Biology and Management of the New Zealand Endemic Wheat Bug, *Nysius huttoni* (Hemiptera: Lygaeidae)

Sundar Tiwari1,*, and Steve D. Wratten

Bio-Protection Research Center, Lincoln University, Lincoln 7647, New Zealand, and 1Corresponding author, e-mail: stiwari@afu.edu.np

Subject Editor: Jeffrey Davis

Received 12 May 2019; Editorial decision 30 September 2019

**Abstract**

The wheat bug, *Nysius huttoni* White, mainly reported as a pest of wheat and forage brassicas, is native to New Zealand. This pest has been accidentally introduced into The Netherlands and Belgium during apple exports from New Zealand. The bug population is abundant in open sparse vegetations and hot-dry habitats, and feeds on dropping seeds. It damages wheat grains during milk-ripe stage by piercing through the glumes into the developing grains that can reduce gluten protein and reduce baking quality. Bugs also suck phloem fluid from seedlings, which can reduce plant establishment in forage brassicas. Early scouting and field monitoring are suggested before making pest management decisions. Seed treatment with neonicotinoids, permethrin, and chlorpyrifos spray in the standing crops are chemical methods of management in New Zealand. These conventional synthetic pesticides have nontarget effects on human health, the environment, and biodiversity. However, preventive measures such as the use of less-susceptible cultivars, and using potential trap crops is other important pest management options. Alyssum (*Lobularia maritima* L. Desv. Brassicales: Brassicaceae) and wheat (*Triticum aestivum* L. Poales: Poaceae) are two potential trap crops of wheat bug. Kale (*Brassica oleracea* L.) cultivars, such as Corka and Regal, and wheat (*Triticum aestivum*) cultivars, such as Batten, Domino, and Oroua, are less-susceptible cultivars. Understanding the biology and ecology of the pest, and utilizing preventative pest management measures such as the use of trap crops and less-susceptible cultivars, and integrating these with ‘soft’ chemicals make a suitable integrated pest management strategy for this pest.

**Key words:** wheat bug, *Nysius huttoni*, host, integrated pest management, trap cropping

---

**Species Description**

The wheat bug, *Nysius huttoni* White (Fig. 1), a New Zealand endemic insect (Eyles 1960a, He et al. 2003, Aukema et al. 2005) is widely distributed in the North and South Islands (Myers 1926, Eyles 1960a, Eyles and Ashlock 1969) from sea level to 1,800 m (Eyles and Ashlock 1969). This species also reported in the Chatham Islands and the Three Kings Islands (Woodward 1954) of New Zealand. It was first named by Buchanan White in 1878 from the New Zealand collections of Hutton and Wakefield (Eyles 1960b); more recently, it has been recorded in the extreme southwest of the Netherlands (Aukema et al. 2005, Bonte et al. 2010) and north-western Belgium (Bonte et al. 2010). In New Zealand, over 142 genera and 319 species belonging to 28 families of Hemiptera (Larivière and Larochelle 2014); of them, two genera (*Nysius* and *Rhypodes*) with 32 species, belong to family Lygaeidae (Larivière and Larochelle 2014). Four *Nysius* spp., including three endemics and one adventive species, have been reported in New Zealand. *Nysius huttoni*, *N. liliputanus* (Eyles and Ashlock 1969), and *N. convexus* (Usinger 1942) are endemic; *N. caledoniae* Distant was accidentally introduced from Lord Howe Island and Tasmania (Eyles and Malipatil 2010) in 2006 and was first recorded in a lettuce crop in Auckland (Eyles and Malipatil 2010, Rowe and Hill 2015).

Adult wheat bugs are gray or black brown or sometimes creamy white. The apices of the femora and tibia are yellow. Adult wings are translucent or transparent. The body is elongate oval and dorsally flattened. The head is triangular, slightly narrower than pronotum, with prominent round eyes. There are one to four antennal segments; segments 1 and 4 are bigger than segments 2 and 3. The forelegs are thin with no spines (Eyles 1960a). The body is covered by a long, erect pubescence (Fig. 1). The morphological variations and other biological features of the four *Nysius* spp. are summarized in Table 1.

