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Review

Strategies to manage weedy rice in Asia

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ABSTRACT

Weedy rice, an emerging problem in Asia, increases production costs and reduces farmers' income through yield reduction and through lowered rice value at harvest. Rice farmers in many Asian countries are shifting from transplanting to direct seeding; however, due to physical and physiological similarities of weedy rice to cultivated rice and the absence of standing water at the time of crop emergence, adoption of direct-seeded rice systems makes weedy rice infestation one of the most serious problems. Selective herbicides to control weedy rice in conventional rice cultivars are not available and therefore managing weedy rice is a challenging and increasing problem for farmers in Asia. In the absence of selective herbicides, various cultural weed management strategies may help reduce the problem of weedy rice. These strategies may include the use of clean seeds and machinery, use of stale seedbed practice, thorough land preparation, rotation of different rice establishment methods, use of high seeding rate and row-seeded crop, use of purple-coloured cultivars, use of flooding, and adoption of crop rotation.

1. Introduction

Rice is a principal source of food for more than half of the world population. It is grown on approximately 153 million ha (Mha) globally, of which 90% of the area is in Asia. Rice is traditionally grown in Asia by manual transplanting of seedlings into puddled soil (soil is puddled after intensive cultivation in wet conditions). In the recent years, there have been concerns of labour and water shortages in many areas in Asia. Rural labour is migrating to the cities and labour costs have thus increased rapidly. It is also hard to find labour at the time of rice transplanting (Mahajan et al., 2011, 2013). By 2025, a significant amount of rice area may suffer from "physical" and "economic" water scarcity (Tuong and Bouman, 2003). Therefore, farmers in Asia are slowly moving towards direct seeding of rice in response to increased costs or decreased availability of water and/or labour (Chauhan, 2012a; Mahajan et al., 2012).

Although there are several advantages of direct-seeded rice, weeds are the major constraints to direct-seeded rice production because of the absence of the suppressive effect of standing water on weed growth at crop emergence and the absence of a size differential between the crop and the weeds (Chauhan and Johnson, 2010a). In general, two major weed complexes have been recognized to be of particular concern in rice: *Echinochloa* species and weedy rice (Labrada, 1997).

Weedy rice is defined as a weed in and around arable area (Suh, 2008). In general term, weedy rice is unwanted plants of the genus *Oryza* that infest and compete with rice and other crops and produces grains with a distinctly red or rough pericarp (Delouche et al., 2007; Suh, 2008). In specific term, weedy rice is unwanted plants of *Oryza sativa* growing together with cultivated rice. Some suggestions were proposed about the origins of weedy rice (Kane and Baack, 2007): weedy rice may have evolved from wild rice; weedy rice may have originated from escaped domesticated rice seeds, which then evolved weedy traits; or weedy rice hybrids may have evolved through interbreeding between cultivated and wild rice. In the United States, weedy rice (called red rice) has been regarded a serious problem for many years (Goss and Brown, 1939). In Asia, however, weedy rice is an emerging problem. Its infestation was first reported in Malaysia in 1988, in the Philippines in 1990, and in Vietnam in 1994 (Mortimer et al., 2000; Second, 1991; Wahab and Suhaimi, 1991). Weedy rice increases production costs and reduces farmers' income quantitatively through yield reduction and qualitatively through lower rice value at harvest (Mortimer et al., 2000). In Asia, rice yield losses due to weedy rice infestation were reported to be from 16% to 74% (Azmi et al., 1994; Chin, 2001). In Malaysia, infestations by about 35 weedy rice panicles m^{-2} caused a yield loss of about 1 t ha^{-1} (Azmi et al., 2005a). In the United States, 1–3 plants m^{-2} of weedy rice were the threshold infestation to prevent yield losses of rice (Smith, 1988).

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An important characteristic of weedy rice is early shattering of the grain; however, shattering varies among different biotypes or accessions (Azmi and Karim, 2008). Weedy rice has variable seed dormancy and it can remain dormant in the soil for several years. In the United States, weedy rice was found to have a greater response to higher nitrogen rates compared with cultivated rice (Burgos et al., 2006). Recently, in Asia too, some weedy rice accessions have been found to have greater nitrogen-use efficiency for shoot biomass than cultivated rice (Chauhan and Johnson, 2011b). In another study, compared with cultivated rice, weedy rice responded more strongly to rising CO_2 level with greater competitive ability, suggesting that weedy rice may become a more problematic weed in the future (Ziska et al., 2010).

Recently, weedy rice has been increasingly reported as one of the major weed problems in many Asian countries, including Malaysia, Thailand, India, Republic of Korea, Philippines, Vietnam, and Sri Lanka (Delouche et al., 2007). The increase in weedy rice infestation in Asia is closely associated with the increase in area under direct seeding. The growing trend towards the adoption of direct-seeded rice in Asia is extending the areas infested with weedy rice and increasing the severity of the infestations (Delouche et al., 2007). In Malaysia, the widespread occurrence of weedy rice has been favoured by the practice of implementing a direct seeding rice culture, the use of easy shattering cultivars, and the use of combine harvesters (Suh, 2008). Factors that determine the population growth rate of weedy rice populations are (Mortimer et al., 2000): weedy rice seed remain dormant in the soil over long time, weedy rice seed spread through crop seed contamination, and weedy rice seed from plants in the previous rice crop. In Vietnam, farmers and specialists emphasized the importance of contaminated rice seeds as a source of weedy rice infestations (Delouche et al., 2007). In a survey in Vietnam, 37% of the farmers opined that weedy rice evolve from cultivated rice, 32% believed that it emerge from the soil seed bank, and 14% of the farmers thought that weedy rice is introduced as contaminants in rice seed.

