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SUSTAINABLE STRATEGIES FOR INTEGRATED MANAGEMENT OF BREVICORYNE BRASSICAE IN CABBAGE CULTURE: ECOLOGICAL APPROACHES AND IMPACT ON BIOLOGICAL CONTROL IN MOZAMBIQUE

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ABSTRACT

Cabbage (Brassica oleracea) is a vegetable widely cultivated due to its nutritional and economic value, especially for small farmers. However, kale production faces significant challenges, mainly due to attacks by aphids (Brevicoryne brassicae), a pest that causes wilting and deformations in plants and acts as a virus vector. In regions such as Southern Africa, inadequate control of this pest has resulted in considerable losses in production, reaching 40% in Mozambique.

The adult stage of Brevicoryne brassicae is the most damaging, especially affecting the cabbage crop during its vegetative phase, when the plants are most vulnerable. Effective management of this pest involves continuous monitoring and the use of Integrated Pest Management (IPM) practices, which include cultural, biological and chemical methods. Applying these techniques in an integrated way, adapted to local conditions, can significantly reduce damage and improve agricultural productivity, promoting food security and sustainability for small Mozambican farmers.

Keywords: Brevicoryne Brassicae. Cabbage. Integrated Pest Management. Mozambique.

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INTRODUCTION

Kale (Brassica oleracea) is one of the most cultivated and consumed vegetables globally due to its nutritional value and culinary versatility, rich in vitamins A, C, K, minerals such as calcium and iron, and antioxidants. Kale is essential in the human diet, being consumed in different forms and in various cultures (FAO, 2021). In addition to its dietary importance, kale also plays a significant economic role, especially for small farmers, providing them with a stable source of income (Agrios, 2017).

However, kale production faces several challenges, with pests being one of the main limitations. Limiting factors in the production of this crop include, in addition to pest pressure, water availability, soil quality, climate change and limited access to modern agricultural inputs, such as fertilizers and pesticides. Among the pests that affect the crop, Brevicoryne brassicae stands out as one of the most harmful, causing severe damage to cabbage production worldwide (Teixeira; Silva, 2019).

In the global context, green aphid is a pest of economic importance due to its negative impact on Brassicaceae crops, such as kale, cabbage and broccoli. The pest feeds by sucking the sap from plants, causing wilting, and deformation growth inhibition. Furthermore, it acts as a vector for several viruses, which can lead to considerable losses in global vegetable production (Blackman; Eastop, 2020). In temperate regions of Europe, North America and Asia, aphid infestation has been associated with significant losses, which can vary between 30% and 50% depending on management conditions and level of infestation (Emden; Harrington, 2017).

In Africa, where subsistence agriculture is the basis of food security, damage caused by pests such as green aphid is exacerbated by environmental conditions such as climate variability and limited resources. In African countries, where access to advanced pest control technologies is limited, the impact of these pests is amplified, resulting in major crop losses and affecting the food security of rural households (Adeniyi et al., 2018). In Southern Africa, aphid infestation is a growing concern, particularly on vegetables grown in urban and peri-urban areas. Ineffective pest control due to lack of access to safe and effective insecticides contributes to crop vulnerability (Adeniyi et al., 2018).

In Mozambique, particularly in the northern and central regions, where farming vegetables such as cabbage is a crucial activity for subsistence and income, green aphid has caused serious problems. Local reports indicate that aphid infestations in cabbage crops are frequent, resulting in losses of up to 40% of production in some areas (Mahlamvu

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et al., 2022). The lack of knowledge about integrated pest management practices and the indiscriminate use of low-cost, often ineffective, insecticides worsen the problem, putting sustainable vegetable production at risk. Furthermore, Mozambique's tropical conditions create an environment conducive to the proliferation of these insects, increasing the challenge for small farmers (Chilundo; Massango, 2021).

Therefore, the adoption of sustainable agricultural practices, such as integrated pest management, which combines biological, cultural and chemical control methods, is essential to mitigate the impact of the pest and guarantee food security and economic viability of Mozambican producers.

INTEGRATED PEST MANAGEMENT

Integrated pest management is an ecological and sustainable approach to pest control, which aims to minimize environmental impacts and pest resistance to pesticides, while maintaining economically viable agricultural production. The concept of integrated pest management emerged in the 1950s in response to growing concerns about the negative effects of the indiscriminate use of chemical pesticides on human health, the environment and biodiversity. Integrated Pest Management combines several pest control strategies, including biological, cultural, physical and chemical methods, with the aim of reducing pest population density to levels that do not cause significant economic losses (Kogan, 1998).

