

EFFECT OF LEGUME-BARLEY INTERCROPPING ON POPULATION DYNAMICS OF CEREAL APHIDS IN DIFFERENT BARLEY VARIETIES

Lilyana KOLEVA, Georgi DIMITROV

University of Forestry, 10 Kliment Ohridsky Blvd, Sofia, Bulgaria

Corresponding author email: lmarkova@ltu.bg

Abstract

Intercropping increases plant diversity in the agroecosystem and thus supports regulatory mechanisms for pest populations. Aphids are economically important pests of barley and represent a significant threat to cereal grain production. The research was carried out in 2021 and 2023 under field conditions in Vrazhdebna, Sofia (42°70'76.1"N, 23°43'73.1"E). The intercropping system consisted of different varieties of winter feed and malting barley and legumes (chickpea and vetch) sown in rows of strips. This study was designed to investigate the effect of legume-barley intercropping on cereal aphid populations and barley production. The data obtained showed that the combination of barley and legumes resulted in a reduction in aphid numbers of up to 31.7%. The analysis revealed no statistically significant differences in aphid attack between different cultivars of winter feed and malting barley grown in mixtures with legumes. The LER values for economic yield indicate that this cropping system is conducive to barley production and effective in pest management within the agroecosystem.

Key words: intercropping, cereal aphids, barley.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is a major cereal crop grown throughout the world. The ability of barley to adapt to different climates and its wide range of uses underline its importance in the world's agriculture and food industries. Barley can grow successfully in temperate climates and is highly valued for its versatility. Approximately 70% of the world's barley production is used as animal feed, while the remaining 30% is used as a source of fermentable material in various products. Barley constitutes an integral component of the Bulgarian agricultural sector, being employed in diverse industrial applications, including animal fodder, brewing, distilling, and numerous other sectors (Gramatikov et al., 2004).

Intensive agriculture is characterised by short crop rotations, inadequate spatial isolation, and a paucity of biodiversity in agrocenoses. This combination of factors results in an elevated risk of the proliferation of significant pests (Tanchyk et al., 2024).

Aphids (Aphididae: Hemiptera) are a group of insects that have been identified as a significant problem for numerous agricultural crops worldwide. There has been a notable increase in their population in recent years, and they have

become a persistent pest (Singh & Singh, 2021). Aphids are one of the most important pests and one of the major plant health problems of barley in Europe (Namara et al., 2024). Infestation with aphids in winter barley can lead to significant yield losses through direct feeding damage and the transmission of plant viruses, particularly Barley Yellow Dwarf Virus (BYDV) (Lau et al., 2021). Aphids extract essential nutrients by feeding on the phloem sap of barley plants. This weakens the plant and can reduce yields by up to 10% (<https://www.agric.wa.gov.au/>). In addition to direct damage, aphids are vectors for barley yellow dwarf virus (BYDV), a virus that poses a significant threat to barley crops. Infected plants often show stunted growth and yellowing of leaves, leading to significant yield losses. In some trials, BYDV has been associated with yield losses of up to 80% in barley (Grauby et al., 2022; <https://cropscience.bayer.co.uk/agronomy-id/pest-and-slugs/>).

During the initial growth stages of cereals, these crops exhibit an increased vulnerability to yellow dwarf disease. Most of the damage to winter cereals is attributable to infections sustained during the autumn season (Fabre et al., 2003). The bird-cherry aphid (*Rhopalosiphum padi* (L.)), for instance, has been observed to

overwinter on volunteer cereals and grasses, thus rendering early sown autumn cereals particularly vulnerable to BYDV infection (White et al., 2023). Climate change, and in particular global warming, may result in the prolonged presence of aphids in cereal fields, thereby increasing the risk of infection with BYDV (Van den Eynde et al., 2020). This suggests a potential increase in aphid damage in the future (Grauby et al., 2022). The most important pests of barley in Bulgaria are Corn leaf aphid *Rhopalosiphum maidis* (Fitch, 1856), Wheat aphid *Schizaphis graminum* (Rondani, 1852) and English grain aphid *Sitobion avenae* (Fabricius, 1775) (Maneva, 2010). The management of aphids is largely contingent upon the application of insecticides. Despite the effectiveness and rapid action of insecticides, their extensive utilisation gives rise to a multitude of deleterious consequences. These include the advent of insecticide resistance in aphids and deleterious effects on beneficial and other non-target organisms (Müller, 2024). Furthermore, there is a risk to human health and environmental pollution. These dangers should not be ignored. Therefore, it is necessary to implement alternative and environmentally friendly pest control practices. Changes in control strategies have led to increased interest in long-term control techniques that have the potential to diminish reliance on insecticides in the context of sustainable agriculture. An important tool in sustainable aphid management is to create an environment that supports and encourages natural enemy population. Intercropping is a practice that has been utilised for this purpose. There is some evidence in the literature that cereal aphid populations decrease in intercropping systems compared to monoculture (Sarwar, 2011; Duan et al., 2022; Grauby et al., 2022). Furthermore, intercropping has the potential to offer valuable food and spatial resources to the agroecosystem for the enhancement of beneficial insects (Liu et al., 2017). Intercropping has been demonstrated to increase plant diversity within the agroecosystem, thereby supporting regulatory mechanisms for pest populations by providing new levels of protection against aphids and, consequently, against viral diseases (Grauby et al., 2022; Saied et al., 2024).

