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Impact of different crop rotations and tillage systems on weed infestation and productivity of bread wheat

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ABSTRACT

Crop rotation and tillage systems have important implications for weed infestation and crop productivity. In this study, five tillage systems *viz.* zero tillage (ZT), conventional tillage (CT), deep tillage (DT), bed sowing (60/30 cm with four rows; BS_1) and bed sowing (90/45 cm with six rows; BS_2) were evaluated in five different crop rotations *viz.* fallow-wheat (FW), rice-wheat (RW), cotton-wheat (CW), mungbean-wheat (MW) and sorghum-wheat (SW) for their effect on weed infestation and productivity of bread wheat. Interaction between different tillage practices and cropping systems had significant effect on density and dry biomass of total, broadleaved and grass weeds, agronomic and yield-related traits, and grain yield of bread wheat. The un-disturbed soils (ZT) under fallow-wheat or mungbean-wheat rotations favoured the weed prevalence (a total weed dry biomass of 72.4–109.6 and 105.6–112.1 g m^{-2} in first and second year, respectively). Contrary to this, the disturbed soils (CT, DT, BS_1 and BS_2) had less weed infestation with either of the rotations (a total weed biomass of 0.4–7.1 and 1.1–5.4 g m^{-2} in first and second year, respectively). Sorghum-wheat rotation had strong suppressive effect on weed infestation in all tillage systems. The impact of crop rotation was more visible during second year of experimentation. Bed sown wheat (BS_1 and BS_2) in mungbean-wheat rotation had the highest wheat grain yield (6.30–6.47 t ha^{-1}) compared to other tillage systems in different crop rotation combinations.

1. Introduction

Wheat is one among the top cereals of the world with a global annual production of 676 million tons. More than one-fifth of human population feeds on wheat products (FAO, 2011). A two-time increase in current wheat production is required to meet the future food demands (Foresight, 2011).

Wheat-based cropping systems provide an inevitable contribution to global food production and food security. These are particularly important in several of Asian countries providing the major portion of food in these areas. For example, the rice-wheat system comprises of 24 million ha in South Asia and China, and nearly 14 million ha in South Asia (including area from Bangladesh, India, Nepal and Pakistan) (Timsina and Connor, 2001; Gupta and Seth, 2007). Cotton-wheat is also an important wheat-based cropping system which helps to produce food and fibre, earn the livelihood by the poor farming community and resolve some of ecological issues created by following the rice-wheat cropping system (Jalota et al., 2006). Legume-wheat and fallow-wheat cropping systems can help to improve the soil health and productivity (Danga et al., 2009).

Wheat-based cropping systems are cultivated with various kinds of tillage systems. Many studies have examined the effect of these cropping systems when combined with a particular type of tillage (Ranamukhaarachchi et al., 2005; Micucci and Taboada, 2006; Bertolino et al., 2010). However, limited information is available regarding the influence of such different wheat-based cropping systems on weed infestation in wheat. For instance, crop productivity has been known to be negatively affected by the conventional tillage (CT) and lack of a well-planned rotation in cropping patterns (Ranamukhaarachchi et al., 2005; Bertolino et al., 2010). In wheat-based cropping systems, a continuous CT for

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preparing a fine seedbed forms a plough pan which affects the crop productivity negatively (Islam et al., 2005; Micucci and Taboada, 2006; Bertolino et al., 2010). Plough pan layers are located shallower than the normal rooting depth and may become a barrier for roots due to low porosity and too high mechanical impedance (Bruand et al., 2004). On the other hand, CT may reduce the influx of weeds (Gajri et al., 1999). Nevertheless, the early season weeds are effectively controlled by CT (Steckel et al., 2007); however, late-season weed infestations may occur with this tillage system. The current cropping systems are highly simplified which are allowing the best adapted weed species to proliferate in the field (Buhler, 1999; Harker and Clayton, 2004). These issues demand the use of alternate tillage and cropping sequence which may compensate these constraints.

Conservation agriculture (CA) includes the soil management practices that minimize the disruption of the soil structure, permanent soil cover and well-planned crop rotation (Ghuman and Sur, 2001; Haggblade and Tembo, 2003; Juergens et al., 2004; FAO, 2007; Farooq et al., 2011a). CA improves soil physical properties like soil water availability (Unger, 1994; Drury et al., 1999) and number of biopores (Francis and Knight, 1993), which may facilitate root growth (Martino and Shaykewich, 1994). CA may be more productive than CT because it improves the soil quality and water use efficiency of plants (Samarajeewa et al., 2006). Zero tillage (ZT) is one of the pillars of CA and reduces expenses for land preparation, fuel consumption, equipment use, labour cost, and ensures good crop stand tied with conservation of soil and water (Mann et al., 2002; Farooq et al., 2011a; Jabran and Mehmood, 2015). However, it also restricts the growth of the main root axis during the initial stages of plant development (Lampurlanes et al., 2001).