**Biology**

Various aspects of the biology and ecology of *N. huttoni* have been studied by many authors (Eyles 1963, Birtles et al. 1992, Farrell and Stufkens 1993, He and Wang 2000, He et al. 2002b, Wei 2008a,
It has been observed that the number of instars varies with temperature and photophase. Higher mortality of wheat bugs has been observed in early instars than in late instars and at lower temperatures (<15°C), higher temperatures (>30°C) and in a short photophase (8-h photophase; Wei 2001). Nymph duration ranges from 20 to 21 d (Wei 2008a).

**Adult**

Adult wheat bugs are small to medium insects (2.4–4.5 mm long) and have various body forms on the basis of wing development (macropterous, sub-brachypterous, and brachypterous), called wing polymorphism (Eyles 1960a). Larger individuals have only macropterous forms (wings longer than the abdomen), whereas the medium and smaller individuals show the three different forms (Eyles 1960a). In field conditions, macropterous forms are predominant (94.1%). Macropterous (male) × macropterous (female) is the predominant mating combination (80.9%; Fig. 7), with macropterous (male) × sub-brachypterous (female) the second combination (13.7%; Wei 2010). Low (<15°C) and high (>30°C) temperatures and short photophase (8-h photophase) lead to sub-brachypterous and brachypterous wing development. Temperature ranging from 20 to 30°C, and a long photophase (12–16 h light) produces macropterous forms.

For larger individuals (macropterous), male and female lengths range from 3.55 to 3.86 mm and 3.74 to 4.34 mm, respectively; male and female widths range from 1.32 to 1.39 mm and 1.61 to 1.75 mm, respectively. The medium size male and female lengths range from 3.00 to 3.48 mm and 3.36 to 3.74 mm, respectively, and widths range from 1.15 to 1.32 mm and 1.44 to 1.53 mm, respectively. In the smallest size category, males and females range from 2.38 to 3.00 mm and 2.47 to 3.19 mm, respectively, and male and female widths range from 0.94 to 1.15 mm and 1.20 to 1.32 mm, respectively (Eyles 1960a). The adult duration ranges from 70 to 90 d. Their populations are abundant in hot and dry condition (Farrell and Stufkens 1993).

**Ecology**

Temperature and photophase are the critical factors for survival, development, reproduction including the geographical distribution and abundance of wheat bugs. Under Canterbury conditions, third-generation adults generally overwinter in mid-April or early May and emerge from overwintering sites in late August or early September (Wei 2008a). In laboratory studies, an equal sex ratio has been reported (Wei 2008b). However, low temperatures and short days produce a greater proportion of males, and high temperatures and long days produce a greater proportion of females (Wei 2008b).
Habitats and Hosts

Habitats

Wheat bugs are found almost all sparse vegetation where full sunlight directly falls on the ground (Fig. 8). In general, weedy fields, gardens, lawns, bare ground between rows of fruit trees, sandy riverbeds, ornamental gardens, pasture, wastelands, sandy ground supporting a few weeds, roadsides, and so on are the most common wheat bug habitat (Wei 2001). *Nysius buttoni* does not prefer dense vegetation and damp habitats. The populations in crop fields are significantly affected by the following potential weeds: *Capsella bursa-pastoris* (L.) medik (shepherd’s purse: Brassicaceae) (Fig. 8), *Coronopus didymum* L. (twins cress: Brassicaceae) (Fig. 9), *Lolium multiflorum* Lam. (ryegrass: Poaceae), and *Bromus willdenowii* Kunth (prairie grass: Poaceae) (Gurr 1952, Every et al. 1990, Wei 2001).

Hosts

*Nysius buttoni* is a polyphagous species that feed on large numbers of cultivated plant species such as cereal crops, vegetables, horticultural crops, and many weeds (Eyles 1965, He et al. 2003, Yang and Wang 2004). Host plants not only support food materials for the wheat bug but also provide shelter during extreme weather conditions. The quantity and quality of the food greatly influence bug survival, adult longevity, population distribution, reproduction, and species development. The list of common host plants and their families is summarized in Table 2.