Despite the existence of literature pertaining to the efficacy of combining cereals with other crops for aphid control, there is a paucity of research focusing on the role of intraspecific diversity, specifically the combination of various cultivars of a given cereal species. In this context, the aim of the present study was to investigate the potential effect of combining barley and legumes in mixed cropping of various barley cultivars on the abundance of cereal aphid. The study will also determine the role of strip intercropping as a barley protection practice and its application under real production conditions.

MATERIALS AND METHODS

The investigations were carried out in the field at the Training field of the University of Forestry in Sofia (42°70'76.1"N, 23°43'73.1"E) during the vegetation period 2021-2023. The region's climate is classified as temperate continental, with an annual mean precipitation of 620.8 mm and an average of 500 to 1.750 hours of sunshine. The mean annual temperature is 12.02 °C. The soil in the area is categorised as slightly stony Fluvisols, as defined by the classification system of the Food and Agriculture Organization (FAO).

Field experiment design

The trial was conducted in a combination of intraspecific (mixture of barley cultivars) and interspecific (barley-legumes intercropping) cropping practices. The cropping system included barley (*Hordeum vulgare* L.) 6 winter feed barley cultivars (LG Zebra, Rafaela, Zanzibar, California, LG Callista and Veslets) and 6 winter malting barley cultivars (Casanova, Hemus, Emon, Tangra, Zagorets and Obzor), vetch (*Vicia sativa* L., cv. Obrasets 666) and chickpea (*Cicer arietinum* L., cv. Plovdiv 8). The barley crop was sown in strips in the autumn, with different cultivars next to each other. The sowing depth was 5 cm, with an inter-row distance of 13 cm and an intra-row distance of 6 cm. In the spring, vetch and chickpea were sown successively between the strips, with a sowing depth of 5 cm, a row spacing of 20 cm, and an inter-row distance of 20 cm. No plant protection measures were applied, except for the application of herbicide after sowing the crops. The total area of the experimental block was 600

square metres, with each experimental plot comprising 18 rows of crops, each measuring 5 metres in length.

The experiment was meticulously designed using a complete randomised block design (RCBD), encompassing 4 distinct variants and 3 replicates. The following variants were subjected to testing: WFB: winter feed barley 18 rows: 3 rows for each cultivar; WMB: winter malting barley: 18 rows; 3 rows for each cultivar; WFB + LVC: 18 rows /6 rows winter feed barley /1 row for each cultivar/ + 3 row vetch и 3 row chickpea +6 rows winter feed barley/1 row for each cultivar/; WMB + LVC: 6 rows /6 rows winter malting barley /1 row for each cultivar / + 3 row vetch и 3 row chickpea + 6 rows winter malting barley/1 row for each cultivar/.

Sampling of cereal aphids

Aphid dynamics in each variant and cultivar were monitored by means of direct visual observations. The start of the assessment coincided with the appearance of the first individuals on the barley plants or at growth stage BBCH 49 and continued until the aphid populations were completely exhausted or at BBCH 87. The quantity of cereal aphids was evaluated on pre-tagged streams, which had been randomly selected. Individuals on the 20 streams for each cultivar were enumerated at 10-day intervals, from which an average value aphid individuals per stream was calculated. The number of aphids of the established species was summarised, as well as the number of winged (alatae) and wingless (apterae) forms. The abundance of aphids over the entire observation period was estimated as the sum of the mean number of individuals in each variant or cultivar for the whole research period.

The effect of intercropping was assessed using a quantitative parameter, the land equivalent ratio (LER), which compares the economic yield obtained by combining the specified crops with the yield obtained by growing the same crops in monoculture (Chapagain & Riseman, 2014).

Statistical analysis

The data were subjected to analysis of variance (ANOVA) and mean differences (3 replicates $\times$ 3 years, $n = 9$) were determined by Duncan's multiple range test ($P \leq 0.05$) using the statistical software package Statistica 13.0.

