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RESEARCH ARTICLE

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Impact of using cover crop on predation slug on corn in pennsylvania

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Abstract
Farmers in Pennsylvania face a significant obstacle in the form of slug insect management. Aims of this study to determine impact of using cover crop against slug attacks in Pennsylvania. This study collaborated with a Pennsylvania regional no-till farming unit to assign three treatments to each farmer: no crop cover (CA), plastic mulch cover (CP), green rye cereal cover (CRH), and dry rye cereal cover (CRK). The experiment was carried out in May – August in 2023. The use of rye cereal cover crops, both in green and dry form, can also have the potential to reduce slug pests. These plants provide shelter and breeding ground for natural enemies of slugs. Plant residue mulching in conservation farming practices provide an effective and sustainable slug pest management strategy. The use of green rye cereal and dry rye cereal cover can reduce slug by 73% and 80% respectively.

KEYWORDS
cover crop, maize, pest management, slug

1. INTRODUCTION

Agricultural land conservation is the main focus in designing sustainable agricultural strategies, with the main aim of minimizing land degradation and increasing land productivity (Mirzabaev et al., 2023). Soil conservation practices, such as the use of ground cover, minimal tillage, and crop rotation, not only improve soil fertility, but also have a significant impact on the population and diversity of organisms in and outside the soil (Rangappa et al., 2024). The more stable and sustainable soil environment produced by soil conservation practices creates optimal conditions for bacteria, fungi, nematodes and other soil organisms (Gutiérrez-Núñez & Gavito, 2024). This diversity is key to supporting healthy soil ecosystem function (Guerra et al., 2020). Furthermore, soil conservation practices have an important impact on the natural enemies of insect pests (Riddick, 2022), as the abundance of soil organisms such as ground beetles, spiders, and nematode predators increases the effectiveness of biological control on insect pest populations (Perez-Alvarez et al., 2019). Therefore, the complex interactions between soil conservation, soil organisms, and natural enemies of insect pests are important in understanding the holistic impact of sustainable agricultural practices on the balance of agricultural ecosystems.

Implementation of no-till soil conservation practices in agriculture has become a major focus for improving the sustainability of agricultural ecosystems (Malone & McClintock, 2023). Although no-till soil conservation is considered beneficial in maintaining soil health and improving sustainability, some studies show unexpected impacts related to pest outbreaks (Ogieriakhi & Woodward, 2022). Cases of pest outbreaks due to no-tillage are a major concern in modern agriculture (Somasundaram et al., 2020), where imbalances in the soil ecosystem can cause pest populations to multiply without control (Deguine et al., 2021). Explosion of slug pest populations is a critical issue that requires in-depth understanding. Various countries have experienced significant cases of slug outbreaks after implementing no-till systems (Rowen et al., 2020). For example, in France, an increase in slug populations was recorded following the adoption of no-till practices in vegetable crops (Zemanova et al., 2017). In Australia, farmers who switched to no-till farming saw a drastic increase in the number of slugs that harm rice crops (Yonow et al., 2023). Likewise, in the United States, no-till practices such as the use of ground covers and reduced traditional tillage have been associated with increased agricultural yield losses due to slug attacks (Dively & Patton, 2022). In a global context, an in-depth understanding of the impact of specific agricultural practices on slug pest populations is crucial for designing sustainable and effective agricultural strategies.

Slug pest control is a serious challenge for farmers in various parts of the world (Ramos et al., 2021). Farmers have implemented a number of methods, both physical and mechanical, to reduce the impact of slug attacks on their crops (Adomaitis et al., 2022). Some physical methods involve the use of traps, manual collection, and physical barriers around plants (Dörler et al., 2019). Meanwhile, mechanical methods include using earthmoving machines and other equipment to limit the movement of slugs and destroy their hiding places (Rae et al., 2023). Even though farmers have tried various methods, the results are often less than satisfactory. Physical and mechanical methods are often less effective in controlling the growing population of slug pests (Barua et al., 2021). Furthermore, tillage control, although efficient, requires high costs, which can be an obstacle for farmers with limited resources.