Injury and Damage

Evidence shows that *N. buttoni* is distributed on at least 75 plant species of >25 families (Table 2) including almost all cultivated brassicas as well as other cultivated crops and weeds (Myers 1926, Eyles and Ashlock 1969, Wei 2001). Hence, this bug is a very adaptable feeder that can live on almost all cultivated crops as well as a variety of weeds. Its infestations on wheat increase when surrounding weeds have matured and died (Wei 2001).

---

**Table 1. Morphological and other biological features of the four *Nysius* species recorded from New Zealand**

| Characteristics            | *Nysius buttoni* | *Nysius convexus* | *Nysius bilipatamus* | *Nysius caledoniae* |
|----------------------------|------------------|-------------------|----------------------|---------------------|
| Morphological features     | Have a complete double row of punctures following claval suture (Eyles and Ashlock 1969) with long and dense hairs on pronotum, scutellum, and hemelytra | A single row of punctures along the side of claval suture (Eyles and Ashlock 1969) and long erect hairs on pronotum, scutellum, and hemelytra | Punctures at claval suture absent and presence of short erect hairs on pronotum, scutellum, and hemelytra | Punctures are absent at claval suture, and scutellum are round |
| Origin                     | Endemic          | Endemic           | Endemic              | Adventive           |
| Wing forms, or type        | Macropterous*, sub-brachypterous*, and brachypterous* (Eyles and Ashlock 1969) | Mainly sub-brachypterous (Eyles and Ashlock 1969) | (Eyles and Ashlock 1969) | Macropterous (Rowe and Hill 2015), sub-brachypterous, and brachypterous (Eyles 1960a) |
| Host                       | Common hosts are Brassicaceae, Polygonaceae, Caryophyllaceae, Compositae, and Leguminosae | Moss associations on glacial moraines and in river-bank vegetations (Larivière and Larochelle 2004) | Moss associations on glacial moraines, on dry river beds, and also on ferns (at night; Larivière and Larochelle 2004) | Lettuce (Rowe and Hill 2015) |
| Damage potential           | Pest of a wide range of cultivated crops (Myers 1926) including weed species | Damage not recorded in cultivated crops (Eyles and Ashlock 1969) | Damage not recorded in crops (Larivière and Larochelle 2004) | First recorded in lettuce but their damage on crops are not recorded (Rowe and Hill 2015) |
| Distribution               | Widely distributed in the North, South, Chatham and Three Kings islands of New Zealand from sea level to 1,800 m, and partly distributed in the Netherland, Belgium, France, and the United Kingdom (Eyles and Ashlock 1969) | South Island (New Zealand; Eyles and Ashlock 1969) | South Island (New Zealand; Eyles and Ashlock 1969) | North Island (Auckland area, New Zealand; Rowe and Hill 2015) |

---

*a Macropterous (wings longer than abdomen).
*b Sub-brachypterous (wings level with abdomen or slightly exceed).
*c Brachypterous (wings are shorter than the abdomen).
The first New Zealand damage record of the wheat bug was on a wheat crop in 1936 (Morrison 1938). Two major wheat bug outbreaks were recorded between 1936 and 1950, and four outbreaks were recorded between 1961 and 1980 (Swallow and Cressey 1987). The worst outbreak was recorded in 1970; it led to the loss of up to 10,000 tons of wheat (Swallow and Cressey 1987). Both adults and nymphs can damage many cultivated crops. Bugs normally damage wheat grains that can reduce the gluten protein and reducing baking quality (Cressey et al. 1987, Every et al. 1992, Every et al. 1998). During feeding, bugs inject toxic saliva that contains a potent enzyme responsible for the quality deterioration of bread (Lorenz and Meredith 1988). Even a negligible infestation in wheat is enough to reduce the market and baking quality. Damaged wheat grains have...
distinct feeding marks, a pale circular area with a dark puncture mark at the center (Gurr 1957, Miller and Pike 2002). Damage to wheat varieties ranges from 10 to 100% (Every et al. 1989). Damage in wheat and other crops increases with increased hot, dry conditions, which result in desiccation of the hosts.

