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A Survey of Insect Pests Attacking Quinoa (*Chenopodium quinoa*) and Their Natural Enemies in Zimbabwe

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Abstract: Quinoa (*Chenopodium quinoa* Wild.) was first introduced in Zimbabwe in 2017. As a new crop introduction, studies to understand the agronomic and biotic factors affecting quinoa cultivation are needed. A study to identify pests associated with quinoa production was therefore carried out at Midlands State University farm in Zimbabwe. A survey was conducted to determine the presence and populations of insect pests attacking quinoa crop during production. Field scouting of five (5) tagged plants per plot was done using canopy observation, buttressed with sticky and pitfall traps. Sampling was done when 50% of the crop had reached key physiological stages i.e early vegetative stage, vegetative stage, flowering, milk dough stage, dough stage, physiological maturity and at harvest. The most abundant pests observed were aphids, brown stink bugs, grasshoppers, and lepidopteron bollworms. Natural enemies observed were black ants, brown ants and ladybird beetles. Signs of insect damage observed include weakening of panicles, chlorosis of leaves, leaf eating and sooty mould development on the panicles. Findings of the study showed that quinoa attracts a diversity of leaf eating and sap sucking insects. This is the first study of insect pests associated with quinoa in Zimbabwe, and the results of the study indicate the need to develop insect pest management strategies for quinoa production in the country.

Keywords: *Chenopodium quinoa*, Taxonomy, Insect Pests, Zimbabwe

1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a highly nutritious pseudo-cereal crop originating from the Andes Mountains of Bolivia, Chile, and Peru. Quinoa has been cultivated for over 6000 years in the Andean countries [1]. Quinoa cultivation has expanded to European countries like France, Sweden and Italy. To date, more than 100 countries have tried quinoa cultivation, including African countries such as Djibouti, Kenya, Somalia, South Sudan, Ethiopia, Uganda, Zambia, Burkina Faso, Cameroon, Chad, Niger, Senegal, Togo, Ghana and Guinea [2]. Quinoa was first officially introduced to Zimbabwe in 2017.

Quinoa has received international recognition owing to its exceptional nutrition and environmental plasticity [2]. Quinoa grain contains superior protein content and balanced amino acid profile superior to wheat, barley and soybean [16]. The quinoa grain has a great amino acid profile, with extraordinary high lysine content [18]. Quinoa grains are rich in minerals, vitamins, and contains essential compounds such as polyphenols, phytosterols and flavonoids with possible neutriceutical benefits [4, 11]. Quinoa is favoured by health conscious consumers because of its nutrition and low glycine index [17]. Most quinoa producers cultivate the crop for its grain which is used in various forms. Quinoa flour can be combined with wheat flour or corn meal to make biscuits, bread and processed food such as spaghetti [3]. Because of the balanced composition of amino acids in quinoa, the grain is also used as a substrate for livestock feed especially for cattle, pigs and poultry [13].

Quinoa is a crop of remarkable versatility, growing from sea level to about 4000 meters above sea level (masl), tolerating

extremes of climates and soils conditions [14, 18]. Quinoa owes its wide adaption to its genetic diversity and origin [8]. In spite of this great versatility, quinoa cultivation is not without its own environmental and biotic challenges. The quinoa crop is susceptible to attack by a number of insect pests [9, 15]. Like any new crop, successful production of quinoa in a new country requires a thorough understanding of the biotic and abiotic factors affecting the crop. The aim of the study was therefore to establish the insect pests of quinoa crop in Zimbabwe.

2. Methods

2.1. Study Site

The study was conducted during the summer season (November 2018- March 2019) at Midlands State University, Agricultural Practice Section (lat. 10.4685°S, long. 29.8121°E), Gweru, Zimbabwe. The area falls under Natural region III of Zimbabwe's agro-ecological zones at altitude of 1428 meters above sea level. The research site receives an average annual rainfall of 600-800 mm with average temperatures of 15.3°C in winter to 26.3°C in summer.

