1}) and categorized as moderately resistant and resistant groups to mites. Therefore, these clones (CMM 03036-7, CMM 03036-5, CMM 03038-7, and CMM 02040-1) have a high chance of being released as high-yielding cassava cultivars that are resistant to red mites.

From 1 WAI to 7 WAI, there was one clone, CMM 02035-3, which consistently had better resistance than the Adira 4. In addition, this clone has the characteristics of dense leaves that do not fall off easily, so it can be used as a parent in the breeding process for high-yielding cassava cultivars resistant to red mites.

Until now, cassava cultivars free from red mites have not been found. Red mites will attack all clones or cultivars in high mite populations. Incubation time for severe red mite infestation on resistant clones is more extended than on susceptible clones.

Acknowledgments

The authors are thankful to the Director of the Indonesian Legumes and Tuber Crops Research Institute (ILETRI), the Indonesian Agency for Agricultural Research and Development (IAARD), and the Ministry of Agriculture of the Republic of Indonesia for providing funding for this research (No. 1807115002052).

References

Adinurani PG. 2016. **Design and Analysis of Agrotrial Data: Manual and SPSS**. Plantaxia, Yogyakarta, Indonesia

Adinurani PG. 2022. **Agrotechnology Applied Statistics (compiled according to the semester learning plan)**. Deepublish, Yogyakarta, Indonesia

Agut B, Gamir J, Jacas JA, Hurtado M and Flors V. 2014. Different metabolic and genetic responses in citrus may explain relative susceptibility to *Tetranychus urticae*. *Pest Manag. Sci.*, **70(11)**: 1728–1741.

Balitkabi. 2016.**Description of Superior Varieties of Various Beans and Tubers**. Balai Penelitian Tanaman Aneka Kacang dan Umbi. Badan Litbang Pertanian. http://balitkabi.litbang.pertanian.go.id/wp-content/uploads/2016/09/ubikayu.pdf

BBPOPT - Center for forecasting plant pests. 2013. Evaluation report on the prediction of the main pest attacks of rice, corn, soybeans and cassava for the 2013 planting season on the incidence of April-July 2013. Ministry of Agriculture, Directorate of Food Crops.
http://bbpopt.info/berita/97-evaluation-ramal.

Bellotti AC, Arias BV, Vargas OH, Rejes JAQ and Guerrero GM. 2012. Insects and mites that attack cassava, and their control in Cassava in the third millennium. In: Ospina B and Veballos H (Eds.) **Modern Production, Processing, Use, and Marketing Systems**. CIAT, Colombia, pp. 213–250.

de Oliveira JRF, de Resende JTV, Maluf WR, Lucini T, de Lima Filho RB, de Lima IP and Nardi C. 2018. Trichomes and allelochemicals in tomato genotypes have antagonistic effects upon behavior and biology of *Tetranychus urticae*. *Front. Plant Sci.,* **9(1132)**:1–9. https://doi.org/10.3389/fpls.2018.01132.

Douglas AE. 2018. Strategies for enhanced crop resistance to insect pests. *Annu. Rev. Plant Biol*., **69**: 637–660. https://doi.org/0.1146/annurev-arplant-042817-040248.

Ekawati I.and Purwanto Z. 2013. Transfer of local resource-based vegetable pesticide technology to rice farmers. *Cemara,***10(1):** 36–40

França SM, Silva PRR, Gomes-Neto AV, Gomes RLF, Silva MJW andBreda MO. 2018. Resistance of lima bean (*Phaseolus lunatus* L.) to the red spider mite *Tetranychus neocaledonicus* (Acari: Tetranychidae). *Front. Plant Sci*., **9(1466)** :1–8. https://doi.org/10.3389/fpls.2018.01466.

Graziosi I, Minato N, Alvarez E, Ngo DT, Trinh XH, Aye TM, Pardo JM, Wongtiem P and Wyckhuys KAG. 2016. Emerging pests and diseases of south-east Asian cassava: A comprehensive evaluation of geographic priorities, management options and research needs. *Pest Manag. Sci.,***72(6)**: 1071–1089. https://doi.org/10.1002/ps.4250

Ikhwan A, Indratmi D, Hasanah F, Atoum MFM and Iqrar I. 2021. Analysis of metabolites from purple cleome extract (*Cleomerutidosperma* Linn.) as potential organic fungicides. *Sarhad J Agric***., 37(Special issue 1)**: 115–121.
https://dx.doi.org/10.17582/journal.sja/2021/37.s1.115.121

Indiati SW. 2012. Resistance of early age cassava varieties/clones to red mite. *Jurnal Penelitian Pertanian Tanaman Pangan,***31(1)**:54–59.

Iwasa T and Osakabe M. 2015. Effects of combination between web density and size of spider mite on predation by a generalist and a specialist phytoseiid mite. *Exp. Appl. Acarol.,***66(2)**: 219–225. https://doi.org/10.1007/s10493-015-9902-7.