The use of cover crops in agriculture has become a promising approach, especially in controlling slug pests (Adetunji et al., 2020). Cover crops, or ground cover plants, have been proven to be one of the best methods for reducing the impact of slug pest attacks compared to other methods (Kulagowski et al., 2016). One of the main advantages of using cover crops is their ability to improve the soil ecosystem. Cover crops not only protect soil from erosion and restore nutrients, but also create an environment that supports biodiversity (Changyeun et al., 2017). These cover crops provide shelter and a food source for the pest's natural enemies, such as predators and parasitoids (Chinta & Araki, 2023). The interaction between cover crops, natural enemies and slug pests is key in increasing control effectiveness (Faqe Ibrahim et al., 2023). Cover crops can increase the abundance of natural enemies, such as predatory arthropods, which contribute significantly to controlling pest slug populations (Craine et al., 2023). Meanwhile, the presence of cover crops also creates environmental conditions that are less favorable for slugs, inhibiting their movement and reproduction.

Aim of this research to investigate effectiveness of using cover crops in suppressing slug pest attacks, with a focus on four experimental treatments, namely (1) without cover crops, (2) plastic mulch cover crops, (3) green cereal rye cover crops, and (4) cover crop dry cereal rye. The research will assess the level of slug attacks on corn plants without the presence of cover crops as a basic control. This study evaluated the effect of using plastic mulch as a cover crop in reducing slug attacks on corn plants. The focus of this research to measure the positive or negative impact of using cover crop against slug attacks. In addition, the research will examine whether dry cereal rye as a cover crop can be effective in controlling slug attacks on corn plants. This research provided further understanding regarding the effectiveness of cover crops in controlling slug pests, as well as providing a scientific basis for the development of sustainable agricultural practices.

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2. MATERIALS AND METHODS

2.1 Study sites and field design

This study collaborated with a no-till farmer unit in the Pennsylvania agricultural region. Three treatments were assigned to each farmer, including: no cover crop (CA), plastic mulch cover (CP), green rye cereal cover (CRH), and dry rye cereal cover (CRK). The experiment was carried out in May – August in 2023 used Dent corn (*Zea mays* var. indentata) which had been coated with 0.25 mg thiamethoxam per seed for corn. The experimental field has an area of 800 m^2 and each treatment was tested on 4 different farmers. The distance between farmers was 120 m and replicated three times each (12 plots).

Farmers plant corn with 38 cm row spacing using a planter equipped with splitters on each row unit. Before corn is planted, a cover crop is placed on the ground to make installation easier. Each plot is given 1.5 kg of dry and wet rye cereal crop cover, while the plastic mulch is adjusted to the plotting area (9 m^2).

2.2 Cover crop residue and yield

To assess the influence of cover crops on cash-crop establishment, we measured plant populations during the V5 growth stage for maize. Growth observations including height, leaf area and root weight were calculated when the plants were 28 and 42 days after planting (dap) by taking 3 plant samples. Exclusion of samples at edges to avoid edge effects. Leaf area in this research measured using leaf area meter (CID Bioscience CI340 EARS Mini PPm 150 SPAD 502 Plus). In order to ascertain the extent of slug herbivory, we thoroughly inspected every seedling inside each transect. Our objective was to quantify the proportion of plants that had been injured by slugs, as well as to estimate the approximate amount of leaf area that had been consumed. To achieve this, we employed a four-point scale. 0: No damage; 1: 1-25% harm; 2: 25-50% damage; 3: 50-75% damage; and 4: 75-100% damage (Douglas & Tooker, 2012). Slug damage in maize is distinct from other early-season herbivores. Slugs utilize a radula to feed on plant tissue, resulting in irregular and linear strips of damage. This damage is often accompanied by a noticeable slime trail. Simultaneously, we evaluated the cover crop or crop residue per plot by measuring the percentage of cover using the line-transect method (Laflen et al., 1981). In summary, we placed a 15.24 m rope with 100 beads spaced 15.24 cm apart perpendicular to the crop rows. Then counted the number of beads that were positioned over the residue (thus, x beads over residue / 100 beads = % residue coverage).