2.2. Materials and Methods

The quinoa crop was planted in four (4) plots measuring 7.5 m x 6 m. The seeds were sown by way of drilling in open furrows 90 cm apart. Three weeks after emergence (3 WAE), the crop was thinned to a stand of 0.2 m x 1 m. Insect sampling was done when 50% of the crop had reached key physiological stages i.e. early vegetative stage, flowering, milk dough stage, dough stage, physiological maturity and at harvest. From each plot, five (5) plants were randomly selected, tagged and used as observation plants. Insects were observed on the stems, leaves and panicles. In addition, two sticky and two pitfall traps were placed in each plot 48 hours before the day of field scouting. Briefly, the pitfall traps comprised of plastic cups (8.5 cm diameter, 11 cm deep) obtained from the local supermarket. The pitfall traps were filled to half volume with 5% formalin. The yellow sticky cards (30cm x 25cm) were obtained from the local seed and pesticide merchants. Sticky adhesive glue was evenly applied on the surface of the sticky cards for insects to trap. The sticky cards and pitfall traps were placed 3 meters apart in the center of the plot, in between rows. Collected pests were identified, counted and data recorded for analysis.

Scouting for arthropod pests was done forty-eight hours (around mid-morning) following installation of insect pitfall and sticky traps. Scouting involved carefully examining the presence of pests on the leaves, panicles and stems. Insect pests were counted and the data was recorded. The average number of insects identified in plant canopies was added with pitfall and sticky trapped insects to determine total number of insects per plot. Plant parts where insects were identified were also recorded. Insect identification keys were used for positive identification [6].

2.3. Statistical Analysis

Data was analysed using excel programme for Windows. Mean separation of insect counts was performed using the mean ± SD.

3. Results

3.1. Aphids

Two major species of aphids were identified, namely the green aphid (*Hayhurstia spp*) and the black bean aphid (*Aphis fabae*) (Figure 1). The green aphid was first observed on quinoa leaves during the early vegetative stage, and persisted till the milk dough stage. The black bean aphid was first observed during flowering, appearing mostly on the panicles and persisting till physiological maturity.

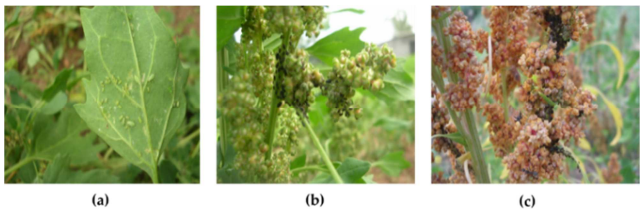

Figure 1. *Aphid species observed in quinoa canopies in the Agricultural Practice Section at Midlands State University, Zimbabwe during the 2018/ 2019 season. a) Green aphid (Hayhurstia spp), b) Black bean aphid (Aphis fabae) on the panicles during the milk dough stage and* ***c****) the black bean aphid persisting during the maturity stage.*

Green aphids were first observed at early vegetative stage (i.e 2 weeks after emergence) with a count of 15±13.0 per plant, increasing to 18±15.3 per plant during the vegetative stage. Aphid numbers increased further to an average of 31±25.8 per plant during the reproduction stage and to a highest of 58±42.4 per plant during the milk dough stage. Green aphid numbers fell to 50±28.9 per plant during the dough stage and then to 42±16.7 per plant during the physiological maturity stage before reaching a low of 4±2.8 per plant during harvest time (Figure 2).

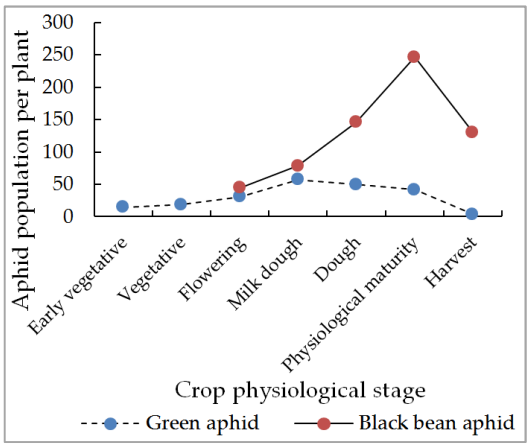

Figure 2. *Aphid infestation observed in quinoa canopies in the Agricultural Practice Section at Midlands State University, Zimbabwe during the 2018/ 2019 season.*

The first infestation of the black aphid was observed during the reproductive stage (45±28.1 aphids per plant). The aphid population increased to 79±27.5 at the milk stage and peaked to 146±55.2 and 147±71.4 aphids per plant during the dough and physiological maturity stages, respectively. During the reproductive stages, black bean aphid had grown into colonies on panicles, considered as ±30 aphids per plant. As the plant dried up, black aphid population fell to around 130±57.7 aphids per plant during harvesting.

