PEST STATUS AND MANAGEMENT OPTIONS FOR *Plutella xylostella* L. (Lepidoptera: Plutellidae) IN IRINGA AND MOROGORO, TANZANIA

HAPPINESS CHRISTOPHER

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2020

EXTENDED ABSTRACT

Introduction

Plutella xylostella L. is the pest of economic importance in production of Brassica crop. This pest can cause up to 90% loss if not controlled. The pest has been reported to exist in Tanzania but the actual assessment of its abundance and inflicted damages are lacking. This has made production of brassica to be dependent on a number of pesticide applications to allow harvesting of marketable heads. Interrupted mating through overhead irrigation has been reported to minimize pest damage but the exact timing for irrigation has never been established. The present study aimed at understanding the pest status of *P. xylostella* in major production areas and exact the irrigation water based management as potential alternative to pesticides. Specifically, the study sought to: (1) determine the spatial distribution of *P. xylostella* in cabbage growing areas of Iringa and Morogoro Regions, and (2) determine the effect of timing of overhead irrigation on occurrence and perpetuation of *P. xylostella* on cabbage crop.

Methods

A survey was conducted in Iringa and Morogoro Regions from May 2017 to July 2017 to assess pest status and its distribution in tandem with the first specific objective. A total of 80 respondents' were interviewed using questionnaires and field visits made for diagnostic assessments of 80 brassica farms owned by the respondents. Assessments of the abundance and damages inflicted by *P. xylostella* were done. Collected data included; respondents' demographic variables, awareness of the pest and its seasonal occurrence, practiced control measures against the pests, grown varieties, field incidences of the pests, damage severities, and general management of the crop. The collected data were descriptively analyzed by using the Statistical Package for Social Science (SPSS 16.0) software. In

addition, Chi square tests (p = 0.05) were used to test the statistical significances among variables. Regression (R^2) analyses were performed to determine the relationship between *P. xylostella* incidence and altitude, cropping system, varieties commonly grown, previous crop and crop growth stage. Obtained results were presented in tabular form and graphs.

The second objective was accomplished through a field experiment set at SUA Horticultural Training Farm. The effect of timing of overhead irrigation on occurrence and perpetuation of *P. xylostella* on cabbage crop was investigated. The experiment was laid out in a two factor Split plot arranged in a Randomized Complete Block Design (RCBD) and replicated thrice. Main-plot consisted of two Brassica spp namely; Chinese cabbage (*Brassica rapa*) and Head cabbage (*Brassica oleraceae var. capitata*) while, Sub-plot consisted of three time intervals for sprinkler irrigation namely; T1 (5 pm), T2 (6 pm), T3 (7 pm) and Control (plants treated with insecticide-Phosphorothioate and irrigated using watering can). Data collected on pest incidences, developmental stages and magnitude of damages was subjected to Analysis of variance (ANOVA) and means separated using The Least Significant Difference Test (LSD; p = 0.05) was also performed as means separation test. Genstat v.16 Statistical package (VSN International) was used for statistical analyses. In addition, relationships among test variables and *P. xylostella* were established through regression (R^2) analysis was performed using MS-Excel v.16 software.

Findings

Results from comparative analyses among surveyed wards in Iringa and Morogoro Regions suggested no significant differences (χ^2 = 12.27, df = 16, p = 0.73). Thus, brassica crop in almost all fields succumbed equally to *P. xylostella*. Recorded field incidences were (67.2%) and (50.2%) in Iringa and Morogoro regions respectively. Detailed analyses of the four surveyed wards in Iringa indicated that Mangalali had the highest incidence (93.3%)

while Ulanda had the lowest (47.3%). In Morogoro region Mlali had the highest incidence (79.0%) while Dumila had lowest incidence (37.3%). Up to 66.7% of assessed fields were infested with *P. xylostella* in combination with other pests, while 28.9% of the sampled fields were infested with *P. xylostella* alone. Further analysis suggested a significant relationship (R^2 = 0.032, p = 0.019) between mono-cropping system and *P. xylostella* incidences. The pest incidences increased with the crop growth stage (R^2 = 0.031, p = 0.02).

There was a positive significant relationship between larvae counts and damage score for Head cabbage (R^2 = 0.42, p = 2.23 x 10^{-5}) and Chinese cabbage (R^2 = 0.43, p = 1.22 x10^{-5}). Control plots recorded significantly lower larvae count (1.63), adults count (1.46) and damage score (2.07) than T1 (1.83 larvae, 1.60 adults, 3.01 damage score), T2 (1.81 larvae, 1.64 adults, 3.22 damage score) and T3 (1.80 larvae, 1.64 adults, 3.07 damage score). The crop type had a significant (LSD = 63, p < 0.013) effect on yield. Chinese cabbage recorded higher yield (578 kg Ha^{-1}) than Head cabbage (461 kg Ha^{-1}).

Conclusions

The survey established that *P. xylostella* was abundantly existent in Iringa and Morogoro regions wherever Brassicas are grown. Brassica production was not without the application of insecticides in fear of damages inflicted by *P. xylostella*. Interrupted mating through irrigation water somehow reduced the pest incidences but no significant variation was recorded with varied timing of irrigation. Insecticides application significantly minimized the number of *P. xylostella* and its effects on brassicas. Thus, the application of insecticides remained one most effective control strategy against *P. xylostella*.

Recommendations

In the current study insecticide application proved to be superior to sprinkler irrigation in suppressing *P. xylostella* but there was no significant difference in obtained yield. Since the yield obtained was in terms of weight, further studies should assess the quality of obtained yield in relation to the market price such that profit accrued from quality yield can be estimated to guide informed decision. Moreover, it is recommended that future studies should seek to establish water pressure that would be adequate to force the *P. xylostella* larvae to dislodge from cabbage leaves.

DECLARATION

I, **HAPPINESS CHRISTOPHER**, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my original work done within the period of registration and that it has neither been submitted nor is being concurrently submitted to any other institution.

Happiness Christopher | Date

(MSc. Crop Science Candidate)

The above declaration is confirmed by;

Prof. Gration M. Rwegasira | Date

(Supervisor)

COPY RIGHT

ACKNOWLEDGEMENT

I thank the Almighty God my maker and keeper for the precious gift of life and health. I would like to express special thanks to my supervisors Prof. G. M. Rwegasira for his encouragement, advice and intellectual input afforded to me towards the completion of this work.

My sincere gratitude goes to the USAID-funded project "East Africa Vegetable Crop Integrated Pest Management-Innovation Lab" which financially supported this research. Furthermore, my appreciation goes to my parents and siblings for their moral and material support during the period of my studies. In a special way I appreciate the patience, support and prayers of my dear husband Mr. Samuel Kazimil.

I thank each and every one whom in way or the other contributed to the success of my MSc studies especially the staff of Department of Crop Science and Horticulture who encouragements to endeavor on my studies. I appreciate you all.

DEDICATION

I dedicate this dissertation to my Mother, Martha Bayo for her continuous prayers, loving care, support and encouragement; there was no moment that she did not shared with me. I thank her for being part of a successful story.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 Background Information

Cabbage (*Brassica* spp) is an important source of dietary fiber, vitamins, minerals and income to many vegetable respondents in Tanzania. Hilly and mountainous areas with cooler temperatures of Eastern, Northern and Southern Zones of the country are known to be major feeder of cabbages to the urban populations in cities and big towns. Production occurs throughout a year in areas with irrigation facility mostly in monoculture. Cabbage originated in Northern Europe where it has been grown for more than 3000 years and it is adopted to cool moist conditions (Thompson, 2002). The crop grows well in wide range of soils with fertility and adequate moisture. It is a heavy feeder crop therefore it needs ample fertilization for good plant growth and high yield (Ghosh *et al.,* 2009). Being a heavy feeder cabbage requires special attention to allow harvesting of good yield.

Apart from fungal and bacterial diseases, the production of Cabbage is largely affected by insect pests particularly the diamond back moth (*Plutella xylostella* L; Lepidoptera: Plutellidae) (Said and Itulya, 2003). *Plutella xylostella* is one of the major oligophagous pest and is mainly responsible for low production (Sarfraz *et al.,* 2006). All cruciferous vegetable including cauliflower, cabbage, broccoli, brussel sprouts, Chinese cabbage, collard, kale, kohlrabi, mustard, radish, turnip are attacked by this pest. *Plutella xyllostela* is attracted by free mustard oil present in cruciferous crops (Ratzka *et al.,* 2002). This pest is now reported and documented from at least a hundred and twenty eight countries of the world and is believed to be most universally distributed of all lepidopterous insect pests (Shelton, 2001). According to Shelton (2001) this insect pest is currently present all over the world wherever the crucifers exist. The larval development stage is what exerts attack on the crop. Outbreak of *P. xylostella* was reported to occur in various parts of the world and led to severe losses (Shelton, 2001).

The use of insecticides is the commonest management approach but the effectiveness is never warranted because of the pests' behavior (Abdel-Razek *et al*., 2006). Vast populations of *P. xylostella* have developed resistance to the available insecticide and subsequently lacked sufficient control by natural enemies due to regular application of broad spectrum insecticides. The adult moth often lay eggs at late evening which are subsequently hidden in leaves avoiding contact with contact insecticides which are commonly used on the crop. As such damages from the pests are encountered regardless of the frequencies of pesticide application.

Increased temperature and reduced rain are favorable condition for population increase of *P.xylostella* which results to more generations in a season and increased rainfall can result to increased incidence of fungal diseases (Talekar and Shelton, 1993). However, sprinkler irrigation has been shown to reduce the population of *P. xylostella* by disrupting mating when applied at a possible mating time (McHugh and Foster, 1995). Intercropping with non-host crops has also proved effective to some extent (Asare-Bediako *et al*., 2010) but very often, farmers prefers mono cropping to intercropping.

The exceptional pest status of *P. xylostella* in most parts of the world is due to diversity and abundance of host plants, lack or absence of natural enemies especially parasitoids, its ability to migrate long distance and high rate of fecundity and genetic elasticity facilitating rapid resistance of chemical insecticides (Vickers *et al*., 2004).

For sustainable management of this pest it is important to look at ways to reduce the population of this pest by other means than chemicals. Integration of more than one method of controlling this pest may be effective. The current Research intended to establish a management strategy that centers on interrupted mating and egg lying by the adult moths.

1.2 Origin, Distribution and Importance of Brassica

Cabbage *(Brassica oleraceae var. capitata)* is one of the most important leaf vegetables worldwide (Fordham and Hadley, 2003). It originated in Northern Europe and the Mediterranean region (Vural *et al*., 2000), where it has been grown for more than 3 000 years and is adapted to cool moist conditions (Thompson, 2002). Cabbage is cultivated for its head which consists of water, protein, calcium and iron. Leaves are eaten raw in salads or cooked.

The optimum mean temperature for growth and quality head development is 15 - 18°C, cabbage grows well on a range of soils with adequate moisture and fertility, pH ranges 5.5 - 6.8 and it's a heavy feeder. Cabbage requires constant supply of moisture when coupled with proper management, cabbage can produce 25-30 t/ha. Cabbage heads are ready for harvest after 80 - 120 days after germination, depending on genotype and climate. Africa has 100 000 ha planted with head cabbage (Van der Vossen *et al.*, 2004). At least 40 000 ha of white-headed cabbage is grown in Kenya, Uganda and Tanzania (Solomon *et al.*, 2018).

In Tanzania, cabbage is grown mostly in cooler highlands areas of Arusha, Tanga, Iringa, Mbeya and Morogoro. In a survey of Arumeru district of Arusha Massomo (2002) noted that cabbage production started in the mid 1970s. Production of the crop is practiced throughout the year in areas with irrigation facilities (Massomo *et al.,* 2004). More than 30 cabbage varieties (open pollinated and hybrid) are cultivated in Tanzania popular varieties are Gloria F1, Glory of Enkhuizen and Romenco (Massomo *et al*., 2003).

1.3 Biology and Ecology of *Plutella xylostella*

The Diamondback moth, *Plutella xylostella* (L.) is among the most serious pest of cultivated Brassicaceae worldwide (Talekar and Shelton, 1993). This crucifer specialist may have its origin in Europe but now is present worldwide wherever its host plant exists (Shelton, 2001). Outbreaks of *P. xylostella* frequently occur in various parts of the world and result in severe losses. This insect has a short life cycle around 18 days, and its population may increase up to 60 folds from one generation to next. Larvae enter leaf parenchyma and feed between upper and lower leaf surfaces creating mines and transparent windows (De Bortoli *et al.,* 2011).

1.4 Management of *Plutella xylostella*

Plutella xylostella has shown significant resistance to almost every insecticide applied (Sarfraz and Keddie, 2006). Populations of natural enemies, which would have provided some level of control, have been reduced due to the use of broad spectrum insecticides used against *P. xylostella* which have developed resistance.

Grower thinks about the management of insect pests on individual basis without sufficient regard to the larger regional context in which the insect operates. This may limit their ability to manage the pest. Inter and intra-regional approaches are needed for more sustainable management practices (Heeb *et al*., 2019). This has promoted increased efforts worldwide to develop IPM programs for *P. xylostella* based principally on new management practices that are not used in the field for this pest (Gallo *et al*., 2013). Techniques such as crop residue removal, management of the interval between crops, use of tolerant cultivars, use of sprinkler irrigation, application of plant and biological products and reduction in the number of pesticide applications.

Intercropping is an efficient soil conservation practice due to increased ground cover that it provides, as well as the exploitation of different soil layers due to different depth of the root systems of the two species (Jarenyama *et al*., 2000). Intercropping enhance crop productivity through effective use of water, nutrients and solar energy (Midmore, 1993). Intercropping is a safer, more stable system of agricultural production in small farms where capital is limited and labor (Guvenc and Yildrim, 1999). Intercropping can usefully contribute to the control of pest or disease populations and the reduction of yield loss (Baumann *et al.,* 2000) it has been acclaimed internationally as the most reliable approach to safeguard sustainable vegetable production (Coolman and Hyot, 1993). Intercropping targets to lower population and growth rate of the attacking organism also makes targeted plant to be less good hosts, they interfere directly with activities of the attacker and they change the environment in the intercrop so that natural enemies of the attacker are favored.