2.3 Slug activity

Laying roofing material measuring 0.10 square meters as a shelter for 4 slugs was carried out to measure the number of slugs that appeared in each treatment. The shelter is placed some distance from the edge to prevent edge effects in data collection. Slugs attached to the shelter or on the ground were counted when the plants were 14, 28, 42, and 56 dap in the morning (before 11:00 am). The type of slug found in the field is Deroceras reticulatum.

2.4 Predator density

Natural enemies are measured by setting traps. 3 plastic deli containers (9 length x 9 width x 12 height) in the center of each plot in the soil so that the lip was level with the soil surface. A total of 60 mL of propylene glycol is mixed with water (1:2) in each trap to kill and preserve natural enemies. Traps were installed when the plants were 14, 28, 42, and 56 dap. This research focused our assessment on beetles in the family Carabidae, in particular Pterostichus melanarius, which was previously identified as a significant slug predator in Pennsylvania (Foltan, 2004)

2.5 Statistical analysis

The last observed data were ANOVA (analysis of variance) and RBD (randomized block design). If there is a significant effect, then the LSD test (least significant difference) will be continued at the 5% level to determine the difference between the treatments and the parameters observed.

3. RESULTS AND DISCUSSION

3.1 Growth maize

There was a significant effect on corn height due to the cover crop model (**Fig. 1**). This research recorded plant height at 28 and 42 dap for various treatments. At 28 dap, the CA treatment had an average plant height of 60 cm, CP (75 cm), CRH (85 cm), and CRK (99 cm). Meanwhile, at 42 dap, plant height significant increased to 132 cm, 154 cm, 160 cm for CA, CP, and CRH respectively, meanwhile CRK increased to 182 cm (P>0.05). Looking at the data pattern, it can be seen that plant height in all treatments increased from 28 to 42 dap.

In particular, the CRK treatment showed signficant increase from 99 cm to 182 cm (P>0.05) in this period which was significantly higher than CA and CP but not significantly different from CRH. CRH treatment also showed a significant increase from 85 cm to 160 cm (P>0.05). Based on the observation results, it can be concluded that the CRK treatment had the highest plant height at both observation times, namely 99 cm at 28 and 182 cm at 42 dap even though at both planting ages it was not significantly different from CRH (P>0.05). Meanwhile, the CA treatment had the lowest plant height at both observation times with 60 cm at 28 and 132 cm at 42 dap. Differences in plant height in various treatments at 28 and 42 dap can be explained by complex interactions between the type of soil cover used and plant growth time. At 28 dap, the CA treatment showed lower plant height (60 cm) compared to other treatments. This can be caused by the absence of soil protection (Wan et al., 2023), which allows pest attacks and other environmental factors that affect plant growth (Poelman et al., 2023). Meanwhile, the CRK treatment stood out with a plant height of 99 cm at 28 dap, indicating the effectiveness of dry cereal rye ground cover in increasing plant growth in the early stages (Gustavo Barizon et al., 2023).

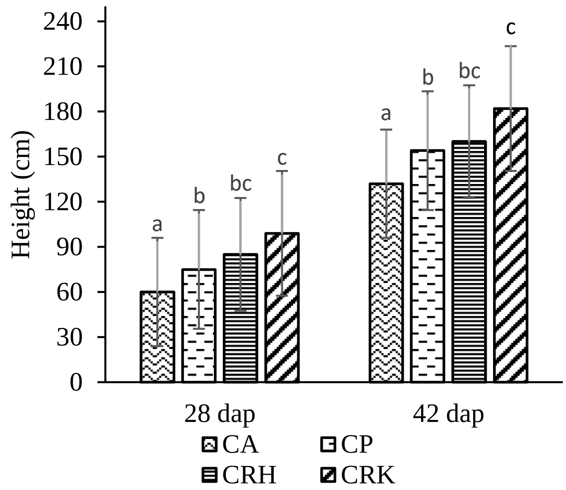

Figure 1. Height plant per plot in 28 and 42 dap treatment in maize. Numbers with the same lowercase show not significant difference in LSD test (P<0.05), dap = days after planting.

