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Weed dynamics as influenced by tillage system, sowing time and weed competition duration in dry-seeded rice

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Cultural practices alter patterns of crop growth and can modify dynamics of weed-crop competition, and hence need to be investigated to evolve sustainable weed management in dry-seeded rice (DSR). Studies on weed dynamics in DSR sown at different times under two tillage systems were conducted at the Agronomic Research Farm, University of Agriculture, Faisalabad, Pakistan. A commonly grown fine rice cultivar 'Super Basmati' was sown on 15th June and 7th July of 2010 and 2011 under zero-till (ZT) and conventional tillage (CONT) and it was subjected to different durations of weed competition [10, 20, 30, 40, and 50 days after sowing (DAS) and season-long competition]. Weed-free plots were maintained under each tillage system and sowing time for comparison. Grassy weeds were higher under ZT while CONT had higher relative proportion of broad-leaved weeds in terms of density and biomass. Density of sedges was higher by 175% in the crop sown on the 7th July than on the 15th June. Delaying sowing time of DSR from mid June to the first week of July reduced weed density by 69 and 43% but their biomass remained unaffected. Tillage systems had no effect on total weed biomass. Plots subjected to season-long weed competition had mostly grasses while broad-leaved weeds were not observed at harvest. In the second year of study, dominance of grassy weeds was increased under both tillage systems and sowing times. Significantly less biomass (48%) of grassy weeds was observed under CONT than ZT in 2010; however, during 2011, this effect was non-significant. *Trianthema portulacastrum* and *Dactyloctenium aegyptium* were the dominant broad-leaved and grassy weeds, respectively. *Cyperus rotundus* was the dominant sedge weed, especially in the crop sown on the 7th July. Relative yield loss (RYL) ranged from 3 to 13% and 7 to 16% when weeds were allowed to compete only for 20 DAS. Under season-long weed competition, RYL ranged from 68 to 77% in 2010 and 74 to 80% in 2011. The sowing time of 15th June was effective in minimizing weed proliferation and rectifying yield penalty associated with the 7th July sowing. The results suggest that DSR in Pakistan should preferably be sown on 15th June under CONT systems and weeds must be controlled before 20 DAS to avoid yield losses. Successful adoption of DSR at growers' fields in Pakistan will depend on whether growers can control weeds and prevent shifts in weed population from intractable weeds to more difficult-to-control weeds as a consequence of DSR adoption.

1. Introduction

The types and the degree of weed infestation in rice (*Oryza sativa* L.) fields are often determined by the type of rice culture, stand establishment technique, moisture regime, land preparation, and cultural practices (Bhagat et al., 1999; Matloob et al., 2014). Tillage systems greatly influence the composition of weed communities (Arif et al., 2007) through their effects on the vertical distribution of weed seeds in soil (Chauhan et al., 2006), the relative time of emergence, the abundance of a particular weed species (Grundy et al., 2003), weed seed survival (Reuss et al., 2001), and the proportion of annual versus perennial weeds (Cardina et al.,

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2002). Depending upon the production system, dry-seeded rice (DSR) can be sown into a prepared seed bed or under zero-till (ZT) conditions (Chauhan, 2012). Tillage operations account for 15% of the total production cost in irrigated rice (AgStat, 2004). Farmers in the Indo-Gangetic Plains spend about 50–60 US$ ha^{-1} on land preparation (Hobbs, 2001). Direct-seeding of rice under ZT lowers the production cost, saves fuel and labour, while contributing to improvements in soil physical and chemical properties (Erenstein and Laxmi, 2008). Comparison of the change in weed flora with the adoption of ZT or reduced tillage techniques can provide an indication of the preventive control measures arising from conventional tillage (CONT) practices, given similar water regimes subsequently (Rao et al., 2007). Shifts in weed species have been reported to occur with the adoption of ZT and dry seeding, with annual grass weeds particularly increasing in density (Tuong et al., 2005). Considerable increase in the densities of *Echinochloa colona* (L.) Link., *Portulaca oleracea* L., *Ageratum conyzoides* L., *Digitaria ciliaris* (Retz.) Koel., *Eleusine indica* (L.) Gaertn., *Eclipta prostrata* (L.) L., and *Ludwigia octovalvis* (Jacq.) Raven was observed in DSR during the second season of ZT (Chauhan and Johnson, 2009; Chauhan and Opeńa, 2012). Reduced tillage often favours annual grasses and discourages annual broad-leaved weed species (Gill and Arshad, 1995). However, perceptions are difficult to generalize as tillage mediated effects are manifested in the form of species specificity (Buhler, 1992).