*Nysius huttoni* is primarily a seed feeder but may also feed on the vegetative parts of plants such as stems and foliage. This bug is also an economic pest of forage brassicas. Both adults and nymphs damage brassica seedlings. Kale (*Brassica oleracea* L.), rape (*Brassica napus* L. var. *napus*), turnip (*Brassica campestris* L.), and swede (*Brassica napus* L. var. *napo-brassica*) are widely grown brassica crops for animal production systems in New Zealand (Speciality Seeds 2016). In brassica crops, the wheat bug primarily attacks seedlings by sucking fluids from the base of the plants, which leave a feeding puncture (Fig. 10), resulting in cankerous tissue growth or ring barking (Eyles 1965, Wei 2001). This interferes with sap flow and either causes total loss of the plant or makes them susceptible to breakage by wind or stock movement (He and Wang 1999; Fig. 11). Infestations in germinating seedlings can lead to plant death. Damage can reach up to 90% in direct drilled brassica crops (AgPest 2016, Speciality Seeds 2016). He and Wang (1999) reported that
Table 2. The host plant species of wheat bug, Nysius huttoni (Hemiptera: Lygaeidae)

| Family       | Host plants                                                                 | Sources                                                                                                                                                                                                                                                                 |
|--------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Poaceae      | Wheat (Triticum aestivum L.), ryegrass (Lolium spp.), barley (Hordeum vulgare L.; Hordeum marinum Huds.), brome grass (Bromus spp.), oats (Avena sativa L.), rye (Secale cereal L.), Yorkshire fog (Holcus lanatus L.), paspalum (Paspalum dilatatum Poir.), tussock (Nassella trichotoma Hackel ex Arech.), browntop (Agrostis tenuis Sibth.; Agrostis capillaris L.), annual bluegrass (Poa annua L.), vulpia hair grass (Vulpia megahila Rydb.), perennial ryegrass (Lolium perenne L.) | Myers (1926), Morrison (1938), Gurr (1952, 1957), Eyles (1965), Eyles and Ashlock (1969), Cressey et al. (1987), Swallow and Cressey (1987), Lorenz and Meredith (1988), Every et al. (1990), Every et al. (1992), Farrell and Stufkens (1993), Bejakovich et al. (1998), Every et al. (1998), Wise et al. (2000), EPPO (2006), CABI (2011) |
| Brassicaceae | Twin cress (Lepidium didymum L.), shepherd’s purse (Capsella bursa-pastoris (L.) Medic.), swede (Brassica napo-brassica Mill.), turnip (Brassica rapa L.), rape (Brassica napus L.), kale (Brassica oleracea var. acephata L.), narrow-leaved cress (Lepidium pseudotussockianum Thell.), alsyssum (Lobularia maritima (L.) Desv.), fodder beet (Beta vulgaris L.), cabbage (Brassica oleracea L.) | Gurr (1952, 1957), Eyles (1960b, 1963, 1965), Eyles and Ashlock (1969), Pearson and Goldson (1980), Farrell and Stufkens (1993), Ferguson (1994), He and Wang (1999), He and Wang (2000), Wei (2001), He et al. (2002a, 2002b, 2003, 2004), Yang and Wang (2004), EPPO (2006), Wang et al. (2008), Wei (2008a, 2010, 2012) |