Different cropping systems have a varied impact on soil physical properties and crop productivity (Ranamukhaarachchi et al., 2005). For instance, in rice-wheat cropping system, puddling in rice produces unfavourable environment for the following wheat crop which cannot be offset by ZT and results into substantial reduction in wheat yield (Tripathi et al., 2007). Many researchers have noted a shift in existing weed flora after adoption of CA (Torresen et al., 2003; Legere and Samson, 2004; Thomas et al., 2004; Primot et al., 2006; Shahzad et al., 2016a). Moreover, under CA, perennial weeds are a serious problem which may be absent in conventional-tilled systems. It means under CA, shifting of less problematic annual broadleaved weeds and grasses to perennial weeds such as *Cynodon dactylon* L. and *Richardia scabra* L. etc., occurs; these weeds cannot be controlled easily (Vogel, 1994; Muliokela et al., 2001; Nyagumbo, 2008; Mashingaidze et al., 2012). Hence, CA contains high weed densities than conventional systems during initial years of adoption (Cardina et al., 2002; Sosnoskie et al., 2006). Initially, the shift in weed flora due to altered distribution of weed seeds within the soil makes the CA more complex (Buhler et al., 1997). Moreover, the perennial weeds flourishing in reduced-tillage systems would be difficult to manage in some parts of the world with existing post-emergent herbicides (Derksen et al., 1993).

Keeping in view the role of CA in spread of weeds, Farooq et al. (2011a) considered integrated weed management as a component of CA. Similarly, Giller et al. (2009) and Muoni et al. (2013) stated that poor weed control is the main hurdle in widespread adoption of CA. Conservation tillage system is assumed to accelerate weed problems because of higher weed emergence (Barberi and Lo Cascio, 2001). Therefore, it is needed to adopt such practices, which help to eliminate or at least reduce the weed problem in CA. For example, allelopathy is a viable tool for weed management in CA (Farooq et al., 2011b; Jabran and Farooq, 2013; Jabran et al., 2015). Allelopathy (e.g. in the crop rotation) can be used successfully to manage weeds by adding allelopathic crops in existing cropping systems.

Crop sequences (e.g., the one with an allelopathic crop) create differences in resource competition, allelopathic interference, soil disturbance and mechanical damage to develop an unsuitable ecology for weeds which may prevent the proliferation of any particular weed (Liebman and Dyck, 1993; Liebman and Davis, 2000). For instance, the rice-wheat cropping system favours *Phalaris minor* L. while it does not favour *Avena fatua* L. ecologically (Walia, 2006). However, *A. fatua* is a serious problem in non-paddy wheat cropping system (Walia, 2006).

Both the tillage and cropping systems influence the crop productivity by altering the soil physical properties and changing the weed spectra in agricultural systems (Farooq and Nawaz, 2014; Shahzad et al., 2016a, b). Several studies describe the soil physical properties and weed dynamics under different tillage treatments (Farooq and Nawaz, 2014; Shahzad et al., 2016a, b) but to the best of our knowledge, little is known about the interactive effect of different tillage systems and wheat-based crop rotations on weed spectra and wheat productivity. Thus, this two-year field study was conducted to evaluate the impact of different crop rotations and tillage systems on weed infestation and productivity of bread wheat.

2. Material and methods

2.1. Experimental site description

This study was conducted during 2012–13 and 2013–14 at the Research Farm, Department of Agronomy, Bahauddin Zakariya University, Multan (71.43°E, 30.2°N and 122 m a.s.l.), Pakistan. The experimental area was quite uniform having silty clay and slightly saline soil. Experimental soil was analysed for various physico-chemical properties before planting the experiment each year (Table 1). The climate of the region is semi-arid subtropical. The weather data during both years of experimentation are given in Table 2.

2.2. Experimental details

The study included five tillage practices *viz*. zero tillage (ZT), conventional tillage (CT), deep tillage (DT), bed sowing (BS_1) (60/30 cm with four rows) and bed sowing (BS_2) (90/45 cm with six rows); and five cropping systems *viz*. fallow-wheat (FW), rice-wheat (RW), cotton-wheat (CW), mungbean-wheat (MW) and sorghum-wheat (SW). In ZT, wheat seeds were drilled directly into the soil with a zero-till drill, without removing the stubbles of previous crops. In CT, the field was prepared by two cultivations with tractor mounted cultivator followed by levelling. Similarly, two ploughings were done in deep tillage with the help of chisel plough followed by levelling. In both bed sowing treatments, fields were prepared in the same fashion as in CT and then 15 cm elevated beds were prepared by moving soil from both sides of beds according to the specified dimensions with a tractor-mounted bed shaper. BS inverts the soil layers, which puts weed seeds deep in the soil, so the weeds do not emerge easily. Moreover, loose fertile soil in case of beds promotes crop growth due to less resistance to developing roots. All the treatments were replicated three-times in plots with net size of 5 m × 2.7 m. The experiment was laid out in randomized complete block design with split plot arrangement keeping tillage practices in main plots and cropping systems in sub-plots.

2.3. Crop husbandry

Pre-soaking irrigation of 10 cm was applied. When soil reached