Many plant pathogens survive in the soil and can spend the winter in soil debris. Mulch such as straw, bark, leaves, shredded paper or plastic may help prevent both soil from splashing onto plants, fruit and other parts of the plants. This keeps plant cleaner and help prevent diseases like fungal (Gao, 2009) also help conserve soil moisture, reduce weed infestations and improve overall plant health. Some mulch materials, such as straw, leaves, shredded wood or bark, will also add beneficial organic matter as they decompose. Proper Fertilization and Organic Matter Adequate fertilization helps prevent vegetable diseases. Mulch help reduce the disease incidence. Mulch application increase microbial activity and biomass in soil (Bhagat *et al.,* 2016) and reduce some incidence of some above ground diseases of plants (Abbasi *et al.,* 2002). Soil organic matter from decomposed plant materials is an important factor in plant health. Not only are plants better able to absorb and utilize nutrition, but the microbial diversity in organically rich soils also helps keep diseases from becoming established. Mulch is used as environmental and sustainable weed control alternative by suppressing and delaying weed emergence (Teasdale and Monhler, 1993).

1.5 Justification

Diamondback moth (DBM), *P. xylostella*, is one of the most destructive insect pests of economically important cruciferous crops worldwide (Karnam *et al*., 2014). *Plutella xylostella* is a key pest of *Brassica* crops because of its ability to migrate on trajectory winds and find suitable host plants (Miluch *et al*., 2014). It can cause yield loss of up to 60% (Pratissoli *et al.,* 2008). This is a main reason for frequent application of insecticides on cabbage to allow production of marketable heads. This practice has led to the development of multiple resistance by *P. xylostella* to virtually every insecticide in use worldwide (Abdel-Razek *et al.*, 2006). The pest occurs wherever its host plants are grown and the global annual cost of damage and control is estimated to be US$ 4–5 billion (Zalucki *et al.*, 2012). The extensive use of synthetic pesticides combined with the high fecundity of *P. xylostella* has resulted in the pest developing resistance to nearly all classes of insecticides. Moreover, these chemicals have negative impacts to the environment and may affect non-target species, some of which are natural enemies of the pest.

Raining and sprinkling water overhead (overhead irrigation) exerts limits on *P. xylostella* population build up as they cause physical disruption of mating and egg laying activities. Eggs and larvae can also be damaged when washed off the leaf surface, resulting in mortality in most instances (Mahmood, 2005). A study investigating the impact of irrigation systems on *P. xylostella* infestation in cabbage noted that when irrigation water was applied by sprinkler-irrigation, *P. xylostella* infestations were reduced by 37.5 – 63.9% compared with a drip-irrigated control (De Bortoli *et al.,* 2013). The rate of oviposition also decreased when overhead irrigation was used. Sprinkler irrigation influenced *P. xylostella* control by removing 52% of the larvae when first and second stage larvae were used in experiment (Tinoco de Oliveira *et al.,* 2000). Despite being effective, the actual timing of irrigation has never been established. Moreover, the population of the pest in the cabbage growing areas in Tanzania has not been established despite the reports on the existence of the pest (CIE, 1967). The concerns with overhead irrigation on soil splashing which promotes spread of fungal spores leading to another biotic stress to the crops may not be over emphasized. Thus, any initiative meant to promote interrupted mating through overhead irrigation should also consider the strategies to overcome soil splashing such as the use of mulch. The current study intended to fix all these knowledge gaps and promote effective management of *P. xylostella*.

1.6 Objectives

1.6.1 Overall objective

The present study aimed at contributing to increased marketable yield of cabbage with low pesticide residues.

1.6.2 Specific objectives

The study aimed at generating data pertaining to the pest status of *P. xylostella* in major regions where brassica is grown in Tanzania hence the following were the specific objectives;

i) To determine the spatial distribution of *P. xylostella* in cabbage growing areas in Iringa and Morogoro Regions.
ii) To determine the effect of timing of overhead irrigation on occurrence and perpetuation of *P. xylostella* on cabbage crop.

1.7 References

Abdel-Razek, A. S., Abbas, M. H., El-Khouly, M. and Abdel-Rahman, A. (2006). Potential of microbial control of diamondback moth, *Plutella xylostella* (Linnaeus), (Lepidoptera: Plutellidae) on two cabbage cultivars under different fertilizer treatments. *Journal of applied Science and Research* 2(11): 942 – 948.

Asare-bediako, E., Mohammed, A. and Addo-Quaye, A. A. (2010). Control of Diamondback Moth (*Plutella xylostella*) on Cabbage (Brassica oleraceae var capitata) using intercropping with non host crops. *American Journal of Food Technology* 10: 27-39.

Baumann, D. T., Kropff, M. J. and Bastiaans, L. (2000). Intercropping leeks to suppress weeds. *Weed Research* 40: 359– 374.

Bhagat, P., Gosal, S. K. and Singh, C. B. (2016). Effect of mulching on soil environment, microbial flora and growth of potato under field conditions. *Indian Journal of Agricultural Research* 50(6): 542-548.

CIE, (1967). Distribution Maps of Plant Pests, No. 32. Wallingford, UK: CAB International. 34pp.

Coolman, R. M. and Hoyt, G. D. (1993). The effects of reduced tillage on the soil environment. *Horticulture Technology* 3: 143-145.

De Bortoli, S. A., Polanczyk, R. A., Vacari, A. M., De Bortoli, C. P. and Duarte, R. T. (2013). *Plutella xylostella* L. Tactics for Integrated Pest Management in Brassicaceae, Journal of *Weed and Pest Control* 3: 40-48.

De Bortoli, S. A., Vacari, A. M., Goulart, R. M., Santos, R. F., Volpe, H. X. L. and Ferraudo, A. S. (2005). Potential of Entomopathogenic Fungi as Biological Control Agents of Diamondback Moth (Lepidoptera: Plutellidae) and

Compatibility with Chemical Insecticides. *Journal of Applied Entomology* 129 (3): 149 – 157.

Fordham, R. and Hadley, P. (2003). Vegetables of Temperate Climates: Cabbage and Related Vegetables in Encyclopedia of Food Sciences and Nutrition 2nd Ed [https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/cabbage] site visited on 5 September 2019.

Gallo, S., Saliou, N., Dienaba, S., Arvanitakis, L., Bordat, D. and Diarra, K. (2013).Effect of timely application of Bacillus thruringiensis and Neem on agronomical particular of cabbage. *Journal of Agricultural Research* 8: 6164-6170.

Gao, Y., Li, Y., Zhang, J., Liu, W., Dang, Z., Cao, W. and Qiang, Q. (2009). Effects of mulch, N fertilizer and plant density on wheat nitrogen uptake and residual soil nitrate in a dryland area of China. *Nutrient Cycling in Agroecosystems* 85: 109-21.

Ghosh, C., Mandal, J. and Chattopadhyay, G. N. (2009). Effect of vemicompost on growth and yield of cabbage (*Brassica oleracea* L. var *capitata*). In: *International Conference of Horticulture.* (Edited Dr. Prem Nath Agricultural Science Foundation, Bangalore Univesity of Agricultural Sciences). 9-12 November 2009 Bangalore.

Heeb, L., Jenner, E. J. and Cock, M. J. (2019) .Climate-smartpestmanagement: building resilience of farms and landscape to changing pest threats. *Journal of Pest Science* 1007: 1340-1383.

Jeramanya, P., Stephen, R., Waddington, O., Hesterman, B. and Richard, R. H. (2000). Relay intercropping of Sunhemp and Cowpea into a Smallholder Maize system in Zimbabwe. *Agronomy Journal* 92: 239-244.

Mahmood, A. (2005). Diamondback moth *Plutella xylostella:* A review of its biology, ecology and control. *Journal of Agricultural Research* 43(4): 361-382.

Massomo, S. M. S. (2002). Black rot of cabbage in Tanzania: Characterization of *Xanthomonas campestris* pv. campestris and disease management strategies. PhD Thesis for Award Degree at The Royal Veterinary and Agricultural University, Copenhagen, Denmark. 215pp.

Massomo, S. M. S., Mabagala, R. B., Swai, I. S., Hockenhull, J. and Mortensen, C. N. (2004). Evaluation of varietal resistance in cabbage against the black rot pathogen (*Xanthomonas campestris pv. campetris*) in Tanzania. *Journal of Crop Protection* 23: 315-325.

Massomo, S. M. S., Nielsen, H., Mansfield-Giese, K., Mabagala, R. B., Hockenhull, J. and Mortensen, C. N. (2003). Identification and characterization of Xanthomonas camp-estris pv. campestris from Tanzania by pathogenicity tests, Biolog, rep-PCR and fatty acid methyl ester analysis. *Europian Journal of Plant Pathology* 109: 775-789.

Massomo, S., Mabagala, B., Mortensen, R., Carmen, N. and Hockenull, J. (2005). Cabbage Production in Tanzania: Challenges faced by Small holder Famers in the Management of Black Rot Disease. *Journal of Sustainable Agriculture* 26(4): 119-141.

McHugh, J. J. and Foster, R. E. (1995). Reduction of Diamondback Moth (Lepidoptera: Plutellidae) infestation in head cabbage by overhead Irrigation. *Journal of Economic Entomology* 88: 162-168.

Midmore, P. (1993). Input-output forecasting of Regional Agriculture policy Impacts. *Journal of Agriculture Economics* 44(2): 284-300.

Miluch, E. L., Dosdall, M. and Evenden, L. (2014). Factors Influencing Male *Plutella xylostella* (Lepidoptera: Plutellidae) Capture Rates in Sex Pheromone-Baited Traps on Canola in Western Canada. *Journal of Applied Entomology* 107(6): 2067-2076.

Oliveira, M. A., de Pereira, O. G., Garcia, R., Antônio Obeid, J. A., Cecon, P. R., Moraes, S. A. and Silveira, P. R. da (2000). Yield and nutritive value of Bermudagrass 'Tifton 85' (*Cynodon* spp.) at different ages of regrowth. *Review Brassica Zootec* 29(6): 1949-1960.

Pratissoli, D., Polanezyk, R. A., Holtz, A. M., Dalvi, L. P., Silva, A. F. and Silva, L. N. (2008). Selection of *Trichogramma* species controlling the diamondback moth. *Horticultura Brasileira* 26: 194–196.

Ratzka, A., Vogel, H., Kliebenstein, D., Mitchell-Olds, T. and Kroymann, J. (2002). Disarming Mustered oil bomb. In: *Proceeding of the National Academy of Sciences*. (Edited by May R Berenbaum, University of Illinois at Urbana-Champaign). September 2002. 99(17): 1123-11228.

Sarfraz, M., Dosdall, L. M. and Keddie, B. A. (2006). Diamondback moth host plant interactions: implications for pest management. *Journal Crop Protection* 25: 625-639.

Shelton, A. M. (2001). Management of the diamondback moth In: *Proceedings of the fourth international workshop on the management on the diamondback moth and other crucifer pests.* (Edited by Ridland N. M) Melbourne, Victoria, Australia. 3 - 8 pp.

Solomon, T. and Tekile, B. (2018). Adaptability Studies of Head Cabbage (Brassica *oleracea* L.) Varieties at Adola Rede Areas, Southern Oromia, Ethiopia. *International Journal of African and Asian Studies* 51: 2409 – 6938.

Talekar, N. S. and Shelton, A. M. (1993). Biology, ecology, and management of the Diamondback moth. *Journal Article in Agriculture Science* 38: 275-301.

Thompson, J. K. (2002). Yield evaluation of cabbage varieties. *Journal of Agriculture Technolog*y 5: 15-17.

Van der Vossen, H. A. M. and Seif, A. A. (2004). *Brassica oleracea L*. (headed cabbage). In: *Proceedings of Plant Resources of Tropical Africa*. (Edited by Grubben, G. J. H. and Denton, O. A.) April 2004, Wageningen, Netherlands. 74pp.

Vickers, R. A., Furlong, M. J., White, A. and Pell, J. K. (2004). Initiation of fungal epizootics in diamondback moth populations within a large field cage: proof of auto-dissemination. *Experimental and Applied Entomology* 111: 7 – 17.

Zalucki, M. P., Shabbir, A., Silva, R., Adamson, D., Liu, S. S. and Furlong, M. J. (2012). Estimating the economic cost of one of the world's major insect pests, *Plutella xylostella*. *Journal of Economic Entomology* 105: 1115 – 1129.

CHAPTER TWO

2.0 PEST STATUS AND SPATIAL DISTRIBUTION OF *Plutella xylostella* IN FARMERS' FIELDS IN IRINGA AND MOROGORO REGIONS OF TANZANIA

To be submitted to the Journal of Agricultural Sciences

2.1 Abstract

Diamond Back Moth (*Plutella xylostella* L.) is the pest of economic importance in production of Brassica crop. It can cause up to 90% loss if not controlled. The objective of this study was to assess the abundance and damages inflicted by *P. xylostella* in farmers' fields. A diagnostic survey was conducted in Iringa and Morogoro Regions from May 2017 to July 2017 to assess pest status and its distribution. Collected data were respondents' demographic variables, awareness of the pest and practiced management options. The field diagnostics data included crop age and management practices, abundance of *P. xylostella*, damage and severities of inflicted damages. Obtained results suggested that, almost all brassica crops equally (χ^2 = 12.27, df = 16, p = 0.73) succumbed to *P. xylostella*. The mean pest incidences were 67.2% and 50.2% for Iringa and Morogoro respectively. Mono-cropping system and the age of assessed crops had respectively significant relationship (R^2 = 0.032, p = 0.019) and (R^2 = 0.031, p = 0.02) with *P. xylostella* incidences. The study established that *P. xylostella* is abundantly existent in the surveyed regions wherever brassicas are grown. The study demonstrated the pest status and spatial distribution of *P. xylostella* in farmers' fields in surveyed regions of Tanzania. It also provided a baseline for identifying the factors influencing survival and perpetuation of the pest, which in turn will allow effective management strategy to be designated.