| Fabaceae     | Lucerne (Medicago sativa L.), suckling clover (Trifolium dubium Sibth.), red clover (Trifolium pretense L.), subterranean clover (Trifolium subterraneum L.), common broom (Sarothamnus scoparius L.), hare’s foot clover (Trifolium arvense L.), strawberry clover (Trifolium fragiferum L.), clustered clover (Trifolium glomeratum L.), gorse (Ulex europaeus L.), white clover (Trifolium repens L.) | Myers (1921, 1926), Gurr (1952, 1957), Eyles (1960b), Schroeder and Chapman (1995), Wei (2001), EPPO (2006), CABI (2011) |
| Asteraceae   | Sunflower (Helianthus annuus L.), onehunga weed (Soliva sessilis Rulz & Pav.), tauhinu (Cassinia leptophyla (G. Frost) R. Br.), cat’s ear (Hypochaeris radicata L.), hawkweed (Hieracium spp.), narrow-leaved ragwort (Senecio inaequidens DC.), Scotch thistle (Cirsium vulgare (Savi) Ten.), hawksbeard (Crepis spp.), Mexican daisy (Erigon karvinskianus DC.), common fleabane (Pulicaria dysenterica (L.) Berth.), dandelion (Taraxacum officinale G. Weber.), button weed (Cotula spp.) | Myers (1921, 1926), Eyles (1965), Eyles and Ashlock (1969), Syrett (1993), Wei (2001), He et al. (2002b), He et al. (2004), Yang and Wang (2004), EPPO (2006), Wang et al. (2008) |
| Polygonaceae | Red clover (Trifolium pratense L.), wireweed (Polygonum aviculare L.), lady’s thumb (Polygonum maculosa S.F. Gray) | Eyles and Ashlock (1969), Farrell and Stufkens (1993), Wei (2001), He et al. (2002b, 2004), Yang and Wang (2004), EPPO (2006), Wang et al. (2008) |
| Caryophyllaceae | Catch fly (Silene gallica L.), chickweed (Stellaria media (L.) Vill.), red sand spurry (Spergularia rubra (L.) J. Presl & C. Presl.) | Myers (1921, 1926), Eyles and Ashlock (1969), EPPO (2006), Myers (2001), EPPO (2006) |
| Rosaceae     | Strawberry (Fragaria spp.), raspberry (Rubus spp.), apple (Malus spp.) | Gurr (1952, 1957), Wei (2001), EPPO (2006) |
| Geraniaceae  | Common storksbill (Erodium cicutarium (L.) L’Her.), cranesbill (Geranium sp.) | Gurr (1952, 2001) |
| Various families | Flax (Linum spp.): Linaceae, cornrow’s curse (Calandrinia caulescens Phil: Montiacae), lamb’s quarters (Chenopodium album L.: Amaranthaceae), flowering kanuka (Kunzea ericoides (A. Rich) Joy Thoms: Myrtaceae), moss (Triquetrella papillata (Hook.f. & Wilson) Broth: Poteciaceae), red pimpernel (Anagallis arvensis L.: Primulaceae), pine (Pinus radiata D. Don: Pinaceae), kapuka (Griselinia littoralis Raoul: Griseliniaceae), moss (Gleichenia ciricina Swartz: Gleicheniaceae), pimelea (Pimelea arenaria A. Cunn.: Thymelaceae), viper’s bugloss (Echium vulgare L.: Boraginaceae), mallow (Malva spp.: Malvaceae), flannel leaf (Herbescum thapsus L.: Scrophulariaceae), kiwifruit (Actinidia spp.: Actinidiaceae), Monterey cypress (Cupressus macrocarpa Gordon: Cupressaceae), sleeping beauty (Oxalis comulcata L.: Oxalidaceae), horokaka (Diaphyllum spp.: Aizoaceae) | Myers (1921, 1926), Gurr (1952, 1957), Eyles (1965), Eyles and Ashlock (1969), Farrell and Stufkens (1993), Wei (2001), EPPO (2006) |

