Research Article

INTEGRATED MANAGEMENT PROTOCOL FOR NEW ZEALAND ENDEMIC WHEAT BUG (*Nysius huttoni*) IN FORAGE BRASSICAS

S. Tiwari[1]*, N. Dickinson[2] and S. D. Wratten[3]
[1] Agriculture and Forestry University, Rampur, Chitwan,, Nepal
[2] Department of Pest Management and Conservation, Lincoln University, New Zealand
[3] Bio-Protection Research Centre, Lincoln University, New Zealand

*Corresponding author: stiwari@afu.edu.np

ABSTRACT

Wheat bug, *Nysius huttoni,* is considered as an economic pest of forage Brassicas and many other cultivated crops, such as wheat, kale, and vegetables in New Zealand. Insecticides- as seed coatings and sprays are frequently used to manage this pest, but a high proportion of these insecticidal compounds enter the soil and leads to pesticide resistance, and they may impact beneficial arthropods and soil microorganisms, creating an adverse effect on ecosystem services (ES). In this paper, we discuss a technology, that we have developed to trap , for example, wheat bug away from kale seedlings, and integrating these in less suceptible kale cultivars that can potentially reduce over-reliance on orthodox pesticides on brassicas. Laboratory studies were conducted to screen the suitable trap crop among nine other plants (alyssum, wheat, phacelia, buckwheat, coriander, white clover, alfalfa, and kale) mainly by considering growth stages (vegetative and flowering), and select less susceptible kale cultivars among six other (Kestrel, Gruner, Sovereign, Regal, Corka and Colear). Alyssum (*Lobularia maritima*) and wheat (*Triticum aestivum*) were the most favoured potential trap plants for the wheat bug in a laboraotry study. Flowering stage of alyssum is the most susceptible growth stage by the bug damage. Kestrel and Coleor are the most popular kale cultivars used as forage brassicas in New Zealand, but they are the most susceptible to the wheat bug. Corka and Regal were the least susceptible cultivars. The integration of trap cropping technology by using alyssum as the trap crop, preferably depolying flowering stage, along with sowing less susceptible kale cultivars such as Corka and Regal in main fields have been suggested to protect brassica seedlings from bug damage.

Key words: Economic pest, pesticide resistance, trap cropping, *Lobularia maritima*,

INTRODUCTION

Wheat bug, *N. huttoni*, is a New Zealand endemic insect (Eyles, 1960) widely distributed in the North and South Islands (Myers, 1926). Nymphs and adults feed on at least 75 plant species belonging to > 25 plant families including vegetables, cereals, forage brassicas, and many weeds (He et al., 2003). *Nysius huttoni* damages wheat grains during the milk-ripe stage by piercing through the glumes into the developing grains, which reduces the gluten protein so as the baking quality (Every et al., 1998). Brassica seedlings are readily attacked by this pest (Eyles, 1965). The damage potentially ranges up to 70 - 90 % (AgPest, 2016). In New Zealand, conventional pesticides are common for pest and disease management in forage brassicas (Trevor, 2010). Hence, investigating a sustainable pest management approach to avoid environmental, economic, and social problems of pesticides is duly valued. An agro-ecological management approach, such as use of trap cropping, deploying in their appropriate growth stages and integrating them into less susceptible kale cultivars could be an option of sustainable wheat bug management. Growing one or more trap plant species adjacent to or within the main crop, and at farm, or landscape scales (Landis et al., 2000) can reduce the pest population density in the main crop (Shelton & Nault, 2004). Hokkanen (1991) and Shelton & Badenes-Perez (2006) confirmed that trap cropping had the potential to manage the pests in field crops. The idea was such that when pests used the trap crops, the main crops would be protected from this pest (Hokkanen, 1991).