Key words: *Plutella xylostella*, Pest status, Brassica, incidences, farmer awareness, and management practices.

2.2 Introduction

Diamond Back Moth (*Plutella xylostella* L; Lepidoptera: Plutellidae) is a major, ubiquitous, and year-round insect pest hindering the economic production of brassica crops (Talekar and Shelton, 1993). Small-scale farmers are facing difficulties coping with *P. xylostella* damage-induced losses and management challenges (Munthali, 2009). The economic importance of *P. xylostella* is derived from its exceptional pest status that originates from its genetic diversity, high and year-round abundance, high reproductive potential, high genetic elasticity, cosmopolitan distribution, multivoltinity, and continuous suppression of the pest's natural enemies by synthetic pesticides (Canico *et al.,* 2013). The possible survival failures of efficient natural enemies in the pest's new invasion areas compound the problems in farmers' fields (Chidawanyika *et al.*, 2012). *Plutella xylostella* constitute important threat of brassica supply because it can cause up to 90% loss (Safraz and Keddie, 2005). Global losses of leafy vegetables attributed to damage and control costs of *P. xylostella* alone were estimated to be around US$ 4–5 billion (Zalucki *et al.,* 2012). This insect species is a problem in the tropical and subtropical countries where cabbage is grown all year round. Weather conditions are highly favorable for its biological development and it's associated with a high reproduction rate which results in more than 20 generations of *P. xylostella* per year (Vickers *et al.*, 2004). Studies from different countries shows that *P. xylostella* is the pest of economic importance in *Brassicas,* In Tanzania, there is limited information about the pest, therefore this study was of importance to assess pest status and its distribution.

2.3 Materials and Methods

Diagnostic survey was conducted in cabbage growing areas of Iringa Region during May 2017 and Morogoro Region during July 2018. The timing was during cabbage production season, a period characterized with condition of growth and survival of Diamond back moth. Surveyed areas were Iringa rural and Kilolo Districts in Iringa Region and Morogoro municipal, Kilosa and Mvomero Districts in Morogoro Region as shown (Figure 2.1) below.

2.3.1 Sample size determination

Cabbage growing areas of Iringa and Morogoro were selected for this study due to their long history of producing cabbage and other Brassicaceae related crops for several years. Farmers' interviews were administered using questionnaires followed by field assessments. Extension officers in the surveyed areas were contacted to arrange for the meeting with farmers who grows Brassica particularly the two species, *Brassica oleraceae* and *Brassica rapa* to participate in the interview. The target was to interview 20 farmers in each district totaling to 100 respondents. However, only 80 respondents were interviewed due to limited turn up by respondents. The sample was considered adequate based on Bailey (1994) argument that 30 cases is the bare minimum for a study in which statistical data analysis is to be done.

The sample size for the research was determined using the following formula recommended by Kothari (1993).

$$N = Z^2pq/e^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

N = Desired sample size (where proportion is greater than 1000)

Z= is the standard error associated with the chosen level of confidence (1.96) corresponding to 95% confident interval

P = is the proportion in the largest population estimated to have particular characteristics if not known use 50%

Q = 1.0 – p

e^2 = Degree of accuracy desired, usually set at 0.05 or occasionally at 0.01

Therefore, the sample size was calculated as: $(1.96)^2 * 0.1*(1-0.1)/ (0.05)^2 = 80$

2.3.2 Field data collection

Purposeful selection of districts to be surveyed followed by random sampling was done by considering regions where cabbage crop is grown then field assessment was done by picking at random at specified interval of 1 kilometer apart. In each district 10 cabbage fields were visited and in each field a total of 50 plants were picked at random and assessed.

In each farm two diagonal lines of 25 plants each were accessed making a total of 50 plants per field. In total the expected summation was 2500 plants but the pest pressure and increased farmer demands of researchers to visit their farms and assess the pest problem lead to a total of 2954 plants assessed for *P. xylostella*. Sampled fields were along accessible farm roads and pathways. *Plutella xylostella* population was assessed by inspecting leaves of the sampled plants and manually counting the larvae by using hand lens and numbers were recorded alongside damage scores.

Location geographical references were collected by using Geographical Positioning System (GPS) for reference and the points were used to plot maps of data collection points. Data included crop age, crop type, grown varieties, cropping systems, previously grown crops, other pests infesting the crop and altitude in meters above sea level. *Plutella xylostella* field incidences were determined by assessing number of damaged cabbage heads against the total number of assessed plants multiplied by 100%

i.e. Incidence (%) = <u>number of *P. xylostella* damaged plants x 100</u>…………..(2)

Total number of assessed plants

2.3.3 Data analysis

The survey data were descriptively analyzed to establish the distribution of respondents for each variable. The Statistical Package for Social Science (SPSS 16. 0) computer software was used to calculate the descriptive statistics including frequency and percentages for each variable of interest. In addition, Chi square tests (p = 0.05) were used to determine the relationship among variables. Regression (R^2) and simple correlation (r) analysis was performed to determine the relationship between altitude, cropping system, varieties commonly grown, previous crop, most destructed crop growth stage and *P. xylostella* incidence. Obtained results were presented as tables and graphs.

2.4 Results

2.4.1 Demographic information of interviewed respondents

Both age and gender were factors in cabbage farming (Table 2.1). The minimum age of respondents was 20 years while maximum age was 79 years and the average was 49.5 years old. The largest proportion (42.5%) of respondents was aged between 30-39 years, representing the most active farming group in the study area, followed by 27.5% respondents in the age group ranging from 40-49 years and the least was 2.5% respondents aged between 70 years and above. Sex wise, more than 77% of the respondents engaged in brassica production were males while only 22.5% were female.

Table 2.1: Demographic information of interviewed respondents

	Surveyed Wards/ Region										
	Iringa				Morogoro						
	W1	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**Total n=80**	
Sex											
Female	12(24)	2(33.3)	0(0.0)	0(0)	2(33.3)	2(100)	0(0)	0(0)	0(0)	18(22.5)	χ^2=11.63 df=8 p=0.178
Male	38(76)	4(66.6)	6(100)	2(100)	4(66.7)	0(0)	2(100)	2(100)	2(100)	62(77.5)	
Age											
20-29	20-29	0(0)	2(33.3)	0(0)	0(0)	0(0)	2(50)	0(0)	0(0)	3(7.5)	χ^2=42.04 df=40 p=0.38
30-39	30-39	28(56)	0(0)	0(0)	2(33.3)	2(100)	0(0)	0(0)	0(0)	34(42.5)	
40-49	40-49	8(16)	2(33.3)	2(100)	2(33.3)	0(0)	2(50)	2(100)	2(100)	22(27.5)	
50-59	50-59	10(20)	0(0)	0(0)	2(33.3)	0(0)	0(0)	0(0)	0(0)	12(15)	
60-65	60-65	4(8)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	4(5)	
70-79	70-79	0(0)	2(33.3)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(2.5)	

W1 = N'guruhe, W2 = Ulanda, W3 = Malangalali, W4 = Ilula, W5 = Mgeta, W6 = Mlali, W7 = Kingolowira, W8 = Nyandira, W9 = Dumila. Numbers in brackets are percentages of the actual value

Table 2.2: Respondents' farm size and cabbage varieties grown

	Surveyed Wards/ Region										
	Iringa				Morogoro						
	W1	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**Total n=80**	
Farm size											
Quarter acre	6(28.6)	2(18.2)	1(11.1)	5(62)	5(38.5)	2(25)	2(25)	6(50)	4(50)	31(31.9)	χ^2=25.467, df=24, p=0.381
Half acre	15(59.5)	3(54.5)	7(77.8)	3(37.5)	5(38.5)	11(68.8)	4(50)	4(33.3)	3(37.5)	55(53.3)	
Three quarter	1(2.4)	1(18.2)	1(11.1)	0(0)	3(23.1)	0(0)	3(18.3)	0(0)	0(0)	9(7.40)	
> 1 acre	2(9.50	1(9.1)	0(0)	0(0)	0(0)	1(6.2)	1(6.2)	2(16.7)	1(12.5)	8(7.4)	
Varieties grown											
Gloria F1	21(100)	5(81.8)	2(44.4)	5(62.50)	5(79.9)	4(50)	6(81.2)	3(50)	4(100)	55(77.80)	χ^2=29.246, df = 24, p=0.211
Victoria F1	0(0)	2(18.2)	0(0)	0(0)	0(0)	2(12.5)	3(18.8)	0(0)	0(0)	7(5.2)	
Local variety	0(0)	0(0)	5(33.3)	3(37.5)	3(23.1)	3(18.8)	0(0)	0(0)	0(0)	14(10.4)	
Hybrid	0(0)	0(0)	0(0)	0(0)	0(0)	3(18.8)	0(0)	6(50)	0(0)	9(6.7)	

W1 = N'guruhe, W2 = Ulanda, W3 = Malangalali, W4 = Ilula, W5 = Mgeta, W6 = Mlali, W7 = Kingolowira, W8 = Nyandira, W9 = Dumila. Numbers in brackets are percentages of the actual value

2.4.2 Abundance of *P. xylostella* in the survey fields

Surveyed fields had shown *P. xylostella* presence, pest was found infesting brassica crop in all the fields regardless of the location, fields from Iringa and Morogoro were succumbed equally all fields grown with brassica were infested with P. *xylostella* causing different levels of damages from the pest should be expected regardless of the previously grown crop grown as shown in (Fig 2.1a and 2.1b).

