Crop Protection 100 (2017) 138–149

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Cultural practices to reduce damage by borer insects in commercial cultivars of *Amaranthus*

Selene Niveyro [a,*], Adriana Salvo [b]

[a] Facultad de Agronomía, Universidad Nacional de La Pampa, Ruta 35 Km 334, Santa Rosa 3300, La Pampa, Argentina
[b] Centro de Investigaciones Entomológicas de Córdoba, Instituto Multidisciplinario de Biología Vegetal, CONICET, Facultad de Ciencias Exactas Físicas y Naturales, Universidad Nacional de Córdoba, Vélez Sarsfield 1611, Córdoba 5000, Argentina

ARTICLE INFO

Article history:
Received 15 January 2017
Received in revised form
24 June 2017
Accepted 26 June 2017

Keywords:
Amaranthus
Herbivory
Stem borer insects
Insect-plant interaction
Agronomic practices
Conotrachelus spp. curculionidae
Cerambycidae

ABSTRACT

Stem borer insects are one of the most important pest groups of *Amaranthus* crops on a global scale. In this study, we evaluated the magnitude of borer herbivory in five cultivars of *Amaranthus* experimentally in La Pampa, Argentina, during two growing seasons. We tested the effect of several plant attributes of five cultivars of *Amaranthus* on the herbivory caused by three stem borer species. In turn, we evaluated the effect of cultivar and plant density (both as factors modifying the thickness of the stems) and the effect of cultivar and planting time (both as factors modifying the length of the life cycle of the plants) on the herbivory caused by the stem borers in two cultivars of *Amaranthus hypochondriacus*.

We report a wide variation in the susceptibility of the cultivars to stem borer herbivory and discuss the effects of the plant features investigated. Phenological and morphological features of the stems (especially the diameter) influenced the selectivity of host plants by the adult females. The management practices tested here, including plant density and sowing date manipulations, modified plant structure and consequently influenced the damage by stem borers. High density sown plants presented thinner stems and suffered reduced damage by borers than plants sown at low density, whereas delayed sown plants had thinner stems and were less attacked by borer insects than earlier sown plants. The implementation of these cultural practices seems to be a promising alternative for the management of borer species, to which *Amaranthus* is particularly vulnerable.

1. Introduction

Resistance to diseases and pests is one of the objectives in *Amaranthus* plant breeding, since the crop is affected by numerous insects (Bürki et al., 1997; Brenner et al., 2010). Among them, the stem borer guild is one of the prevalent pest groups, with about twenty-six different species reported worldwide (Louw et al., 1995; Niveyro and Salvo, 2014). The stem borer guild includes mainly weevils (Curculionidae: Coleoptera), cerambycid beetles (Cerambycidae: Coleoptera) (Louw et al., 1995; Niveyro and Salvo, 2014), but also flies (Diptera: Agromyzidae) (Torres-Saldaña et al., 2004) and moths (Lepidoptera: Crambidae) (Oliveirade et al., 2012). The occurrence of borer species varies widely across the world e.g. the weevil *Hypolixus truncatulus* (Fabricius) is reported in India and Mexico (Gupta and Rawat, 1954; Torres-Saldaña et al., 2004), *Conotrachelus cervinus* Hustache in both America and Europe (Niveyro and Salvo, 2014), while *Gasteroclisus* cf. *cuneiformis* (Fahraeus) has been reported only in Africa (Louw et al., 1995). Stem bored damage is caused when females oviposit into the stems and then juvenile stages bore into the main and secondary stems; but depending on the borer species, thick stalks and even roots can be affected (Niveyro and Salvo, 2014). As a consequence of borer feeding, plants are prone to breakage, with subsequent loss of seeds (Terry and Lee, 1990). Moreover, some studies mentioned that entry or exit holes caused by borers allowed the entrance of fungi and bacteria, contributing to further plant decline (Anno-Nyako et al., 1991). In spite of a great number of reports describing damage by different stem borer species on *Amaranthus* crops, no studies have yet been performed to determine action threshold levels. In turn, the habit of boring and feeding into stems limits the efficiency of chemical control (Wilson, 1989) underlying the need to search for pest management alternatives with low economic and environmental costs.

In the semi-arid region of La Pampa, the simultaneous

* Corresponding author.
E-mail address: niveyro@agro.unlpam.edu.ar (S. Niveyro).

http://dx.doi.org/10.1016/j.cropro.2017.06.020
0261-2194/

occurrence of the three species: *Conotrachelus cervinus* Hustache, *C. histrio* Boheman (Coleptera: Curculionidae) and *Aerenea quadriplagiata* Boheman (Coleoptera: Cerambycidae) is reported in *Amaranthus*, coinciding with advanced phenological stages of the crop (Niveyro and Salvo, 2014). A previous study demonstrated that *A. quadriplagiata*, tends to oviposit in cultivars with particular stem diameters (Riquelme et al., 2013). Therefore, the choice of cultivars displaying features less preferred by stem borer females for oviposition could be a recommendable measure to reduce damage in *Amaranthus* crops, but further information about *Amaranthus* genotypes grown under field conditions is required. Agronomic practices such as altering sowing date and plant density are modifiers of the size and structure of plants in crops (Gimplinger et al., 2008). Both agronomic practices have been employed as pest management strategies in other crop species (Dosdall et al., 1999; Echezona, 2007) but scarcely studied in grain amaranth (Torres-Saldaña et al., 2004).

