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RESEARCH ARTICLE

Including predator presence in a refined model for assessing resistance of alfalfa cultivar to aphids

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Abstract

The aphid quantity ratio (AQR) is defined as the number of aphids on each cultivar divided by the number of aphids on all cultivars. AQR is based on the correlation between aphid populations and their host plants and is an important tool that has been utilized in evaluating *Medicago sativa* (alfalfa) cultivar resistance to aphids. However, assessment of alfalfa resistance to aphids can be confused by the presence of aphid predators, causing the assessment of plant resistance to aphids to be based on incorrect aphid population data. To refine the AQR and account for the effect of predators on aphid population assessments, we introduced a parameter 'α', corresponding to the predator quantity ratio, and used αAQR as the ratio to quantify aphid populations. Populations of both aphids (4 species) and their predators (12 species) occurring in 28 *M. sativa* cultivars were sampled over two years at a research station near Cangzhou, Hebei Province, China. Results showed that the most suitable evaluation period was from May to June, as the aphid population was stable during this period. Compared with the AQR method, the predator population numbers based on the αAQR had a significant inverse relationship with aphid population numbers and the 28 cultivars were clustered into three classes: the resistant class, tolerant class, and susceptible class. In addition, 17 cultivars were reassigned when evaluated using αAQR. All numerical values calculated by αAQR were displayed as a Gaussian distribution, which showed that the 28 cultivars could be clustered into nine groups using a median value (±SE) of 1±0.1. Hence, ongoing alfalfa breeding trials will be assessed using the αAQR to establish a robust system that includes agronomic performance parameters in order to generalize the new method for further studies.

Keywords: aphid quantity ratio (AQR) model, alfalfa cultivar resistance to aphids, natural enemy

1. Introduction

Aphids are widespread throughout the world and cause severe damage to a variety of economically important crops (Gutierrez and Ponti 2013; Yang 2013). For this reason, control of aphids using plant resistance and biological control as part of integrated pest management (IPM) programmes has been the focus of extensive and ongoing research in many economically important crops (Smith and Clement 2012). Statistical models of pest population density are

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widely used to evaluate variety resistance in IPM strategies (Luginbill 1969). Numerous researchers have worked to improve the accuracy of such models over the years. For example, Rana (1999) suggested that aphid quantity on plants could be used to estimate cultivar resistance to *Sitobion avenae* (Fabricius). Havlíčková (1997) analyzed tolerance differences of five winter wheat cultivars to cereal aphids using aphid population density. Thackray *et al.* (1990) evaluated wheat cultivar tolerance to *Rhopalosiphum padi* L. using the intrinsic growth rate of populations on the plants, while Souza *et al.* (1991) proposed an aphid damage index to evaluate wheat cultivar tolerance to *Diuraphis noxia* Mordvilko. More complex evaluations, such as that undertaken by He and Zhang (2006), have evaluated alfalfa (*Medicago sativa* L.) resistance to aphids using an aphid damage index and plant infestation index. Hesler *et al.* (1999) proposed a method to study resistance differences of wheat cultivars to *R. padi* using aphid quantity, aphid development duration, and intrinsic growth rate. All of these authors made important contributions to the methods of evaluating crop variety resistance to aphids. However, the accuracy of these models is limited mainly due to plant variety and different levels of resistance (Chen *et al.* 1997).

In an effort to provide a more robust assessment of *M. sativa* resistance to aphids, the aphid quantity ratio (AQR) model was developed in China. AQR has been used in theoretical and applied research on resistance to plant pests (Sun 2006; Qu *et al.* 2012), including studies of aphids on *M. sativa* (Huang 2007) and oat bird-cherry aphids on wheat cultivars (Li and Ye 2002). Chen (2005) evaluated 12 goat weed resistance to *S. avenae* using a combination of the AQR model, weight loss of plants, and changes in chlorophyll content. The AQR model has played an important role in assessing plant resistance to pests, but it does not indicate which factor produced resistance of the cultivars (Farmer 2001; Schnee *et al.* 2006; Shiojiri *et al.* 2006; Zeng 2008). Natural enemies affect pest population dynamics, but they are only a part of the intrinsic components of crop resistance to pests, and the relationship between natural enemies and pests is not entirely clear (Huang *et al.* 2008; Fang *et al.* 2010). For example, host plant resistance has been clearly defined as inherited qualities that result in less damage by pests (Souza *et al.* 1991). Therefore, evaluation methods should explore parameters, including natural enemies that reflect inherent traits of the plant.

Unfortunately, the current AQR model leads to incorrect conclusions about plant susceptibility to aphid pests, with discrepancies between the predicted *vs*. actual field observation of plant species resistance (Temuer *et al.* 2005; Cheng *et al.* 2009; Liu *et al.* 2012). In this paper, we investigated the value of a modified AQR model for evaluating resistance of *M. sativa* varieties to aphids by monitoring populations of aphids and their predators over growing seasons in two consecutive years.

2. Materials and methods

2.1. Region description and cultivar source

The field experiment was conducted at Cangzhou City, Hebei Province, China (39°37′N, 98°30′E, 40 m above sea level) from May 2013 to August 2014. The site was on cultivated farmland, with a saline-alkali soil (Bohai alkaline moisture soil) and it was unirrigated. The plots were sown in May 2012 using a precision seeder, with N, P, K fertilizer applied once prior to sowing and once after sowing. The experiment used a randomized complete block design and evaluated 28 *M. sativa* cultivars (Table 1) with three replications per cultivar. Each plot measured 4 m by 5 m, with the seed planted at a rate of 15 kg ha^{-1}, a seeding depth of 2 cm and a between-row spacing of 20 cm. There was a 1-m spacing between plots which was kept clear of weeds

Table 1 Origin of alfalfa cultivars assessed in the experiment to evaluate aphid resistance

Reference no.	Cultivar	Origin
1	FD4	Canada
2	SARDI 10	Australia
3	SARDI 7	Australia
4	53HR	America
5	Zhongmu 1	China
6	Alfaking	America
7	Farmers Treasure	America
8	WL319HQ	America
9	Algonquin	Canada
10	Sanditi	France
11	Zhongmu 3	China
12	WL354HQ	America
13	WL343HQ	America
14	KRIMA	Hungary
15	Gongnong 1	China
16	WL363HQ	America
17	WL440HQ	America
18	Sitel	France
19	WL168HQ	America
20	Zhongmu 2	China
21	Derby	Holland
22	Cangzhou	China
23	WL323	America
24	Apex	America
25	Queen	America
26	SARDI 5	Australia
27	Gongnong 2	China
28	SOCA	Hungary