Biological control: is one of the pillars of integrated pest management, and consists of the introduction or conservation of natural enemies of pests, such as predators, parasites and pathogens. For example, ladybugs (Coccinellidae) are widely used to control aphid populations, while some species of parasitoid wasps attack pest larvae. Biological control is seen as a sustainable alternative to pesticides, as it tends to have fewer negative impacts on the environment (Lenteren, 2012).

Cultural practices: these are agricultural techniques that can prevent or reduce the incidence of pests. These practices include crop rotation, interplanting, use of resistant varieties, and adequate soil and irrigation management. For example, crop rotation helps break the life cycle of pests that depend on a specific plant (Altieri; Nicholls, 2004).

Physical and mechanical control: include the use of physical barriers, such as screens or fences, the use of traps and the manual removal of pests. Such techniques are

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often used in organic farming systems, where the use of chemical pesticides is restricted (Gurr et al., 2016).

Chemical control: although integrated pest management promotes the reduction of pesticide use, chemical control is still an important tool, used strategically and selectively. The aim is to apply pesticides in a way that minimizes impacts on the environment, humans and non-target organisms. This includes using less toxic products and applying them at specific times in the pest's life cycle. Chemical control can be integrated with other methods, ensuring that chemicals are used only when necessary, and in doses that minimize environmental and human health impacts (Pimentel; Peshin, 2014).

MONITORING AND DECISION MAKING

Regular monitoring of pest populations is essential in integrated pest management. Through trapping, field sampling and direct observations, farmers can determine when pest populations reach a level that warrants intervention. This helps ensure that control actions are taken in a timely and effective manner, avoiding unnecessary pesticide use (Pimentel; Peshin, 2014).

EDUCATION AND TRAINING

Continuous education and training of farmers is crucial to the success of integrated pest management. Farmers must be informed about the best management practices, the correct identification of pests and their natural enemies, and monitoring techniques. Community involvement is also important, as pest management over large areas requires the cooperation of all producers in the region (Pimentel; Peshin, 2014).

Name of the pest you chose (scientific name in italics)

The cabbage louse, cabbage aphid, cabbage aphid or cabbage aphid **(**Brevicoryne brassicae), is an aphid that colonizes brassicaceae (cruciferous) (Pérez-Hedo et al., 2015).

Description of the pest *Brevicoryne brassicae* (Cale aphid)

Brevicoryne brassicae, known as cabbage aphid, is a pest that significantly affects Brassicaceae crops, including kale, cabbage, broccoli, and others. This pest is particularly harmful due to its habit of feeding in dense colonies, which can cause extensive damage to plants (Pérez-Hedo et al., 2015).

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Damage caused to culture

Brevicoryne brassicae causes direct and indirect damage to host plants. Direct damage occurs due to the sap-sucking diet, which weakens the plants, causing wilting, yellowing and deformation of the leaves. When in large populations, the aphid can inhibit plant growth, resulting in smaller heads of kale and cabbage with lower commercial value (Pérez-Hedo et al., 2015).

In addition to mechanical damage, aphids excrete large quantities of "honeydew", a sugary substance that favors the development of sooty mold, a black layer of fungi that reduces photosynthesis and transpiration in plants. The presence of sooty mold on the leaves reduces the aesthetic quality of vegetables, making them less attractive to the consumer market (Capinera, 2008).

Description of prague

Adults: Brevicoryne brassicae adults are small, soft-bodied insects measuring approximately 1.5 to 2.5 mm in length. They are grayish-green to yellowish in color, with a whitish waxy coating covering their body, giving them a powdery appearance. Females can be winged or apterous (wingless), with apterous forms predominating in dense colonies (Blackman; Eastop, 2020). The winged forms are darker and have the ability to migrate to other host plants, which facilitates the spread of the pest (Ferreira; Cardoso, 2019).

Nymphs: Nymphs are similar to adults, but smaller and wingless. They go through several moults before reaching the adult stage. Nymphs cause similar damage to adults, feeding on plant sap and contributing to a decrease in the vigor of infested plants (Soleyman-Nezhadiyan; Laughlin, 2000).

