

Efficacy of the Pepper Extracts to Control *Zucchini Yellow Mosaic Virus*

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Abstract: The *Zucchini yellow mosaic virus* (ZYMV) (*Potyvirus*) on “zucchini” presents great economic importance for Malagasy farmers. Numerous aphid species (Hemiptera: Aphididae) spread viral particles, which are easily transmitted mechanically, too. Farmers ignored this disease, therefore, its control became extremely difficult with insecticides. This study aimed to evaluate efficacy of chili pepper extracts. Treatments vary as a function of its initiations and were repeated at weekly intervals until harvest. It was conducted in market gardens around the town of Antananarivo. The study compared four treatments and repeated three times: firstly, plots received a protection as soon as installation of culture (preventive protection); secondly, plots received treatment with low infestation (about a quarter plants infested) (late protection); thirdly, plots received treatment with high infestation (about half of plants infested) (latest protection); lastly, plots without treatment (the control). As a result, pepper extracts can provide a significant level to control against aphids attack, and permit to delay virus installation on plots, which received treatment as soon as implementation of culture. However, it cannot eradicate and cannot limit extend of virus disease on plots already infested. Economic analysis shows that preventive treatment of pepper extracts to fight virus attack provides an even greater return on its investment than all other terms. Thus, use of pepper extracts can reduce chemical treatment and pollution.

Key words: *Zucchini yellow mosaic virus*, aphids, preventive control strategy, profitability.

1. Introduction

For many years, organic farming knows particular success to guarantee better management of pesticide and manure to protect human health and environment against adverse effects of these products. It relies on fertilizers of organic origin and places emphasis on practices, such as crops’ rotation and companion planting. Biological pest control of mixed cropping and fostering of auxiliary insect are encouraged. In general, organic standards are designed to allow use of naturally occurring substances, while prohibiting or strictly limiting synthetic substances [1].

International Federation of Organic Agriculture Movements (IFOAM), established in 1972 [2], defines organic agriculture as “a production system that sustains health of soils, ecosystem, people. It relies on ecological processes, biodiversity and adapted cycles

to local conditions, rather than use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit from shared environment and promotes fair relationships and a good quality of life” [3].

Madagascar’s organic sector remains small. Only about 129 ha concerned organic cultivation, which accounted for less than 0.005% of total agricultural area [3, 4]. Several attempts to develop commercial organic sector in Madagascar foundered, because of poor quality crop, lack of communication between buyers and sellers, non-competitive prices and high transport costs. Another obstacle, general lack of awareness about crop protection strategy approved for pest continues to inhibit growth.

Malagasy zucchini products, estimated at 60,000 tons contribute to face chronic and acute malnutrition (marasmus and kwashiorkor) [5]. International change required a zucchini standard to fruit present roller form, straight and pale green to

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dark green without deformation. This deformation, consequence of virus attack, involves great losses on quality and amount after early assault [6]. *Zucchini yellow mosaic virus* (ZYMV) (*Potyvirus*) constitutes one of dangerous enemy of crop, which transmitted by several manners: mechanical with upkeep implement; short bite of aphids, in particular *Aphis gossypii* Glover (Hemiptera: Aphididae) [7, 8]. Farmers do not know this disease and protect their crops with insecticides to control aphids attack. Furthermore, there are not any curative solutions for virus, so it is needed to control aphids, one of dangerous enemies of crop, with insecticides which permit to delay virus installation [9]. However, use of insecticides has various consequences on environment and on human health [10]. Official plant protection organization proposed to remove whole plant infected from farmers' fields.

Insuring agricultural products (of good quality, healthy and safe), alternative search of chemical fight constitutes a priority and emergency as use of pesticide in plants. This study aimed to reduce virus attack on zucchini with pepper extract and permit to reduce chemical treatment. In fact, a number of natural pesticides are permitted for use in organic production, and pepper extract represents one of them.

2. Materials and Methods

This study took place in market gardens around the city Antananarivo, Madagascar. Plant tested was zucchini, *Cucurbita pepo* (Cucurbitaceae) var. *vanga* that presented short stalk with growing season of almost 90 d [11].

