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Weed growth and crop yield loss in wheat as influenced by row spacing and weed emergence times

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ABSTRACT

Reducing crop row spacing and delaying time of weed emergence may provide crops a competitive edge over weeds. Field experiments were conducted to evaluate the effects of crop row spacing (11, 15, and 23-cm) and weed emergence time (0, 20, 35, 45, 55, and 60 days after wheat emergence; DAWE) on *Galium aparine* and *Lepidium sativum* growth and wheat yield losses. Season-long weed-free and crop-free treatments were also established to compare wheat yield and weed growth, respectively. Row spacing and weed emergence time significantly affected the growth of both weed species and wheat grain yields. For both weed species, the maximum plant height, shoot biomass, and seed production were observed in the crop-free plots, and delayed emergence decreased these variables. In weed–crop competition plots, maximum weed growth was observed when weeds emerged simultaneously with the crop in rows spaced 23-cm apart. Less growth of both weed species was observed in narrow row spacing (11-cm) of wheat as compared with wider rows (15 and 23-cm). These weed species produced less than 5 seeds plant^{-1} in 11-cm wheat rows when they emerged at 60 DAWE. Presence of weeds in the crop especially at early stages was devastating for wheat yields. Therefore, maximum grain yield (4.91 t ha^{-1}) was recorded in the weed-free treatment at 11-cm row spacing. Delay in time of weed emergence and narrow row spacing reduced weed growth and seed production and enhanced wheat grain yield, suggesting that these strategies could contribute to weed management in wheat.

1. Introduction

Wheat (*Triticum aestivum* L.) is the prominent cereal food grain and major staple food in Pakistan. However, weed infestation is a major bottleneck to higher wheat productivity, and accounts for more than 48% loss of potential wheat yield (Khan and Haq, 2002). Weeds are omnipresent pests that compete with crops for water, nutrients, space, and light; host pests and diseases; and release allelochemicals into the rhizosphere (Khaliq et al., 2013a, 2014a,b). The magnitude of weed-related losses, however, depends on the type and density of a particular weed species, its time of emergence, and the duration of interference (Estorninos et al., 2005; Hussain et al., 2015). Yield losses are most severe when resources are limited and weeds and crops emerge simultaneously (Zimdahl, 2007; Hussain et al., 2015). Crop yields decrease with increasing weed competition. A strong relationship exists between the duration of competition and the competition pressure exerted on the crop, which reduces yield (Ciuberkis et al., 2007; Fahad et al., 2014).

Among various weeds infesting wheat fields, *Galium aparine* L. (Rubiaceae) and *Lepidium sativum* L. (Brassicaceae) are particularly pernicious and prevalent annual weeds in Pakistan that can grow under a wide range of ecological conditions (Hassan et al., 2003; Hussain et al., 2004; Marwat et al., 2013). *G. aparine* is thought to be native to Europe, whereas *L. sativum* is native to Southwest Asia and has spread to Western Europe (Shehzad et al., 2013). *G. aparine*

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has a climbing, prostrate, or sometimes low and erect habit and is found in grassy, partially shaded habitats at lower elevations (Marwat et al., 2013). Because of its large seeds, it is relatively resistant to depth of sowing and soil aggregate size, and can therefore germinate in a wide range of conditions. Besides competing with wheat, *G. aparine* might also distort wheat plants and reduce light availability by shading it (Hussain et al., 2004). Wright and Wilson (1987) reported 12–57% losses in grain yield of winter wheat under the infestation of *G. aparine*. Mennan (1998) observed that infestation of ten *G. aparine* plants m^{-2} reduced wheat grain yield by 18%. *L. sativum* is an erect herb, and is well suited to all soils and climates, and in temperate conditions, it grows very rapidly. It grows sub-spontaneously in croplands and vacant places near crops (Marwat et al., 2013).

Increasing use of herbicides to manage agricultural weeds is a primary concern today (Khaliq et al., 2013b). Widespread and indiscriminate herbicide use during the last few decades has caused serious ecological and environmental problems, such as weed resistance, weed population shifts, and dominance of minor weeds (Chauhan and Johnson, 2010a,b; Chauhan et al., 2012). To decrease dependence on herbicides and establish more weed control methods, integrated weed management (IWM) programs have received increasing attention (Gibson et al., 2001; Chauhan and Johnson, 2010a; Chauhan, 2012; Khaliq et al., 2013c). Therefore, all those approaches which can prevent weed germination, supress weed growth, and enhance crop competiveness must be integrated to control weeds (Rasmussen, 2004).