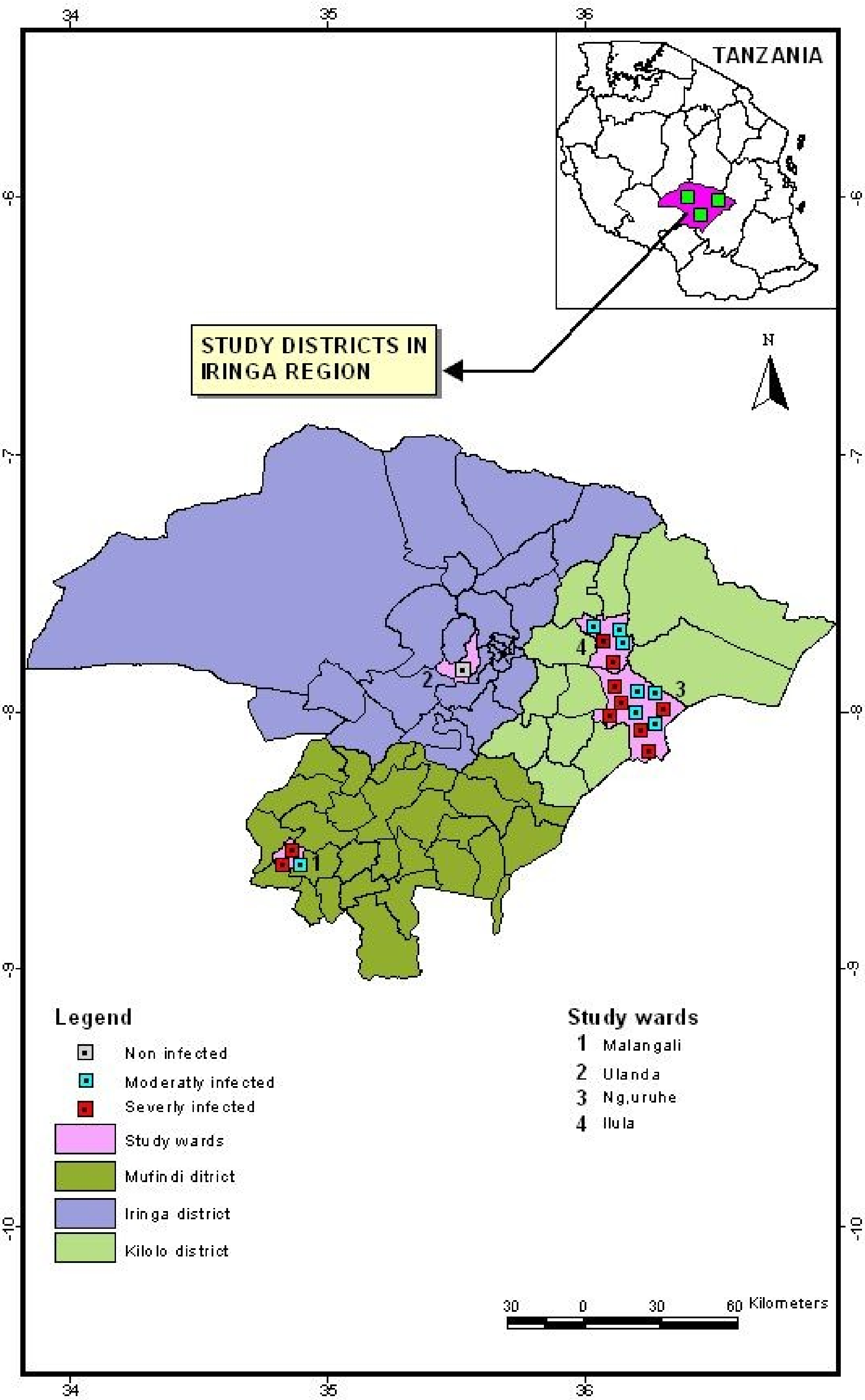

Figure 2.1a: Map of Iringa Region showing the study locations

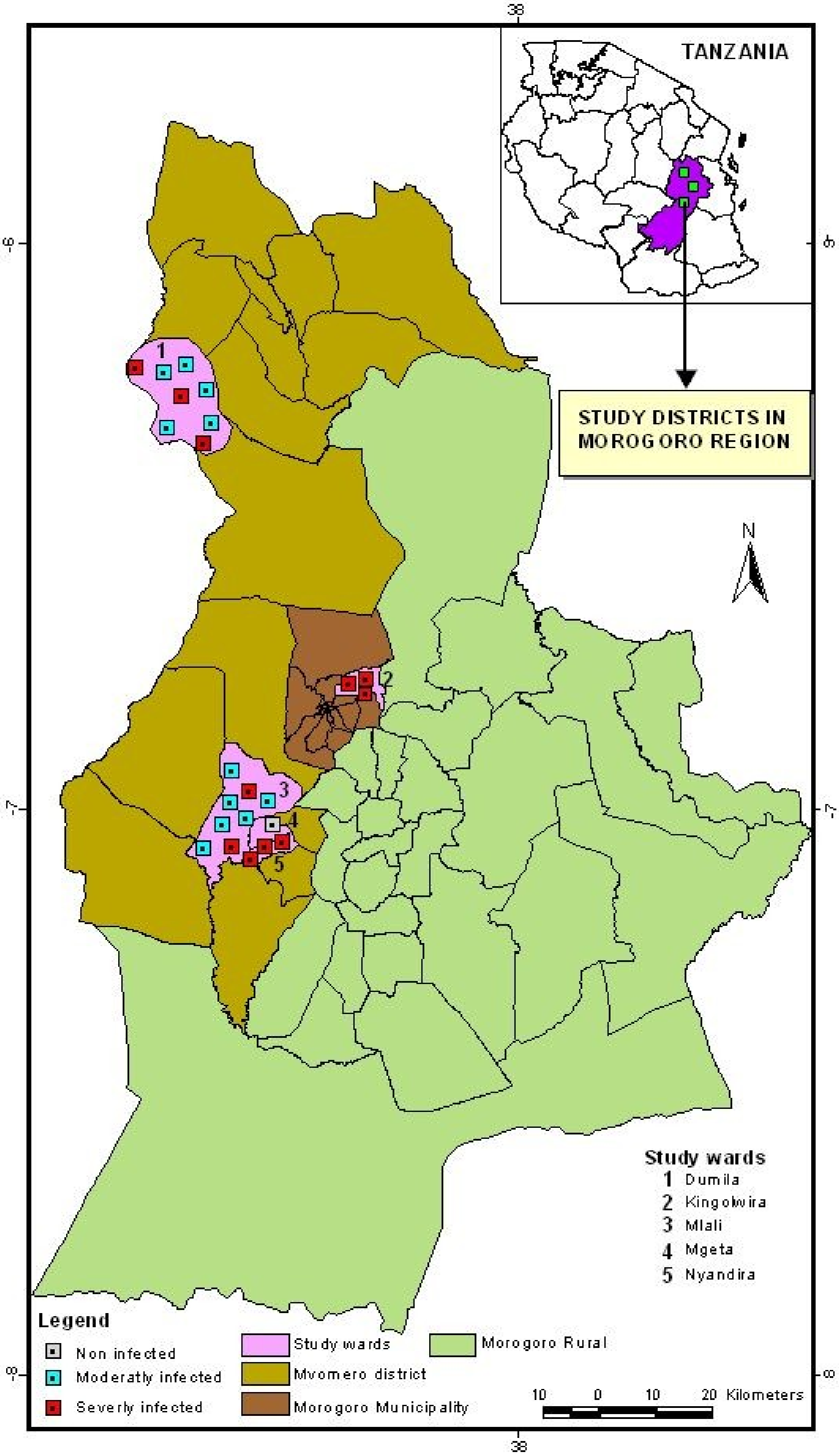

Figure 2.1b: Map of Morogoro Region showing the study locations

2.4.3 Respondents' farm and crop characteristics

The size of the farm affects management especially to small scale respondents where family labor is dependent. Most respondents tended small areas of land because vegetables production was laborious and 53.3% of respondents had 0.5 acre on vegetable production (Table 2.2). It was further observed that most respondents use hybrid varieties, such as Gloria F1 which was recorded in about 78% of the surveyed fields. Nevertheless, some respondents (10.4%) still use local varieties (Table 2.2). 80% of respondents who use hybrid variety particularly Gloria F1 mostly experienced *P. xylostella* damages (Figure 2.2).

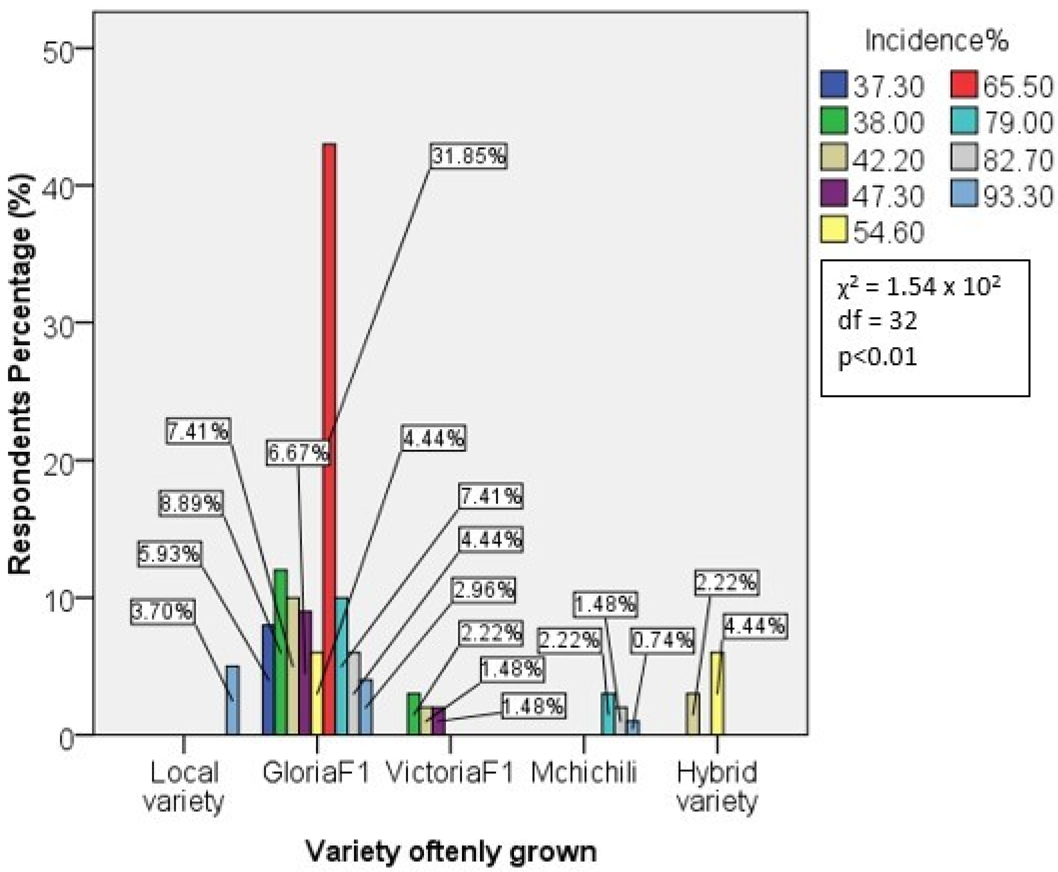

Figure 2.2: **Incidence of *P. xylostella* with respect to variety oftenly grown**

2.4.4 Spatial occurrence of Brassica Pests

Insect pests were one among the most pressing production constraint in the study area. In most cases more than one pest was found infesting brassica crop particularly *P. xylostella* and aphids. Up to 66.7% of assessed fields were infested with *P. xylostella* in combination with other pests while fields infested with *P. xylostella* alone were 28.9% of the sampled fields (Figure 2.3). Despite the small proportion, almost all fields grown with brassica succumbed equally to *P. xylostella* suggesting that damages from the pest should be expected regardless of the previously grown crop (Table 2.4).

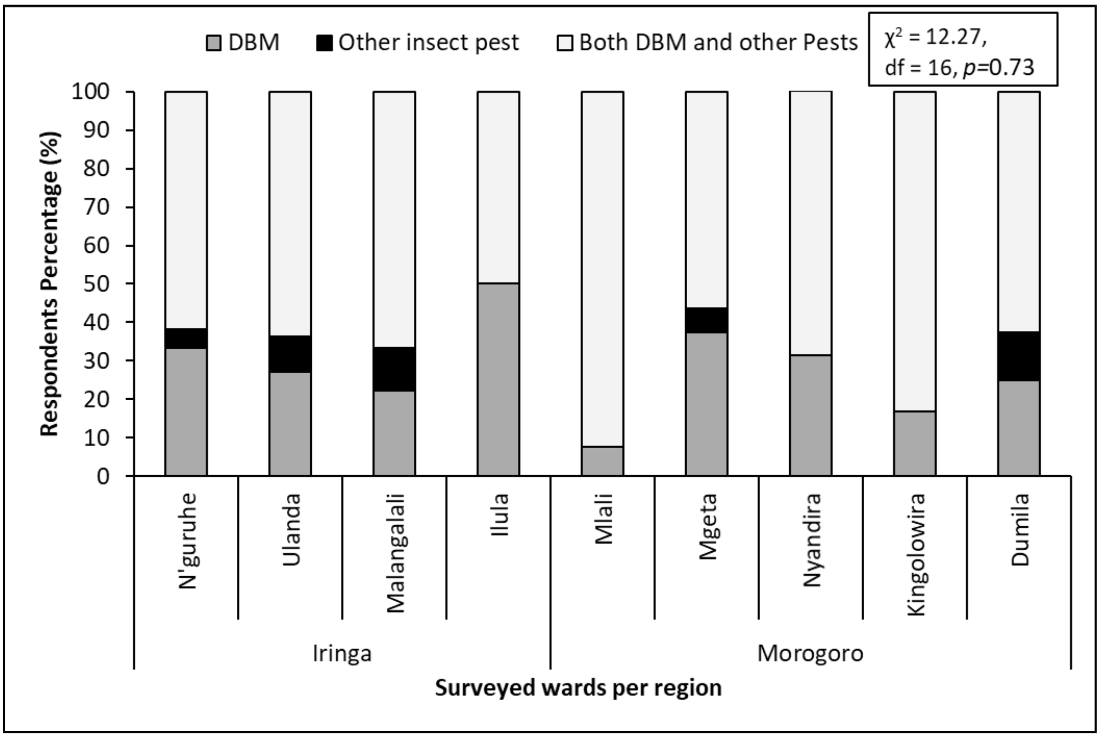

Figure 2.3: Spatial occurrence of Brassica Pests

2.4.5 Cropping system, history and diamond back moth destructive stage

Most respondents produced the crop under monocropping which accounted for 96.3% of respondents while only 3% of respondents grew brassicas under intercropping (Table 2.4). A large proportion (89.6%) of respondents planted a crop once a year because they depend on rainfall, while a handful of respondents planted the crop twice (4.4%) or thrice (5.9%) in a year (Table 2.4). Two thirds (82.97%) of respondents who produced cabbage at least once a year experienced *P. xylostella* damages (Figure 2.4).

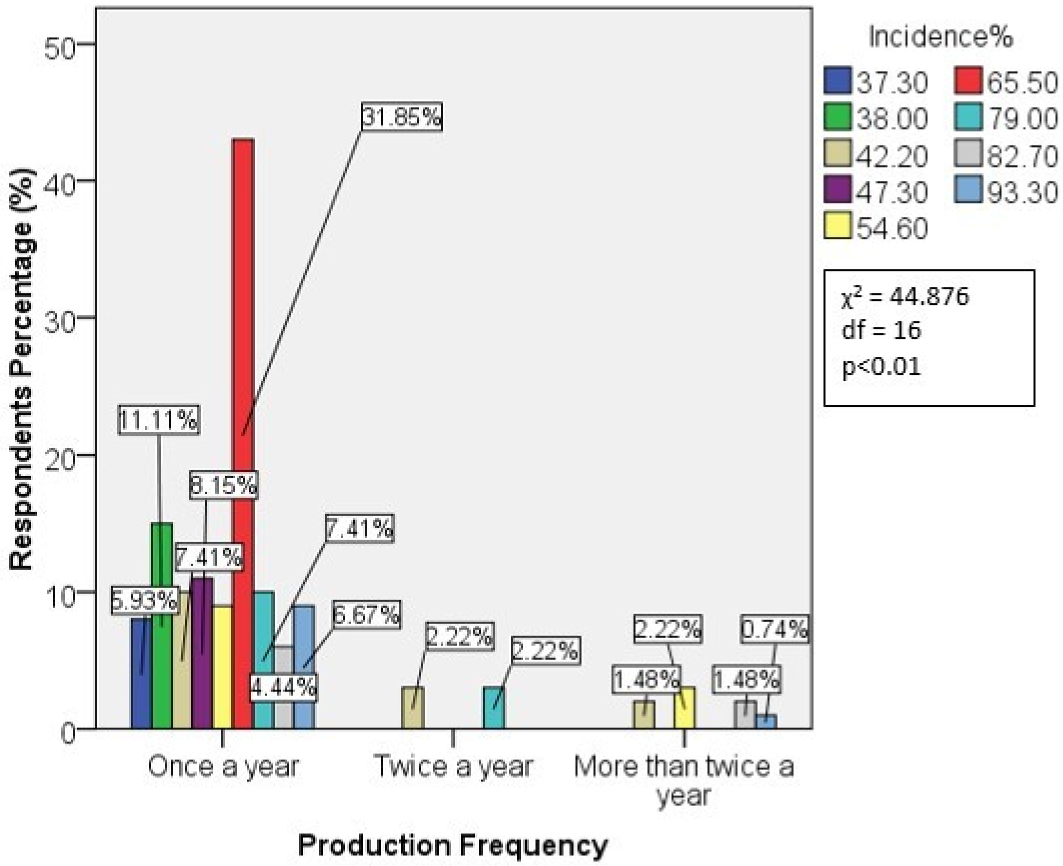

Figure 2.4: **Incidence of *P. xylostella* with respect to production frequency**

Cropping history has often been considered fundamental in the continued existence, favorable breeding environment and perpetuation of the crop pests particularly when same crop or crops of the same family are planted continuously. Thus the possible contribution of previous crop to the observed pest status was also assessed (Table 2.4). Only a small proportion (8%) of the surveyed fields had previously been grown with brassica. All crop growth stages of brassicas were damaged by *P. xylostella* which accounted for 52.6% of the nature of damages recorded. The pest was found attacking the crop from seedling to maturity stages. Damages at heading stage were relatively high recorded in 37.8% of the fields while the least affected was the maturity stage of the crop (Table 2.4).