The use of a trap plant in Brassica fields along with the use of less susceptible kale cultivars, and encouraging farmers to integrate these with other Integrated Pest management (IPM) strategies, such as biological, mechanical control, and the use of ‘soft’ chemicals, can reduce pest pressure and pesticide use (Horrocks et al., 2018). A pest management protocol can be developed using the two kale cultivars in a ‘push-pull’ pest management strategy (Khan et al., 2001). First, deployment of highly susceptible kale cultivars at field edges can attract (‘pull’) the bugs from the main crop, and prevent bugs from entering the main field from outside the field boundary. Low preference kale cultivars in a main field can protect the bugs from landing, which works as a ‘push’ component. Secondly, the use of potential trap crops such as alyssum (*Lobularia maritima,* or wheat (*Triticum aestivum*) at field edges works as a ‘pull’ component and the less susceptible kale cultivars in the main field act as a ‘push’ component to keep *N. huttoni* away from the main crop. These agro-ecological approaches to IPM can be used to develop a pest management protocol and can be used to manage other similar pests.

MATERIAL AND METHODS

Treatments preparation for laboratory bioassay

Choice and no-choice experiments were established to select the potential trap crops of wheat bugs; select the most suitable growth stages of potential trap plant as well as to select the potential kale cultivars. The potential trap plants- considering various crop growth stages, along with different kale cultivars were maintained in a glasshouse with a temperature range of 18 ^{0}C (night) to 30 ^{0}C (day), and 40 % relative humidity (RH). Treatment plants were grown in potting mix (400-litre composted bark, 100-litre pumice [1.0 – 7.0 mm], 1500 g Osmocote [3 - to 4 - month release], 500 g horticultural lime, 500 g Hydraflo) in a glasshouse and transferred them to a controlled temperature (CT) room (temperature 22 ^{0}C, photoperiod 16L: 8D h, and 60 ± 10 % RH) for laboratory bioassay.

Twenty-five newly emerged *N. huttoni* adults from laboratory colony for each test were released in the centre of a plant pot which was covered by a cylindrical sleeve. All *N. huttoni* were starved for 12 h before the release into the study arena. The study comprised a randomized block design, with 10 replicates for choice and no-choice in preference host plant study; 14 replicates for the no-choice tests, and 12 replicates for the choice tests in preference of growth stages study, and 10 replicates in both choice and no-choice tests in preference of kale cultivars study.

Data recording and statistical analysis

In preference of host plant by wheat bugs study, numbers of bugs were recorded over 120 hours in both choice and no-choice conditions. Similarly, numbers of bugs were recorded over 261 h in crop growth stages study and over 216 h in kale cultivar preference study. Survival rate at 261 h (no-choice tests only) were also quantified in crop growth stages study. At the completion of the assay in kale preference trial, the dry weights of the seedlings including roots were measured and the percentage weight change calculated. The percentage reduction in plant dry weight was compared with the control.

Data were subjected to analysis of variance (ANOVA), using the GenStat statistical package (GenStat 16, VSN International, Hemel Hempstead, Hertfordshire HP1 1ES, United Kingdom), to test the effect of plant species on the number of bugs recorded on each treatment in each experiment. The mean numbers recorded at different time intervals were integrated over time period by the area under the curve (AUC) method (Hanley and McNeil, 1983). Count data were normalised in terms of distribution, by using a square root (√) transformation. After normality checking, data were subjected to two-way (treatments and blocks) analysis of variance (ANOVA), and means were separated by employing unprotected least significance difference (LSD) at $p < 0.05$ (Saville, 2015).

RESULTS AND DISCUSSION

Preference of host plants by *N. huttoni* in laboratory The numbers of *Nysius* in choice test observed over 120 h varied significantly between plant species ($p < 0.001$) tests. The number of individuals on wheat was significantly higher than on phacelia, lucerne, kale, coriander, and clover. Kale and lucerne were statistically similar ($p > 0.05$), but each was significantly higher ($p < 0.05$) than clover and coriander (Figure 1).