At 42 dap, the CRK treatment still maintained the highest growth (182 cm), indicating the continued benefits of this soil cover over a longer growth cycle (Haber et al., 2022). The CA treatment which had the lowest plant height at both observation times may have experienced greater pressure from pest attacks and loss of soil nutrients (Xiang et al., 2022). On the other hand, the use of ground cover, as in the CRH and CP treatments, can provide protection and provide additional nutrients, leading to increased plant growth (van Dijk et al., 2022). Apart from its effect on slug, cover crops have a significant role in influencing corn plant height through various mechanisms that improve soil conditions and provide support for the growth of the main crop. One of the main impacts is increasing the availability of soil nutrients (Brewer et al., 2023). Cover crops, especially those belonging to the legume cover crop (LCC) group, are capable of nitrogen fixation, which results in increased nitrogen levels in the soil (Scavo et al., 2022). These additional nutrients support the growth of corn plants, creating taller, healthier plants. This was observed in a study by (Bartel et al., 2022) that corn planted in alternating annual ground cover (PGC) had grain yields similar to controls and greater yields than an evenly spaced PGC system. Another way is through the incorporation of cover crop litter, which can improve soil physical properties and nutrient availability for corn. Leguminous cover crops increased nitrogen uptake by corn, leading to increased productivity (Yang et al., 2019). Thus, the observations show that the type of soil cover has a significant impact on plant growth, and the use of CRK soil cover in particular can be an effective strategy in increasing agricultural productivity.

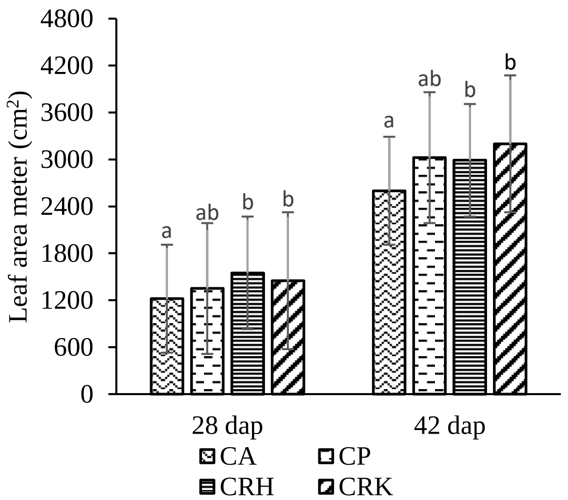

Figure 2. Leaf area meter plant per plot in 28 and 42 dap treatment in maize. Numbers with the same lowercase show not significant difference in LSD test ($P<0.05$), dap = days after planting.

In this study, four different treatments (CA, CP, CRH, and CRK) were evaluated for leaf area at 28 and 42 dap (**Fig 2**). At 28 dap, it was seen that CRH had the highest leaf area of 1550 cm, followed by CP (1350 cm2), CRK (1450 cm2), and CA (1220 cm2). After 42 days of planting, there was a significant increase in leaf area for each treatment ($P>0.05$). CRK was the treatment with the highest leaf area reaching 3200 cm2, followed by CP (3023 cm2), CRH (2989 cm2), and CA (2600 cm2). In a comparison between treatments at 28 dap, CRH had the best growth, while CA had the lowest growth. However, at 42 dap, CRK showed the best growth, while CA remained the treatment with the lowest growth. Thus, the data pattern shows that the CRK treatment had the best performance at both observation times, while CA tended to show lower growth. This comparison provides important insight into selecting treatments to increase leaf area in corn plants.