Pepper came from local spice market. Capsaicin constitutes a major active ingredient of pepper, and consequently, *Capsicum frutescens* (Solanaceae) acts as insects repellent. Pepper extract consists of macerating in 1 L of water, two soup spoons of pepper fruit's powder during one night for extracting all its active ingredients. After that sieve extract, more water was added to adjust solution to 5 L. Each plot received

1 L of solution to 10 m² and treatments were repeated at weekly intervals till harvest.

Three Fisher blocs with four treatments are compared: firstly, plots received a protection as soon as culture installed (preventive protection); secondly, plots received treatment when about a quarter of plants were infested (low infestation), instead of eliminating virus installation (late protection); thirdly, plots received treatment when about half of plants were infested (high infestation) (latest protection); lastly, plots without treatment (control).

All plots were submitted on same itinerary, except for phytosanitary treatment. The first work realized at a depth of 25 cm after one month and it aimed to get lower soft strata. Each plot received 30 t/ha of manure. For plantation, two seeds per hole and a distant of 20-25 cm on board are practiced.

Three parameters are evaluated: physiology (germination capacity, plant length, quantity of harvest), plant health (aphid and virus importance) and economical parameters (cost price (CP), ratio of cost value (RCV) and ratio of labor value (RLV)).

Observations on germination capacity of seed were conducted every second day during two weeks and realized for all plants from seedling to the thirteenth day after seedling.

During development stage of zucchini, plant length was evaluated each week and realized on 10 plants for each plot. Quantity of harvest realized twice a week, and the best and all damaged ones, such as fruits presented larvae attack or deformed were selected.

Observations of zucchini enemies, such as aphid's count and virus symptoms progression, were immediately realized before treatment and 2 d after treatment, and then repeated weekly, which permitted to estimate the importance.

For analysis methods, use of analysis of variance (ANOVA) compared importance of aphid number and virus infestation between plots treated and the control.

Application of Abbott's formula (1925) [12] evaluated treatment efficiency for uniform population.

Efficacy percent (*EP*) as follows by Eq. (1):

$$EP = \left[1 - \frac{n \text{ in T after treatment}}{n \text{ in Co after treatment}} \right] \times 100 \quad (1)$$

where, n = insect population; T = treated; Co = the control.

Three ratios calculated are for this fight method to inform economic profitability:

CP of 1 kg of the products by Eq. (2):

$$CP = \frac{\text{Load value}}{\text{Quantity of product marketed}} \quad (2)$$

RCV by Eq. (3):

$$RCV = \frac{\text{Gross proceeds}}{\text{Total charge}} \quad (3)$$

For $RVC < 1$, fight method constitutes an economic uninteresting; for $1 < RVC < 2$, fight method requires improvement before vulgarization; for $RVC > 2$, fight method interesting can be outreach.

$$\begin{aligned} \text{Total charge} = & \text{intermediate consumption} \\ & + \text{amortization} + \text{labor cost} \quad (4) \end{aligned}$$

RLV will take into account the added value of its activities towards those strains labor, as follows by Eq. (5):

$$RLV = \frac{\text{Value added}}{\text{Workload}} \quad (5)$$

3. Results and Discussion

3.1 Physiology

Laniera zucchini seed was characterized of high germination rate with $87.83\% \pm 2.76\%$ 10 d after seedling.

From beginning, all plants grow similarly whatever treatments. It is learnt that plants can move, feed and breathe similar to other living creature. As time passed, plots severely or moderately infested of aphids presented a same development as the control. Over time, plants which received a treatment from the beginning showed a better development than others (Fig. 1, Table 1).

These situations are already been shown for pigweed [13], which explained that plant growth regulators assured this part [14]. It is noticed that consumption of fruits treated with pepper extract cannot alter taste in any way of dishes [15].

3.2 Evolution of Aphids

Treatments start 13 d after seedling for preventive protection, 27 d after seedling for late protection and 37 d after seedling for the latest. After each activation, treatments were repeated weekly.

