Crop Protection xxx (2016) 1–7

Contents lists available at ScienceDirect

Crop Protection

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

Weed management using crop competition in the United States: A review

Prashant Jha [a,*], Vipan Kumar [a], Rakesh K. Godara [b], Bhagirath S. Chauhan [c]

[a] Montana State University-Bozeman, Southern Agricultural Research Center, Huntley, MT, USA
[b] Crop Protection Division, Monsanto Company, St. Louis, MO, USA
[c] The Centre for Plant Science, Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Toowoomba, Queensland, Australia

ARTICLE INFO

Article history:
Received 14 April 2016
Received in revised form
21 June 2016
Accepted 27 June 2016
Available online xxx

Keywords:
Crop competition
Competitive cultivars
Row spacing
Seeding rate
Weed interference
Yield losses

ABSTRACT

Exploiting the competitive ability of crops is essential to develop cost-effective and sustainable weed management practices. Reduced row spacing, increased seeding rates, and selection of competitive cultivars can potentially manage crop–weed competition in cotton, soybean, wheat, and corn. These cultural weed management practices facilitate a more rapid development of crop canopy that adversely affect the emergence, density, growth, biomass, and subsequently the seed production of weeds during a growing season. These cultural practices can also favour the weed suppressive ability of the crop by influencing the canopy architecture traits (plant height, canopy density, leaf area index, rate of leaf area development, and leaf distribution). These crop-competition attributes can potentially reduce the risk of crop yield losses due to interference from weed cohorts that escape an early- or a late-season post-emergence herbicide application. Furthermore, reduced row spacing, increased seeding rates, and weed-competitive cultivars are effective in reducing reliance on a single site-of-action herbicides, thereby reducing the selection pressure for development of herbicide-resistant weed populations in a cropping system.

1. Introduction

Weeds adversely affect the crop growth and yield by competing with crops for limiting resources such as light, water, and nutrients (Harper, 1977; Swanton et al., 2015). The intensity and duration of the crop-weed competition determines the magnitude of crop yield losses (Swanton et al., 2015). Avoiding or reducing crop yield losses due to weed competition requires the utilization of diverse and effective weed management programs (Chauhan and Opeña, 2013; Swanton et al., 2015). Herbicides are the dominant tools used for weed control in global agriculture, and an annual worldwide herbicide sale is estimated to be US $27 billion (Kraehmer, 2012). As an outcome, the over reliance on the same-site-of-action herbicide in a cropping system has resulted in an increased development of herbicide-resistant (HR) weed populations worldwide (Heap, 2016). Globally, the US ranks first, with more than 150 unique cases of HR weed evolution, followed by Europe and Australia (Heap, 2016). Commercialization of glyphosate-resistant (GR) trait in soybean [(*Glycine* max (L.) Merr.] (1996), cotton (*Gossypium* spp.) (1997), and corn (*Zea mays* L.) (1998) in the US, and its increasing use for weed management in these GR crops (Duke and Powles, 2009) has resulted in evolution of 15 GR weed species over the last 20 years in the North America (Johnson et al., 2009; Beckie et al., 2014; Kumar et al., 2014, 2015; Heap, 2016). In addition, HR weed populations have also been reported in wheat (*Triticum aestivum* L.) grown in the US (Heap, 2016). Insurgent reports on HR weed populations pose a serious threat to the sustainability of the US cropping systems. Moreover, an increasing cost of managing HR weeds in the absence of any new site-of-action herbicide discovery over the last two decades further exacerbates the problem (Duke, 2012). Current data and future projections on HR weeds strongly suggest the need for development and implementation of integrated weed management (IWM) strategies in cotton, corn, soybean, and wheat to curb the resistance problem (Norsworthy et al., 2012; Vencill et al., 2012).

Developing cost-effective and sustainable weed management strategies further necessitates the in-depth understanding of

* Corresponding author. Montana State University-Bozeman, Southern Agricultural Research Center, 748 Railroad Highway, Huntley, MT 59037, USA.
E-mail address: pjha@montana.edu (P. Jha).

http://dx.doi.org/10.1016/j.cropro.2016.06.021
0261-2194/

concepts and factors involved in crop-weed competitive interactions (Blackshaw et al., 2000; Swanton et al., 2015). The competitive ability of a crop depends on various physiological and morphological attributes that allow the crop to utilize light, water, nutrients, and other limited resources effectively in the presence of the weed pressure. A variety of cultural practices such as crop planting dates, competitive cultivars, seeding rates, row widths, cover crops, nutrient management, and irrigation strategies can manage crop-weed competition and favour the crop competitiveness against weeds (Chauhan and Opeña, 2013; Swanton et al., 2015). Furthermore, the use of reduced crop row spacing, increased seeding rates, and competitive cultivars in a cropping system can potentially minimize reliance on herbicides with the same site of action and manage HR weed seed banks (Norsworthy et al., 2012; Vencill et al., 2012). In the U.S., soybean, cotton, corn, and wheat account for more than 70% of all crop acres planted annually (Price et al., 2011). Therefore, the aim of this review article is to highlight the importance of weed management using crop competition though manipulations in crop row spacing and seeding rates and use of competitive cultivars in these crops grown in the US.