Differences in results between CA, CP, CRH, and CRK treatments on corn plant leaf area at 28 and 42 dap could be explained by various factors. Soil cover has a significant impact on plant growth and weed control (Masera et al., 2023). The CRH treatment, which used a ground cover in the form of growing green rye cereal, showed the highest growth at 28 dap. Green rye cereal not only provides good soil coverage but may also have a positive effect on soil nutrition and the condition of soil microorganisms, supporting the growth of corn plants (Hasan et al., 2023). However, at 42 dap, CRK, which used dry cereal rye ground cover, showed the best performance. Covering the soil with dry organic matter may provide better protection against slug attacks that can damage corn plants (Ochoa-Hueso et al., 2024). Cover crops has been proven to be an effective strategy in increasing soil fertility and soil biodiversity (Honvault et al., 2024). Cover crops, with their complex root systems, can improve soil structure, increase water retention, and produce root exudates that stimulate soil microbial activity (Fontaine et al., 2024). This not only provides additional nutrients for plants, but also creates a healthy microbial environment (Gil et al., 2023). Some literature supports the concept that ground covers can reduce the risk of pest attacks, including slugs, and increase nutrient availability. Study by (Craine et al., 2023) showed that the use of cover crops can have a positive impact on maize plant growth, as observed in the leaf area index. By increasing soil biodiversity, cover crops make a positive contribution to the balance of the soil ecosystem (Mairata et al., 2023). The presence of various microorganisms, including bacteria and mycorrhizal fungi, helps in the decomposition of organic matter, humus formation, and increases the availability of nutrients for plants (Solangi et al., 2023). Apart from that, cover crops also play a role in protecting the soil from erosion and reducing the risk of soil pollution due to the use of pesticides and chemical fertilizers (Mariscal-Sancho et al., 2023). Thus, the choice of soil cover type and its condition at a particular time can influence the growth of corn plants, including the response to slug attacks.

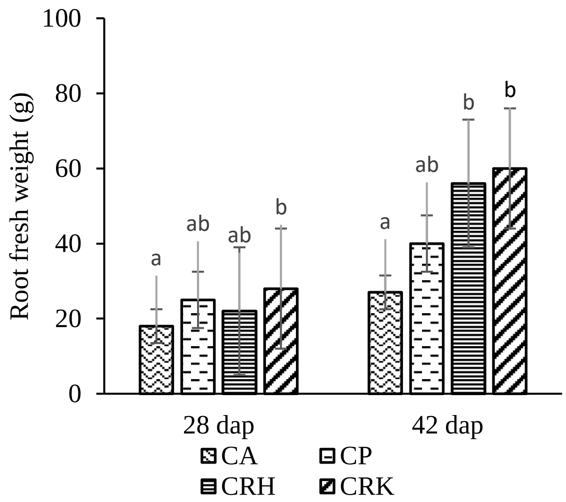

Figure 3. Root fresh water plant per plot in 28 and 42 dap treatment in maize. Numbers with the same lowercase show not significant difference in LSD test (P<0.05), dap = days after planting.

At 28 dap, the CA treatment had the lowest root weight of 18 g then the other treatment but not significantly different with CP and CRH treatment (P>0.05). Meanwhile, at 42 dap, the CA treatment still had the lowest root weight at 27 g, followed by CP (40 g), CRH (56 g), and CRK (60 g) (**Fig. 3**). Thus, the CRK treatment had the highest growth in root weight at both observation times, while CA showed the lowest growth in root weight (P>0.05). Comparison between treatments showed that CRK consistently had the highest root weight, indicating the effectiveness of this treatment in stimulating root growth in corn plants. On the other hand, CA showed lower performance, both at 28 and 42 dap, indicating that corn plants in the treatment without soil cover had slower root growth.

Comparison between treatments showed that CRK consistently had the highest root weight, indicating the effectiveness of this treatment in stimulating root growth in corn plants. On the other hand, CA showed lower performance, both at 28 days of planting and 42 days of planting, indicating that corn plants in the treatment without soil cover had slower root growth. The use of cover crops has been proven to be effective in increasing plant root growth. Cover crops play an important role in creating optimal environmental conditions for roots, through increasing the activity of mycorrhizal fungi that support symbiosis with plant roots (Moreira et al., 2023). Additionally, cover crops provide a protective layer over the soil, reducing soil erosion and preserving moisture essential for root development (Cheng et al., 2023). By adding organic matter to the soil, cover crops also improve soil structure, facilitate root penetration, and increase the soil's capacity to store water (Ogunleye et al., 2023). All of these mechanisms contribute to improved plant root health and growth, creating a solid foundation for sustainable agricultural productivity (Kobusinge et al., 2023). Planting cover crops and using dry cover crops in plastic have significant differences in influencing plant root growth. Planting cover crops directly on land provides benefits by increasing the activity of soil microorganisms, providing nutrients, and protecting the soil from erosion (de Goes et al., 2023). Meanwhile, the use of dry crop covers in plastic strengthens the soil cover effect by creating micro conditions that support plant root growth (Gibson et al., 2023). However, plastic covers can also limit air circulation and soil moisture, possibly inhibiting aeration and water availability for plant roots (Masera et al., 2023). On the other hand, planting cover crops directly on land tends to be more environmentally friendly because it does not use plastic material which is difficult to decompose (Bahl et al., 2021). However, both planting cover crops and using dry cover crops in plastic aim to increase soil fertility, suppress erosion, and ultimately improve plant root growth conditions to support sustainable agricultural production.