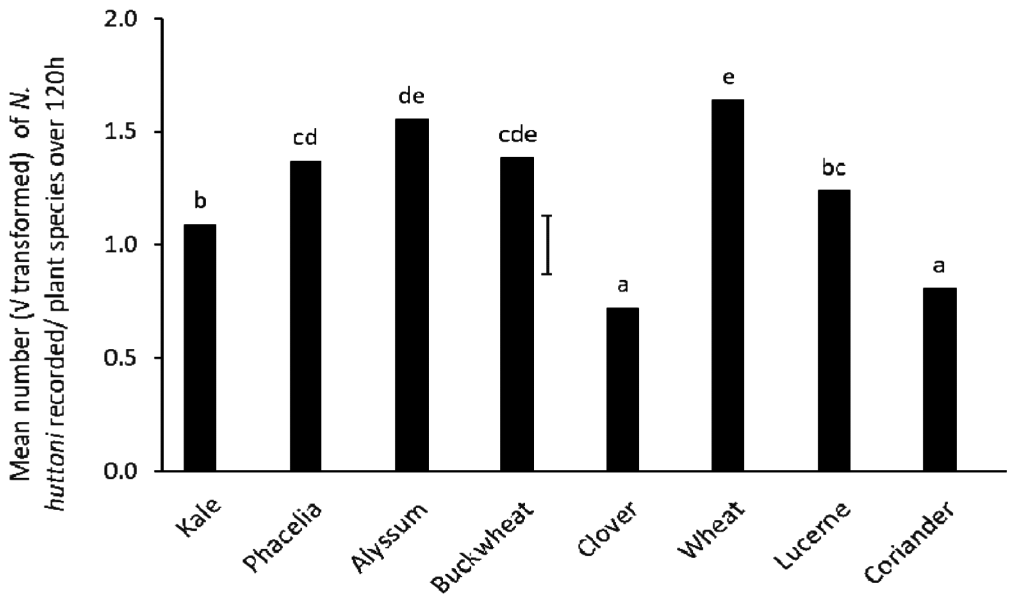

Figure 1. Choice tests. Mean numbers (√ transformed) over 120 h of *Nysius huttoni* adults recorded on each of eight plant species. The vertical bar is the least significant difference, LSD (5 %). Means with no letters in common are significantly different (Unprotected LSD; p < 0.05)

The numbers of *Nysius* observed over 120 h also varied significantly between plant species ($p < 0.001$). The number of *Nysius* observed on alyssum was significantly higher ($p < 0.05$) than on buckwheat, kale, clover, lucerne, and coriander but were statistically similar ($p > 0.05$) to phacelia and wheat. Kale, buckwheat, clover, lucerne, and coriander did not differ significantly ($p > 0.05$) (Figure 2).

