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Review

Weed management in rice using crop competition-a review

Anchal Dass [a,*], Kapila Shekhawat [a], Anil Kumar Choudhary [a], Seema Sepat [a], Sanjay Singh Rathore [a], Gulshan Mahajan [b], Bhagirath Singh Chauhan [c]

[a] Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi, 110012, India
[b] Punjab Agricultural University, Ludhiana, 141001, India
[c] The Centre for Plant Science, Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Gatton, Toowoomba, Queensland 4343/4350, Australia

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ABSTRACT

Rice is the principal food commodity for millions of people. Its growing demand invokes for an enhanced productivity, but with limited land and water resources. Among various biotic stresses limiting rice yields, the major stress is imposed by weeds, particularly in direct-seeded rice (DSR) under aerobic situations. In weedy situations, the yield losses may ascend to 50–60% in puddled transplanted rice and 70–80% in DSR. Herbicidal weed management is the most widely adapted strategy, however, the large scale application of herbicides mainly of same or similar mode of action is constrained by the risks of environmental trade-offs, introduction of herbicide-resistance in different bio-types of weeds, non-selectivity and narrow-spectrum of herbicides. Hence, ecological approaches, like weed-competitive cultivars, alterations in seed rates, and planting patterns could be highly useful in reducing the weed menace. This review reveals that main characteristics imparting weed-competitiveness to rice include selection of cultivars, seedling vigour, early and faster establishment of seedlings, root-shoot characteristics, and self-supportive allelopathy. In DSR, a higher seeding rate of 50–60 kg ha^{-1} has been found to reduce weed biomass by ~50%, without imposing any yield penalty and, thus desirable under weedy conditions. Similarly, a narrow row spacing of 15–25 cm in DSR and 20 × 10 cm in puddled transplanted rice resulted in higher productivity with minimum weed infestations. Although all such practices are not sufficient enough to suppress weeds completely, they are useful in reducing the herbicide dose up to 50% on 158 m ha area under rice cultivation in the world, thereby, reducing huge environmental trade-offs.

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1. Introduction

Rice (*Oryza sativa* Linn.), is the principal food for more than 50% people and contributes about one-fifth to the total calories

* Corresponding author.
E-mail address: anchal_d@rediffmail.com (A. Dass).

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consumption of the world (Singh et al., 2012). Globally, rice crop occupies 158 million ha (m ha) of the arable land. The global production and productivity of rice is 744.9 million tonnes (mt) and 4.71 t ha^{-1}, respectively (FAO, 2014). Asia alone accounts for over 90% of the global rice production and consumption and the prominent Asian countries that produce substantial quantities of rice include China, India, Indonesia, Thailand, Bangladesh, Myanmar, Vietnam, Laos, Cambodia, Korea, Japan, and the Philippines. Outside Asia, Latin America and the Caribbean region, East and South Africa and Sub-Saharan Africa are the important rice growing ecologies in the world. To meet the food and nutritional requirements in these densely populated and rice dominant regions, the projected demand for rice by 2030 has been estimated at 904 mt for the world and 824 mt for Asian region (Kubo and Purevdorj, 2004). India alone would require about 156 mt of rice by the year 2030 (ICAR, 2010) at an annual increment of 3 mt in the current rice production (Dass et al., 2016).

Rice is grown over a widely divergent environments, such as irrigated uplands, rainfed lowlands, and rainfed upland ecosystems (Choudhary and Suri, 2014; Kaur et al., 2015). The challenges and constraints in rice production vary from environment to environment. Weeds are the major pests that affect the rice yields to the greatest extent (Paul et al., 2014). The average yield losses in rice due to weed competition are estimated to vary between 40 and 60% which may go up to 94–96% with uncontrolled weed growth (Chauhan and Johnson, 2011). Mahajan et al. (2009) reported that unchecked weed growth reduced crop yield by up to 57% in puddled transplanted rice and 82% in DSR. Currently, the area under DSR is increasing due to rapid depletion in ground water and escalating cost of its pumping vis-à-vis labour scarcity, besides several other production vulnerabilities under transplanted rice. A significant shift in the crop-weed competition is envisaged with the change in rice cultivation practices, and weed infestation and rice-weed competition are predicted to increase and will remain to be a foremost challenge to the rice scientists, rice producers and agricultural policy makers for enhancing and maintaining higher rice yields in the changing climate scenario (Soezer, 2015).