Among the factors influencing weed dynamics and weed-rice interference, sowing date is of immense importance (Matloob et al., 2014). Soil preparation at different sowing time inflicts a seasonal variation in temperature and moisture regimes, the two principle determinants of species survival and distribution, thereby governing periodicity of weed seed emergence (Berzsenyi, 2000). Composition of weed communities are known to differ in mid- and late-season planted crops (Milberg et al., 2001). The timing of soil disturbance will govern which weed seeds in what state of dormancy are available for germination; thereby, regulating germination and subsequent weed growth (Busing and Clebsch, 1983; Squiers, 1989). Seed availability as well as their dormancy status is influenced by environmental attributes that may contrast within the same growing season. There is a relation between the timing of weed emergence and the pressure exerted to the crop through competition and resulting loss in crop yield (Khaliq and Matloob, 2011). Yield losses are usually higher when weeds emerge earlier or at the same time as the crop (Aldrich, 1987). During the period of early establishment, weeds accomplish 20–30% of their growth as compared to rice that makes only 2–3% of its growth (Moody, 1990). In field trials of direct-seeded irrigated rice, 95% of the weed-free rice yield was obtained when weeds were controlled up to 32 days after sowing (DAS) in the wet season and 83 DAS in the dry season (Johnson et al., 2004). Nevertheless, in field crops, a yield penalty, often proportional to the duration of delayed period, is also observed when the planting is delayed beyond the optimum time (Matloob et al., 2014). The tradeoff between weed suppression and crop yield reduction should be considered while using planting time as a tool for weed management.

Quantitative information on weed dynamics under the influence of varying tillage and planting time can yield information essential for successful weed control in DSR. A crop plant experiences intra-specific weed competition from its neighbouring plants in a weed-free field but suffers both intra- and inter-specific competition in a weedy field. The productivity of DSR is believed to largely depend on effective and timely weed control (Rao et al., 2007). This, in turn, requires knowledge about the critical period of weed competition under specific agro-climatic conditions. Information on the critical period of weed competition could result in improved post-emergence herbicide application timing in DSR (Khaliq and Matloob, 2011). Reducing the number of herbicide applications as a result of better timing will improve efficiency and may reduce potential environment contamination and the selection pressure for herbicide resistant weeds. Hence, it is essential to arrive at a tillage system and sowing time which provide less competitive weed species that can then be managed by suitable herbicide/s. A large scope exists to manipulate these factors for understanding weed dynamics and their management in DSR. The objective of present study was therefore to ascertain the weed dynamics, and yield response of DSR under different tillage systems, sowing times and durations of weed competition.

2. Material and methods

2.1. Site description

The proposed study was conducted at the Agronomic Research Farm of the University of Agriculture, Faisalabad, (31.25° N, 73.09° E, 184 m a.s.l.), Pakistan. The soil of the experimental site belongs to Lyallpur soil series (Aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplargid in USDA classification and Haplic Yermosols in FAO classification, Cheema and Khaliq, 2000). The physico-chemical properties of the soil are mentioned in Table 1. Due to high evapotranspiration, Faisalabad features an arid climate with mean annual rainfall of about 200 mm. The meteorological data during the course of crop growth were obtained from AgroMet Observatory, Department of Crop Physiology (Fig. 1).

2.2. Experimentation

Experiments were conducted during the summers of 2010 and 2011 and comprised of three factors (1) tillage systems (TS): ZT and CONT, (2) sowing times (ST): 15th June and 7th July, and (3) durations of weed competition (WC): 20, 30, 40, and 50 days after sowing (DAS). Season-long weed competition (weedy check) and weed-free plots were also maintained for comparison. CONT was accomplished by cultivating the soil with a disc plough and then cultivating thrice with a tractor-mounted cultivator followed by planking each time. Sowing in the ZT plots was performed using a single row hand drill into undisturbed seed bed in a single pass operation. A randomized complete block design (RCBD) with the split–split arrangement employing three replications was used. Tillage systems were kept in main plots, while the sowing times and the durations of weed competition were assigned to sub- and sub–sub plots, respectively. The net plot size was 7 m × 2.2 m. In all, there were 72 experimental units during both the years. The previous crop was wheat which followed the same tillage practices as for the next rice crop. Glyphosate was applied in ZT plots 20 days before sowing to curtail established weeds that were eradicated through cultivation in CONT. Seeds of popular fine rice *cv.* 'Super basmati' were obtained from Rice Research Institute, Kala Shah Kaku, Sheikhupura, Pakistan. A soaking irrigation (10 cm) was applied 7 days before rice planting to soften the ZT plots and also helped seed bed preparation in the CONT plots. A basal fertilizer dose of 114 kg N, 65 kg P_2O_5, and 50 kg K_2O ha^{-1} was applied in the form of urea (46% N), diammonium phosphate (18% N, 46% P_2O_5), and sulphate of potash (50% K_2O). The whole P and K and a one-third of N (38 kg) were applied at the time of sowing. The remaining N (76 kg) was top dressed in two equal splits at tillering (30 DAS) and panicle initiation (65 DAS). Crop was sown on the respective sowing times during both the years at a seeding rate of 50 kg ha^{-1} with a single row hand drill in 20 cm spaced rows. The first irrigation (7.50 cm) was applied 5 DAS. The crop was irrigated subsequently as and when needed. There was no water ponding at