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Crop Protection 26 (2007) 1689–1696
Crop Protection
www.elsevier.com/locate/cropro

Effect of tillage and herbicides on weeds and productivity of wheat under rice–wheat growing system

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Received 2 January 2007; received in revised form 12 January 2007; accepted 26 January 2007

Abstract

Field experiments were carried out to evaluate the effect of tillage and herbicides on weeds and wheat (*Triticum aestivum* L. emend. Fiori and Paol.) productivity under rice (*Oryza sativa* L.)–wheat growing system. *Rumex dentatus* was significantly higher (12.1 plants/m^2) under zero tillage (ZT) compared to conventional tillage (CT) (1.9 plants/m^2). CT favored *Phalaris minor*. The average *P. minor* dry-weight under ZT and CT was 234.7 and 386.5 g/m^2, respectively. This differential response reflected was due to variation in seed distribution during puddling performed for rice transplanting. The lower density of *R. dentatus* seeds led to its concentration in upper soil layer particularly on the surface, under ZT. Of the total seed found in upper 12.5 cm soil layer on the soil surface, about 0.02% and 1.24% were of *P. minor* and *R. dentatus*, respectively. Among the three tillage crop establishment methods, ZT and CT drill provided about 0.3 t/ha higher wheat grain yield over farmer's practice of CT-broadcast sowing. The reduced expenditure on tillage and higher yield, provided additional profit of about US $ 161.3 ha^{-1} for ZT over farmer's practice. In CT, the performance of sulfosulfuron at 25 g/ha, clodinafop at 60 g/ha and sulfosulfuron + metsulfuron at 25 + 1.6 g/ha was similar, where fields were dominated by *P. minor*. However, in ZT, overall tank mix application of sulfosulfuron + metsulfuron was the most effective treatment for control of the weed flora and improving wheat yield. Metsulfuron alone due to its effectiveness against broad-leaved weeds only was inferior. Considering the benefits of ZT in reducing the cost of cultivation and lowering the infestation of *P. minor*, this technology should be integrated with other weed control measures for economic and sustainable wheat production.

Keywords: Clodinafop; Metsulfuron; *Phalaris minor*; Puddling; *Rumex dentatus*; Seed distribution; Soil strength; Sulfosulfuron

1. Introduction

Rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L. emend. Fiori and Paol.) have been the staple food for a large population in Asia and their assured supply is essential for food security. As a system, rice–wheat occupies about 24 m ha area worldwide (Ladha et al., 2000) and in India it is the most popular and prevalent sequence covering about 10 m ha area (Timsina and Connor, 2001). These two crops meet about 80% of the carbohydrate food requirement of India. However, degradation of natural resources, factor productivity decline (Yadav, 1998) and weeds are some of the major concerns in the rice–wheat system and these factors cause significant annual regional productivity losses in wheat (Harrington et al., 1992).

Both grassy and broad-leaved weeds infest wheat. Among grassy weeds, *Phalaris minor* Retz. and among broad-leaved weeds *Rumex dentatus* L. are of major concern in irrigated wheat under rice–wheat system in India (Singh et al., 1995; Chhokar et al., 2006; Balyan and Malik, 2000). Both *P. minor* and *R. dentatus* are highly competitive weeds and can cause drastic yield reduction under heavy infestation. The yield reduction by weeds in wheat may be up to 80% depending upon weed type, density, timing of emergence, wheat density, wheat cultivar and soil and environmental factors (Afentouli and Eleftherohorinous, 1996; Chhokar and Malik, 2002; Cudney and Hill, 1979; Khera et al., 1995; Malik and Singh, 1995; Mehra and Gill, 1988). Besides reduction in yield and quality of wheat, heavy *Rumex* spp. populations can cause

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0261-2194/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cropro.2007.01.010

hindrance in combine harvesting (Chhokar, per. obs.) and heavy *P. minor* populations thus causing crop lodging. Resistance has evolved in *P. minor* (Malik and Singh, 1995; Chhokar and Malik, 2002) against isoproturon and as a result, it has emerged as a single weed species limiting wheat productivity in the North Western plains of India. For sustaining wheat productivity, its control is essential. For the control of isoproturon-resistant *P. minor*, clodinafop, fenoxaprop and sulfosulfuron have been found effective (Chhokar and Malik, 2002). Clodinafop and fenoxaprop control only grasses, whereas sulfosulfuron controls grasses and some of the broad-leaved weeds (Chhokar and Malik, 2002; Chhokar et al., 2006). In areas where the farmers are using graminicides like clodinafop and fenoxaprop, the broad-leaved weed flora particularly *Rumex* spp. has increased enormously. Under these conditions, broad-spectrum weed control is essential and for that combinations of herbicides are needed.