Eggs: Females usually produce eggs in the fall. The eggs are very small, oval and black in color, and are deposited in protected parts of the plants, such as the base of the leaves (Capinera, 2008). However, in warmer climates, such as in many regions of Mozambique, the life cycle can be amphigonic, with reproduction occurring mainly by parthenogenesis (females giving rise to new females without fertilization) (Soleyman-Nezhadiyan; Laughlin, 2000).

Sampling of *Brevicoryne brassicae*

Pest monitoring

Pest monitoring is an essential practice in integrated pest management, playing a fundamental role in preventing economic damage caused by pests in agricultural crops. Through regular and systematic observation, monitoring allows farmers to identify the presence of pests in the field, understand their populations and their dynamics over time (Pedigo; Rice, 2009). This process helps detect early signs of infestation, which allows for more effective and timely interventions, reducing excessive pesticide use and preventing the development of pest resistance. Monitoring also contributes to making more informed decisions about pest control, optimizing resources and minimizing environmental impacts (Kogan, 1998).

Pest sampling

Pest sampling refers to the process of collecting quantitative data on pest populations in a given agricultural area. It is a critical tool for determining the level of infestation and for calculating economic thresholds, which are the population levels at which pest control is economically justifiable (Dent, 2000). Through standardized sampling methods, such as the use of traps, visual inspections, or pest counts, farmers can accurately assess population density and distribute control efforts more efficiently. Sampling is, therefore, essential for rational pest management, ensuring that interventions are made only when necessary, based on reliable and field-specific data (Naranjo et al., 2015).

Brevicoryne brassicae sampling

Sampling for Brevicoryne brassicae is a crucial step towards effectively monitoring this pest in Brassicaceae crops such as kale, broccoli and cabbage. The objective is to quantify the aphid population, whether adults, nymphs or eggs, to determine infestation levels and identify the need for control interventions. Regular sampling allows population increases to be detected before they reach economically damaging levels, enabling appropriate interventions within integrated pest management (Pedigo; Rice, 2009).

Visual Sampling

The visual sampling method is widely used to monitor Brevicoryne brassicae populations. In this method, inspectors manually observe plants to identify aphids at different stages of development, such as adults, nymphs and eggs. Inspection usually involves choosing plants at random from different points in the field to ensure adequate representation of the area. Inspectors look at younger leaves and sheltered parts of plants, where aphids tend to concentrate, especially in leaf veins (Ferreira; Cardoso, 2019).

The leaves are carefully inspected, and the number of aphids on each leaf is counted. Depending on population density, handheld magnifying glasses may be used to facilitate observation of nymphs and eggs. Using visual sampling is simple, but time-consuming and requires experience to be effective. This method is especially useful in small-scale agricultural systems where farmers can visually monitor small plots of crops (Blackman; Eastop, 2020).

Sampling with yellow traps

Another effective monitoring method is the use of yellow sticky traps, which are widely used to capture winged forms of Brevicoryne brassicae. Yellow traps attract aphids due to their color, which simulates the light reflected by young leaves. These traps are placed at an appropriate height above the plant canopy and distributed evenly across the field. The traps capture winged aphids that migrate to new areas of the crop, allowing farmers to assess the risk of new infestations (Capinera, 2008).

This method is particularly useful for monitoring the movement of winged forms and the spread of the pest in larger fields or in times of transition between seasons. Traps should be checked regularly, and the number of aphids caught is recorded to determine the need for control.Amostragem por Batida de Folhas (Pérez-Hedo et al., 2015).

Leaf tapping sampling is another method used to estimate the density of Brevicoryne brassicae. This method involves vigorously shaking the plant's leaves onto a white tray or cloth, where the aphids fall and can be counted. This method is effective for collecting large numbers of aphids quickly, especially in field conditions where visual monitoring may be hampered by dense plants or unfavorable light conditions (Chilundo; Massango, 2021).

However, leaf tapping sampling may not capture eggs or smaller nymphs that are still firmly attached to the plant, making it more appropriate for adults and larger nymphs. This method is useful for quickly monitoring large agricultural areas, providing an overview of the infestation (Chilundo; Massango, 2021).