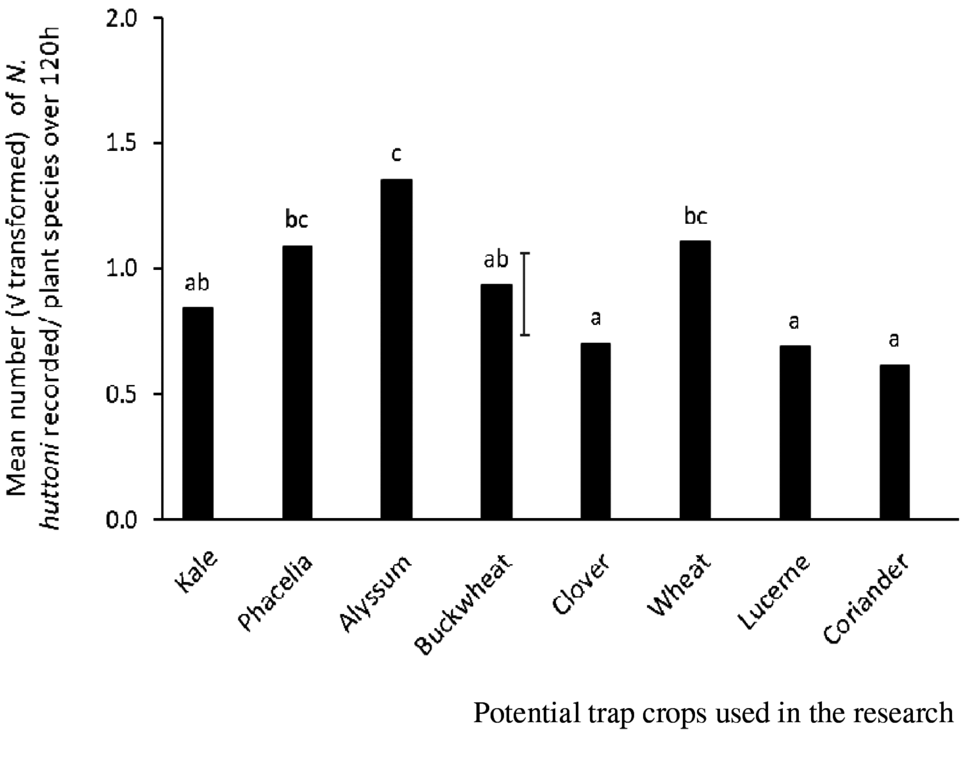

Figure 2. Mean numbers (√ transformed) over 120 h of *Nysius huttoni* adults recorded in each of eight plant species in no-choice tests (n = 10)

Based on the results obtained in this work, alyssum is potentially the most suitable host for *Nysius.* The work of Wei (2001) supports the fact that *Nysius* uses alyssum in summer in the Southern Hemisphere. It also overwinters on alyssum in New Zealand. It is a potentially good candidate trap crop for oviposition by the diamondback moth

(*Plutella xylostella*), but alyssum is relatively unsuitable for larval development of this insect (De Groot et al., 2005). Based on the laboratory findings here, wheat was the second most important potential trap crop of this pest. Several other authors also reported that wheat is a potential host of wheat bugs (Yang and Wang, 2004). In fact, *N. huttoni* uses wheat during its panicle and milk-ripe stages at a time when the usual annual host plants have desiccated, or died (Farrell and Stufkens, 1993). Relatively high populations of *N. huttoni* on wheat can potentially damage this crop which could lead to the death of plants. In a commercial crop, this potential damage may lead to use of insecticide, increasing the management cost needed for bug control.

Preference of crop growth stages by *N. huttoni* in laboratory

Bugs numbers were significantly higher at the flowering stage than on the vegetative in the no-choice ($t = 3.39$; $df = 13$; $p = 0.004$) (Figure 3a) and choice tests ($t = 12.4$; $df = 11$; $p < 0.001$) (Figure 3b). This result matches well to the conclusions of Yang et al., (2017) for the kudza bug *Megacopta cribraria* Fab. (Heteroptera: Plataspidae) in soybean (*Glycine max* L.) in which preference of *M. cribraria* on the flowering stage of soybean was higher than on the vegetative, pod or seed stages.