RESULTS AND DISCUSSIONS

The most important species of cereal aphids: *Rhopalosiphum padi* (Linnaeus, 1758), *Rhopalosiphum maidis* (Fitch, 1856), *Schizaphis graminum* (Rondani, 1852), and *Sitobion avenae* (Fabricius, 1775) (Hemiptera: Aphididae) were identified on the barley crop. Only a few specimens of *Myzus (Nectarosiphon) persicae* Sulzer, 1776 and *Metopolophium dirhodum* (Walker 1849) have been recorded. Despite the variability in the percentage of the four species (*R. padi*, *R. maidis*, *S. graminum* and *S. avenae*) observed over the course of the study, the most frequently encountered species were *S. avenae* (73.2%) and *S. graminum* (18.4%). The species *R. padi* (5.1%) and *R. maidis* (3.3%) were found in limited quantities. The data were obtained from the mean number of aphids per plant, as recorded during the BBCH growth stage 49÷87, with the mean calculated over the three-year study period. The highest number of aphids was observed during the BBCH growth stage 65÷71. The mean total aphid number for the three sampling seasons is demonstrated in Figure 1.

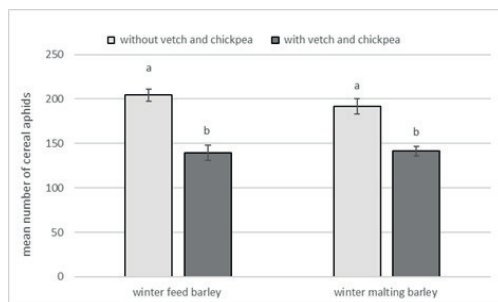


Figure 1. Figure 1. Mean total number of cereal aphids during the period 2021-2023

(mean $\pm$ SE; different letters within the same variant (bars with the same color) indicate statistically significant differences, Duncan's multiple range test, $P \leq 0.05$)

The abundance of cereal aphids exhibited variation amongst the different variants, with the highest recorded numbers observed in winter feed barley (204.3 aphid individuals) and winter malting barley (191.7 aphid individuals). Conversely, the mixed chickpea and vetch variants exhibited a reduced aphid abundance, with 139.1 individuals/stream recorded in the WFB variant and 141.3 aphid individuals in the

WMB variant. The most significant reported decrease in numbers by 31.7% was in the winter feed barley and legume variant, in comparison to the winter feed barley cultivars cultivated without legumes. The total number of aphids in combinations of all cultivars of winter feed and winter malting barley with legumes was statistically proven, as compared to the total number of aphids when grown without legumes (Figure 1).

The results of the analysis of the attack data for each cultivar are shown in Figures 2 and 3. When growing winter feed barley cultivars without legumes, cv. LG Zebra had the lowest number of aphids (15.3 individuals/stream), and cv. Veslets the highest (53.6 individuals/stream) followed by cv. Zanzibar (49.1 individuals/stream) and cv. Rafaela (37.4 individuals/stream), while the cultivars California and LG Callista were intermediate with numbers of 25.4 and 23.5, respectively. The statistical analysis confirmed the differences found between the varieties (Fig. 2).

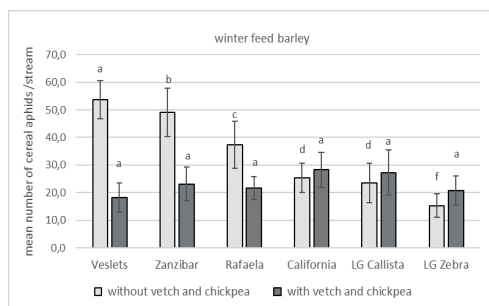


Figure 2. Mean number of cereal aphids on various winter feed barley cultivars

(mean $\pm$ SE; different letters within the same variant (bars with the same color) indicate statistically significant differences, Duncan's multiple range test, $P \leq 0.05$)

When winter malting barley cultivars were cultivated without legumes, similar data were reported. The statistically highest aphid abundance was found in the cv. Emon (50.9 aphid individuals/leaf and ear) and cv. Tangra (42.2 individuals/stream). The lowest abundance was observed in the cv. Obzor (12.7 individuals/stream) and cv. Casanova (21.4 individuals/stream), while the cv. Zagorets and cv. Hemus occupied an intermediate position with abundances of 36.4 and 28.1 individuals/stream, respectively (Figure 3).