Interpretation of sampling data

Once the sampling data has been collected, it is compared to previously established economic thresholds, which indicate when an intervention is necessary. These thresholds vary according to culture, climate and region, and continuous monitoring allows adjustments in control strategies (Dent, 2000). In tropical regions such as Mozambique, where aphid populations can increase rapidly due to favorable climatic conditions, frequent sampling is crucial to prevent extensive damage (Mahlamvu et al., 2022).

Brevicoryne brassicae population monitoring

Monitoring the Brevicoryne brassicae population involves sampling techniques and continuous surveillance to determine the population density of the pest at different stages of development, including adults, nymphs and eggs. This process is essential for making informed decisions about pest management and for implementing integrated pest management. Monitoring allows farmers to identify population increases before infestations reach economically damaging levels, providing a solid foundation for effective control interventions (Pedigo; Rice, 2009).

Adult monitoring

Adults of Brevicoryne brassicae, which can be winged or wingless, are monitored mainly through visual sampling and yellow sticky traps. Visual inspections are carried out directly on the plants, especially observing the youngest leaves and the lower parts, where aphids concentrate. Close inspection involves counting aphids on multiple plants at random to obtain an accurate estimate of population density (Blackman; Eastop, 2020).

To capture winged adults, yellow sticky traps are widely used. These traps are placed in various parts of the field and checked regularly to count the number of aphids captured. They are particularly useful in monitoring the spread of the pest, since the winged adults are responsible for migrating to new cultivation areas (Capinera, 2008).

Nymph monitoring

The monitoring of *Brevicoryne brassicae* nymphs follows similar methods to that of adults, with visual inspections being the main technique used. Nymphs, which are smaller, wingless versions of adults, are often found in dense colonies on the undersides of leaves, close to the midribs. During visual inspections, nymphs are manually counted on randomly selected leaves in the field, which allows the assessment of the growth of the developing aphid population (Ferreira; Cardoso, 2019).

Additionally, the leaf tapping method can also be used to collect nymphs. When the leaves are shaken on a white tray, the nymphs fall and can be easily counted. This method is useful for evaluating large areas in a short period, but may underestimate the small nymphs that remain attached to the leaves (Chilundo; Massango, 2021).

Egg monitoring

Monitoring of *Brevicoryne brassicae* eggs is less common in tropical regions, where viviparous reproduction predominates and eggs are less frequently observed. However, in temperate regions where eggs are the main survival stage during the winter, inspecting plants for eggs may be necessary. These eggs are deposited in sheltered parts of plants, such as leaf veins and axils, and are small, greenish to black in color, which requires careful visual inspection, often using magnifying glasses (Capinera, 2008).

Interpretation of monitoring data

Data collected during Brevicoryne brassicae population monitoring is used to determine whether pest populations have reached economic thresholds. These thresholds, established based on potential economic damage, indicate when control is necessary to avoid significant yield losses (Dent, 2000). Regular and continuous monitoring allows for more precise interventions, reducing unnecessary use of pesticides and promoting the use of sustainable control alternatives, such as biological control (Mahlamvu et al., 2022).

Decision making index

The decision making index, also known as economic damage threshold, is an essential criterion in integrated pest management that helps decide when and if it is necessary to implement control measures for a given pest, such as Brevicoryne brassicae. The economic damage threshold is based on the relationship between the level of infestation and the economic impact caused by the pest (Pedigo; Rice, 2009).

Decision making index

Economic damage threshold: The level of infestation of a pest where the cost of control is balanced with the cost of damage caused by the pest. If the pest population

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exceeds this threshold, it is economical and justifiable to implement control measures. We can calculate economic damage threshold, using the following formula (Pedigo; Rice, 2009):

$$LDE = \frac{C}{V \times D}$$

Where:

• C is the cost of the control intervention;

• V is the value of the crop yield;

• D is the amount of yield loss caused by each individual pest (Pedigo & Rice, 2009).

The economic damage threshold provides a reference point for making rational decisions about the use of control measures.

For example, if the economic loss due to Brevicoryne brassicae is 200.00 MT per hectare, and the cost to apply the control is 100.00 MT per hectare. The critical infestation density can be calculated considering that 50 aphids per plant cause this loss. If sampling indicates an average of 60 aphids per plant, this may justify application of control (Maharjan et al., 2018).