3.2 Slug density

CA, CP, and CRH treatments showed the 4 of slugs in 14 dap, while the CRK treatment had a slightly higher number of slugs (5 slugs). On the 28 dap, an increase in the number of slugs was seen on all treatment, with CA and CP remaining at 4 and 5 slugs, while CRH and CRK increased to 7 and 8 slugs (**Fig. 4**). On the 42 dap, the CA treatment reached 12 of slugs, while CP, CRH, and CRK remained at 7 slugs. However, on the 56 dap, the CA treatment recorded the highest number of slugs at 15, while CP , CRH, and CRK experienced a decrease in the number of slugs to 7, 4, and 3 respectively.

CA treatment consistently showed an increasing number of slugs over time, while the CP, CRH, and CRK treatments tended to have fluctuations in the number of slugs. Overall, CP, CRH, and CRK was increased in the presence of slugs at 28 dap and 42 dap, however at 56 dap the presence of slugs the presence of slug stagnated. Compared with CA, the use of CP can reduce the presence of slugs by 53% at the age of 56 dap. Meanwhile, in the CRH and CRK treatments, there was a decrease in the presence of slugs compared to CA by 73% and 80% respectively. Current research aims to control slug and mouse populations, especially in autumn crops. The results showed that ground covers such as rye cereal or winter beans as plant traps for corn crops can reduce slug activity (Scaccini et al., 2020). It is important to note that the effectiveness of this ground cover as a trap crop is not as optimal as for soybeans. Previous studies have shown that cover crops can have a positive effect on slug activity and density, which can be reduced by tillage (Benaissa, 2023). Successful slug control is also linked to specific cultivation practices, and the use of pesticides is an important consideration in these efforts (Egleton et al., 2021).

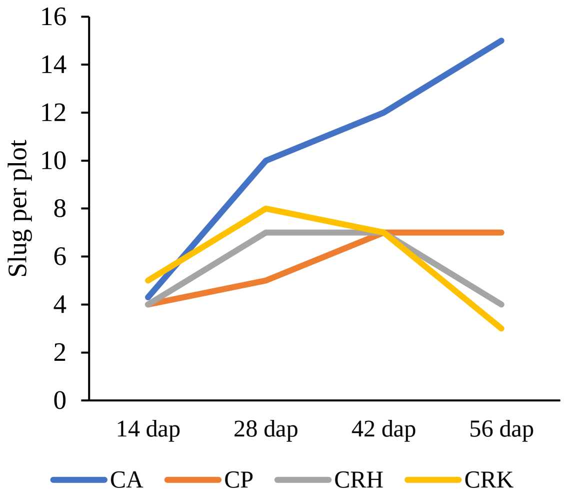

Figure 4. Total slug per plot in 14, 28, 42, and 56 dap treatment in maize.

Evaluation of cultural and chemical control practices indicates that slugs, especially Deroceras reticulatum, can be detrimental pests of corn crops grown in conservation systems (Le Gall et al., 2022). Therefore, an integrated approach that includes agricultural practices, trap crops, and chemical control strategies is key to reducing the impact of slugs and rodents on maize crops in the context of agricultural conservation (Costa et al., 2021). Previous studies emphasize that a deep understanding of the ecology of slugs and rodents, as well as the implementation of appropriate management strategies, can support crop resilience and agricultural sustainability in the face of these insect challenges in maize crops (Howe et al., 2018). Plastic mulch has been found to reduce slug populations. In a study evaluating the molluscidal effects of the plastic film mulching cover method, it was observed that the slug mortality rate ranged from 96.92% to 100% 30 days after the intervention

(Salama & Geyer, 2023). Another study focused on the invasive spotted wing drosophila, but also evaluated the efficacy of plastic mulch in reducing Deroceras reticulatum populations (McIntosh et al., 2022). It was found that black, white, and metal plastic mulches reduced adult Deroceras reticulatum populations by 42-51% and larvae populations by 52-72% compared to farmer standards (McIntosh et al., 2023). These findings suggest that plastic mulching may be a promising cultural practice for managing pests such as slugs and Deroceras reticulatum, and can be incorporated into integrated pest management programs in both organic and conventional systems.