Table 2.3: Cropping system, history and diamond back moth destructive stage

	Surveyed Wards/ Region										
	Iringa				Morogoro						
	W1	W2	W3	W4	W5	W6	W7	W8	W9	Total n=80	
Cropping system											
Monocrop	25(97.6)	5(90.9)	5(77.8)	5(100)	6(92.3)	5(100)	8(100)	7(100)	6(100)	75(96.3)	χ^2=12.64,df=8, *p*=0.125
Mixed Crop	1(2.4)	1(9.1)	2(22.2)	0(0)	1(7)	0(0)	0(0)	0(0)	0(0)	5(3.7)	
Production Frequency											
Once a year	21(100)	6(100)	5(100)	5(62.5)	5(76.9)	4(68.8)	4(100)	6(75)	4(100)	64(89.6)	χ^2= 96.269, df = 16, *p*= 0.001
Twice a year	0(0)	0(0)	0(0)	0(0)	3(23.1)	3(18.8)	0(0)	0(0)	0(0)	6(4.4)	
More than twice	0(0)	0(0)	0(0)	3(37.5)	0(0)	2(12.5)	0(0)	3(25)	0(0)	10(5.9)	
Previous Crop											
None	10(40.5)	1(9.1)	2(22.2)	1(9.1)	6(46.2)	5(31.2)	3(37.5)	5(41.7)	2(25)	37(34.8)	χ^2=191.82, df= 48, *p*=0.0001
Maize	12(45.2)	3(45.5)	2(22.2)	2(50)	2(15.4)	2(37.5)	3(37.5)	4(41.7)	1(25)	31(34.8)	
Tomato	0(0)	2(36.4)	3(55.6)	0(0)	0(0)	2(12.5)	0(0)	0(0)	0(0)	7(8.1)	
Potato	1(2.4)	1(9.1)	0(0)	0(0)	1(7.7)	0(0)	1(12.5)	1(16.7)	1(12.5	3(3.3)	
Brassica	5(11.9)	0(0)	0(0)	0(0)	1(7.7)	0(0)	2(12.5)	2(16.7)	1(12.5)	11(8.1)	
Beans	0(0)	0(0)	0(0)	0(0)	3(23.1)	0(0)	0(0)	0(0)	0(0)	2(2.2)	
Onion	0(0)	0(0)	0(0)	0(0)	0(0)	3(18.8)	0(0)	0(0)	0(0)	3(22.2)	
DBM most destructive stage											
All stages	11(42.9)	6(81.8)	1(11.1)	5(37.5)	2(30.8)	9(87.5)	3(37.5)	4(66.7)	2(50)	43(52.6)	χ^2=39.096, df=24, *p*=0.027
Seedling stage	1(4.8)	0(0)	0(0)	0(0)	1(15.4)	1(6.2)	1(6.2)	1(8.3)	1(12.5)	6 (5.9)	
Heading stage	10(47.6)	2(18.2)	4(88.9)	1(12.5)	3(46.2)	1(6.2)	4(43.8)	1(8.3)	2(37.5)	27(37.8)	
Maturity stage	1(4.8)	0(0)	0(0)	0(0)	1(7.7)	0(0)	2(12.5)	0(0)	0(0)	4(3.7)	

W1 = N'guruhe, W2 = Ulanda, W3 = Malangalali, W4 = Ilula, W5 = Mgeta, W6 = Mlali, W7 = Kingolowira, W8 = Nyandira, W9 = Dumila. Numbers in brackets are percentages of the actual value

2.4.6 Incidence of *Plutella xylostella* in surveyed farms

From the survey conducted in Iringa and Morogoro regions it was observed that *P. xylostella* was present as the most important pest in cruciferous production across all surveyed sites as it shown in a map (Figure 2.1). Iringa region had incidence (67.2%) where Malangalali ward had highest incidence (93.3%) and Ulanda had (47.3%) which was the lowest, and Morogoro region had (50.2%) incidence where Mlali had highest incidence of 79.0% and Dumila had lowest incidence of 37.3%. Between and within Regions there was highly significant (p<0.001) difference with *P. xylostella* Incidence (Figure 2.5).

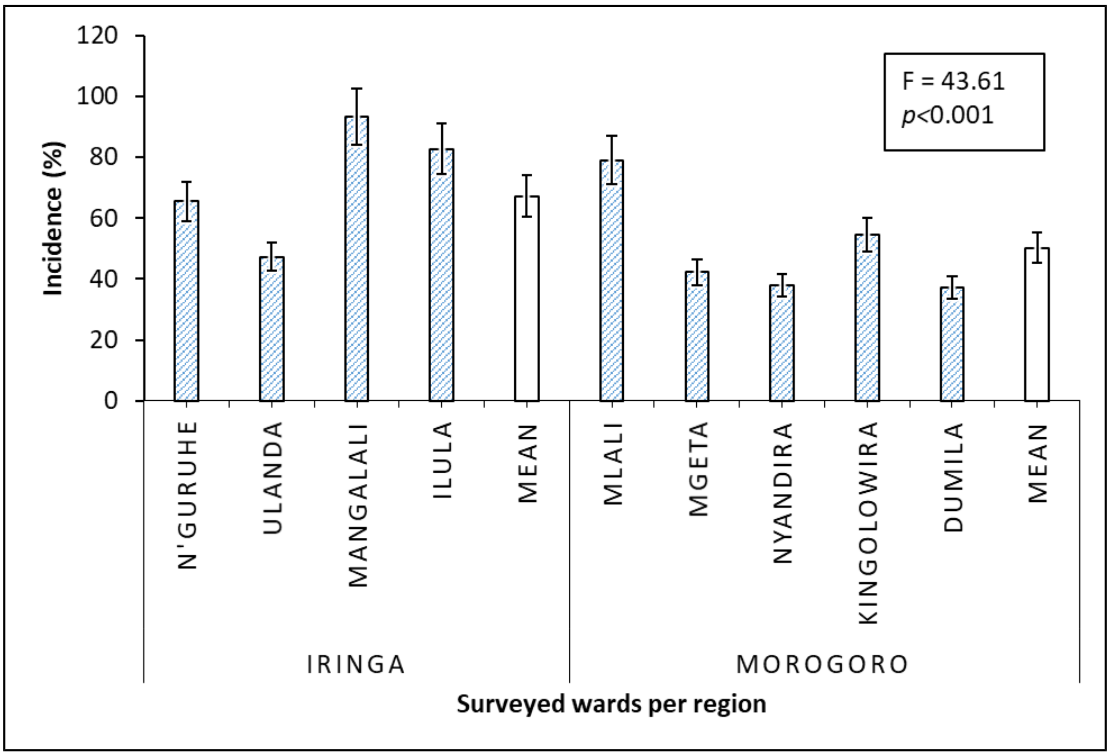

Figure 2.5: ***Plutella xylostella* incidence in surveyed areas**

Most respondents expressed frustration by the damages caused by *P. xylostella* to the extent that hopes to obtain tangible benefits from the crop that for long sustained them economically are fading. In most of visited farms *P. xylostella* was evident either in form of damage signs on crops or the larval stage of the pest which was observed (Figure 2.6).

Damage was severe, rendering some damaged cabbages neither marketable nor fit for home consumption. The high losses caused by *P. xylostella* together with other pest and diseases threatens respondents investments on brassica forcing them to apply pesticide on weekly basis in attempt to attain appreciable harvest that would ensure the adequate marketable heads to offset the increased production costs.

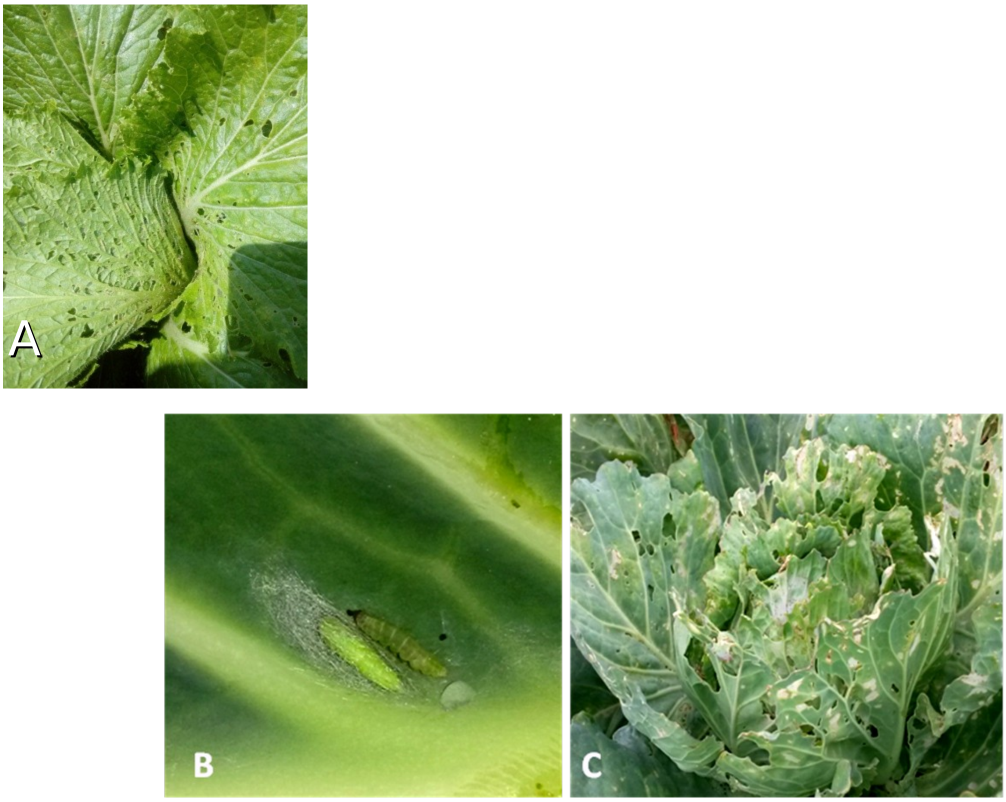

Figure 2.6: **Damages inflicted by *P. xylostella* on brassicas: A. Damaged *Brassica rapa*; B. last larval instar and pupating *P. xylostella* stages on *Brassica oleracea*; C. highly damaged *Brassica oleracea* plant in one of farmer's field in Iringa.**

2.4.7 Factors associated with *P. xylostella* incidence

From this study it was established that previously grown crop and type of variety had limited influence on the occurrence of *P. xylostella*. There was a non-significant relationship between previously grown crop (R^2 = 0.014, p = 0.085), type of variety (R^2 = 0.003, p = 0.263) and the incidence of *P. xylostella*. Cropping system had a significant relationship (R^2 = 0.032, p = 0.019) with the incidence of *P. xylostella.* The incidence of *P. xylostella* increased with increase in production frequency (R^2 = 0.002, p = 0.294) and altitude (R^2 = 0.001, p = 0.37), however the relationship was not significant. The study revealed that, damages caused by *P. xylostella* were relatively high as the crop progressed towards maturity stages particularly at heading stage. Therefore, a significant relationship was observed between the incidence of *P. xylostella* and most destructed brassica growth stage (R^2 = 0.031, p = 0.02).

2.5 Discussion

The survey findings showed that *P. xylostella* was present in all the places where its host was grown. Given the fact that more than 90% of the respondents confirmed to have experienced *P. xylostella* in their brassica fields, it suggests that the surveyed areas were environmentally friendly to the survival and perpetuation of the pest. Shelton (2001) reported that this pest of crucifer has its origin in Europe but now is present worldwide wherever its host plant exist. Outbreaks of diamondback moth, *Plutella xylostella*, frequently occur in various parts of the world and results in severe losses (Safraz *et al*., 2005). The absence of effective natural enemies and fast development of resistance to insecticide are the causes of increasing of *P. xylostella* status in various parts of the world (Shakeel *et al.*, 2017).

Geographical influence through altitude of the location could not be established since *Plutella xylostella* infested the brassica crop at different locations regardless of the altitudes. According to Mohandass and Zalucki (2004), it is unlikely that clear geographical differences in thermal response would be generated in a highly mobile species like *P. xylostella*. The surveyed locations in low altitude at about 520 m.a.s.l such as Mvomero and Dumila had similar rates of *P. xylostella* infestation to those above 1600 m.a.s.l such as Mgeta, Nyandira, and Kilolo. Such unlimited presence of the pest suggests its adaptation to wide range of climatic conditions and would therefore affect brassica wherever is grown. Other studies have similarly indicated the unlimited presence of *P. xylostella* wherever brassica is grown regardless of the environment (Honest *et al.*, 2016).

Plutella xylostella equally infested all grown varieties but inflicted severe damages to hybrid varieties particularly Gloria F1. Most respondents perceived *P. xylostella* as a most significant among important pests of Brassica despite their limited knowledge on its management. Failure to control can lead to 100% loss of the crop as was evidenced in one of the farms in Iringa rural district whereby after being challenged with high infestation with *P. xylostella* while the farmer was too poor to afford insecticides abandoned the field. Apart from being heavily infested with weeds all cabbage heads in the respective field were also infested with *P. xylostella*, other pests such as aphids, and caterpillars of diverse species as well as diseases such as soft rots. The economic importance of *P. xylostella* is derived from its exceptional pest status attributed to its genetic diversity, high and year round abundance, high reproductive potential, and continuous suppression of pest's natural enemies by synthetic pesticides (Motshwari *et al.,* 2008).

