Crop Protection 78 (2015) 151–163

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Review

Weed management in aerobic rice systems

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ARTICLE INFO

Article history:
Received 6 May 2015
Received in revised form
27 July 2015
Accepted 5 September 2015
Available online 20 September 2015

Keywords:
Aerobic rice systems
Weed management
Weeds
Yield losses

ABSTRACT

Aerobic rice systems can substitute the conventional rice cultivation system in the wake of water shortage and energy crises. The major constraint in the success of aerobic rice is high weed infestation. Hence, we have discussed the weed flora, yield losses, herbicide-resistant weeds, need for integrated weed management, and approaches to manage weeds in aerobic rice systems. A review of several studies indicated that 90 weed species were competing with rice under aerobic systems, causing 23–100% reductions in grain yield. Weed control in aerobic rice gets difficult due to shifts in weed flora and herbicide resistance development in weeds. A wide increase in grain yield (15–307%) by implementing different weed control practices elaborates the scope of weed management in aerobic rice. Practices, such as soil solarization, sowing of competitive crop cultivars, stale seedbed preparation, mulch application, correct fertilization, and intercropping, were found to have particular significance for managing weeds in aerobic rice systems. Moreover, hand weeding and mechanical control were more effective when combined with other weed control methods. Herbicides, such as pendimethalin, 2,4-D, penoxsulam, ethoxysulfuron, bispyribac-sodium, triclopyr, imazosulfuron, bensulfuron, pretilachlor, and metsulfuron, were found most effective in aerobic rice systems. Keeping in view the severity of weed infestation in these systems and the evolution of herbicide resistance, reliance on a single control method is out of question. Hence, the approach of integrated weed management is the most appropriate for proper weed management and the subsequent success of rice cultivation using aerobic systems.

Contents

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http://dx.doi.org/10.1016/j.cropro.2015.09.005
0261-2194/

1. Introduction

The human culture and rice possess a historical and profound interrelationship. Rice has had always an inevitable role in the food, economy, religion, and civilization of many countries in the world. There have also been different mythologies about the origins of rice in Myanmarese, Chinese, and Japanese histories.

Rice contributes more than 60% and 25% to the cereals production of Asia and of the world, respectively, and it formulates nearly 30% of all the food being consumed in Asia (Timmer, 2010). It is the major food item for billion residents of Asia and is the principal source of nutrition for many of the world's densely populated countries such as China and Bangladesh. In fact, the approximate contribution of rice to the total calories being consumed is 30, 30, 50, 70, 60, 50, and 30% for China, India, Indonesia, Bangladesh, Vietnam, Philippines, and South Korea, respectively (Timmer, 2010). According to estimates, nearly a half of the world population consumes rice as their principal food. Alongside this, the labour force required to produce rice provides livelihood especially to those belonging to the underprivileged. The steady rise in population further underlines the importance of rice. The worldwide per capita rice consumption increased until 2000 but faced a little decline afterwards.

Originating in the Niger River delta more or less around 1000 BC, African rice makes up more than 15% of the cereal production in this continent and contributes nearly 4% to Africa's gross domestic product (Timmer, 2010). It plays an important role in feeding the population of Africa and in being a major source of livelihood.

Of the 25 species of the genus *Oryza*, 22 are wild, one is extinct, and two are domesticated. The domesticated species, *Oryza sativa* and *Oryza glaberrima* originated from South Asia and West Africa, respectively. Today, the number of countries growing rice has reached ahundred, although 80–90% of rice is grown in Asia. Worldwide rice production is estimated at nearly 700 million tons with China being the largest rice producer [>200 million tons (mt) rice annually], followed by India (~150 mt), Indonesia (~70 mt), Vietnam (~44 mt), Thailand (~38 mt), Bangladesh (~34 mt), and Myanmar (~33 mt).

The conventional way of growing rice involves flooding the fields and rice seedlings are transplanted manually or mechanically under inundated conditions. However, huge labour and water requirements are the major drawbacks of growing rice using this method. Growing rice under aerobic conditions requires 36–41% less water than under the conventional method (Belder et al., 2005). In response to the labour and water shortage problem, some alternative rice production methods were suggested by researchers worldwide including alternate wetting and drying, and direct-seeded and aerobic rice production systems (Pinheiro et al., 2006; Chauhan et al., 2012; Mahajan et al., 2013; Jabran et al., 2015 a,b). Compared with flooded rice, aerobic rice had lower production cost, higher water productivity, and a comparable outcome (Jabran et al., 2015 a,b).

Aerobic rice can be grown in a variety of ways depending on soil type, climate, available resources, and farmers' convenience. Direct drilling of rice (also called dry direct-seeding) seeds in a finely prepared seedbed using a manual or tractor-drawn drill is the most common method of growing aerobic rice. Time, labour, water, and energy savings are the important characteristics of this method. The other important method of sowing aerobic rice is wet seeding, in which pre-germinated rice seeds are broadcast on saturated soil after puddling or without puddling. Wet seeding after puddling is the most common method. Later, the crop is irrigated like the dry direct-seeded aerobic rice system. Time, labour, energy, and water are saved in this method (compared with the conventional transplanting); however, water inputs are little higher than in dry direct-seeding. In another method of the aerobic rice system, rice seedlings are transplanted on a flat saturated area. The crop is irrigated on drying of the soil in a similar manner to crops like maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.); however, the frequency of irrigation is a little higher for the transplanted aerobic rice system. This method requires higher labour, time, and energy than the dry direct-seeding or wet direct-seeding methods, owing to the time and labour needed for seedling raising and transplanting. Another attractive method of aerobic rice cultivation is the furrow-bed system. Under this system, furrow-beds are made with the help of a tractor-drawn bed shaper. Later, either the rice seedlings are transplanted on the upper surface of beds, or the rice seeds are drilled on the raised-beds. The irrigation is applied in the furrows only until the water approaches the roots of rice plants through seepage. Hence, most of the soil surface does not get wet, resulting in higher water saving compared with growing aerobic rice on flat lands. Sometimes, this system is also named as “furrow-irrigated raised-bed system”. Furrow-ridge is another method suitable for growing rice using an aerobic method (Jabran et al., 2012b). Under this system, the ridges and furrows are shaped after seedbed preparation using a ridge shaper. Later, the rice is sown on the sides of ridges and irrigation is provided only in furrows, leaving the ridges dry. Water inputs for growing rice are supposed to be reduced significantly using the furrow-ridge aerobic rice method since the roots of rice plants can grasp the water reaching them by seepage. Also, in this method of growing aerobic rice, either the rice seedlings are transplanted on the ridges or seeds are drilled directly, and both the manual and mechanical seed drilling on the ridges are possible. Recently, rice planting on no-tilled flat soils and no-tilled beds has also been advocated by some researchers (Devkota et al., 2013). In most recent forms of aerobic rice systems, rice seeds are directly planted in the field, and irrigation is provided by sprinkler or drip systems.

Heavy weed infestation has been proved to be the major constraint for the success of aerobic rice systems (Farooq et al., 2011b; Singh et al., 2009), given that weed prevalence is higher than in the conventional method of growing rice in flooded conditions. In aerobic rice systems, yield losses due to weeds are reported to be 70–80% (Hussain et al., 2008; Mahajan et al., 2009; Singh et al., 2007). Further, rice yield in aerobic conditions has been reported to be improved by 27–300% through implementation of suitable weed control methods (Hussain et al., 2008; Mishra and Singh, 2012). Although previous research suggested focussing on the application of diverse control methods to manage weeds in aerobic rice systems, literature regarding the practical execution of