3.3 Predator density

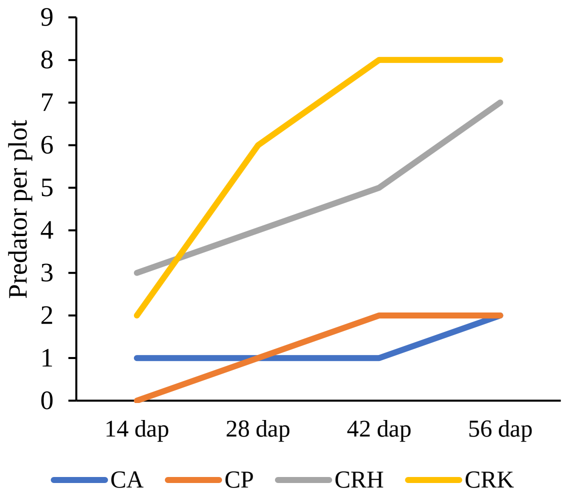

Figure 5. Total predator per plot in 14, 28, 42, and 56 dap treatment in maize.

CP treatment showed the lowest number of natural enemies, while the CRH treatment had the highest number of natural enemies at 14 dap (**Fig. 5**). On the 28 dap, the CA and CP treatments had 1 natural enemies, while the CRK treatment showed a significant increase to 6. Meanwhile, CA and CP treatments had a low number of natural enemies 1 and 2 respectively on 42 dap. CRK treatment reached 8 natural enemies and highest then other treatment. On the 56 dap, the CA and CP treatments remained at 2 natural enemy, while the CRH and CRK treatments increased to 7 and 8. Overall, the CRK treatment tended to had a higher number of natural enemies, especially in the middle and end of the observation period. The lowest treatment was recorded at CP on day 14 (0 natural enemies), while the highest treatment was CRK on days 42 and 56 (8 natural enemies).

Planting cover crops has a significant impact on the presence of natural enemies of Carabidae slugs (Depalo et al., 2020). Directly, planting cover crops provides an ideal place for Carabidae to activity, increasing their population by providing habitat and food sources. On the other hand, the use of dry cover crops, such as raffia rope, poses challenges due to the lack of moisture needed by Carabidae for survival and activities (Laffon et al., 2024). Plastic, as a ground cover material, provides a different impact by retaining soil moisture, supporting Carabidae activity (DiTommaso et al., 2020). Direct planting of cover crops effectively increases the sustainability of the Carabidae ecosystem, while dry cover crops tend to inhibit their activities. Plastic, as a ground cover material, creates environmental conditions that support Carabidae activities by providing a more stable habitat (DuPre et al., 2021). The presence of natural enemies of Carabidae slugs tends to be more abundant and diverse in direct and plastic planting, while dry cover crops provide challenges for Carabidae populations (Barbercheck et al., 2020). Overall, choosing a cover crop planting method directly or using plastic can better support the existence and balance of the Carabidae population compared to the dry cover crop method. Carabidae egg laying occurs in soil covered by dry plant cover litter, creating optimal conditions for egg incubation and protecting them from predators (Inveninato Carmona et al., 2022). Next, the eggs hatch in the moist, nutrient-rich environment of the dry cover crop, with the Carabidae larvae developing in the soil as a shelter and food source. Adults, Carabidae actively search for prey, including slugs, and dry crop cover creates an attractive environment for insect prey (Carabajal-Capitán et al., 2021). They effectively prey on slug eggs and juveniles, with the presence of dry crop cover providing protection for Carabidae and attracting slugs as potential prey (Poelman et al., 2023).

The use of dry cover crops in agriculture not only supports the life cycle of Carabidae but also contributes to natural control of slug populations. This has a positive impact in reducing potential losses to agricultural crops. Thus, a strategy based on dry cover crops creates a sustainable ecosystem, supports egg laying, development and predation activities of Carabidae, becoming an effective solution for controlling plant pests.

