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Weed spectrum in different wheat-based cropping systems under conservation and conventional tillage practices in Punjab, Pakistan

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ABSTRACT

Excessive tillage in conventional agriculture has led to soil and environmental degradation. Conservation agriculture (CA) has evolved as an alternate and sustainable crop production system. However, weed control is a serious issue in CA; nonetheless, allelopathy offers a viable option for weed management. This study was conducted to evaluate the shift in weed spectra in different wheat-based cropping systems under different tillage practices in Punjab, Pakistan. Wheat was planted in fallow-wheat, rice-wheat, cotton-wheat, mungbean-wheat and sorghum-wheat cropping systems with zero tillage (ZT), conventional tillage (CT), deep tillage (DT) and CT with beds sowing (BS; 60/30 and 90/45). The most important weeds identified were fat hen, common goosefoot, horseweed, garden spurge, broad-leaved dock, yellow sweet clover, false daisy, salt marsh, rabbit foot grass, bermuda grass, red sprangletop, corn spurry and littleseed canarygrass. Maximum diversity of weeds (number of weed species) was recorded in cotton-wheat under ZT; whereas the sorghum-wheat system had minimum diversity of weeds under DT. Fallow-wheat and mungbean-wheat systems had more grassy and broad leaf weeds, respectively, while sorghum-wheat had less density of these weeds. Likewise, ZT had higher while DT and BS had less density of grassy and broad leaf weeds. However, CT favored some broad leaf weeds like fat hen and common goose foot; DT stimulated only common goose foot; whereas ZT supported some broad leaf and all grassy weeds. Sorghum-wheat system suppressed most of the weeds, grasses in particular, and three grassy weeds (salt marsh, bermuda grass and red sprangletop) were absent owing to its strong allelopathic potential; however, this system favored littleseed canarygrass under ZT. In conclusion, divergent wheat-based cropping systems had different weeds spectra under different tillage practices; and choice of cropping sequence may help suppressing weeds. Inclusion of allelopathic crops, like sorghum, in the wheat-based cropping system may help managing weeds under conventional and conservation tillage practices.

1. Introduction

Excessive tillage in conventional agricultural systems triggers soil movement that leads to more soil erosion and environmental degradation (Fowler and Rockstrom, 2001; Penescu et al., 2001). Conventional tillage systems may reduce weed infestation (Gajri et al., 1999) but accelerate the degradation of soil resources (World Resources Institute, 2000). Early season weeds are effectively controlled by conventional tillage (Steckel et al., 2007); however, the problem of weed infestation is aggravated during later crop growth stages in these tillage systems.

Conservation agriculture (CA) involves minimal soil disturbance, permanent soil cover and planned crop rotations (Reicosky and Saxton, 2007; Hobbs et al., 2008; Thierfelder et al., 2012). Reduced tillage is the most important component of CA as minimal soil disturbance and permanent residue cover, the two pillars of CA, can only be achieved through reduced tillage. CA thus helps reducing the input expenses for land preparation, and soil and water conservation (Juergens et al., 2004; FAO, 2007; Farooq et al., 2011a).

Nonetheless, CA alters the weed flora and infestation levels (Torresen et al., 2003; Legere and Samson, 2004; Thomas et al., 2004; Primot et al., 2006). For instance, CA increases the weed

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infestation during initial years of infestation (Cardina et al., 2002; Sosnoskie et al., 2006; Farooq et al., 2011a). Moreover, perennial weeds tend to dominate in CA (Farooq et al., 2011a; Mashingaidze et al., 2012). This indicates that in CA the weed flora changes from easy to control annual broad leaf and grasses to obnoxious perennial weeds such as couch grass (*Cynodon dactylon* L.) and mexican clover (*Richardia scabra* L.) (Nyagumbo, 2008; Mashingaidze et al., 2012).

Chemical weed control has been an effective weed management option in CA (Farooq et al., 2011a). However, indiscriminate use of herbicides has resulted in the development of herbicide-resistant weed biotypes (Llewellyn and Powles 2001; Owen et al., 2007; Farooq et al., 2011a); and has also disturbed the ecological balance (Owen et al., 2007) and human health (Sheikh et al., 2011; Morais et al., 2012). Considering the challenge of herbicide resistance in weeds, Farooq et al. (2011a) proposed careful and wise use of herbicides with more emphasis on integrated weed management options, and recognized integrated weed management as the 4th pillar of CA. In this regard, allelopathy is an attractive and pragmatic option for weed management in CA (Farooq et al., 2011b; Jabran and Farooq, 2013). Inclusion of crops with strong allelopathic potential, like sorghum, rice, wheat, in the existing cropping systems may help in weed management (Jabran and Farooq, 2013). The chemicals released from the allelopathic crops may suppress the associated weeds (Miri, 2011).