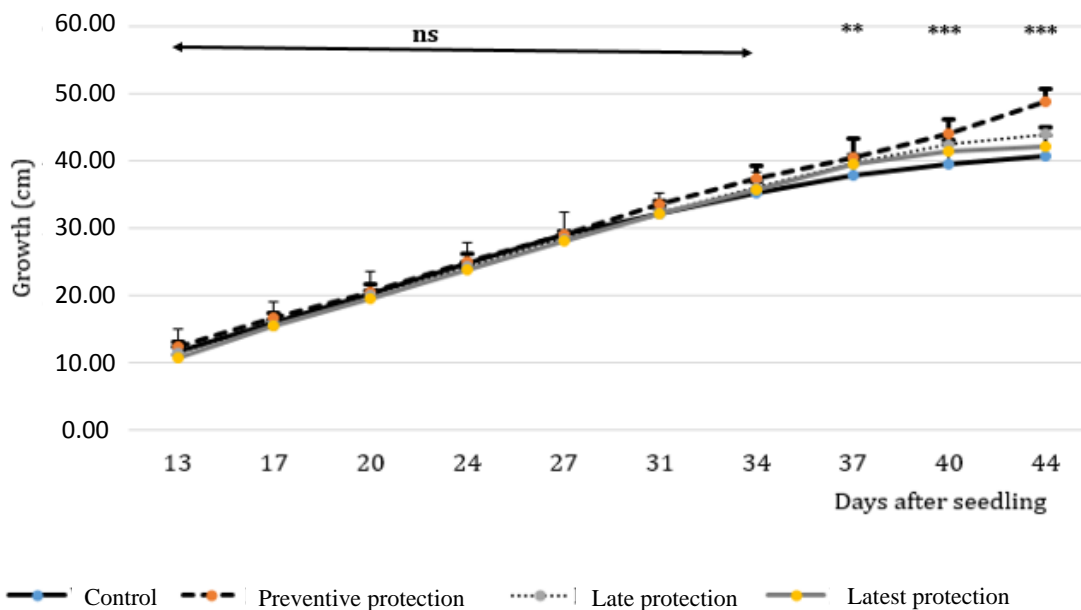
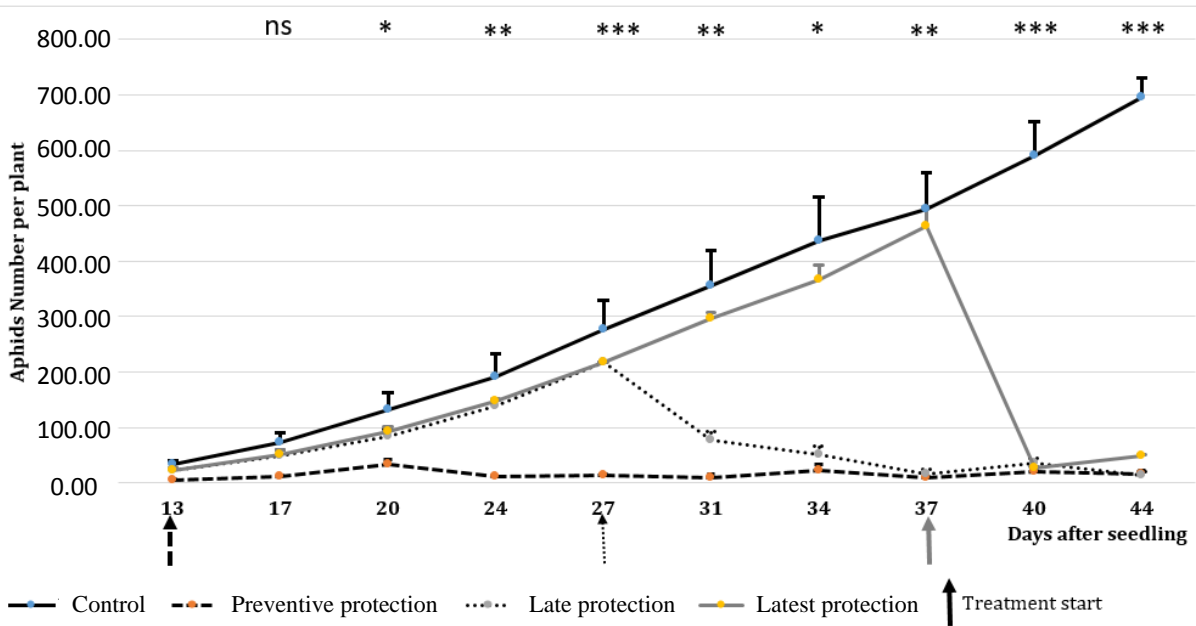


Fig. 1 Growth evolution of zucchini in function of treatments.

ns: $p > 0.05$; ** $p = 0.01$; *** $p < 0.001$.