the highest percentage of damage to swede seedlings was recorded during a windy period.

**Integrated Management Strategies**

**Field Monitoring**

Regular monitoring and frequent field observations help assess pest populations and provide early detection of crop damage by the pest. A suction machine (Shred n Vac Plus, Stihl BG 75, 80 cm long x 12.0 cm inlet diameter) is a common monitoring tool used to study the population expansion of wheat bug in crop fields (Fig. 12). Wheat bugs management action should be followed when three or more bugs can be seen in a 10 x 10 cm area (AgPest 2016). Ring-barking symptoms, wilting of seedlings, leaf distortion, and breakage of seedlings in a windy period or after stock movement are the most visible signs of a wheat bug damage and likely in forage brassicas (Wei 2001, AgPest 2016). Damage to wheat grains is a distinct pale circular mark with a unique dark puncture at the center (Wei 2001). Therefore, monitoring adults and nymphs, and damage assessment early in the season have been recommended to evaluate the bug damage in crops.

**Trap Cropping**

Trap cropping is a common wheat bug management practice in forage brassicas in New Zealand (Tiwari et al. 2018a). This is based...
on growing one or more trap plant species adjacent to or within the main crop that can reduce pest density in the main crop (Shelton and Nault 2004). Alyssum (Lobularia maritima L. (Desv.)) and wheat (Triticum aestivum L.) are two potential trap crops of the wheat bug in forage brassicas (Tiwari et al. 2018a; Fig. 13). These trap crops can be deployed in brassica fields as a single trap crop (alyssum or wheat only) or as a multiple trap crop (alyssum and wheat together) around the perimeter of the brassica fields (Tiwari et al. 2018a). Depolyment of such trap crops in main field can protect the main crop either by preventing the wheat bug from reaching it or by leading them to a certain pat of the field where the insect can be economically managed either by removal of the trap refuges or using insecticides locally (Rea et al. 2002, Shelton and Nault 2004) The flowering stage of alyssum and the milk-ripe stage of wheat are the suitable growth stages for the wheat bug (Tiwari et al. 2019b). Flowering alyssum is a garden plant that can also deliver multiple ecosystem services in crop field by providing shelter, nectar, alternative food, and pollen to the pest natural enemies such as predators and parasitoids (González-Chang et al. 2019, Tiwari et al. 2019a).

Selection of Suitable Cultivars

The selection of suitable crop cultivars could be a viable option to reduce bug infestations. Some cultivars are less susceptible to wheat bug and some are more susceptible. A study conducted in New Zealand over a wide range of kale (B. oleracea) cultivars suggested that cultivars Regal and Corka are less susceptible than Kestrel, Gruner, Sovereign, and Coleor. The two commercial popular kale cultivars in New Zealand, Kestrel, and Gruner are more prone to bug damage (Tiwari et al. 2018b). Similarly, Oroua, Batten, and Domino wheat cultivars are relatively less susceptible than Karamu, Otane, WW378 and ASPS 9927 (Every et al. 1998).

Chemical Control

In New Zealand, prophylactic use of pesticides is a common method of pest and disease management in forage brassicas (Trevor 2010). These synthetic chemicals have been used to attract, reduce, or kill selected crop pests. Seed treatment with neonicotinoids and spraying with chlorpyrifos and permethrin insecticides are common practices in N. huttoni management in forage brassicas (Trevor 2010, Goldson et al. 2015, Young 2018).

Biological Control

There are a very few records of biological control agents of N. huttoni in the literature. Some potential predators are Neocicindela parryi White (Coleoptera: Cicindelidae), Metaglymma moniliferum Bates (Coleoptera: Carabidae), Coccinella trifasciata L. (Coleoptera: Coccinellidae), Nabis maoricus Walker (Hemiptera: Nabidae), Lycosa bilaris Koch (Araneae: Lycosidae), and Pardosa bellucos Goyen (Araneae: Lycosidae) (Wei 2001). Chrysopidae species are other potential predators (Capinera 2001). Birds are suitable
vertebrate predators of the wheat bug in irrigated pasture land in New Zealand (Lobb and Wood 1971).

Future Research Recommendations

Future research should be focused to develop a ‘push–pull strategy’ to manipulate the behavior of the pest and beneficial insects (Pyke et al. 1987), which is certainly useful in developing future integrated pest management (Aldrich et al. 2003, Cox 2004, Cook et al. 2006). The ‘push’ factor could be less-susceptible kale cultivars, deployment of such kale cultivars in kale fields, repel or deter the wheat bug or make the crop unsuitable for landing or feeding by the wheat bug (Khan and Pickett 2004). The efficiency of a less-susceptible kale cultivar ‘push’ factor can be enhanced by exogenous application of repellents (Griffiths et al. 1991, Gerard et al. 1993) or other biotechnological approaches (Eigenbrode et al. 1991). These could be research options in the future. The ‘pull’ factor could be a potential trap plant that can lure or attract wheat bugs and other insects away from the main crop (Khan and Pickett 2004, Cook et al. 2006). The wheat bug normally damages brassica seedlings (4- to 6-wk old; AgPest 2016). Hence, kale seedling protection using a trap crop could be a future important and challenging issue. Future research could also focus on the time of deployment of alyssum in kale fields, so that 4- to 6-wk-old kale seedlings can be protected from the bug damage. In summary, research should be focused on ‘push–pull’ strategies as a holistic agroecological wheat bug management strategy in forage brassicas and other crop fields.