Weed seedlings emerging at different times after crop emergence may differ in growth and productivity, depending on the conditions during early development of the crop plants (Lindström and Kokko, 2000). For example, late-emerging weeds are usually less aggressive and produce less biomass and fewer seeds than early-emerging ones (Hartzler et al., 2004). Cultural practices that favour crop establishment and discourage weed growth can reduce the weed burden and significantly enhance the crop competitive ability. To enhance crop competitiveness, augmented seeding rates, narrow row spacing, and altered plant spatial arrangements have been tested as part of IWM tactics in cereals (Kristensen et al., 2008; Kolb and Gallandt, 2013; Ehsanullah et al., 2014; Khaliq et al., 2014a,b). In modern agriculture, field crops, especially cereals, are planted in distinct rows with various row spacings and plant densities (Chen et al., 2008). Kaur et al. (2002) have shown that even seed distribution increases crop establishment and dry matter production per unit area, resulting in higher competitiveness against weeds. In another experiment, significant effects of both crop density and spatial distribution on weed growth were observed (Weiner et al., 2001). They further reported that high crop density (600 m^{-2}) and grid sowing pattern recorded 60% less weed biomass and produced 60% higher yield as compared to lower crop densities (200 and 400 m^{-2}) and normal sowing in rows. In addition, sowing cereal crops at wider row spacing resulted in increased competition within the crop plant clusters (i.e., the rows), resulting in decreased crop growth and yield compared with narrow row spacing (Shapiro and Wortmann, 2006).

Holt (1995) suggested that manipulating the crop row spacing and orientation may reduce light interception by weeds. Crop shading via narrow row spacing can improve weed control without extra costs or negative environmental impacts (Barberi, 2002). Narrow rows provide a competitive edge to the crop over weeds due to early and rapid canopy closure (Kristensen et al., 2008; Mashingaidze et al., 2009; Chauhan and Johnson, 2010a; Khaliq et al., 2014a,b). Sowing of wheat in a uniform pattern reduces the total amount of light reaching the smaller weed plants because of the exponential nature of light extinction within canopies (Weiner et al., 2001). In weed-crop competition, availability of resources (water, nutrients, and space) and environmental factors like light and temperature affect the extent of the competition (Kropff et al., 1993; Weiner et al., 2001; Guillemin et al., 2013). Studies with a number of crops like wheat (Kristensen et al., 2008; Mashingaidze et al., 2009), rice (Chauhan and Johnson, 2010a; Khaliq et al., 2014a,b), barley (Kolb et al., 2010), cotton (Reddy, 2001), millet (Shinggu et al., 2009), sorghum (Grichar et al., 2004), and soybean (Hock et al., 2006), have shown inverse relationships between narrow crop rows and weed growth. Although wider crop rows facilitate weed control by intercultural operations, weed growth in wheat is usually suppressed by narrow row spacing (Shrestha and Fidelibus, 2005).

Understanding weed–crop interference is critical in designing a successful, integrated, and sustainable weed management program. Making appropriate and sound decisions using the principles of biological and ecological weed management can significantly reduce herbicide usage (Chauhan, 2012; Hussain et al., 2015). To our knowledge, no data have been published on how the growth and seed production of *G. aparine* and *L. sativum* are influenced by their emergence times and wheat row spacing. Therefore, the present study aimed to determine the effects of weed emergence time and row spacing on wheat productivity and seed production of *G. aparine* and *L. sativum*. The outcomes of the present study will guide future work on planning an IWM package and reducing seed production by these weeds.

2. Materials and methods

2.1. Site description

Field experiments were conducted at Quaid-I-Azam University, Islamabad (33°42′N, 73°10′E), Pakistan, during the 2009–2010 and 2010–2011 growing seasons. Islamabad lies at the edge of the Potohar Plateau with a humid sub-tropical climate. The weather ranges between 3.9 °C (in January) and 46.1 °C (in June) with mean annual rainfall of about 1000 mm. Most of the rainfall occurs during monsoon months (July–August), while wheat seasons (November–April) receive nearly 350 mm rainfall. The previous crop in both years was mungbean (*Vigna radiate* L.). Soil samples (0–30 cm) from the experimental site were collected prior to sowing for soil physico-chemical analyses. Soil textural class as determined by hydrometer method (Gee and Bauder, 1982) was silt loam. Averaged across two years, the chemical properties of the soil were: pH 6.90, EC 2.41 dsm^{-1} (McLean, 1982), organic C 19.7 g kg^{-1} (Nelson and Sommers, 1982), total N 1.39 g kg^{-1} (Keeney and Nelson, 1982), available P 8.37 mg kg^{-1} (Jackson, 1973), and available K 87.78 mg kg^{-1} (Hanway and Heidel, 1952). The bulk density and cation exchange capacity was 1.49 g cm^{-3} and 4.32 cmolc kg^{-1} (Jackson, 1973).

2.2. Experimentation

In both growing seasons, the seedbed was prepared by cultivating the soil once with a tractor-mounted disk, and twice with a cultivator, followed by planking. A standard fertilizer dose of 120:60 kg $N:P_2O_5$ ha^{-1} was applied in the form of urea and diammonium phosphate. All of the phosphorus and one-third of the N was applied as a starter basal dose while the remaining N was added in equal doses at tillering and booting. The wheat crop (cv. Sehar-2006) was sown with a single-row hand drill at 11, 15, and 23-cm row spacing using a seed rate of 125 kg ha^{-1}. Plots were separated by a 1-m-wide alley with plastic film inserted into the soil to a depth of 0.50 m. The crop was irrigated six times. First irrigation was applied 15 days after crop emergence, with subsequent irrigations at tillering, jointing, booting, anthesis, and grain