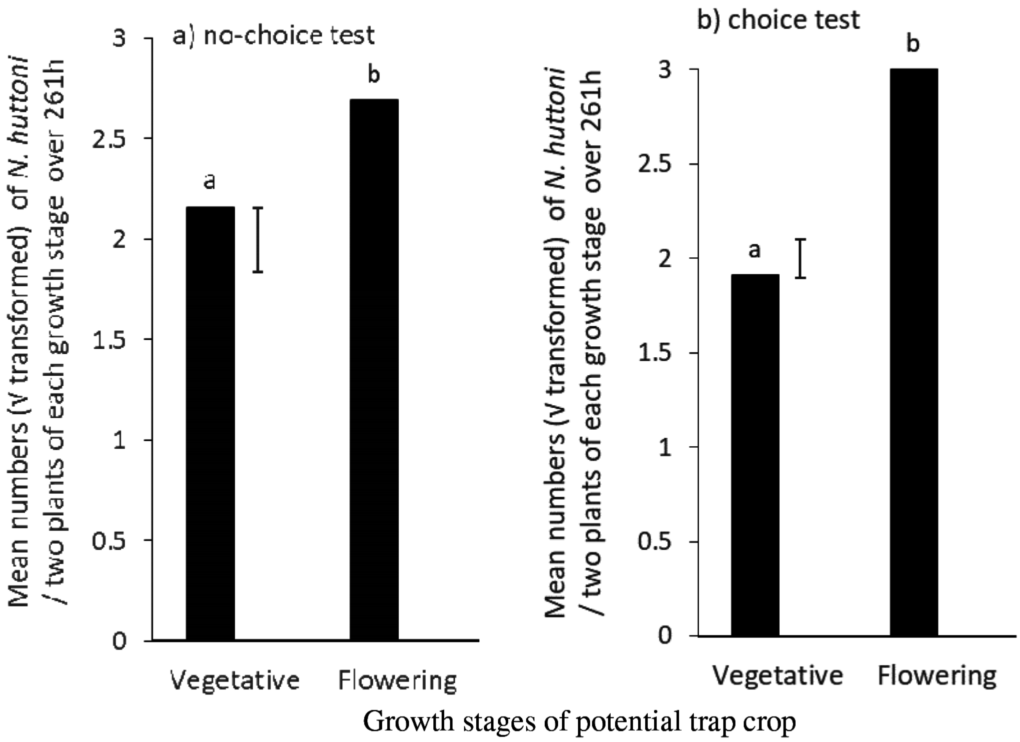

Figure 3. (a) a no-choice, and (b) a choice tests in the laboratory. Mean numbers (√ transformed) of *Nysius huttoni* adults on two alyssum growth stages over 261 h in no-choice (n = 14) and choice tests (n = 12).

Survival rate

The survival rate of *N. huttoni* did not differ significantly ($p > 0.05$) between the two alyssum stages (Fig. 4). Only no-choice tests were carried out for this parameter ($t = 1.121$; $df = 13$; $p = 0.282$). Survival at flowering was 38 % and at the vegetative stage, it was 28 %. The use of appropriate plant phenology is an important parameter for efficient trapping of insect pests (Hokkanen, 1991). In the current system, alyssum trap plants should be cultivated so that they flower when kale plants are at the seedling stage to maximise their effectiveness as a trap plant (Shelton & Badenes-Perez, 2006). However, careful attention should be given to the beneficial arthropods and pollinators while using pesticides to manage the trapped *N. huttoni* in flowering alyssum plants in brassica fields (Hokkanen, 1991).