Table 1 Plant growth statistical analysis.

Days after seedling	<i>F</i>	<i>p</i>	<i>R</i> ²
17	2.34	0.08	0.06
20	0.86	0.47	0.02
24	1.04	0.38	0.03
27	1.09	0.35	0.03
31	1.70	0.17	0.04
34	2.46	0.07	0.06
37	3.94	0.01	0.09
40	10.85	< 0.0001	0.22
44	38.67	< 0.0001	0.50

**Fig. 2** Evolution of aphid as a function of treatments.

ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Fig. 2 showed that pepper extract presented an exceptional efficiency to control aphids for few population aphids treated or more ones (Table 2). After each treatment, pepper extract reduced significantly aphids' outbreak, such as 27 d after seedling for moderate infestation and 37 d after seedling for high seedling. Use of this extract maintained probably aphid population to a very small number.

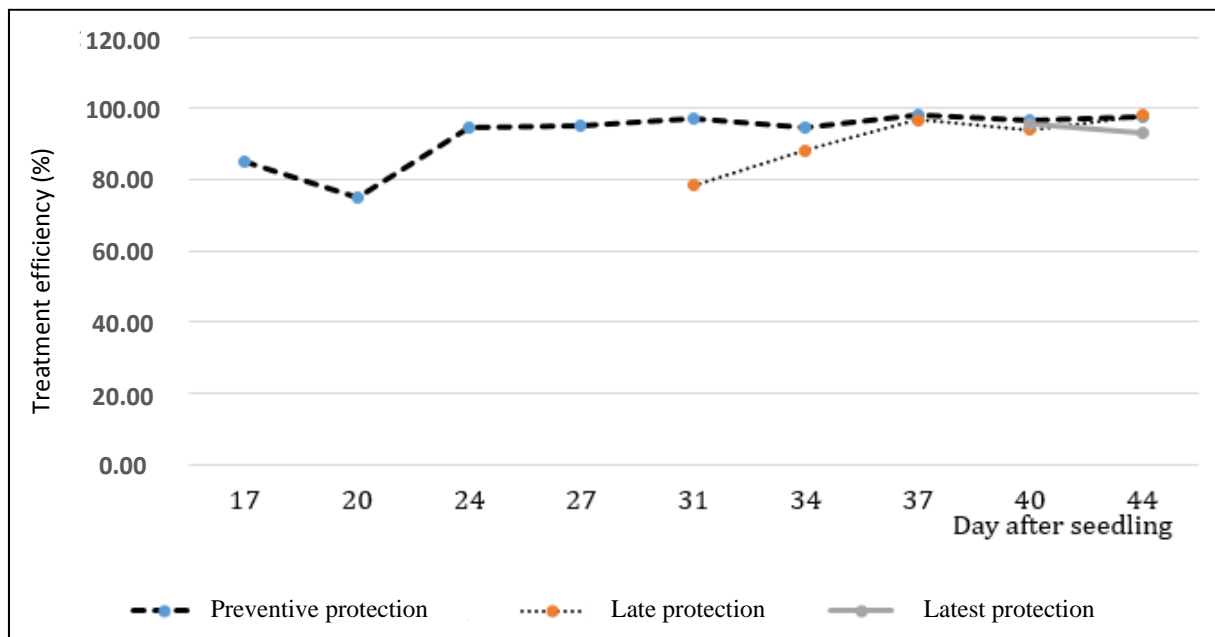
Analyses of efficiency explain that pepper extract shows a sustained and high efficiency (efficiency rate about 70% to 90%) to control the aphids (Fig. 3, Table 1). Ramparany [16] presented the same result with 10 g pepper extracts diluting with 5 L of water,

which decreased 50% of aphids. Other study showed that the same extract can control neonate larvae [15]. In comparison with other plants insecticides, such as nettles (efficiency rate around of 40% to 80%), male fern (efficiency about 50% to 80%) and garlic (efficiency about 40% to 70%) [17], the performance of pepper extract remained exceptional.