The use of dry cover crops in agriculture not only supports the life cycle of Carabidae but also contributes to natural control of slug populations. This has a positive impact in reducing potential losses to agricultural crops

3.4 Plant damage

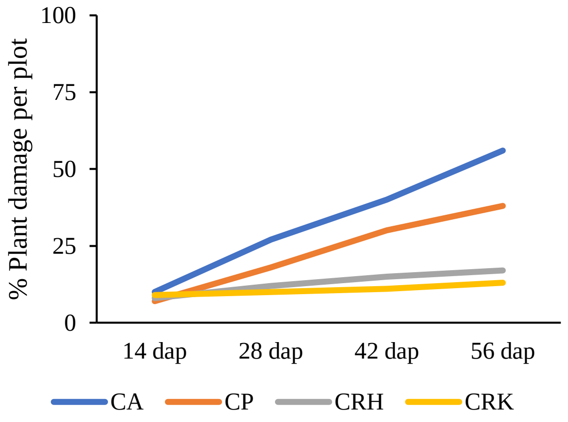

Figure 6. Percentage plant damage per plot in 14, 28, 42, and 56 dap treatment in maize.

Comparisons of the percentage of plant damage in various treatments were observed at various planting times (**Fig. 6**). CP treatment achieved the lowest damage at 7%, while the CA treatment had the highest damage at 10% at 14 dap. Moreover, CRK treatment showed the lowest damage of 10%, while the CA treatment achieved the highest damage of 27%. CRK treatment still had the lowest damage at 11%, while the CA treatment again recorded the highest damage at 40%. CP treatment again showed the lowest damage at 38%, while the CA treatment achieved the highest damage at 56% in observation 56 dap.

In general, the observation results showed significant variations in plant damage between treatments at each planting time. The CP treatment consistently recorded the lowest damage, while the CA treatment tended to have the highest damage at various stages of plant growth. With this understanding, determining optimal treatment can be the key to reducing agricultural yield losses during harvest (Karaca et al., 2024).

Plant residue mulching can suppress slug attacks through various mechanisms. First, the presence of plant residues on the soil surface creates a physical barrier that inhibits slug movement and access to plants (de Pedro et al., 2020). Second, plant residues provide habitat for natural enemies of slugs, such as ground beetles, which helped suppress slug populations (Wenninger et al., 2020). Additionally, increasing residue coverage from plant mulches can reduce slug damage to commercial crops (Robert L. Meagher et al., 2023). Additionally, the use of organic mulch, such as straw, can release biologically active substances that deter slugs and other insect pests (Perera-Fernández et al., 2023). Lastly, the use of cover crops as mulch can act as a food distraction for slugs, reducing their feeding on cash crops (Philpott et al., 2019).

Overall, the incorporation of plant residue mulching in conservation farming practices can provide an effective and sustainable slug management strategy. Plant residue mulching can be effective in suppressing slug infestations, but several factors can influence its effectiveness. One factor is tillage, which can reduce the positive effect of cover crops on slug activity density (Seidl et al., 2020). Another factor is the variety and quality of the mulch. Mulch particle size can also play a role, as long residue mulches tend to maintain soil fertility for longer periods of time than short ones (Massaloux et al., 2020). Additionally, weather conditions such as rainfall and temperature can influence slug activity density, with slug activity density decreasing with decreasing rainfall and increasing average temperature (Dively & Patton, 2022).

4. CONCLUSION

This research to measure the positive or negative impact of using cover crop against slug attacks. The used of cover plants cereal rye, both in green and dry form, can also potentially reduce slug pests. These plants provide shelter and breeding ground for natural enemies of slugs. The use of green rye cereal and dry rye cereal cover can reduce slug by 73% and 80% respectively. To develop better planting-green guidelines for growers, future studies should evaluate how different planted-green cover crops affect slug pressure.

This research to measure the positive or negative impact of using cover crop against slug attacks.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Paolo Biella: Writing – original draft, Conceptualization, review, editing, Methodology, Supervision, Data curation. James M Bullock: Conceptualization, Methodology, Supervision.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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