The damage associated with the aphids included weakening of panicles, blackening of heads and development of sooty mould (Figure 1C). Attacked grain heads were exposed to premature ripening and eventually dried off a few days after attack.

3.2. Brown Stink Bugs

Brown stink bug infestation of the quinoa crop was observed starting at the vegetative state (6±2.4 bugs per plant) onwards (Figure 3). The population increased slightly to 7±4.8 aphids per plant at flowering, peaking at an average of 15±7.1 per plant during the milk stage, then decreased to 9.0±2.2 during the dough stage, 3±2.2 at physiological maturity and finally to a low of 1.0±1.4 at harvesting.

3.3. Grasshoppers

Grasshoppers were first observed in the quinoa foliage at the vegetative stage, with an average of 1.5±1.3 grasshoppers per plant canopy (Figure 3). The numbers steadily increased to 1.8±1.0 during the flowering stage, then 1.8±1.5 during the milk dough stage. Grasshopper numbers peaked to 4.5±1.9 during the dough stage, falling to 1.8±1.0 during the physiological maturity stage. Grasshoppers were also observed within the crop at harvest although the numbers (1.3±1.0) were low.

Grasshoppers were observed feeding on the foliage and panicles particularly during the milk dough stage.

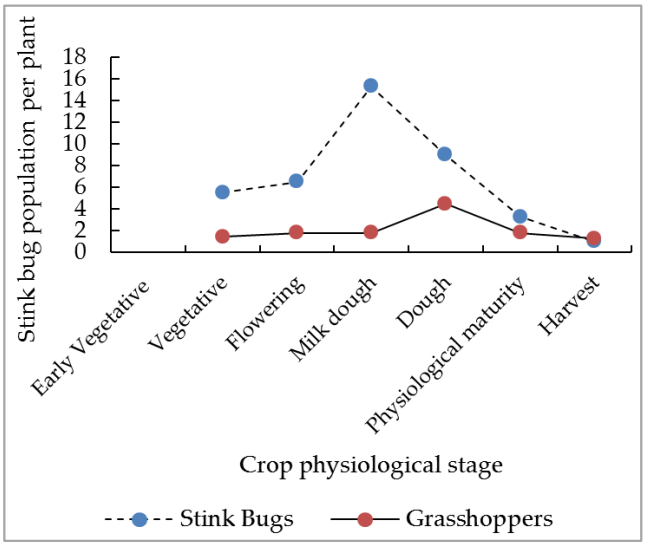

Figure 3. *Brown stink bugs and grasshoppers observed in quinoa canopies in the Agricultural Practice Section at Midlands State University, Zimbabwe during the 2018/ 2019 season.*

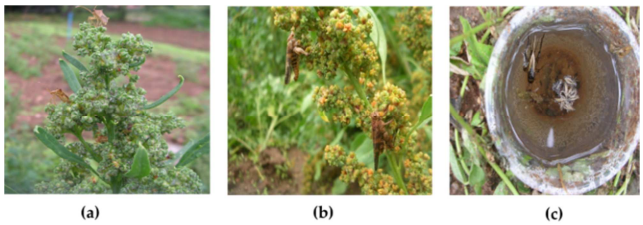

Figure 4. *a) Stink bug infestation at milk dough stage, b) Grasshopper at physiological maturity stage, c) Mole cricket and ants trapped in the pitfall trap.*

Observations from this study showed that the green aphid was found most abundant on the leaves while the black aphid favoured the panicles. Stink bugs were mostly found on the panicles (Figure 4a) whilst grasshoppers were found on both panicles and leaves, but mostly on the panicles. Black ants, the lady bird beetles, hymenopteran wasps and adult ladybird beetles were observed in the quinoa foliage (Figure 5).

3.4. Green Beetles

Green beetles were identified in the Agriculture Practice Section during 2019 season. No damages were associated with this pest, however, the pest has potential to cause crop damage.

3.5. Bollworms

The bollworm (*Heliothes* sp) was observed occasionally during the early vegetative stages and physiological maturity.

3.6. Predatory Arthropods Found in Quinoa Plots

Lady bird beetles and hymenopteran wasps were found to be associated with patches where aphids were abundant. Lady birds and hymenopteran wasps were found pitched on quinoa panicles during the reproductive stages. The *Eripsis connexa* was observed predominantly on leaves.