Brevicoryne brassicae control methods

To control *Brevicoryne brassicae* in Mozambique, several approaches can be applied, combining cultural, biological and chemical methods. The choice of methods must consider the local context, such as climatic conditions and available resources. Of the different methods, we can highlight the following:

Cultural control

Crop Rotation: Alternating brassicas with non-host crops can reduce the aphid population by interrupting their life cycle. The rotation may include legumes or other plants that are not hosts of Brevicoryne brassicae (Gordon et al., 2020).

Planting Resilient Cultivars: Using brassica varieties that are less susceptible to aphids can help reduce the impact of the pest. Selection of resistant cultivars is a recommended strategy to reduce infestation (Maharjan et al., 2018).

Soil Management Practices: Improving soil health and proper plant management can increase crop resistance to pests and improve the effectiveness of other control methods (Ogunwolu et al., 2017).

Biological control

Insect predators and parasites: Introducing or conserving natural enemies of aphids, such as ladybugs (Coccinellidae), lacewings (Chrysopidae) and aphid-specific parasites, can help control the Brevicoryne brassicae population. The effectiveness of natural predators has been documented in several tropical regions (Moraes et al., 2019).

Pathogenic Microorganisms: Using entomopathogenic fungi, such as Beauveria bassiana, can help reduce aphid populations. These microorganisms are effective in hot and humid climates, such as Mozambique (Hajek et al., 2021).

Chemical control

Insecticides: applying appropriate insecticides may be necessary in severe infestations. However, use must be managed carefully to avoid resistance and negative impacts on natural enemies. Products based on pyrethroids or neonicotinoids are often used (Khan et al., 2022).

Insecticidal oils and soaps: insecticidal oil or soap-based products can be effective in controlling aphids, especially in small areas or vegetable gardens. These products help suffocate aphids and are less harmful to the environment (Norris et al., 2020).

Physical and Mechanical Methods

Manual Removal: In cases of localized infestations, manual removal of aphids from plants can be a practical solution, although it is not scalable to large areas (Miller et al., 2021).

Traps: Using sticky traps to capture adult aphids can help monitor and control populations. These traps are particularly useful for detecting and monitoring the presence of aphids (Walton et al., 2019).

Use of resistant varieties

The use of resistant or tolerant varieties is an effective strategy for controlling Brevicoryne brassicae in cabbage crops in Mozambique. Resistant varieties can

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significantly reduce aphid infestation and impact, helping to reduce the need for chemical control and promote production sustainability (Walton et al., 2019).

Resistant and tolerant varieties to *Brevicoryne brassicae*

In Mozambique, choosing kale cultivars that are resistant or tolerant to Brevicoryne brassicae can help improve productivity and reduce damage. Genetic resistance in kale cultivars can vary in effectiveness, but some varieties have shown significant resistance to aphids (Walton et al., 2019).

Variety Recommendations

Kale Varieties (Brassica oleracea)

Winterbor: This variety is known for its hardiness and resistance to various pests, including aphids. It is a variety of kale with ribbed leaves that has shown good tolerance to Brevicoryne brassicae infestation (Pritchard et al., 2019).

Dwarf Blue Curled: A variety of cabbage with curved leaves that is naturally resistant to aphids and other pests. It is suitable for hot and humid climates such as those found in Mozambique (Mugisha et al., 2020).

Brussels sprouts (Brassica oleracea var. gemmifera)

Jade Cross: Variety of Brussels sprouts that is tolerant to Brevicoryne brassicae. It is known for its ability to withstand harsh conditions and resist aphid infestations (Lee et al., 2018).

Cabbage Leaves (Brassica rapa)

Tokyo Bekana: Kale variety that has shown resistance to several pests, including aphids. It is ideal for cultivation in tropical climates (Thakur et al., 2021).

The use of resistant varieties reduces infestations, in addition to drastically reducing the use of pesticides and improving plant health (Thakur et al., 2021).

To ensure the successful adoption of these varieties, it is recommended to carry out field tests and monitor the effectiveness of the chosen cultivars in the specific context of Mozambique. Integrating resistant cultivars with other integrated management practices can further improve Brevicoryne brassicae control and overall crop health (Lee et al., 2018).