2. Row spacing

2.1. Cotton

Traditionally, cotton in the US is grown in wide rows spaced 76- to 102-cm apart. The concept of Ultra Narrow Row (UNR) spacing originated in 1990s, with cultivation of cotton in narrow rows (twin rows) with a spacing of 19–38 cm (Reddy, 2001; Wilson et al., 2007). The UNR system allows the use of higher seeding rates of cotton per unit area. The major goals of adopting the UNR cotton system are to reduce production cost, improve weed control, and increase yield as well as economic return by increasing the plant population (Parvin et al., 2000; Nichols et al., 2004). Early and rapid canopy closure under the UNR cotton system also helps conserve soil moisture and suppress weeds early in the season (Reddy, 2001; Molin et al., 2004). Several studies conducted in the US have shown a mixed response on weed control under the UNR vs. the traditional wide row (76–102 cm) cotton production system (Parvin et al., 2000; Bryson et al., 2003; Molin et al., 2004). Rogers et al. (1976) reported that only 6 weeks of weed-free period was needed to obtain high yields in cotton grown in narrow rows (53 cm); whereas, 10–14 weeks of weed-free period was required to obtain similar yields in wide rows (79–106 cm). A four-year study showed that *Sida spinosa* L. under the UNR cotton system had 74–82% less total dry weight, and 71–90% less number of capsules per plant, compared with the wide row cotton system (Molin et al., 2004). The study also reported a 67–85% decline in the total dry weight plant^{-1} of *Euphorbia hyssopifolia* L. under the UNR vs. the wide row cotton system (Molin et al., 2004). Stephenson and Brecke (2010) found that cotton planted in 19-cm twin rows, with each set of twin rows being 76-cm apart, had greater control of *Commelina benghalensis* L., *Senna obtusifolia* L. Irwin & Barneby, and *Jacquemontia tamnifolia* L. compared with the single-row (76 cm apart) planting pattern of cotton. In addition, the end-season total weed dry biomass was reduced by 35% in the twin-row (two rows 38 cm apart on 102-cm beds) compared to the single-row (on 102-cm beds) cotton planting system (Reddy and Boykin, 2010). Aulakh et al. (2011) observed that sequential post-emergence applications of pyrithiobac at 2- to 4-leaf stages of conventional cotton increased the *S. obtusifolia* control in 38-cm compared to 102-cm wide rows. In contrast, Miller et al. (1983) observed no differences in total density of grass or broadleaf weed species with tillage plus trifluralin and prometryn, and tillage plus trifluralin and fluometuron treatments, in cotton grown under narrow (51 cm) vs. wide (102 cm) rows. Similarly, a minimal effect on annual grass and broadleaf weed control was observed with various pre-emergence followed by post-emergence herbicide programs in glufosinate-resistant cotton planted in 38-cm vs. 97-cm rows (Wilson et al., 2007).

2.2. Soybean

Numerous studies conducted in the US have reported the potential benefits of the narrow-row spacing on weed management in soybean. The benefits are mainly attributed to the early canopy closure in the soybean planted in narrow (19- or 38-cm wide) that enhances the competitive ability of the crop against weeds, compared to wide (76 cm or more) rows (Steckel and Sprague, 2004; Jha et al., 2008; Jha and Norsworthy, 2009). Shibles and Weber (1966) reported that the 95% solar light interception occurred 17 d earlier in the 25-cm wide rows compared to the 102-cm wide rows. In addition, soybean canopy closure occurred 40 d earlier in soybean planted in 25-cm vs. 76-cm wide rows (Mickelson and Renner, 1997). Reducing soybean row spacing from 76 to 19 cm delayed the critical timing of weed control (CTWR) from the first-trifoliate to the third-trifoliate stage of soybean, indicating enhanced weed competitive ability of the narrow-row soybean (Knezevic et al., 2003). Reducing the soybean row spacing from 91 to 23 cm reduced the weed density from 16 to 2 plants m^{-2} and the aboveground biomass from 141 to 33 g m^{-2} (Yelverton and Coble, 1991). There was a greater control of *Setaria faberi* Herrm. and *Amaranthus rudis* Sauer., and an increase in soybean yield in the GR soybean planted in narrow (19- or 38-cm) vs. wide (78-cm) rows (Young et al., 2001). Similar results on the suppressive effect of the narrow-row soybean on weed density and biomass were evident for several other weeds including, other *Amaranthus* species, *Chenopodium album* L., *S. obtusifolia*, *Ipomoea* species, *Xanthium strumarium* L., and *Ambrosia artemisiifolia* L. which are predominant in the US soybean production (Legere and Schreiber, 1989; Mickelson and Renner, 1997; Buehring et al., 2002; Steckel and Sprague, 2004; Hock et al., 2006; Harder et al., 2007). A single application of glyphosate at the V3 stage of soybean eliminated seed production from *Amaranthus palmeri* S. Wats plants in 19-cm soybean rows, compared with 600 seeds m^{-2} produced by plants grown in 97-cm soybean rows (Jha et al., 2008). Furthermore, in majority of these studies, soybean yields were greater in narrow compared to wide rows.

A dense canopy of soybean when planted in narrow rows (19 cm) resulted in decreased photosynthetic active radiation (PAR) and red/far-red ratio of light available to seed on or near the soil surface under no-tillage conditions (Norsworthy, 2004). This resulted in reduced emergence of *X. strumarium*, *S. obtusifolia*, and *A. palmeri* by 33, 68, and 76%, respectively, in plots in the presence compared to those in the absence of soybean (Norsworthy, 2004; Jha and Norsworthy, 2009). Thus, the early canopy formation trait of narrow-row soybean can potentially reduce weed resurgence and reduce reliance on multiple post-emergence glyphosate applications in GR soybean (Steckel and Sprague, 2004; Jha et al., 2008).

2.3. Wheat

There is relatively limited research conducted in the US on assessing the effect of row spacing on crop–weed competition in wheat. Nalewaja and Arnold (1970) reported that reducing the row spacing could enhance the wheat competitiveness against weeds, and improve wheat yields. There was a 12% increase in the yield of hard red winter wheat, with a decrease in the row spacing from 23

Please cite this article in press as: Jha, P., et al., Weed management using crop competition in the United States: A review, Crop Protection (2016), http://dx.doi.org/10.1016/j.cropro.2016.06.021