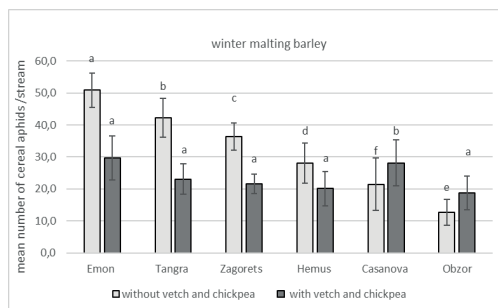


Figure 3. Mean number of cereal aphids on various winter malting barley cultivars

(mean $\pm$ SE; different letters within the same variant (bars with the same color) indicate statistically significant differences, Duncan's multiple range test, $P \leq 0.05$)

Data on the number of aphids in different cultivars of winter feed barley grown together with legumes (chickpea and vetch) showed that there were no statistically proven differences between the varieties when compared with the same varieties grown without legumes. It should be noted that among the cultivars of winter malting barley grown with legumes, the differences are not significant, but the cultivars that were most affected (Emon and Tangra) when grown without legumes then occupy an intermediate position when grown with legumes. However, the cultivars most severely attacked in the absence of legumes presented an intermediate response when grown in conjunction with legumes.

The reported significant reduction in numbers of aphids in the mixed crop of the cultivars with legumes does not allow us to reject the hypothesis that aphid populations do not decrease when grown without legumes. This is because in our study the varieties were not grown independently, and comparisons cannot be made. However, the results regarding the reported differences between cultivars, or lack thereof, in the two cropping practices could be explained by the fact that the effect of intraspecific diversification on pest regulation depends on biotic pressures (Huang et al., 2012). Similar results were documented by Mansion-Vaquié et al. (2019), who ascribed the absence of an impact on aphid abundance when combining distinct wheat varieties to the minimal biotic pressures. During the period of our studies, the highest aphid abundance recorded was (53.6 individuals/stream),

indicating a low level of attack (Schnelle, 1995). The results show that the abundance of aphids differed in the two cropping systems. A significant interactive effect was observed in co-cropping with legumes, which resulted in a reduction in the number of aphids. Based on information from the literature (Sarwar, 2011; Grettenberger & Tooker, 2016) and our research, it should be assumed that the number of aphids in cereal crops depends on annual variations and specific environmental conditions, microclimatic and stress factors, such as prolonged drought, and the growing seasons during which we conducted the surveys were characterised by below-normal rainfall. Therefore, research over a longer period is needed. The expected reduction in aphid populations by mixing barley and legumes was confirmed by our results. This was true for both feed and malting barley.

The extant literature pertaining to the mechanisms of this form of intercropping is diverse. According to Mansion-Vaquié et al. (2019), the reduction in aphid numbers during the co-cropping of wheat and white clover is associated not only with the diversity of the aboveground cover, but also with differences in the nitrogen content of the plants. The nitrogen content is an important parameter for determining the quality of the plant as a host for aphids (Zehnder & Hunter, 2008). The authors further report that during this period, the nitrogen content in the wheat grain was lower. Another factor that must be considered is the way the crops that enter the intercropping system are arranged. (Lopes et al., 2016). Since the findings of our study, we can conclude that the use of strip cropping systems for mixed cultivation, which resulted in an increase in species diversity in the agroecosystem, led to a reduction in the number of aphids. Liu et al. (2020) also reported a few successful examples of aphid control using strip intercropping, where wheat-pea intercropping reduced populations of pea aphid *Acyrtosiphon pisum* (Hemiptera: Aphididae) and *S. avenae* compared to pure stands. A reduction in the infestation of wheat by aphids such as *S. graminum* and *S. avenae* was observed when wheat was intercropped with strips of lucerne (Saeed et al., 2013). Intercropping systems increase crop diversity in agroecosystems, have an impact on the

abundance of herbivorous insects and their natural enemies, and can be an important tool in the reduction of cereal aphid abundance (Arshad et al., 2018).

The Land Equivalent Ratio (LER) was calculated to determine the effect of competition between the species used in the intercropping system. The total LER was found to be 2.01 in the winter malting barley and legume variant and 2.07 in the winter feed barley variant. The LER values indicated good crop development (Dhima et al., 2007).

CONCLUSIONS

The present study has concluded that the intercropping system of barley and the legumes chickpea and vetch influences the abundance of cereal aphids by reducing their numbers. The reduced aphid damage prevents yield losses in barley without affecting the yield of the legumes. This finding indicates that the proposed cropping system is a viable approach for both production and aphid management within cereal and legume agroecosystems.

However, extensive research is necessary, including the identification of the factors that led to the specific reactions of the studied varieties in the system of intraspecific diversification and the monitoring of meteorological parameters in specific agricultural regions. This will assist in the identification of suitable pest control strategies within the framework of integrated plant protection.

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