In this study, we assessed whether differences in morphological and phenological features of five commercial cultivars of *Amaranthus* affect the herbivory caused by stem borers. In addition, we studied the effect of cultivar and planting density (both as factors modifying the thickness of the stems) experimentally and the effect of cultivar and planting time (both as factors modifying the length of the life cycle of the plants) on the herbivory caused by these insects in two cultivars of *Amaranthus hypochondriacus*. We hypothesized that differences in stem thickness and life cycle length of the cultivars will affect the resource availability for borers and consequently, herbivory levels will decrease (Riquelme et al., 2013). Cultivars with thicker stems and longer cycles are expected to be more heavily attacked by borers and hence, they will harbor a greater number of larvae than plants with thinner stems or shorter cycles (Dubbert et al., 1998). Furthermore, we predicted that plants sown at higher densities and sown later will display lower levels of herbivory by borer insects given their thinner stems and shorter life cycles.

2. Material and methods

2.1. Experiment 1: susceptibility of Amaranthus cultivars to borer insects

In order to assess the effects of plant features on the susceptibility of *Amaranthus* cultivars on the herbivory by stem borer insects, a field experiment was conducted during the summer season of 2008/2009 at the Experimental Station of the Agronomy Faculty, in Santa Rosa, La Pampa, Argentina (36°37′S, 64°16′W). Five cultivars of *Amaranthus* belonging to three different species were chosen on the basis of their good agronomic performances (Covas, 1987; Niveyro et al., 2013). Plants of different cultivars have shown differences in morphological, phenological and chemical features (phenolic acids and betalains contents) (Niveyro et al., 2013; Niveyro, 2015). The studied cultivars were: one cultivar of *Amaranthus cruentus* (Don León), three cultivars of *A. hypochondriacus* (San Antonio, 280 FK-FH1 and Artasa 9122) and one of *A. mantegazzianus* (Don Juan), hereinafter named as "*Cruentus*", "*Hyp SA*"; "*Hyp 280*"; "*Hyp Artasa*" and "*Mantegazzianus*", respectively (Table 1).

The experiment was arranged in a Latin Square design of 5 × 5 plots (n = 25). Plots were sized 3.20 m × 2 m (6.4 m^2) and separated from each other by a distance of 1 m. Seeds were planted into five rows of 3.20 m length, separated by 0.50 m, using approximately 3.5 kg of seeds per hectare (Henderson et al., 2000). Weeding was done manually and no fertilizers, herbicides or pesticides were used during the trial.

Variables relating to plant morphology were recorded in 5 plants per cultivar and plot (total n = 125 plants), at maturity stage (R7) according to the methodology of Fomsgaard et al. (2010). The measured variables were: total length of the stem (from the ground to the neck of the panicle), stem diameter (40 cm above the ground) and length of panicle, in all cases expressed in cm. On seven dates during the growing season (9th, 16th, 22nd, 29th of January, 24th of February, 5th of March and 11th of April), the phenological stages of 5 plants randomly chosen from each plot were measured following the scale of Mujica and Quillahuamán (1989), and the number of days required to reach anthesis stage (R4) and to complete the ontogenetic cycle (R7) were quantified.

On two sampling dates: at the middle of the plant cycle (21st to 22nd of February 2009) and at end of the plant cycle (15th to 16th of April 2009), herbivory by *Conotrachelus cervinus*, *C. histrio* and *Aerenea quadriplagiata* was estimated in 10 plants randomly chosen from each experimental unit (total n = 500 plants). Stems and panicles were longitudinally sectioned and borer larvae and galleries were quantified. The variables measured were percentage of damaged stems and panicles (number of damaged organs/total of observed organs), number of galleries per stem, number of larvae per plant organ (stem and panicle) and damaged stem area (cm^2). To calculate the latter variable, stems damaged by borer insects was estimated visually in the field by assigning a percentage of stem area lost by herbivory on a 0–10 scale with the following categories: 0: 0%, 1: 1–5%, 2: 6–10%, 3: 11–20%, 4: 21–30%, 5: 31–40%, 6: 41–50%, 7: 51–65%, 8: 66–75%, 9: 76–95%, 10: 100%. The percentages were later converted to area values (cm^2) to allow comparisons among cultivars. For this conversion, the diameter and length of dissected stems were also measured and the formula of

Table 1
Morphological and phenological features and plant tissue pigmentation in five cultivars of *Amaranthus*.

Features		Cruentus	Hyp SA	Hyp 280	Hyp Artasa	Mantegazzianus
Origin		Argentina	Mexico	Hungary	Argentina	Argentina
Specie		*Amaranthus cruentus*	*Amaranthus hypochondriacus*	*Amaranthus hypochondriacus*	*Amaranthus hypochondriacus*	*Amaranthus mantegazzianus*
Growing cycle (days)		142	126	59	175	162
Height (cm)		166.8 ± 5.4 (n = 37)	152.1 ± 5.3 (n = 40)	107.6 ± 2.2 (n = 45)	121.46 ± 4.3 (n = 35)	195.1 ± 7.4 (n = 36)
Foliage		abundant	abundant	poor	abundant	abundant
Panicle	shape	amaranthiform	amaranthiform	amaranthiform	amaranthiform	globular
	size	medium	large	small	large	large
	color	yellowish green	purple	purple	purple	yellow/orange
Stem	thickness	thick	thick	thin	thick	thick
	branching	scarce	scarce	scarce	intermediate	abundant
	color	green	reddish green	reddish	reddish green	green
Grain yield (kg/ha)		1763 ± 446 (n = 13)	858 ± 125.4 (n = 12)	1215 ± 245 (n = 12)	1626 ± 281 (n = 11)	2045.4 ± 522 (n = 12)