In India, rice is mainly grown as puddle transplant and wheat as conventional till involving 8–16 tractor operations with various implements (Chauhan et al., 2003; Sharma et al., 2002). Changes in soil structure during puddling in rice as well as rice straw residues forces farmers into multiple tillage operations for seedbed preparation for growing wheat. The intensive tillage performed combined with factor productivity decline and degradation of resources has contributed to an increased cost of cultivation. Adopting ZT technology in wheat reduces the expenditure on field preparation and saves more than 90% fuel and time as well as advances the sowing time compared to conventional tillage practices (Chauhan et al., 2003; Sharma et al., 2002). The advancement of sowing by adopting ZT can be a useful mean to increase yield of late sown wheat. The sowing of wheat in India is generally delayed when sown after either *Basmati* rice or two crops of rice (rice–rice–wheat) or after sugarcane or cotton harvesting. The extent of yield reductions in different zones in India vary with an average loss of about 26.8 kg/ha/day, when sowing is delayed (Tripathi et al., 2005). Although yield increase may not always accompany reduced tillage operations, but savings in fuel, equipment and labor costs along with its role in conservation of soil and water (Unger and Cassel, 1991) makes it a viable economic option.

Tillage influences soil bulk density, penetration resistance, aggregate mean weight diameter and surface roughness (Carman, 1996). Therefore, the changes in mechanical characteristics of the seedbed due to tillage can influence the crop and weed emergence. Tillage affects weed seed distribution in soil profile (Pareja et al., 1985; Yenish et al., 1992, 1996) and the differential distribution of the seed in soil profile has the potential to change weed population dynamics (Buhler, 1991, 1995, 1997; Froud-Williams et al., 1983; Harper, 1957). It also affects soil properties, such as organic matter, microbial populations, soil moisture, temperature and pH (Blevins et al., 1983), which can affect herbicide activity by influencing herbicide adsorption, movement, persistence and efficacy.

As the ZT wheat area is likely to increase in India and a shift from an intensive tillage system to reduced tillage system can cause major changes in weed population dynamics (Buhler, 1995), ultimately affecting the herbicide efficacy due to change in microclimate and weed flora. The present study was carried out with the aim to determine the effect of tillage and herbicides in wheat on weeds and wheat productivity in a rice–wheat growing system.

2. Materials and methods

Studies were conducted at the research farm of the Directorate of Wheat Research, Karnal, Haryana, India (Latitude 29°43′N, Longitude 76°58′E at an elevation of 245 m above mean sea level) and at farmer's fields around Karnal.

2.1. Herbicide performance under CT and ZT wheat

Two field experiments were conducted, one in CT and another in ZT for evaluation of the herbicides performance. The soil of the experimental field was sandy loam with pH of 8.5 and organic matter content of 0.35%.

Under the CT system, wheat cultivar (PBW 343) was sown (20 cm row spacing) with seed cum-fertilizer drill using seed rate of 100 kg/ha on 28 November 2002 and 12 November 2003. For field preparation, 4, 2 and 3 passes of harrow, cultivator and plank were performed, respectively. During both the years, grassy weed *P. minor* was dominant and during second year low infestation of broad-leaved weeds, *Melilotus alba, Medicago denticulata* and *Coronopus didymus* were also observed. Six weed control treatments i.e. sulfosulfuron (Leader 75 WG) 25 g a.i./ha, sulfosulfuron + metsulfuron (25 + 1.6 and 30 + 2.0 g a.i./ha), metsulfuron (Algrip 20 WP) 4 g a.i./ha and clodinafop (Topik 15 WP) 60 g a.i./ha and untreated control were evaluated (Table 1) in a randomized block design with three replicates. Fertilization (150 kg N, 60 kg P_2O_5, 40 kg K_2O) and irrigations (six) were done according to recommended practice for wheat.

In the second experiment, efficacy of sulfosulfuron 25 g, sulfosulfuron + metsulfuron (25 + 1.6 g/ha), metsulfuron 4 g and clodinafop 60 g/ha were examined under zero tillage sown wheat under rice–wheat system. After manual rice harvesting (harvested close to the ground), pre-sowing irrigation was given and at optimum soil moisture, wheat seeding was done using ZT machine (having inverted T-type slit openers) on 18 November 2002 and 14 November 2003. Except sowing in untilled conditions, the practices were similar to that of CT wheat as mentioned earlier. This experiment was also conducted in randomized block design with three replicates. The main weeds infesting were *P. minor*, *R. dentatus*, *M. alba*, *M. denticulata* and *C. didymus. P. minor* was the major during both the years, whereas, *R. dentatus* was dominant among broad-leaved weeds during 2002–2003.