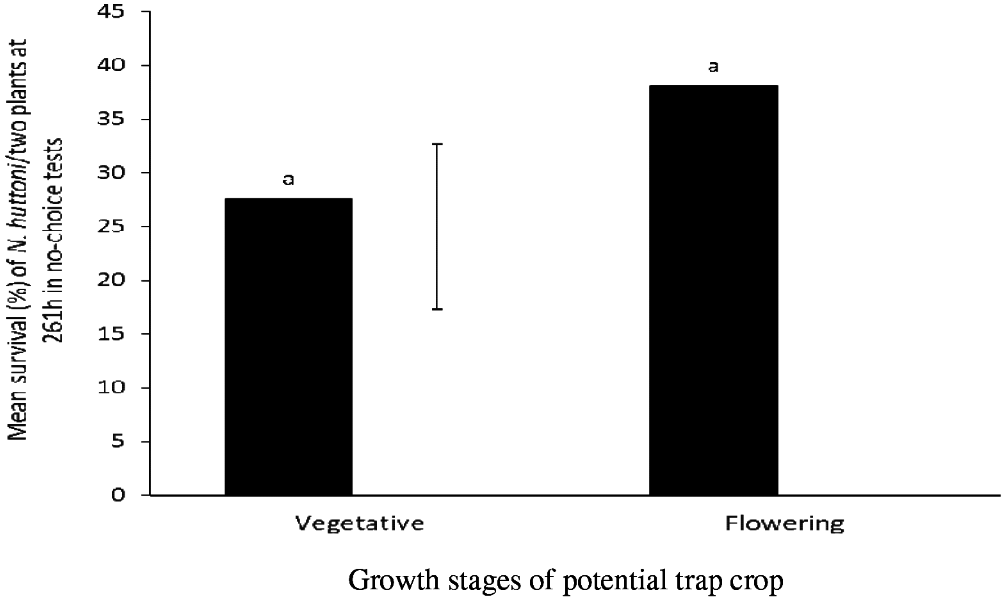

Figure 4. No-choice laboratory tests. Mean survival (%) of *Nysius huttoni* adults at two growth stages of alyssum plant at 261 h after release of *Nysius huttoni* (n = 14).

Preference of kale cultivars by *N. huttoni* in laboratory

The number of wheat bugs observed on Kestrel seedlings was significantly higher ($p < 0.05$) than on Corka but not significantly different ($p > 0.05$) from Gruner, Sovereign, Coleor or Regal (Figure 5). The number of wheat bugs on Kestrel, Gruner, Sovereign, Regal and Coleor were statistically similar.The bug's preference for Kestrel and Coleor could be partly caused by various cultivar characteristics, such as digestibility, palatability, leaf to stem ratio, growth vigour, and concentrations of S-methyl cysteine sulphoxide (SMCO) compared with the other cultivars (PGG, 2009). Damage to the bugs' favoured cultivars that can later lead to the death of the seedlings and further reduces their seedling number per unit area in brassica fields. Hence, this pest sometimes called a crop establishment pest (AgPest, 2016).

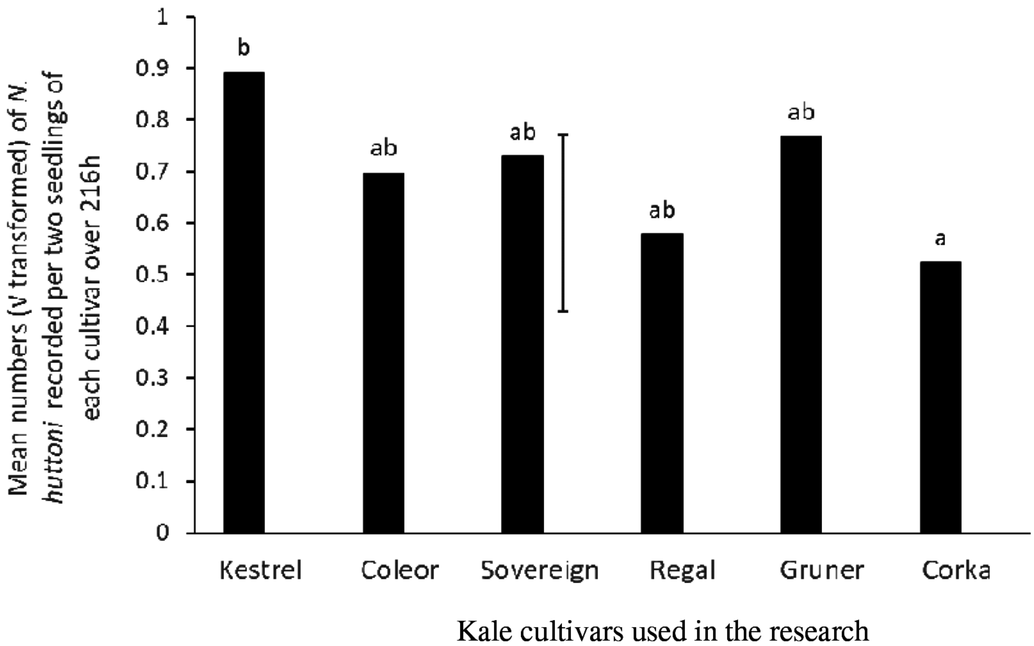

Figure 5. No-choice tests. Mean numbers (√ transformed) of adult *Nysius huttoni* recorded on each of six kale cultivars over 216 h.