Pepper extract persisted around 7 d after treatment initiation for this experimentation (Fig. 2), which confirmed study that use the same product [18], but different as the result of Rafalimanana and Randrianarisoa [19], which showed 3 d after treatment initiation. In fact, efficiency probably depended on pepper harvesting season. In comparison with other plants

Table 2 Statistical analysis of aphid evolution in function of treatment.

Days after seedling	<i>F</i>	<i>p</i>	<i>R</i> ²
17	10.43	0.0905	0.98
20	32.63	0.0301	0.99
24	264.85	0.0038	0.99
27	13,840.55	< 0.0001	1
31	217.18	0.0046	0.99
34	66.48	0.0149	0.99
37	59.65	0.0166	0.98
40	12,623.81	< 0.0001	1
44	17,813.68	< 0.0001	0.99

**Fig. 3** Evolution of treatment efficiency of pepper extract on aphids.

insecticides, pepper persistence remains similar as garlic, nettle and male fern [17].

To increase effectiveness, it's always preferable to apply the protection with pepper extracts, as soon as installation plots, which provided a significant level of control of aphids' attack than all other terms (Fig. 2).

3.3 Evolution of Virus Disease

Virus infection appears to be a very important issue to early attack of aphid-involved installation on control and on plots treated with high infestation.

At the start of plots with low infestation for treatment, use of pepper extract attenuated attack after each application, but could not limit virus extension

on the plots. On plots highly protected by pepper extract, apparition of the first viral symptom started latest, in comparison with competitive plots (according to per plant and per severity in phenological stage) (Fig. 4, Table 3). Therefore, pepper extracts delay virus installation, but it could not eradicate or limit extend of virus disease on plots already infested.

Taussig et al. [9] approved that any fight method can be applied to control virus. However, prevention measurements, such as pesticides application in plants decreased aphid propagation action. Viral disease installation may be transmitted by few aphids. After that, epidemic occurred without this vector, since it could

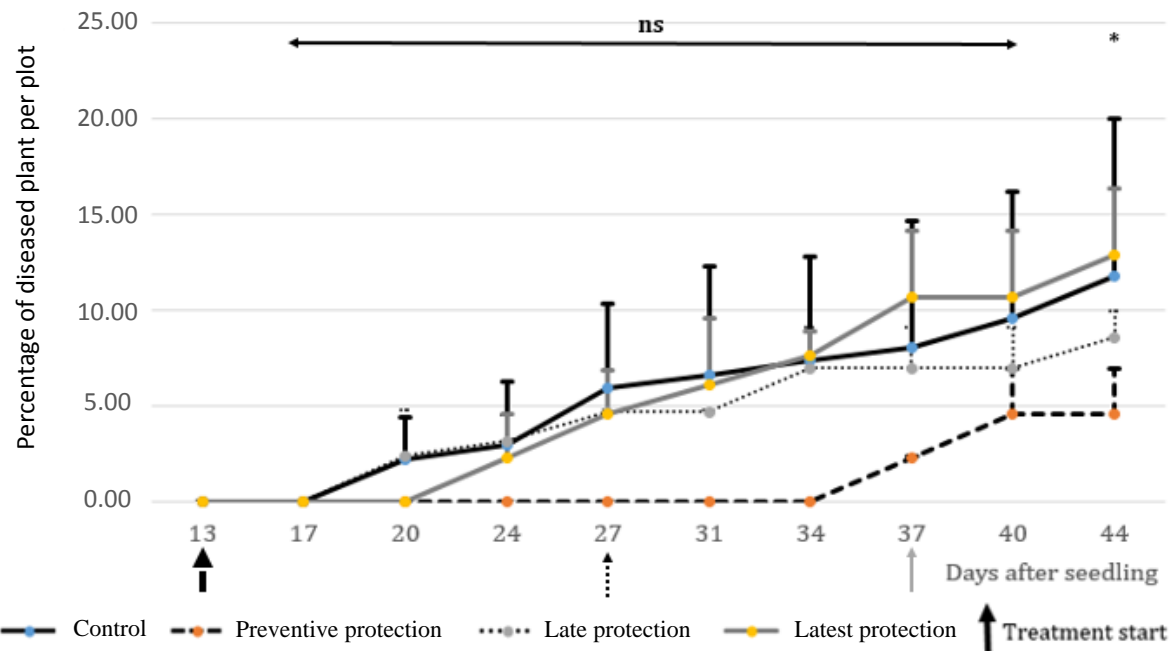


Fig. 4 Evolution of zucchini disease ZYMV in function of treatment.