Figure 5. *Predators observed in quinoa canopies: a) Ladybird beetle, b) Hymenopteran wasp, and c) Eriopsis connexa.*

4. Discussion

Quinoa (*Chenopodium quinoa*) is a highly nutritious crop gaining recognition throughout the world. Quinoa has been introduced to many African countries over the past 30 years. Quinoa was recently introduced in Zimbabwe in 2017 [12]. In this study, pests inhabiting and attacking quinoa were observed in experimental plots at Midlands State University. Results from this study showed that quinoa was favoured mostly by aphids, stink bugs and grasshoppers, with occasional visitation by green beetles and bollworms.

The green aphid (*Hayhurstia* spp) and the black bean aphid

(*Aphis fabae)* were present on quinoa plants throughout the growth stages of the crop. The former appeared in the early growth stages, occurring 3 weeks after emergence while the later appeared during the early reproductive stage. Numbers of both aphid species peaked during milk and dough stages. The green aphid numbers decreased drastically while *Aphis fabaei* persisted right through to harvest. The green aphids were mostly identified underneath the leaf surface. The black bean aphid attacked the panicles, appearing in clusters of black colonies comprising large numbers. In the current study, both aphid species peaked around the milk dough stage. The immediate infestation of the quinoa crop by the green aphid could be accounted for by the presence of cruciferous crops during the winter. Cruciferous crops such as rape grown in Zimbabwe are common favourites of the green aphid whilst the black aphid is a common pest of cowpea and citrus. Aphid losses in quinoa yield ranging from 5 to 67%, with an average of 33.37% have been reported in Southern Altiplano, and 6 to 45% in the Central Altiplano, with an average of 21.31% and 44.1% in Kenya [10].

Stink bugs (*Nysii* spp) were observed in the quinoa crop at four weeks after emergence. Also notable were relatively huge numbers of grasshoppers and green leaf beetles (*Chrysomelidae*) on the quinoa foliage. Similar observations were made in the study carried by [5].

Findings from this study reveal that quinoa attracts and harbours a diversity of insect species. In its centre of diversity, the Andean region quinoa is infested by several pests [7]. Quinoa is a close relative of lambsquarters (*Chenopodium album*) and pigweed (*Amaranthus* spp) and resembles lambsquarter during its early growth stages [9]. Insects accustomed to lambsquarter and pigweed could easily adapt to the new crop. This could be the most plausible explanation of the high infestation by aphids, stink bugs and grasshoppers observed in this study. The potato aphid (*Macrosiplum euphorbiae*), *Hayhurstia atriplicis* and the *Lygus* bugs have been reported on quinoa in Idaho [9]. Aphids, stink bugs, leafminers and several other noctuids have been reported in North America, Europe, Italy and Egypt [5]. Stink bugs on the other hand, are polyphagous insects as are the majority of quinoa pests [15]. In addition, quinoa fields are associated with a characteristic smell, which could also attract a diversity of arthropods. Quinoa leaves are soft and edible, similar to cruciferous crops such as rape, a desirable character for arthropods and mammals.

The study showed that aphids, stink bugs and grasshoppers attack quinoa at all growth stages during quinoa production. Occasionally, insects such as green beetles and bollworms were also observed. Although the current study could not quantify the damage caused by the identified insects, the findings point to a need for future studies to evaluate the impact of insect pests on yield and yield components of quinoa.

5. Conclusion

The green aphid (*Hayhurstia spp*), the black bean aphid (*Aphis fabae*), brown stink bugs, grasshoppers and green beetles were identified as common pests of quinoa in this study. Natural enemies observed include black ants, ladybird beetles and hymenopteran wasps. Our study is the first report of insect pests of quinoa in Zimbabwe. This study is important in giving clues and guidelines to the management of quinoa pests. In addition, the study showed the onset and progression of pest infestation and therefore provides insight into the management of quinoa pests. The study has also revealed the possible natural enemies of pests of quinoa, thus providing clues to biological control and integrated management of insect pests for quinoa farming in Zimbabwe.

6. Recommendations

We recommend the development of pest management strategies for quinoa production in Zimbabwe. As this is the first study of quinoa insect pests in Zimbabwe, we recommend further studies on the same subject in other parts of the country to establish problematic pests in those areas not covered in this study. We also recommend future studies to evaluate the impact of insect pests on yield and yield components of quinoa.

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