CONCLUSION

The overall findings of this study contribute to reducing prophylactic pesticide use in forage brassicas and promote agro-ecological pest management approaches. In this study, habitat manipulation in brassica fields using a trap crop and less susceptible cultivars has been considered as an integrated management strategy. The laboratory bioassays on a range of potential trap plant species for wheat bug suggested that alyssum (*L. maritima*) and wheat (*T. aestivum*) are the suitable trap crops. Deployment of these trap crops in a trap cropping (alyssum only), or multiple trap cropping (alyssum plus wheat) can intercept/divert wheat bugs and prevent their movement from the trap crops to the main crop. In this study, a single trap crop using alyssum was more efficient than a multiple trap cropping with alyssum plus wheat. The findings of this also revealed that the flowering stage of alyssum is more favoured by *N. huttoni* than the vegetative stage. Habitat manipulation using the appropriate growth stages of alyssum at the seedling stage of kale in main fields can produce risk-free brassica seedlings from bug damage.

The finding s also suggested that the kale cultivars Corka and Regal are relatively less susceptible to the wheat bug damage. This fact can be integrated into other pest management approaches, such as trap cropping, biological control and while using selective chemicals for sustainable results. Highly susceptible kale cultivars, such as Kestrel, Gruner, Sovereign, and Coleor, should be avoided by farmers. Maintaining flowering alyssum strips at kale (cv. Corka or Regal) field edges can reduce bug damage on kale seedlings.. While dealing on these pests by using agro-ecological pest management strategy, kale cultivars such as Corka and Regal, can be used in main fields as a 'push' (repel) and alyssum crops at the edges as a 'pull' (trap) factor.

Overall, the findings of this study suggests that habitat manipulation using alyssum trap cropping in brassica fields and integrating them to other compatible pest management approaches, such as using less susceptible kale cultivars (Cork and Regal), can protect brassica seedlings from wheat bug damage, and reduce pesticide costs.. All these techniques are components of 'ecological' or 'sustainable intensification' practices, an alternative to 'agricultural intensification'.

ACKNOWLELDGEMENTS

The authors would like to acknowledge to all the helping hands for their support during the course of this experiment period in the glasshouse and laboratory.

REFERENCES

AgPest. (2016). *Nysius; Wheat Bug.* Ministry of Primary Industries. Retrieved October 26, 2016, from https://agpest.co.nz/?pesttypes=nysius-wheat-bug.

De Groot, M., Winkler, K., & Potting, R. (2005). Testing the potential of white mustard (*Sinapis alba*) and Sweet alyssum (*Lobularia maritima*) as trap crops for the Diamondback moth *Plutella xylostella*. *Proceedings of the Netherland Entomological Society Meeting, 16*, 117-123.

Eyles, A. C. (1960). Insects associated with the major fodder crops in the North Island. *New Zealand Journal of Agricultural Research, 3* (*6*), 994-1008. https://doi:10.1080/00288233.1960.10419310.

Every, D., Farrell, J., Stufkens, M., & Wallace, A. (1998). Wheat cultivar susceptibility to grain damage by the New Zealand wheat bug, *Nysius huttoni*, and cultivar susceptibility to the effects of bug proteinase on baking quality. *Journal of Cereal Science, 27* (*1)*, 37-46. https://dx.doi.org/10.1006/jcrs.1997.0142.