Concluding Remarks

The wheat bug is a major pest of wheat and brassica seedlings in New Zealand and is a quarantine pest in Australia, Europe, and the United States. Accidentally, this pest has been introduced into some European countries such as the Netherlands, Belgium, France, and the United Kingdom. It is a polyphagous pest and has a wide host range from cultivated crops to several weed species. High temperatures and long photophase are the most suitable environment for their survival, reproduction, and abundance. Low temperatures (<15°C) and short day length (<12h light duration) induce reproductive diapause. Diapause is an adaptive mechanism for insect survival under unfavorable condition. This is normally occurs at a specific stage and specific season. This bug has seven life stages: egg, five instars (1–5), and adult. Sparse vegetation, hot and dry conditions, and bright sunlight provide the most congenial environment for the wheat bug. Nymphs and adults primarily damage brassica seedlings and wheat grains and reduce grain quality and the number of brassica seedlings.

A range of control options is available to manage wheat bugs such as trap cropping, use of less-susceptible kale cultivars, and prophylactic use of pesticides. Integrated pest management has been considered an integral part of pest management to reduce pesticide risk to human health and the environment. Regular bug sampling with a suction machine (see above) and early damage assessment are suggested to assess the economic threshold level. Alyssum and wheat are two potential trap crops. Kale varieties Corka and Regal are less susceptible as are wheat cultivars Batten, Domino, and Oroua. Integration of potential cultivars with suitable trap crops, and using ‘soft’ chemicals on an as needed basis could be a useful integrated wheat bug management option in forage brassicas and other crops in some countries.

Acknowledgments

We thank the Ministry of Foreign Affairs and Trade (MFAT), New Zealand; the Bio-Protection Research Center (BPRC); Lincoln University and the Agriculture and Forestry University, Nepal for Ph.D. support. Special thanks to Dr. Marie-Claude Lariviére for species identification. I am very much indebted to Dr. Eric Scott for his support in English editing and proofreading this manuscript. Also, we thank Myles Mackintosh, Brian Kwan, and Sue Bowie for their technical and administrative help.

References Cited

AgPest. 2016. Nysius; wheat bug. AgResearchNZ. Ministry of Primary Industries, New Zealand. (http://agpest.co.nz/?pesttypes=nysius-wheat-bug).

Aldrich, J. R., R. J. Bartelt, J. C. Dickens, A. L. Knight, D. M. Light, and J. H. Tumlinson. 2003. Insect chemical ecology research in the United States Department of Agriculture-Agricultural Research Service. Pest Manag. Sci. 59: 777–787.

Aukema, B. J., M. Bruers, and G. Viskens. 2005. A New Zealand endemic Nysius established in The Netherlands and Belgium (Heteroptera: Lygaeidae). Belg. J. Entomol. 7: 37–43.

Bejakovich, D., W. Pearson, and M. O’Donnell. 1998. Nationwide survey of pests and diseases of cereal and grass seed crops in New Zealand, pp. 51–59. In M. O’Callaghan (ed.), Proceedings, New Zealand Plant Protection Conference, 11–13 August 1998, Hamilton, New Zealand.

Birles, D., B. Waddell, J. Maindonald, and A. Popay. 1992. Mortality responses of Nysius buttoni to a dry heat disinfection treatment for apples, pp. 269–273. In A. J. Popay (ed.), Proceedings, New Zealand Plant Protection Conference, 11–13 August 1992, Wellington, New Zealand.

Bonte, J., H. Casteels, M. Maes, and P. D. Clercq. 2010. Occurrence, ecology and potential impact of the New Zealand wheat bug Nysius buttoni White (Hemiptera: Lygaeidae) in Belgium. OEPP/EPPO Bul. 40: 188–190.

(CABI) The Center for Agriculture and Bioscience International. 2011. Nysius buttoni. Distribution maps of plant pests. CABI, Wallingford, United Kingdom. (http://www.cabi.org/dnmpb/abstract/20113166049).

Capineri, J. L. 2001. Hemiptera, pp. 243–278. In J. L. Capineri (ed.), Handbook of vegetable pests. Academic Press, San Diego, CA.

Cook, S. M., Z. R. Khan, and J. A. Pickett. 2006. The use of push-pull strategies in integrated pest management. Annu. Rev. Entomol. 52: 375.