Cultural practices play a key role in determining the crop-weed competition, and may thus influence weed management strategies (Donovan et al., 2001; Grichar et al., 2004). Continuous growing of same crops allow the best adapted weed species to proliferate (Buhler, 1999; Harker and Clayton, 2004). For instance, number of weed seeds were about six times more in continuous cropping system than in a diversified cropping system (Forcella and Lindstrom, 1988). The weeds having similar life cycles and growth habits as of crops can well adapt in the existing cropping systems and may become difficult to control (Moyer et al., 1994). Differential resource competition and allelopathic interference, caused by diversified crop rotations, develop an unsuitable ecology for weeds, which prevent or encourage the proliferation and dominance of any particular weed (Liebman and Dyck, 1993; Liebman and Davis, 2000). For instance, the rice-wheat cropping system favors littleseed canarygrass (*Phalaris minor* L.) while it restricts wild oat (*Avena fatua* L.) ecologically. However, wild oat is a serious problem in non-paddy wheat cropping system (Walia, 2006).

The role of weed spectra in developing weed management strategy in different tillage systems conducted under wheat-based cropping systems has been rarely studied. It was hypothesized that weed flora changes under different wheat-based cropping systems and tillage practices. Therefore, this study was conducted to evaluate the shift in weed spectra in different wheat-based cropping systems under conservation and conventional tillage practices.

2. Materials and methods

2.1. Site and soil

A two-year field trial was conducted at Research Farm, Department of Agronomy, Bahauddin Zakariya University, Multan (71.43°E, 30.2°N and 122 m a.s.l.), Pakistan during two successive years 2012–13 and 2013–14 to evaluate the shift in weed flora in wheat-based cropping systems under different tillage practices. The soil of experimental field was clay loam with pH 8.38, ECe 3.30 dS m^{-1}, organic matter content of 0.57%, 0.03 ppm total nitrogen, 8.81 ppm available phosphorus and 188 ppm available potash, and belonged to Sindhlianwali soil series (clay loam, mixed, hyperthermic, sodic haplocambids in USDA classification). Before conducting this experiment, rice-wheat cropping system was being practiced on experimental site for the last four years under conventional tillage system. The weather data during both years of the study are given in Table 1. The rainfall was unimodal during both years of research (Table 1).

2.2. Experimental details

Five cropping systems viz. fallow-wheat, rice-wheat, cotton-wheat, mungbean-wheat and sorghum-wheat were evaluated under zero tillage (ZT), conventional tillage (CT), deep tillage (DT), and two types of bed sowing (BS; 60/30 cm with four rows and 90/45 cm with six rows) after conventional tillage. In ZT treatment, wheat seeds were drilled into the soil directly without tillage and removal of stubbles. In CT, the field was cultivated twice with a tractor-mounted cultivator (Model HFI-38, Hanif Farm Industries, Multan, Pakistan) up to a depth of 20 cm followed by levelling before seeding. For DT, the field was ploughed twice, up to a depth of 45 cm, with a tractor-mounted chisel plough (Model HFI-01, Hanif Farm Industries, Multan, Pakistan) followed by two cultivations with a tractor-mounted cultivator (Model HFI-38, Hanif Farm Industries, Multan, Pakistan) up to a depth of 20 cm. The field was then levelled before seeding. In case of BS, the plots were prepared similar to that of CT and then both types of beds were prepared with a manual bed maker. BS inverts the soil layers, which puts weed seeds deep in the soil and weeds did not emerge easily. Moreover, loose fertile soil in case of beds promote crop

Table 1
Weather data during the course of the study at the experimental site.

Months	Year 2012–2013				Year 2013–2014			
	Mean temperature (°C)	Mean relative humidity (%)	Mean daily sunshine (hours)	Total monthly rainfall (mm)	Mean temperature (°C)	Mean relative humidity (%)	Mean sunshine (hours)	Total rainfall (mm)
May	32.55	55.85	8.50	1.10	32.90	54.95	9.80	0.00
June	34.00	61.15	8.19	0.00	34.00	67.85	8.19	50.70
July	33.46	66.64	7.80	16.90	33.97	64.505	7.90	16.9
August	31.80	74.10	7.00	10.90	31.55	72.20	7.10	74.2
September	29.40	83.55	7.01	167.00	30.30	71.65	8.70	0.00
October	25.30	72.50	8.33	3.20	28.25	71.35	7.10	0.00
November	19.95	84.10	6.11	0.00	20.00	79.35	5.70	0.00
December	14.85	83.50	6.10	4.00	14.85	82.35	4.90	0.00
January	12.35	80.45	5.60	0.00	12.95	79.25	5.50	0.00
February	16.00	87.35	5.70	72.90	14.90	81.75	6.40	18.00
March	22.00	76.10	8.40	16.70	19.80	74.20	6.70	33.40
April	26.95	60.95	7.70	1.30	25.80	58.50	6.30	7.10