Eyles, A. C. (1965). Damage to cultivated cruciferae by *Nysius huttoni* White (Heteroptera: Lygaeidae). *New Zealand Journal of Agricultural Research, 8* (*2*), 363-366. https://doi:10.1080/00288233.1965.10422367.

Farrell, J. A., & Stufkens, M. W. (1993). Phenology, diapause, and overwintering of the wheat bug, *Nysius huttoni* (Hemiptera: Lygaeidae), in Canterbury, New Zealand. *New Zealand Journal of Crop and Horticultural Science, 21* (*2*), 123-131. https://doi:10.1080/01140671.1993.9513757.

Hanley, J. A., & McNeil, B. J. (1983). A method of comparing the areas under receiver operating characteristic curves derived from the same cases. *Radiology, 148* (*3*), 839-843.

He, X., Wang, Q., & Carpenter, A. (2003). Thermal requirements for the development and reproduction of *Nysius huttoni* White (Heteroptera: Lygaeidae). *Journal of Economic Entomology, 96* (*4*), 1119-1125.

Hokkanen, H. M. (1991). Trap cropping in pest management. *Annual Review of Entomology, 36* (*1*), 119-138.

Horrocks, A., Horne, P. A., & Davidson, M. M. (2018). Demonstrating an integrated pest management strategy in forage-and seed-brassica crops using a collaborative approach. *New Zealand Plant Protection, 71*, 112-120.

Khan, Z., Pickett, J., Wadhams, L., & Muyekho, F. (2001). Habitat management strategies for the control of cereal stemborers and striga in maize in Kenya. *International Journal of Tropical Insect Science, 21* (*4*), 375-380.

Landis, D. A., Wratten, S. D., & Gurr, G. M. (2000). Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology, 45* (*1*), 175-201.

Myers, J. G. (1926). Biological notes on New Zealand Heteroptera. *Transactions and Proceedings of the New Zealand Institute, 56,* 449-51*1.*

PGG (Pyne Gould Guinness Wrightson). (2009). *Forage Focus.* PGG Wrightson Seeds. Retrieved March 26, 2018, from *https://www.pggwrightsonseeds.com.au/Forage-Focus/Wilpena-Forage-Focus.au.*

Saville, D. J. (2015). Multiple comparison procedures—cutting the Gordian knot. *Agronomy Journal, 107* (*2*), 730-735. https://doi:10.2134/agronj2012.0394.

Shelton, A., & Badenes-Perez, F. (2006). Concepts and applications of trap cropping in pest management. *Annual Review of Entomology, 51*, 285-308.

Shelton, A. M., & Nault, B. A. (2004). Dead-end trap cropping: a technique to improve management of the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae). *Crop Protection, 23* (6), 497-503. https://doi.org/10.1016/j.cropro.2003.10.005.

Trevor, J. (2010). *A Review of Insecticide Use on Pastures and Forage Crops in New Zealand*. Insect Science Ltd, Christchurch, 77p. Retrieved January 07, 2018, from https://agpest.co.nz/wp-content/uploads/2013/06/A-review-of-insecticide-use-on-pastures-and-forage-crops-in-New-Zealand.pdf.

Wei, Y. J. (2001). *Nysius huttoni* (Hemiptera: Lygaeidae): life history and some aspects of its biology and ecology in relation to wing development and flight. PhD dissertation, University of Canterbury, New Zealand. (https:// books.google.co.nz/books?id=snm9MgAACAAJ).

Yang, L., & Wang, Q. (2004). Precopulation sexual selection in *Nysius huttoni* White (Heteroptera: Lygaeidae) in relation to morphometric traits. *Journal of Insect Behavior, 17* (*5*), 695-707.

Yang, L., Hu, X., van Santen, E., & Zeng, X. (2017). Attractiveness of host plants at different growth stage to kudzu bug, *Megacopta cribraria* (Heteroptera: Plataspidae): Behavioral responses to whole plant and constitutive volatiles. *Journal of Economic Entomology, 110* (6), 2351-2356.