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Cultural control of *Brevicoryne brassicae*

Cultural control is a fundamental strategy in integrated pest management, and can be particularly effective in controlling Brevicoryne brassicae in kale crops. This approach involves modifying cultivation and management practices to reduce infestation and spread of the pest. Among the various approaches to cultural control, it includes crop rotation, planting resilient crops, managing plant density, eliminating unnecessary host plants, adopting appropriate irrigation practices, using mulch, cleaning and disinfecting tools and equipment, and incorporation of host plants (Pedigo; Rice, 2009).

Chemical control

Chemical control of Brevicoryne brassicae is an effective approach to managing severe aphid infestations in kale crops. However, it should be used with caution to avoid the development of resistance and minimize environmental impacts. Here is a detailed description of best practices for chemical control of this pest, including pesticide types, dosages, sprays, and the economic threshold for applying chemical treatments (Pedigo; Rice, 2009).

Types of pesticides

a) Pyrethroids, such as Lambda-cyhalothrin, cypermethrin, whose neurotoxic action interferes with the nervous function of aphids, resulting in rapid death. Generally, 25-50 g of active ingredient per hectare, diluted in 200-400 L of water (Capinera, 2008).

b) Neonicotinoids, for example Imidacloprid, clothianidin. These act as nicotinic acetylcholine receptor agonists, leading to paralysis and death of aphids. Normally, the recommended dosage is 20-50 g of active ingredient per hectare, diluted in 200-400 L of water (Capinera, 2008).

c) Insecticidal Oils: Margosa oil, this acts by suffocating aphids and has a repellent effect. The dosage depends on the manufacturer's recommendations, generally around 1-2% solution in water (Capinera, 2008).

Type of sprayer

Manual Knapsack Sprayer: suitable for small to medium fields, ideal for precision in specific areas (Zhou, 2019).

Tractorized Sprayer: Recommended for large areas, providing more uniform and efficient coverage (Zhou, 2019).

Mist Blower: Can be useful for spraying hard-to-reach areas and obtaining broad coverage (Zhou, 2019).

Critical phase of the pest to be sprayed

It is advisable to spray during the early stages of the infestation when the aphid population is lower and the application may be more effective. The critical phase for application is when the majority of aphids are in the nymph and adult stages, as these are the stages most vulnerable to treatment. Depending on the severity of the infestation and the pesticide used, it may be necessary to apply the treatment every 7-14 days. Monitor the aphid population and adjust the schedule as necessary (Chilundo; Massango, 2021).

Economic threshold or economic damage level

The economic threshold for *Brevicoryne brassicae* varies depending on local conditions and crop type. In general, the economic threshold or economic damage level for aphids on brassicas is often established at around 10-20 aphids per leaf or 50-100 aphids per plant when significant infestation and visible leaf damage are observed. Chemical control practices must be integrated with other management strategies to ensure effectiveness and minimize environmental impacts. Responsible pesticide use, along with constant monitoring and cultural practices, can help manage Brevicoryne brassicae infestations effectively (Chilundo; Massango, 2021).

CONCLUSIONS

The literature review on the control of Brevicoryne brassicae, a significant pest for cabbage crops in Mozambique, reveals an important understanding for the effective management of this infestation. The following are key findings based on analysis of control practices and pest characteristics:

Brevicoryne brassicae can cause damage of approximately 30-50% to kale crops if management measures are not implemented. This pest is capable of significantly reducing crop quality and yield, impacting farmers' productivity and profits.

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The stage that causes the most damage is the adult stage. Brevicoryne brassicae adults actively feed on leaves, causing deformation and weakening plants, which can result in loss of yield and leaf quality.

The cabbage crop is more susceptible to infestation during the vegetative phase. At this stage, plants are actively growing and are most vulnerable to damage caused by aphids, which feed on leaf juice and can transmit viruses.

Brevicoryne brassicae monitoring is carried out using conventional sampling methods. This includes counting aphids on plants and leaves per hectare, assessing crop damage, and inspecting plants showing symptoms of infestation. For grass-infested areas, monitoring may include counting weeds per square meter. Sampling must be done regularly to assess pest density and make appropriate management decisions.

The main management methods for Brevicoryne brassicae include: cultural control, biological control and chemical control. Overall, an integrated approach that combines cultural, biological and chemical control, adapted to local conditions and the stage of infestation, is essential to effectively manage Brevicoryne brassicae in cabbage crops in Mozambique. Continuous monitoring and careful application of management practices can help reduce damage and improve crop productivity.

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