1.1. Growing weed problems with changing rice establishment methods

Globally, more than 50% rice area is cultivated under puddled transplanting conditions. The higher yield potential under these production systems is mainly due to the protection of crop from weeds during initial growth period (Choudhary et al., 2008). But burgeoning rice cultivation expenses, primarily for human-labour and irrigation water (Pandey and Velasco, 2005) and increasing paucity water needed for rice cultivation, particularly in South and Southeast Asia (Bouman and Tuong, 2003), have led to a shift from transplanting to DSR. The elimination of practice of maintaining about a 5 cm depth of standing water, that would other-wise keep a check on weed growth, and the emergence of weed seedlings earlier or together with crop seedlings under DSR cultivation method has seriously mounted the risk of severe crop-weed competition ultimately culminating into heavy losses in yield (Chauhan and Johnson, 2010a; Choudhary and Suri, 2013). Oerke and Dehne (2004) have reported about 35% rice yield losses in DSR owing to weed competition worldwide. The most serious grassy weeds found under DSR are *Echinochloa crus-galli* (L.) Beauv., *Echinochloa colona* (L.) Link., *Cyperus rotundus* L., *Cyperus iria* L., and *Cyperus difformis* L. (Chauhan and Johnson, 2010b). The most common weed of rice, *E. colona* may reduce the yield of DSR by up to 76% (Mercado and Talatala, 1977); whereas *E. crus-galli* can cause a 57% reduction in yield of rice (Maun and Barrett, 1986). Overall yield losses of 15–35% in transplanted rice, 30–65% in DSR, and 45–90% in upland rice have been reported by DRR (2011). Up to 80% of the soil nitrogen could be removed by a dense population of *E. crus-galli* (Holm et al., 1991). Unless interrupted, the crop and weed generally continue to co-exist. The period of non-interference of weeds in rice, particularly in uplands and DSR, is very short, as the weeds start competing with crops as early as at the three-leaf stage of weeds (Reddy and Reddi, 2002). The competition between crop-and weed-plants is governed by the kind and the concentration of both crop-and weed-plants, crop row arrangement, availability of resources like water, nutrients, period of competition, and emergence of weeds in relation to the crop (Malik and Singh, 1995). Besides, allelopathic effects of weeds on crop and vice-versa, also determine crop-weed competition or interference.

Management of weeds using weed control practices that, on one hand, do not allow weeds to cross the yield losses beyond the economic threshold level and also do not cause any adverse effects on different agro-ecosystems, and on the other hand, is the dire need of the hour when rice is to be cultivated using the DSR method. Of various weed control practices, the most traditional method, i.e. manual weeding, has become almost impractical owing to non-availability of labour in time, escalating human-labour charges and impeding drudgery. The herbicide-based weed management, though is considered an ideal, convenient and cost-effective way for timely weed control in rice, has several limitations, such as (i) inability to control all types of weeds, (ii) environmental pollution, increased herbicide residues in soil, toxicity to soil bio-diversity, soil-ground water load in the soil and chemical contamination of food due to use of different types and higher doses of herbicides to control different weeds, (iii) development of herbicide resistance in weeds as an upshot of regular use of the same herbicide for a longer period, (iii) phyto-toxicity in crops with slight deviation in application dose, time and method. These issues call for exploration of some eco-friendly alternate strategies that may provide effective weed management while being benign to our environment. Making crop plants to attain a larger, competitive edge over weeds could be one of the potential alternate options to check the density and vigour of weed plants (Mortensen et al., 1998; Gibson et al., 2002).Various eco-friendly weed management approaches like growing of weed-competitive cultivars, exploring allelopathic interactions of rice cultivars against weeds, optimization of the plant population density by manipulating seed rate and spacing, etc., should be explored (Johnson and Mortimer, 2008; Chauhan, 2012). Hence, this review article is based upon the available literature on three most striking eco-friendly, non-chemical based weed management options, such as weed-competitive cultivars, row spacing, and seed rate.

2. Weed competitive cultivars/hybrids

Inbred rice varieties and hybrids differ in their weed competitive abilities. Hybrid rice yielded 15–25% more over inbred cultivars and demonstrated higher weed suppression, especially after one of planting (Walker et al., 2008; Chauhan et al., 2012). The competition among rice and weeds is more serious when the root system, morphology and growth habit of majority of the rice weeds resemble to the rice plants. Thus, through selection of weed-competitive cultivars, the weed emergence and its subsequent growth can be suppressed and the amount of herbicide and the cost of weed management can be amply curtailed; this will also considerably delay the inducement of herbicide-resistance in weeds-a serious repercussion of herbicidal weed-kill (Gibson et al., 2002, 2003; Caton et al., 2003; Gibson and Fischer, 2004; Zhao et al., 2006; Rao et al., 2007; Mahajan and Chauhan, 2011, 2013; Chauhan, 2012).

The cultivars, that acquire higher initial growth and develop