Jones IJ, Sokolow SH and Leo GAD. 2022. Three reasons why expanded use of natural enemy solutions may offer sustainable control of human infections. *People Nature,* **4(1):**32–43. https://doi.org/10.1002/pan3.10264

Olbricht K, Ludwig A, Ulrich D, Spangenberg R, Guenther M and Neinhuis C. 2014. Leaf morphology and anatomy in the genus Fragaria: Implications for resistances. *Acta Hortic*, **1049**: 269–273. https://doi.org/10.17660/ActaHortic.2014.1049.34

Poovizhiraja B, Chinniah C and Kumar AR. 2018. Influence of nitrogen and phosphorus on the biological parameters of TSSM *T. urticae* Koch. on cassava, french bean and pumpkin. *J. Entomol. Zool. Stud.,* **6(1)**: 757–762.
https://www.entomoljournal.com/archives/2018/vol6issue1/PartK/5-4-374-484.pdf

Pramudianto and Sari KP. 2016. Red mite (*Tetranychus urticae* Koch) on cassava plants and how to control it. *Palawija Bulletin,***14(1)**: 36–48.

Radhakrishnan AS, Girija S and Anil AT. 2015. Organic vs conventional management in cassava: Growth dynamics, yield and soil properties. *J. Root Crops.,***39(2)**:93–99.

Rioja C, Zhurov V, Bruinsma K, Grbic M and Grbic V. 2017. Plant-herbivore interactions: A case of an extreme generalist, the two-spotted Spider Mite *Tetranychus urticae*. *Mol. Plant Microbe Interact.,* **30:** 935–945.
https://doi.org/10.1094/MPMI-07-17-0168-CR

Roeswitawati D, Kristova I, Muhidin M, Endarto O, Atoum MFM, Iqrar I and Shah LA. 2021. Assessment of three natural pesticide concentration on the imago phase red mites persistency. *Sarhad J. Agric***., 37(Special issue 1**): 153–158.
https://doi.org/10.17582/journal.sja/2021.37.s1.153.158

Santoso S and Astuti W. 2019. Resistance of four cassava cultivars against *Tetranychus kanzawai* Kishida (Acari: Tetranychidae). *Agrovigor*, **12(2):** 87–93.

Sato Y, Alba JM, Egas M and Sabelis MW. 2016. The role of web sharing, species recognition and host-plant defence in interspecific competition between two herbivorous mite species. *Exp Appl Acarol.,* **70(3)**: 261–274. https://doi.org/10.1007/s10493-016-0079-5.

Sholihin, Indiati SW, Noerwijati K,Wahyuni TS, Kuswantoro K, Suhartina, Soehendi R, Bayu MSI, Sutanto GWA, Mejaya MJ and Budiono R. 2022. Improving the genetics of tuber yield and resistance to mite to avoid mite incident and to increase the productivity of cassava (*Manihot esculenta* Crantz). *Scientifica*, **2022(6309679)**:1–9.
https://doi.org/10.1155/2022/6309679.

Shoorooei M, Lotfi M, Nebipour A, Mansouri AI, Kheradmand K, Zalom FG, Madadkhah E and Parsafar A. 2013. Antixenosis and entibiosis of some melon (*Cucumis melo*) gentotypes to the Two-Spotted Spider Mite (*Tetranychus urticae*) and a possible mechanism for resistance. *J. Hortic. Sci. Biotechnol.,***88(1)**: 73–78.https://doi.org/10.1080/14620316.2013.11512938

Silva CAD and Junior MGCG. 2016. First record and characteristics of damage caused by the spider mite *Tetranychus neocaledonicus* André on peanuts in the State of Paraíba, Brazil. Bragantia. *Campinas,***75(3)**:331–334.
http://dx.doi.org/10.1590/1678-4499.483

Sobha TR, UmmukulsoomOP and Shabana TP. 2017. Impact of climatic factors on the population density of vegetable spider mite, *Tetranychus neocaledonicus* (Acari: Tetranychidae) infesting cassava. *Int. J. Adv. Res*., **5(7):** 2174–2178. http://dx.doi.org/10.21474/IJAR01/4956

Wahyuningsih S, Indriani FC, Restuono J, Noerwijati K, Taufiq A, Baliadi Y, Budiono R, Minh NV, Soni P. 2021. Growth and productivity of four cassava cultivars on several levels of mixed fertilizers*. Jordan J. Biol. Sci*., **14(5)**: 939–944 https://doi.org/10.54319/jjbs/140509

Wani SH, Choudhary M, Barmukh R, Bagaria PK, Samantara K, Razzaq A, Jaba J, Ba MN and Varshney RK . 2022. Molecular mechanisms, genetic mapping, and genome editing for insect pest resistance in field crops. *Theor Appl Genet.,***135**: 3875–3895. https://doi.org/10.1007/s00122-022-04060-9

Yang Y, Luo X, Wei W, Fan Z, Huang T and Pan X. 2020. Analysis of leaf morphology, secondary metabolites and proteins related to the resistance to *Tetranychus cinnabarinus* in cassava (*Manihot esculenta* Crantz). *Sci Rep.,* **10(14197):**1–13. https://doi.org/10.1038/s41598-020-70509-w.