Growth stages of the crop significantly influenced *P. xylostella* infestation on the plants. The crop was attacked at different age ranging from few weeks to matured crop and even after harvesting whereby remnants of the harvested plants were found heavily infested with *P. xylostella*. Furlong *et al.* (2013) reported that, *P. xylostella* non-selectively infest the host crop as the larvae feed on leaves of their host from seedling to harvest, and greatly reduce yield and quality of the produce.

The high incidence of *P. xylostella* would also be attributed to cropping system, since higher population buildup of the pest were recorded in most fields that produce cabbage as a monocrop compared to mixed cropping. Similarly, Adati *et al.* (2011) reported lower *P. xylostella* larval and pupae densities when cabbage was intercropped with coriander compared to cabbage monoculture. Likewise, Karavina *et al.* (2014) reported that higher larval counts were observed in cabbage (*Brassica oleracea*) grown in monoculture than cabbage intercropped with garlic (*Allium sativum*). The low pest counts in intercropped fields could be more attributed to garlic's repellence effect which was comparatively effective to such insecticides like Malathion 25WP. Root (1973) hypothesized that, in an intercropping system the intercrop interferes with pest's host-finding ability, and decreases the attractiveness of the host plant to the insect. The interference includes physical obstruction, visual camouflage or alteration of host chemical profile (Issa *et al.*, 2016).

Crop diversification (mixed/intercropping) is an agricultural strategy that can be used to manage insect populations, susceptible plants may be supported by nearby host plants reducing density of the host plant and increasing the presence of natural enemies (Andow, 1991). The common perception in most research is that intercropping can reduce the incidence of *P. xylostella* in contrast to monocropping which encourages higher population buildup of the pest (Baumann *et al.*, 2000). Intercropping has a great potential for insect pest, disease reduction, and has been claimed internationally as most reliable approach to safeguard sustainable vegetable production and reducing pollution (Coolman and Hyot, 1993; Lithourgidis *et al.*, 2011).

Unfortunately, in most surveyed areas suggestively production of cruciferous crops for the market purpose is highly dependent on frequent application of pesticides which make it expensive to produce the crops, and as such safety of consumers' health and environment are usually compromised (Zaluchi *et al.*, 2012). Elsewhere, it has been reported that management of *P. xylostella* is mostly through application of a number of pesticides after every one week or more than twice a week (Furlong *et al.*, 2013) to ensure production of marketable heads.

2.6 Conclusion

The study established that *P. xylostella* is abundantly existent in Iringa and Morogoro regions wherever Brassicas are grown. Infestation with *P. xylostella* was about 60% suggesting that the pest is a main production constraint in the regions. Previously grown crop, production frequency and the type of variety had limited influence on the occurrence of *P. xylostella*. However, a significant positive relationship was observed between cropping system, crop growth age and the incidence of *P. xylostella*. The study provided knowledge on *P. xylostella* pest status and basis for identifying the factors influencing survival and perpetuation of the pest, which in turn will guide designing of effective management strategies.

2.7 Acknowledgement

I thank the Almighty God my maker and keeper for the precious gift of life and health. I would like to express special thanks to my supervisors Prof. G. M. Rwegasira for his encouragement, advice and intellectual input afforded to me towards the completion of this work.

My sincere gratitude goes to the USAID-funded project "East Africa Vegetable Crop Integrated Pest Management-Innovation Lab" which financially supported this research. I thank each and every one whom in way or the other contributed to the success of my MSc studies especially the staff of Department of Crop Science and Horticulture who encouragements to endeavor on my studies. I appreciate you all.

2.8 References

Abang, A. F., Kouamé, C. M., Abang, M., Hanna, R. and Fotso, A. K. (2014). Assessing vegetable farmer knowledge of diseases and insect pests of vegetable and management practices under tropical conditions. *International Journal of Vegetable Science* 20(3): 240-253.

Bailey, K. D. (1994). *Methods of Social Research.* (4th Ed.). Free Press. Collier Macmillan Publsher, New York. 96pp.

Bailey, K. D. (1998). *Methods of Social Science Research*. Free Press. Collier Macmillan Publisher, New York. 589pp.

Canico, A., Santos, L. and Massing, R. (2013). Development and adult longevity of diamondback moth and its parasitoids *Cotesia plutellae* and *Diadegma semiclausum in uncontrolled conditions*. *African Crop Science* 11: 257–262.

Chidawanyika, F., Mudavanhu, P. and Nyamukondiwa, C. (2012). Biologically based methods for pest management under changing climates: Challenges and future directions. *Journal Insects* 2012(3): 1171–1189.

Furlong, M. J., Wright, J. and Dosdall, L. M. (2013). Diamondback Moth Ecology and Management: Problems, Progress and Prospects. *Annual Review of Entomology* 58: 517–41.

Gadgil, D. and Dabas, Y. P. S. (2005). Effect of Socioeconomic Variables on the level of knowledge and training needs of livestock. *Kurukshetra* 55(4): 11-15.

Heong, K. L., Monina, E., Sengsoulivong, V. and Schiller, J. (2002). Insect management beliefs, and practices by rice farmers Laos. *Journal Agriculture Ecosystem and Environmen*t 92: 2-3.

Honest, M., Brighton, M. M. and Casper, N. (2016). Diamondback Moth, *Plutella xylostella* L. in Southern Africa: Research Trends, Challenges and Insights on

Sustainable Management Options. *International Journal of Pest Management* 2016: 1-8.

Jones, G. A. and Sieving, K. E. (2006). Intercropping sunflower in organic vegetables to augment bird predators of arthropods. *Journal of Agriculture, Ecosystems and Environment* 117(2-3): 171-177.

Kothari, C. R. (1993). *Research Methodology, Methods and Techniques*. US Johri for Wiley Eastern Limited. 288pp.

Motswari, O., David, M. and Matilo, B. (2008). Farmers knowledge, perception and management of vegetable pest in Botswana. *Journal of Crop Protection* 27(8): 1220-1224.

Munthali, D. C. (2009). Evaluation of cabbage varieties to cabbage aphid. *African Entomology* 17: 1-7.

Nachinuthu, K. (2002). Socioeconomic and Technological impact of animal husbandry programmes in Pondicherry. *Effectiveness of NGO-led Food Security Programmes in Bo District Southern Sierra Leone*, Unpublished MPhil Thesis, Njala University, Sierra Leone. 142-145pp.

Ngowi, A. V., Mbise, T. J., Ijani, A. S., London, L. and Ajayi, O. C. (2007). Pesticide use by smallholder farmers in vegetable production in Northern Tanzania. *Crop Protection* 26(11): 1617-1624.

Raney, T., Anríquez, G., Croppenstedt, A., Gerosa, S., Lowder, S., Matuschke, I. and Skoet, J. (2011). *The Role of Women in Agriculture* 20-45 pp.

Sarfraz, M., Dosdall, L. M. and Keddie, B. A. (2005). Biological control of the diamondback moth. *Bio control science and Technology* 16: 763-789.

Shakeel, M., Farooq, M., Nasim, W., Akram, W., Khan, A. F., Jaleel, W., Zhu, X., Yin, H., Li S., Fahad, S., Hussain, S., Chauhan, B. S. and Jin, F. (2017). Environment polluting conventional chemical control compared to an environmentally friendly

IPM approach for control of diamondback moth, *Plutella xylostella* (L.), in China: a review. *Environmental Science and Pollution Research* 24: 14537–14550.

Shelton, A. M. (2001). Management of the diamondback moth In: Endersby, N. M., Ridland, P. M. (eds.) *Proceedings of the fourth international workshop on the management on the diamondback moth and other crucifer pests*. Melbourne, Victoria, Australia. 3 – 8pp.

Sigh, S. (2003). Impact of farming Interventions implemented through Technology. *Assessment Refinement under IVLP of NDRI, Karnal,* Unpublished PhD Thesis, NDRI, Karnal. 37-42pp.

Talekar, N. S. and Shelton, A. M. (1993). Biology, ecology and management of the diamondback moth. *Annuals Review of Entomology* 38: 275 – 301.

Thompson, J. K. (2002). Yield evaluation of cabbage varieties. *Journal of Agriculture and Technology* 5: 15-21.

Uthamasamy, S., Kannan, M., Senguttuvan, K. and Jayprakash, S. (2015). Status, damage, potential and management of diamondback moth *Plutella xystella* (L); in *The* 6*Th* *International workshop on management of DBM and other crucifer insect pest (*Edited by Job, M). September 2015 Tanul Nadul India.

Vickers, R. A., Furlong, M. J., White, A. and Pell, J. K. (2004). Initiation of fungal epizootics in diamondback moth populations within large field cage: proof of concept of auto-dissemination. *Journal of Applied Entomology* 111: 1–17.

Wasim, A., Dwaipayan, S. and Ashim, C. (2009). Impact of pesticides use in agriculture: their benefits and hazards. *Journal of Interdisplinary Toxicology* 2(1): 1-12.

Zalucki, M. P., Shabbir, A., Silva, R., Adamson, D., Shu-shen, L. and Furlong, M. J. (2012). Estimating the Economic Cost of One of the World's Major Insect Pests, *Plutella xylostella* (Lepidoptera: Plutellidae). *Journal Economic Entomology* 105: 1115 – 1123.

CHAPTER THREE

3.0 EFFECT OF TIMING OF OVERHEAD IRRIGATION ON OCCURRENCE AND PERPETUATION OF *PLUTELLA XYLOSTELLA* ON CABBAGE CROP

To be submitted to the Journal of Insect Science

3.1 Abstract

Cabbage is among most important vegetables grown for income by smallholder farmers in Tanzania. Diamond Back Moth (*P. xylostella*) is the most devastating pest whose management solely depends on insecticides that put farmers' health and environment at risk. Interrupted mating through overhead irrigation has been reported to control the pest but the exact timing has never been established. The current study was aimed at bridging the knowledge gaps. A two factors Split plot experiment involving (*Brassica rapa* and *Brassica oleraceae var. capitate*) as main factor and timing of irrigation (T1 (5 pm), T2 (6 pm), T3 (7 pm) and phosphorothioate insecticide (applied at 2 ml/L) as sub-plots was laid out in a Randomized Complete Block Design (RCBD) with three replications. The control treatment recorded significantly lower counts of larvae (1.63), adults (1.46) and damage scores (2.07) compare to irrigated treatment where T1 (1.83 larvae, 1.6 adults, 3.01 damage score), T2 (1.81 larvae, 1.64 adults, 3.22 damage score) and T3 (1.8 larvae, 1.64 adults, 3.07 damage score) were recorded. There were no significant difference among treatments applied at different time suggesting that sprinkler irrigation can be applied at any time in the evening (from 5 – 7 pm) to interrupt mating of *P. xylostella* adults or wash away eggs soon after being laid. Further studies should be target to determine the actual water pressure that would impact and significantly cause mortality of *P. xylostella*.

Key words: Overhead irrigation, Damage score, Population, Vegetables, Insect Pests, Pest management, insecticides

3.2 Introduction

Diamond Back Moth (*Plutella xylostella* L; Lepidoptera: Plutellidae) has been a pest of economic importance to cabbage respondents, its population vary with environmental condition and treatments, together with other pest Diamond Back Moth (DBM) has made cabbage production to depend on higher pesticide spray incidences, in most cases more than three sprays per week in order to harvest marketable heads. These pesticides are expensive and have a negative impact on human, other organisms and environment (Furlong *et al.,* 2012). Another impact is increase of production cost and risk of occurrence of resistant strains (Huang *et al.,* 2010).

The pest constitutes an important threat for food supply because it can cause yield loss higher than 90% (Safraz *et al.,* 2005). *Plutella xylostella* is a problem in the tropical and subtropical countries where cabbage is grown all year round. Weather conditions suitable for brassicas are also highly favorable to its biological development coupled with high reproduction rate which results in more than 20 generations per year (Vickers *et al.,* 2004).

Because of the negative consequences related to pesticides, alternative control methods are needed. Among them, the biological control methods which constitutes among the efficient methods for the control of *P. xylostella* larvae population (Sarfraz *et al*., 2005). Another way is cultural control by disrupting mating through overhead irrigation. Sprinkling water overhead (overhead irrigation) exerts limits on *P. xylostella* population build up as they cause physical disruption of mating and egg laying activities. Eggs and larvae can also be damaged when washed off the leaf surface, resulting in mortality in most instances (Mahmood, 2005).

Despite the general understanding of the effect of sprinkler irrigation on *P. xylostella* population, the knowledge on the exact timing of irrigation was inexistent. Whether should be applied during early or late evening hours, the specifics were unknown. According to Talekar and Shelton (1993), the sprinkler systems could manage to reduce the amount of damage on crops but are not sustainable for conventional or organic farming in brassicas in temperate climate due to costs and the risk of fungal infections. Thus suitability of the sprinkler for management of *P. xylostella* would be considered alongside assessments of the incidences of fungal diseases on the crop.

The present study was conducted to fix such knowledge gaps. It aimed at determining the effectiveness of the sprinkler irrigation against the pest, determine the correct timing for application of the irrigation and assess the attainable yield subject to damages inflicted by *P. xylostella*. Here we report the outcome of the study which basically has shaded lights on the influence of timing of irrigation on magnitude of damages inflicted by the pest of brassicas.

3.3 Material and Methods

3.3.1 Description of the study area

This study was conducted under field conditions at the horticulture unit of Sokoine University of Agriculture in experimental plots from August to November, 2018. SUA is located at latitudes 06°50’41.478”S, longitudes 37°39’43.476”E and 523 m above sea level. The region falls within the coastal zone which experiences a tropical climate, the temperature here averages 23.4°C in September and 26°C in november and annual rainfall averages 935 mm. Humidity is often around 96% in the morning and 67% in the afternoons.