Cox, P. 2004. Potential for using semichemicals to protect stored products from insect infestation. J. Stored Prod. Res. 40: 1–25.

Cressey, P. J., J. A. K. Farrell, and M. W. Stufkens. 1987. Identification of an insect species causing bug damage in New Zealand wheats. N. Z. J. Agric. Res. 30: 209–212.

Eigenbrode, S. D., K. A. Stoner, A. M. Shelton, and W. C. Kain. 1991. Characteristics of glossy leaf waxes associated with resistance to diamondback moth (Lepidoptera: Plutellidae) in Brassica oleracea. J. Econ. Entomol. 84: 1609–1618.

EPPO European and Mediterranean Plant Protection Organization. 2006. CSL Pest risk analysis for Nysius buttoni. (http://www.eppo.org/characters/alert_list/insects/Nysius.html).

Every, D. J. A. K. Farrell, and M. W. Stufkens. 1989. Effect of Nysius buttoni on the protein and baking properties of two New Zealand wheat cultivars. N. Z. J Crop Hort. Sci. 17: 55–60.

Every, D. J. A. K. Farrell, and M. W. Stufkens. 1990. Wheat-bug damage in New Zealand wheats: the feeding mechanism of Nysius buttoni and its effect on the morphological and physiological development of wheat. J. Sci. Food Agric. 50: 297–309.

Every, D. J., J. Farrell, and M. Stufkens. 1992. Bug damage in New Zealand wheat grain: the role of various heteropterous insects. N. Z. J. Crop Hort. Sci. 20: 305–312.

Every, D. J. A. K. Farrell, M. W. Stufkens, and A. R. Wallace. 1998. Wheat cultivar susceptibility to grain damage by the New Zealand wheat bug, Nysius buttoni, and cultivar susceptibility to the effects of bug proteinase on baking quality. J. Cereal Sci. 27: 37–46.

Eyles, A. C. 1960a. Variation in the adult and immature stages of Nysius buttoni White (Hemiptera: Lygaeidae) with a note on the validity of the genus Brachynysius Usinger. Trans. R. Entomol. Soc. Lond. 112: 53–72.

Eyles, A. C. 1960b. Insects associated with the major fodder crops in the North Island. N. Z. J. Agric. Res. 3: 994–1008.
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, Christchurch, New Zealand. (https://books.google.co.nz/books?id=snm9MgAACAAJ) (accessed 25 March 2017).

Wei, Y. 2014. Flight initiation of *Nysius huttoni* (Hemiptera: Orsillidae) in relation to temperature and wing forms. Appl. Entomol. Zool. 49: 119–127.

Wei, Y. J. 2008a. Sex ratio of *Nysius huttoni* White (Hemiptera: Lygaeidae) in field and laboratory populations. N. Z. J. Zool. 35: 19–28.

Wei, Y. J. 2008b. Studies of life history and some aspects of field biology and ecology of *Nysius huttoni* White (Hemiptera: Lygaeidae). J. R. Soc. N. Z. 38: 149–162.

Wei, Y. J. 2010. Variation in the number of nymphal instars in *Nysius huttoni* White (Hemiptera: Lygaeidae). N. Z. J. Zool. 37: 285–296.

Wei, Y. J. 2012. Effect of water and glucose on the adult longevity of *Nysius huttoni* White (Hemiptera: Orsillidae). N. Z. Entomol. 35: 68–74.

Wise, I. L., J. R. Tucker, and R. J. Lamb. 2000. Damage to wheat seeds caused by a plant bug, *Lygus lineolaris* L. Can. J. Plant Sci. 80: 459–461.

Woodward, T. 1954. New records and descriptions of Hemiptera-Heteroptera from the Three Kings Islands. Records of the Auckland Institute and Museum. pp. 215–233. (https://www.jstor.org/stable/42906068) (accessed 8 August 2019).

Yang, L., and Q. Wang. 2004. Precopulation sexual selection in *Nysius huttoni* White (Heteroptera: Lygaeidae) in relation to morphometric traits. J. Insect Behav. 17: 695–707.

Young, S. 2018. New Zealand Novachem agrichemical manual. Agrimedia Ltd, Christchurch, New Zealand. pp. 912.