Table 3 Statistical analysis of virus evolution.

Days after seedling	F	p	R^2
20	0.22	0.94	0.69
24	0.38	0.86	0.86
27	3.46	0.40	0.97
31	5.38	0.32	0.98
34	8.95	0.25	0.99
37	11.95	0.22	0.99
40	9.28	0.25	0.99
44	320.47	0.04	1.00

progress mechanically by contact or friction with disease for healthy plant [7, 8]. Consequently, any correlation between number of virus disease and aphids' vector is observed, so insect is not the only transmission possibility. In fact, distance of 25 cm for zucchini seedling amplified contact area between plants and facilitated virus transmission, which permitted installation of epidemic disease. It has to be noted that technical broadsheet is recommend to establish the culture on 1.40 cm × 50 cm [20].

For this part, pepper extracts provided a significant level of control against aphids attack, and permit to delay virus installation on plots, which received a treatment as soon as implementation of culture. With

latest intervention to control aphids, ZYMV infestation remained significantly high and destroyed plantation. So, aphids constitute major vectors of virus disease. Therefore, hypothesis which supposed that pepper extract cured ZYMV is erroneous, but pepper extract action which mitigates virus propagation accepted.

3.4 Crop Productivity

Plots that received high protected treatment present the best return than others (Fig. 5) with high quality and quantity of fruits. On control and plots with latest protection, waste with fruit distortion represented half of return. This result seems that once per week treatment