As mentioned earlier, farmers in many Asian countries are shifting from transplanting to direct seeding. However, due to physical and physiological similarities of weedy rice to cultivated rice and the absence of standing water at the time of crop emergence, adoption of direct-seeded rice systems makes weedy rice infestation one of the most serious problems that farmers encounter (Azmi and Karim, 2008; Chauhan, 2012a,b; Chauhan and Johnson, 2010b). In some countries where direct seeding is already a common practice, farmers are reverting to mechanized transplanting to manage weedy rice (Chauhan, 2012a).

Selective herbicides to control weedy rice in conventional rice cultivars are not available and therefore managing weedy rice is a challenging and increasing problem for farmers in Asia. In the absence of selective herbicides, various cultural weed management strategies may help reduce the problem of weedy rice. This article reviews potential strategies to manage weedy rice in Asia.

2. Weed management strategies

2.1. Preventive measures

The first and the most important step in reducing weedy rice infestation is the use of clean rice seeds. The spread of weedy rice from an infested area to a clean area has occurred in many countries through the distribution of contaminated rice seeds to farmers (Azmi and Karim, 2008). Contamination with a small fraction of weedy rice seeds may result in a heavy weedy rice infestation within a year in rice–rice and rice–rice–rice cropping systems. Therefore, to obtain clean seeds, it is important that weedy rice plants in the field are not allowed to produce seeds. In a survey in Vietnam, 40% of the collected rice seed samples were contaminated with weedy rice seed and these occurred in all the provinces (18) surveyed (Mai et al., 2000). In Sri Lanka, farmers who opted to uproot weedy rice plants at heading sometimes throw the seed-bearing plants into canals and unknowingly helped in spreading the weedy rice seeds to adjacent fields (Abeysekara et al., 2010).

Farmers should inspect their fields regularly and must rogue weedy rice plants whenever these appear. For effective field inspections, farmers should be familiar with the characteristics of the rice variety planted and be able to distinguish them from the off-type and weedy rice accessions (Delouche et al., 2007). Therefore, there is a need to increase awareness of weedy rice among farmers. The machines used for land preparation, sowing, harvesting, and threshing should be cleaned before moving from one field to another. In addition, field margins and irrigation canals should be free from weeds, including weedy and wild rice.

2.2. Land preparation

Straw and stubble burning is considered an effective strategy in eradicating weedy rice seeds present on the soil surface (Azmi and Karim, 2008). However, this practice has been banned in many countries because of smoke pollution. Similar to that of other weed species, the seed bank of weedy rice can be reduced using the stale seedbed practice (Chauhan, 2012a). After a light shower or irrigation, weedy rice and other weed seedlings are allowed to germinate and then killed with tillage or non-selective herbicides. The use of stale seedbed practice has been reported to reduce the number of weedy rice plants in the crop (Delouche et al., 2007). However, the efficacy of this practice will depend on the degree of dormancy in the weedy rice seeds, as dormant seeds will not germinate. Although stale seedbed practice is useful in reducing weedy rice seed bank, the practical possibility of this practice needs to be evaluated by farmers themselves when the period between the harvesting of the preceding crop and sowing of the next crop is short and when crop intensification is the main aim of the farming (Chauhan, 2012a). In some cases, there may be a yield penalty if crop planting is delayed by the preplanting operations (Chauhan, 2012a; Liebman et al., 2001).

Thorough land preparation is done for seedbed preparation and this has been used to control weeds ever since the origin of agriculture. Repeated cultivation is effective in reducing the weedy rice seed bank and seedlings in rice fields. Weedy rice seedlings that emerge after the first cultivation are killed by the subsequent cultivation operations. In different direct seeding systems, tillage is performed in dry or wet soil conditions. In aerobic and dry-seeded rice systems, soil is cultivated in dry conditions, whereas in wet-seeded rice, soil is cultivated in wet conditions (the process is called *puddling*). These tillage operations could be used to bury weedy rice seeds below the maximum depth of their emergence. In the United States, weedy rice ecotypes emerged from buried depths of 7.5 cm (Gealy et al., 2000). In a recent study in the Philippines, three of four weedy rice accessions could not emerge from a burial depth of 8 cm (Chauhan, 2012b). These results suggest that emergence of weedy rice could be suppressed by deep tillage that buries seeds below 8 cm. However, subsequent tillage operations in the next few seasons should be shallow to avoid bringing back the buried seeds on the soil surface. In earlier studies, weedy rice in Vietnam showed a dormancy of 20–65 d (Thanh et al., 1999) and weedy rice in Italy showed a dormancy of 170 d (Vidotto and Ferrero, 2000). In Asia, dormancy in weedy rice accessions has been reported to be between 0 and 300 days (Suh, 2008), suggesting variable degrees of dormancy in different weedy rice accessions. There is a need to study the weedy rice seed longevity for different accessions occurring in different rice-based cropping