3.3.2 Experimental design

The study was laid out as a Split plot experiment arranged in a Randomized Complete Block Design (RCBD) with three replications. Main-plot consisted of two Brassica spp namely; Chinese cabbage (*Brassica rapa*) and Head cabbage (*Brassica oleraceae var. capitata*) while, Sub-plot consisted of three time intervals for sprinkler irrigation namely; T1 (5 pm), T2 (6 pm), T3 (7 pm) and Control (plants treated with insecticide i.a phosphorothioate (2 ml/L) and irrigated using watering can). Treatments were applied daily in overhead irrigation plots in their respective times by using multiple channel sprinkler systems and Phosphorothioate (50W) was applied weekly on control plots at a rate of 2 ml/L. Plots were made of equal size (1.0 m x 3.0 m) with a 2 meter space between the plots. The seedlings were transplanted at different spacing for Chinese cabbage (45 cm x 30 cm) and Head cabbage (60 cm x 45 cm). A total of 10 plants were transplanted per experimental unit for Head cabbage and14 plants for Chinese cabbage.

3.3.3 Experimental materials and management

Seedlings of Chinese cabbage (*Brassica rapa*) and Head cabbage (*Brassica oleraceae var. capitata*) were transplanted into the well irrigated field. Both crops were transplanted simultaneously on 6 August 2018. A recommended rate (5 g) of Diammonium Phosphate fertilizer (DAP) was enriched in each hole during transplanting. Top dressings of straight fertilizer UREA (46-0-0) was applied one week after transplanting at a rate of 5 g per plant. Sprinkler irrigation at water pressure of 30 psi was applied during growing period to replace water lost through evapotranspiration. Weeds were manually controlled by hand pulling and hand hoe on weekly basis.

3.4 Data Collection

Data on *P. xylostella* adult counts, DBM larvae count and yield were collected. Assessment of insects was done by visual examination of the entire plants aided by a hand lens (Lal, 1998). Yield data were collected at harvesting by taking counts and weight of harvested crops from each treatment.

3.5 Statistical Analysis

Data collected was subjected to Analysis of variance (ANOVA) and when significant differences exist ($p < 0.05$), Least Significant Difference Test (LSD; $p = 0.05$) was used as a means separation procedure. All statistical analysis was performed using Genstat v.16 Statistical package (VSN International). In addition, Regression (R^2) analysis was performed using MS-Excel v.16 software to determine the relationship between *P. xylostella* life stages, damage and crop yield. The statistical model considered in analyzing the obtained data is presented below:

$$X_{ijk} = \bar{X} + M_i + B_j + d_{ij} + S_k = (MS)_{ik} + e_{ijk} \quad \text{.........................(1)}$$

X_{ijk} = an observation

$\bar{X}$ = the experiment mean

M_i = the main plot treatment effect

B_j = the block effect

d_{ij} = the main plot error (error a)

S_k = the subplot treatment effect

$(MS)_{ik}$ = the main plot and subplot treatment interaction effect

e_{ijk} = the subplot error (error b)

i = a particular main plot treatment

j = a particular block

k = a particular subplot treatment

3.6 Results

3.6.1 Effects of crop type and irrigation time on population of *P. xylostella* larvae

The crop type had no significant (LSD = 0.05, $p = 0.143$) effect on *P. xylostella* larvae population (Table 3.1). On the other hand, irrigation time had a significant (LSD = 0.07, $p < 0.001$) influence on *P. xylostella* larvae population. Control (treated with phosphorothioate recorded significantly lower (1.63) larvae count than at irrigation time (7 pm) with 1.80 larvae, followed by irrigation time (6 pm) with 1.806 larvae and irrigation time (5 pm) with 1.83 larvae.

3.6.2 Effects of crop type and irrigation time on population of adult *P. xylostella*

The crop type had no significant (LSD = 0.05, $p = 0.468$) *P. xylostella* adult population (Table 3.1). On the other hand, irrigation time had a significant (LSD = 0.07, $p < 0.001$) influence on *P. xylostella* adult population. The control (treated with phosphorothioate) recorded significantly lower (1.46) adults count than at irrigation time (5 pm) with 1.602 adults, followed by irrigation time (7 pm) with 1.64 adults and irrigation time (6 pm) with 1.64 adults.

3.6.3 Effects of crop type and irrigation time on *P. xylostella* damage score

The crop type had no significant (LSD = 0.15, $p = 0.453$) *P. xylostella* damage score (Table 3.1). On the other hand, irrigation time had a significant (LSD = 0.22, $p < 0.001$) influence on *P. xylostella* damage score. Control (treated with phosphorothioate recorded significantly lower (2.07) damage score than at irrigation time (5 pm) with 3.01 damage score, followed by irrigation time (7 pm) with 3.07 damage score and irrigation time (6 pm) with 3.22 damage score.

3.6.4 Effects of crop type and irrigation time on crop yield

The crop type had a significant (LSD = 88.6, $p < 0.001$) effect on yield (Table 3.1). Chinese cabbage recorded higher yield (578 kg Ha^{-1}) than Head cabbage (461 kg Ha^{-1}). On the other hand, irrigation time had no significant (LSD = 125.3, $p = 0.873$) influence on crop yield. Nevertheless, irrigation time (5 pm) recorded higher yield (531.2 kg Ha^{-1}) compared to Control (528.6 kg Ha^{-1}).

Table 3.1: **Effect of crop type and timing of irrigation on *P. xylostella* life stages, damage and crop yield**

Factor A: Crop type	**DBM larvae**	**Adult DBM**	**Damage score**	**Yield**
Cabbage	1.8	1.6	2.9	461.0
Chinese	1.7	1.6	2.8	578.0
Grand mean	1.8	1.6	2.8	519.0
SE±	0.02	0.02	0.05	29.6
CV%	5.4	9.0	9.8	24.9
L.S.D(0.005)	0.05	0.05	0.15	88.6
p-value	0.143	0.468	0.453	0.013
Factor B: Treatments (irrigation time)				
T1 (5 pm)	1.833b	1.602b	3.014b	528.2a
T2 (6 pm)	1.806b	1.644b	3.218b	531.2a
T3 (7 pm)	1.801b	1.644b	3.074b	489.2a
Control (insecticide)	1.634a	1.463a	2.065a	528.6a
Grand mean	1.8	1.6	2.8	519
SE±	0.02	0.02	0.07	41.8
CV%	5.4	9.0	9.8	24.9
L.S.D(0.005)	0.07	0.07	0.22	125.3
p-value	<0.001	<0.001	<0.001	0.873
Interaction (A x B)				
Cabbage x T1	1.861c	1.63ab	3.065b	471.9a
Cabbage x T2	1.833c	1.648b	3.231b	492.6a
Cabbage x T3	1.815c	1.667b	3.083b	424.6a
Cabbage x Control (insecticide)	1.667ab	1.444a	2.102a	455a
Chinese x T1	1.806c	1.574ab	2.963b	584.6a
Chinese x T2	1.778bc	1.639ab	3.204b	569.9a
Chinese x T3	1.787bc	1.62ab	3.065b	553.9a
Chinese x Control (insecticide)	1.602a	1.481ab	2.028a	602.2a
Grand mean	1.8	1.6	2.8	519
SE±	0.03	0.04	0.10	59.1
CV%	5.4	9.0	9.8	24.9
L.S.D(0.005)	0.1	0.11	0.31	177.3
p-value	0.504	0.559	0.973	0.943

Means followed by same letter(s) within a column are not significantly different according to LSD = Least Significant Difference, SE± = Standard error on means, CV = Coefficient of variation.

3.6.5 Interaction effects of crop type and irrigation time on population of *P. xylostella* larvae

The crop type-irrigation time interaction had no significant (df = 3, p = 0.504) influence on *P. xylostella* larvae population (Table 3.1). Nevertheless, higher *P. xylostella* larvae count was recorded on Head Cabbage x irrigation time-T1 (5 pm) with 1.86 larvae and Chinese cabbage x irrigation time-T3 (7 pm) with 1.82 larvae compared to Control-Head Cabbage treated with phosphorothioate (1.67 larvae) and Control-Chinese cabbage treated with phosphorothioate (1.60 larvae).

3.6.6 Interaction effects of crop type and irrigation time on population of adult *P. xylostella*

The crop type-irrigation time interaction had no significant (df = 3, p = 0.559) influence on *P. xylostella* adult population (Table 3.1). However, higher *P. xylostella* adult count was recorded on Head Cabbage x irrigation time-T3 (7 pm) with 1.67 adults and Head Cabbage x irrigation time-T2 (6 pm) with 1.65 adults compared to Control-Head Cabbage treated with phosphorothioate (1.44 adults). On the other hand, Chinese cabbage x irrigation time-T2 (6 pm) had higher *P. xylostella* adult count (1.64) than Control-Chinese cabbage treated with phosphorothioate (2 ml/L) (1.48 adults).

3.6.7 Interaction effects of crop type and irrigation time on *P. xylostella* damage

The crop type-irrigation time interaction had no significant (df = 3, p = 0.973) influence on *P. xylostella* damage score (Table 3.1). Nevertheless, higher *P. xylostella* damage scores was recorded on both Head Cabbage and Chinese cabbage x irrigation time-T2 (6 pm) with 3.2 damage score compared to Control-Head Cabbage treated with Phosphorothioate (2.1 score) and Control-Chinese cabbage treated with Phosphorothioate (2.0 score).

3.6.8 Interaction effects of crop type and irrigation time on crop yield

The interaction between crop type and irrigation time had no significant (df = 3, p = 0.943) influence on yield (Table 3.1). However, Control-Chinese cabbage treated with Phosphorothioate had higher yield (602.2 kg Ha^{-1}) followed by Chinese cabbage x irrigation time-T1 (5 pm) with 584.6 kg Ha^{-1}, Chinese cabbage x irrigation time-T2 (6 pm) with 569.9 kg Ha^{-1}, and Chinese cabbage x irrigation time-T3 (7 pm) with 553.9 kg Ha^{-1}. On the other hand, Head Cabbage x irrigation time-T2 (6 pm) had higher yield (492.6 kg Ha^{-1}) compared to Control-Head Cabbage treated with Phosphorothioate (455 kg Ha^{-1}).

3.6.9 Relationship between *P. xylostella* larvae, adults and damage

The results (Fig. 3.1) indicate that, *P. xylostella* larvae counts had an influence on adults count and damage score. There was a significant relationship between larvae counts and damage score for Head cabbage (R^2 = 0.42, p = 2.23 x 10^{-5}) and Chinese cabbage (R^2 = 0.43, p = 1.22 x 10^{-5}).

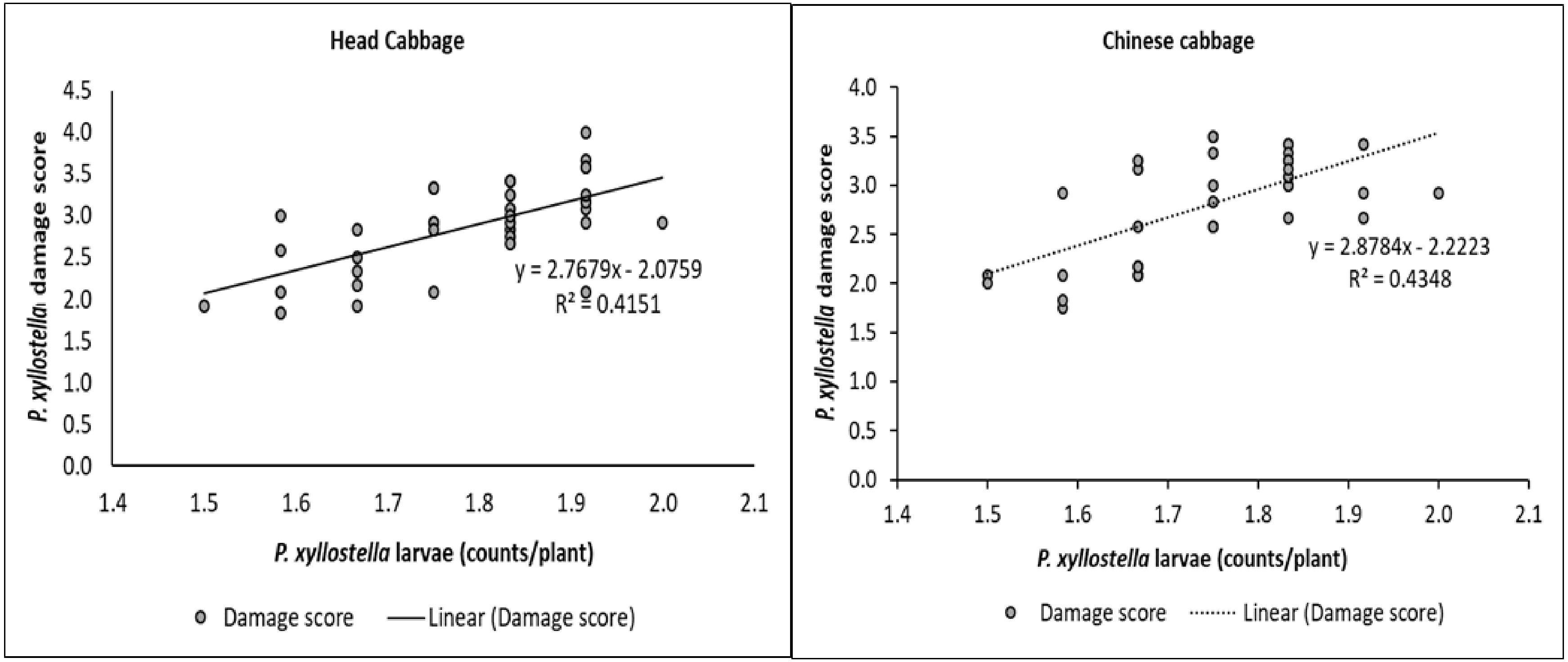

Figure 3.1: **Relationship between *P. xylostella* larvae and damage**

3.7 Discussion

The study revealed that, insecticide application (Control) significantly minimized *P. xylostella* effects on brassicas, particularly reducing the pest's life stages (larvae, adults) and damage than that attained using sprinkler irrigation at varied application time. Insecticide such as phosphorothioate utilized in this study is one among the most effective insecticides hence killed most larvae and adults form of the pest. Suggestively, spraying of crops with insecticides is going to continue to play an important role in managing the *P. xylostella* because of its effectiveness when used correctly despite the unwanted side effects (Faithipour and Mirhossein, 2017). But, there's still an increasing demand for spray products that are more selective, and can highly preserve the natural enemies (Furlong, 2013).