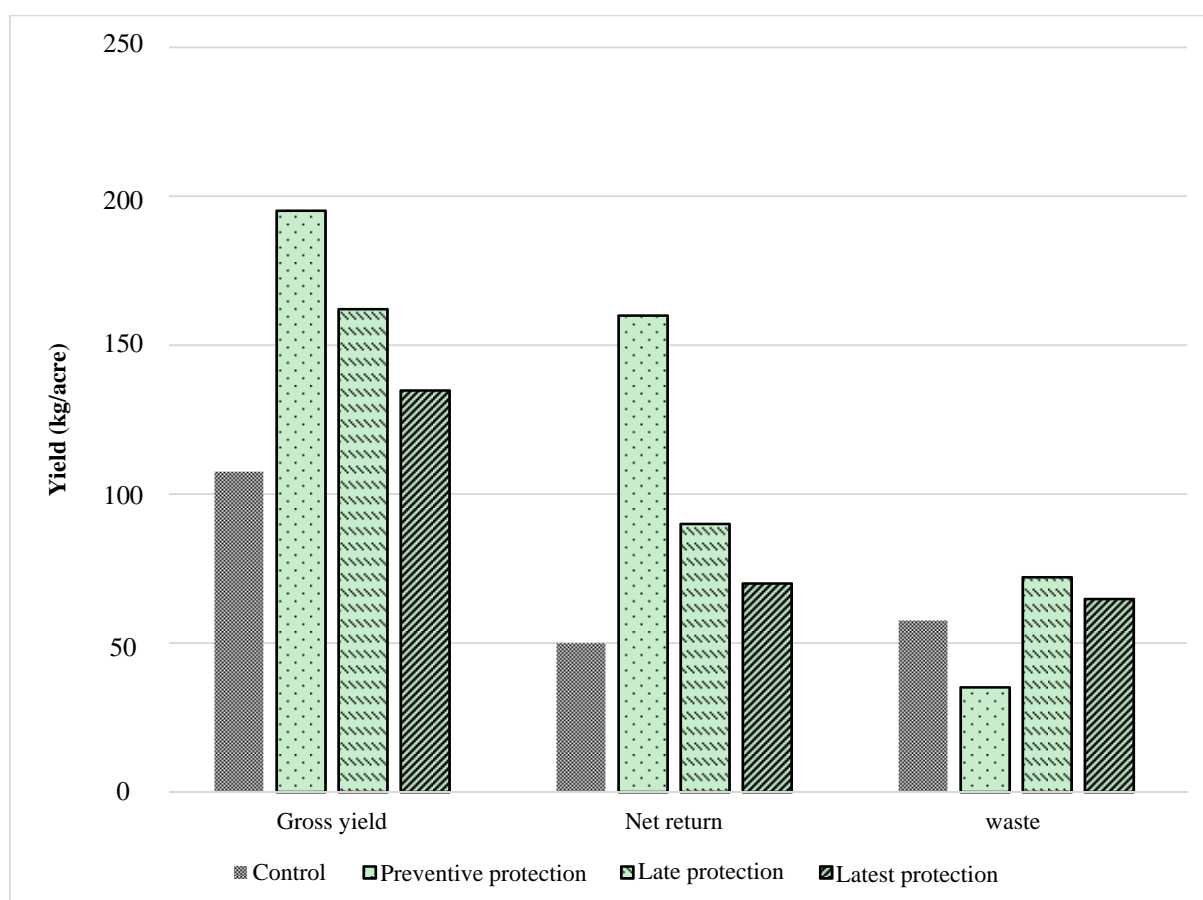


Fig. 5 Yield performance in function of treatment.

Table 4 Economical analysis in function of treatment for 1 acre.

Item	Quantity	Unit price (Ar)	Control	High protection	Moderate infestation	High infestation
Equipment						
Sprayer	1	10,000	0	10,000	10,000	10,000
Total equipment			0	10,000	10,000	10,000
Intermediate consumption (IC)						
Seeds (package)	80	1,000	20,000	20,000	20,000	20,000
Compost (kg)	350	50	17,500	17,500	17,500	17,500
Biological pesticides (kapoka)		4,000	0	16,000	10,000	7,000
Total IC			37,500	53,500	47,500	44,500
Labor costs						
For culture installation		3,000	6,000	6,000	6,000	6,000
For treatment		3,000	0	9,000	6,000	3,000
Total charge			43,500	78,500	69,500	63,500
Workload			2	5	4	3
Cost of product						
Quantity of product tradable			50	160	90	70
Total cost		1,000	50,000	160,000	90,000	70,000
Value added			6,500	81,500	20,500	6,500
Cost price			870.00	490.63	772.22	907.14
RCV			1.15	2.04	1.29	1.10
RLV			3,250	16,300	5,125	2,167

with extract pepper as soon as crop installation allows us to ensure products.

3.5 Economic Profitability

This study uses Malagasy official currency (ariary). Treatment with pepper extracts to protect plot belatedly remains undoubtedly waste of time, finance and energy (Table 4). It's better to do anything as on control than protection starts late [21].

Economic analysis shows that preventive treatment of pepper extracts provides an even greater return on its labor and investment than all other terms. Since in addition to its competitiveness and low business costs, it has a very aggressive trade. Moreover, RCV (> 2) covered local constraints, especially financial ones, so preventive use of pepper extracts to protect market gardening can be outreach. This result confirms other studies which use plants pesticides, such as garlic, nettle [18, 21].

4. Conclusions

This study showed that pepper extracts provided a significant level to control against aphids attack and delay virus installation on plots, which received a treatment as soon as implementation of culture. However, it cannot eradicate or limit extends of virus disease on plots already infested. Consequently, economic analysis shows that preventive treatment of pepper extracts to fight virus attack provides an even greater return on its investment than all other terms.

Malagasy farmer has natural resources exploitable in outer region. Use of pesticide plants is increasingly practiced by some farmers and needs insight and watchfulness in order to maintain a high level to be most effective. Farmers exploit unpolluted small area, which stays a challenge for farmers' family to get and intend great land scale. Use of pesticide plants reconciles interests of consumers and farmers, respects environment and protects human health.

Pepper remains expensive in all season for Malagasy farmer, but rewards with individual

manufacturing possibility. Moreover, organic agricultural production is not competitive, despite the country's immense potential. Application of agricultural sustainability is required. The ultimate goal of this effort is to induce new way of thinking and acting for agricultural production and environment.

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