Despite the performance of insecticide application in contrary to sprinkler irrigation, there was still potentiality of irrigation time with respect to sprinkler irrigation. The results showed that, overhead irrigation decreased *P. xylostella* adults and larvae population, hence there would not be any difference in their population even if irrigation was done at either T1 (5 pm), T2 (6 pm) or T3 (7 pm). A similar study conducted by Mchugh and Foster (1995) suggested that when sprinkler irrigation is applied on *Brassica spp*, the population of *P. xylostella* tend to decrease by 37.5 to 63.9 %. The observed effects of sprinkler irrigation on *P. xylostella* may be attributed to the physical disruption of flying activity, oviposition, and wash-off of larvae and adults (Kenneth *et al.*, 2016).

The lack of variation in number of *P. xylostella* larvae recorded in brassicas under sprinkler irrigation at T1 (5 pm), T2 (6 pm) and T3 (7 pm) indicates that, the larvae are not nocturnal. According to Aur'elio *et al.* (2000) the larvae may be present on the host plant and at any time when sprinkler irrigation was applied they will be washed away. The eggs will also be washed away and won't hatch into larvae, therefore their population will tend to go down regardless of the time the crops were irrigated.

Previous studies showed sprinkler irrigation as alternative control of the *P. xylostella* on cabbage (*Brassica oleraceae* var. *capitata*). When sprinklers were frequently on at dusk in three to four weeks, the system managed to reduce the amount of cabbage damage (Talekar and Shelton, 1993). Nevertheless, information on the significance of sprinkler irrigation on *P. xylostella* in Chinese cabbage (*Brassica rapa*) is scanty. Sprinkler irrigation reduced population of *P. xylostella* larvae by disrupting mating of adults and due to its ability to washed away eggs and larvae from adaxial and abaxial parts of the leaf (John and McHugh, 1995). Overhead watering also decreased codling moths' flight, oviposition, egg and larval survival (Yaghoub *et al.*, 2017).

Other studies have suggested that, any form of overhead irrigation be it rain or even sprinkler irrigation can disrupt the flying of the adults and thus hamper their movement, including possibly oviposition, and this also limits infestation. Moreover, *P. xylostella* is sensitive to abiotic stress and rainfall is a big mortality factor. It can disrupt the *P. xylostella* from flight but also dislodge the larva from the plant. The larvae of this pest are a surface feeder and is frequently washed away or drowned in the cavity created as a result of its peculiar feeding habit (Mahmood, 2005). This is further supported by the fact that in a year 1980, when Taiwan experienced severe drought, *Plutella xylostella* was present throughout the year. In Canada, it has also been reported that rainfall is a major mortality factor in the population dynamics of *P. xylostella* (Zalucki *et al.*, 2012). The study by Lilian *et al.* (2016) suggested that, the immature stages of *P. xylostella* are very susceptible to drowning and are easily washed out of the plant during rain and overhead irrigation.

The significant variation in yield between Chinese and Head cabbage is likely due to the fact that, Head cabbage is mostly preferred host thus lower yield than Chinese cabbage. *P. xylostella* food preference revealed that, its larvae preferred Head cabbage leaves likely due to fleshly and succulent leaves than the rest of Brassica species including Chinese cabbage (Uthamasamy *et al.,* 2015). Studies show that, *P. xylostella* larvae feed on Head cabbage leaves from seedling to harvest, thus greatly reduce yield and quality of produce (Furlong *et al.,* 2013). Both Chinese and Head cabbage under sprinkler irrigation applied at varied time intervals showed no significant difference in their yield. The sprinkler irrigation system played a significant role in several ways to increase crop yield. The frequent sprinkler irrigation kept the soil moist in most of the time providing adequate moisture all the time and makes plant feeding from the soil easy and therefore improved yield (Asrey *et al*., 2018).

3.8 Conclusion

Insecticide application significantly minimized counts of *P. xylostella* larvae and adults subsequently reducing damages on brassica crops compared to overhead irrigation. Nevertheless, sprinkler irrigation had a noticeable effect on the pest although significantly lower than the insecticide. The study revealed further that the impact of irrigation water on *P. xylostella* was not varied with respect to timing of water application. Thus, irrigation to interrupt mating and wash down eggs can be applied at any time in the late evening (5 – 7 pm). The obtained results suggests the need for further investigation on Integrated Pest Management options to minimizing reliance on insecticides and allow production of quality produce for the market.

3.9 Acknowledgement

I thank the Almighty God my maker and keeper for the precious gift of life and health. I would like to express special thanks to my supervisors Prof. G. M. Rwegasira for his encouragement, advice and intellectual input afforded to me towards the completion of this work.

My sincere gratitude goes to the USAID-funded project "East Africa Vegetable Crop Integrated Pest Management-Innovation Lab" which financially supported this research. I thank each and every one whom in way or the other contributed to the success of my MSc studies especially the staff of Department of Crop Science and Horticulture who encouragements to endeavor on my studies. I appreciate you all.

3.10 References

Aurélio, T. O., Ana Maria, R., Junqueira , F. and Humberto, F. (2000). Impact of sprinkler irrigation on diamondback moth injuries on cabbage plants. *Horticultura Brasileira* 18: 7-40.

Fathipour, Y. and Mirhossein, M. A. (2017). Diamond back Moth (*Plutella xylostella*) Management. *Journal Integrated Management of Insect Pest on Canolla and other Brassica Oil Seed Crops* 3: 34-45.

Furlong, M. J., Wright, D. J. and Dosdall, L. M. (2013). Diamondback Moth Ecology and Management: Problems, Progress, and Prospects. *Annual Review of Entomology* 2013: 120811-153605.

Furlong, M. J., Wright, J. and Dosdall, L. M. (2012). Diamondback Moth Ecology and Management: Problems, Progress and Prospects. *Annual Review of Entomology* 58: 517–41.

John, J. and McHugh, R. J. (1995). Reduction of Diamondback Moth (Lepidoptera: Plutellidae) Infestation in Head Cabbage by Overhead Irrigation. *Journal of Economic Entomology* 88: 43-49.

Jones, G. A. and Sieving, K. E. (2006). Intercropping sunflower in organic vegetables to augment bird predators of arthropods. *Agriculture, Ecosystems and Environment* 117(2-3): 171-177.

Kenneth, A. S., Mohankumar, S. and Sona, R. T. (2016). Physical, mechanical and cultural control of vegetable Insects. *Journal of Applied Entomology* 131: 5–27.

Lal, O. P. (1998). Notes summer school on *Advance Technologies in Important Vegetables Crops, including Cole Crops,* May 4-24, IARI, New Delhi. pp. 63-66.

Lilian, F. M., Natalia, C. T., Nathalia, S. and Wellington, G. (2016). Diamond back moth performance and preference for leaves of *Brassica oleracea* of different ages and strata. *Journal Applied Entomology* 5: 54-59.

Mahmood, P. (2005). Biology and Ecology of Diamondback moth (*Plutella xylostella). A review of its biology and Ecology.* pp 22-31.

McHugh, J. J. and Foster, E. R. (1995). Reduction of Diamondback moth (Lepidoptera: Plutellidae) infestation in Head cabbage by overhead irrigation. *Journal of Economic Entomology* 88: 162-168.

Sarfraz, M., Dosdall, L. M. and Keddie, B. A. (2005). Spinosad: a promising tool for integrated pest management. *Outlooks Pest Management* 16: 78-84.

Sarfraz, M., Keddie, B. and Dosdall, L. (2005). Biological control of Diamondback moth. *Biocontrol Science and Technology* 15: 763-789.

Tabashrunk, B. F. and Mau, R. (1986). Suspension of Diamond back Moth Oviposition by overhead irrigation. *Journal of Economic Entomology* 79: 67-78.

Talekar, N. S. and Shelton, A. M. (1993). Biology, ecology, and management of the Diamondback moth. *Journal Article in Agriculture Science* 38: 275-301.

Uthamasamy, S., Kannan, M., Senguttuvan, K. and Jayprakash, S. (2015). Status, Damage, Potential and Management of Diamondback Moth, *Plutella xystella* (L); in *The* 6*Th* *International workshop on management of DBM and other crucifer insect pest* (Edited by Job M) . September 2015 Tanul Nadul India.

Vickers, R. A., Furlong, M. J., White, A. and Pell, J. K. (2004). Initiation of fungal epizootics in diamondback moth populations within large field cage: proof of concept of auto-dissemination. *Journal of Applied Entomology* 111: 1–17.

Yaghoub, R., Hajar, V. and Kazem, G. (2017). The impact of seed priming and integrated plant nutrition on yield components of black mustard. *Journal of Biodiversity and Environmental Sciences* 2017: 1-9.

Zalucki, M. P., Shabbir, A., Silva, R., Adamson, D., Liu, S. S. and Furlong, M. J. (2012) Estimating the economic cost of one of the world's major insect pests, Plutella xylostella. *Journal of Economic Entomology* 105: 1115–1129.

CHAPTER FOUR

4.0 GENERAL CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The survey study, established that *P. xylostella* is abundantly existent in Iringa and Morogoro regions wherever Brassicas are grown. The study demonstrates the pest status and spatial distribution of *P. xylostella* in farmers' fields in Iringa and Morogoro regions of Tanzania. It also provides a baseline for identifying the factors influencing survival and perpetuation of the pest, which in turn will allow effective management strategy to be designated. Based on field experiment, insecticide application significantly minimized *P. xylostella* effects on brassicas, particularly reducing the pest's life stages (larvae, adults) and damage than that attained using sprinkler irrigation at varied application time. However, sprinkler irrigation had a promising control against *P. xylostella* adults.

4.2 Recommendations

In current study insecticide application proved to be superior to sprinkler irrigation in suppressing *P. xylostella* but there was no significant difference in obtained yield. Since the yield obtained was in terms of weight, further studies should assess the quality of obtained yield in relation to the market price to guide informed decision.

Moreover it is recommended that future studies should seek to establish water pressure that would be adequate to force the *P. xylostella* eggs and larvae to dislodge from brassica leaves.

APPENDICES

Appendix 1: Questionnaire for *Plutella xylostella* pest status

Name of interviewer……….

Name of respondent……….. Age …… Sex………

Region……Division…….Ward…….

GPS …………..……….. M above sea level

Name of crop…………. Variety………. Age of crop……….

Cropping system (1/2)…………. Cropping frequency (1/2/3)……..

Farm size ………………..

SN	Plant Observed	Damage score	Insect found	Recommendation
1				
2				
3				
4				
50				

Do you experience *Plutella xylostella* in your field YES/NO……

At what season do you experience *Plutella xylostella* the most….

How do Plutella xylostella affect your crop.………………

At what cropping stage *is Plutella xylostella* the problem….

How do you control *Plutella xylostella.………………………………*

Which crop is highly affected among the *brassica.……….*

What is the damage sign caused by *Plutella xylostella.………*

Are damaged crops marketable (YES/NO) ……… (If yes)Which type of market…

If No what do you do to the damaged crop.…………

Have you heard about IPM………………

What do you know about IPM……………

What do you have to say about this pest………..

What do you think can be done to reduce its effects…….

Appendix 2: Analysis of variance for crop yield

Source of variation	d.f.	s.s.	m.s.	v.r.	P
Crop type x Treatments x Replication stratum					
Crop type	1	244825.	244825.	7.78	0.013
Treatments	3	21827.	7276.	0.23	0.873
Crop type x Treatments	3	11942.	3981.	0.13	0.943
Residual	16	503389.	31462.	1.88	
Crop type x Treatments x Replication *Units* stratum					
	48	804192.	16754.		
Total	71	1586175.			

Appendix 3: Analysis of variance for DBM larvae

Source of variation	d.f.	s.s.	m.s.	v.r.	p
Crop type x Treatments x Replication stratum					
Crop type	1	0.024691	0.024691	2.37	0.143
Treatments	3	0.443673	0.147891	14.20	<0.001
Crop type x Treatments	3	0.025463	0.008488	0.81	0.504
Residual	16	0.166667	0.010417	1.14	
Crop type x Treatments x Replication*Units* stratum					
	48	0.439815	0.009163		
Total	71	1.100309			

Appendix 4: Analysis of variance for adult DBM

Source of variation	d.f.	s.s.	m.s.	v.r.	p
Crop type x Treatments x Replication stratum					
Crop type	1	0.00617	0.00617	0.55	0.468
Treatments	3	0.39583	0.13194	11.79	<0.001
Crop type x Treatments	3	0.02392	0.00797	0.71	0.559
Residual	16	0.17901	0.01119	0.55	
Crop type x Treatments x Replication *Units* stratum					
	48	0.97685	0.02035		
Total 71 1.58179					

Appendix 5: Analysis of variance for damage score

Source of variation	d.f.	s.s.	m.s.	v.r.	p
Crop type x Treatments x Replication stratum					
Crop type	1	0.05556	0.05556	0.59	0.453
Treatments	3	14.91281	4.97094	53.02	<0.001
Crop type x Treatments	3	0.02083	0.00694	0.07	0.973
Residual	16	1.50000	0.09375	1.21	
Crop type x Treatments x Replication *Units* stratum					
	48	3.72685	0.07764		
Total	71	20.21605			