Review paper
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NEED FOR INTEGRATED WEED MANAGEMENT IN FINE GRAINED DRY DIRECT SEEDED RICE

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Abstract

The culture for growing fine grain aromatic basmati rice includes flooding and puddling of the field. These puddled and flooded fields are then transplanted with nearly 30 days old rice nursery. The weeds present in the field sown with rice by this traditional method are suppressed by two means. These are eradicated and buried under the heavy soil layer through tillage done in the form of puddling as well as suppressed by the standing layer of water. The standing layer of water not only suppresses the growth of germinated weeds but also prevents the germination of more weeds. The traditional basmati rice cultivation culture is desired to be replaced with water saving rice cultivation culture (dry direct seeded rice; DDSR) due to water shortage resulting from the climatic changes. However, DDSR is severely constrained by weeds which strongly interfere the rice growth and yield. Further, a variable weed flora was recorded under both the rice cultures. The results of experiments indicated that some herbicides can effectively control the weeds in DDSR. However, relying on a single or combination of two herbicides (one pre- + one post-emergence) may not be a good idea in the wake of environmental pollution and herbicide resistance development. Relying on integrated weed management (IWM) would be the most suitable and sustainable option to effectively control the weeds for the successful production of rice by DDS method. Careful field sanitation, crop rotation, stale seed bed, chemical control, brown mulching and spotted hand weeding can be implemented integrated for an effective weed control in DDSR. The strategies if integrated suitably would result in sustainable weeds control, increased yield and improved quality of basmati rice grown by DDS method.

Keywords: *fine grain rice, weeds, yield losses, integrated weed management*

Introduction

Rice grains are eaten by a huge portion of population on the earth. Moreover, countless byproducts of rice can be listed. Rice bran, paper, oil are important among these byproducts which are utilized from rice. Fine grain rice cultivars are important within the other types of rice due to pleasant fragrance, grain length and greater cooking quality (Bhattacharjee *et al.*, 2002). Hence, these cultivars are preferred over the other rice. The traditional way of growing fine grain rice cultivars is the flooded puddled method which requires a lot of water and labor (Tabbal *et al.*, 2002; Tuong *et al.*, 2005). However, the reduced water availability and labor shortage throughout the rice growing areas of the world leads to a failure in maintaining the fine grain rice production by routine method. In response to labor and water shortage, sowing of fine grain rice under dry soil environment has been suggested as an alternative. The method is named as dry direct seeded (DDS) rice, and possesses the advantage of having lower labor and water requirements than the conventional methods (Farooq *et al.*, 2011). Nevertheless, a number of limitations challenge the sustainability of DDS rice method. Weeds are salient among such challenges (Chauhan, 2012). Weeds even result in 100% crop

loss of DDS rice under certain instances (Chauhan and Johnson, 2011). Usually, applying a single technique was not sufficient for reasonable weed control in DDS rice. Hence, the use of integrated weed management would probably successfully tackle the problem of high weed proliferation in DDS rice (Chauhan and Johnson, 2011; Bhurer *et al.*, 2013). In this article, we have highlighted the importance of fine grain basmati rice cultivars, the traditional way of growing rice, dry direct seeded rice and issues in growing basmati rice by dry seeding method. Further, the weed control methods which can be used for integrated weed management in DDS fine rice have been explained.

Importance of fine grain basmati rice cultivars

The fine grain basmati rice cultivars are grown mainly in Pakistan and India. A number of distinguishing features make the fine grain rice cultivars prominent among the other types of rice in the world (Bhattacharjee *et al.*, 2002). The first character which distinguishes the basmati from other rice types is the strong sweet smell of grain called aroma. The chemical compound supposed responsible for aroma in basmati grains is 2-acetyl-1-pyrroline. The other salient character of basmati rice, which makes it outstanding among the other rice types, is the extra-long size of grain. This makes it attractive for the consumers. Moreover, the grain size is further increased after the cooking (almost doubled upon cooking). Outstanding cooking quality is the other distinguishing character of the basmati rice. The basmati rice grains do not stick with each other during cooking owing to specific concentration of amylose contents. Based on these characters, the basmati rice is sold in the world market at the highest price compared with all other types of rice. A price comparison of different important rice types from around the world are presented in the Fig. 1.

Therefore, the basmati rice types are unique among the several of rice types found all over the world. Hence, this type of rice is liked more than the other types and fetches higher economy benefits.

The traditional way of growing rice

The traditional way of growing rice is one which needs high amounts of water and labor. For sowing rice under this system, the first step is to grow nursery seedlings. Meanwhile, the agricultural fields are flooded and then puddled with tractor mounted cultivator and planker. The flooded and puddled fields are transplanted with nursery seedling, either through a machine or manually (San-Oh *et al.*, 2004; Mishra and Salokhe, 2008). The major drawbacks of this system are the higher water requirement and labor needs. Hence, the dry-seeded rice is suggested as an alternate to the traditional way growing rice in order to save significant amount of water and labor (Bouman *et al.*, 2007).

Dry direct seeded rice

Dry direct seeding (DDS) is the way of growing rice where the nonflooded fields are sown with the rice seeds. The seed drilling is done using seeding machines. The crop is irrigated before the complete soil drying (Farooq *et al.*, 2011). The purpose of growing rice by this method is to save the huge energy and water, as needed in case of traditionally grown rice (Bhushan *et al.*, 2007).

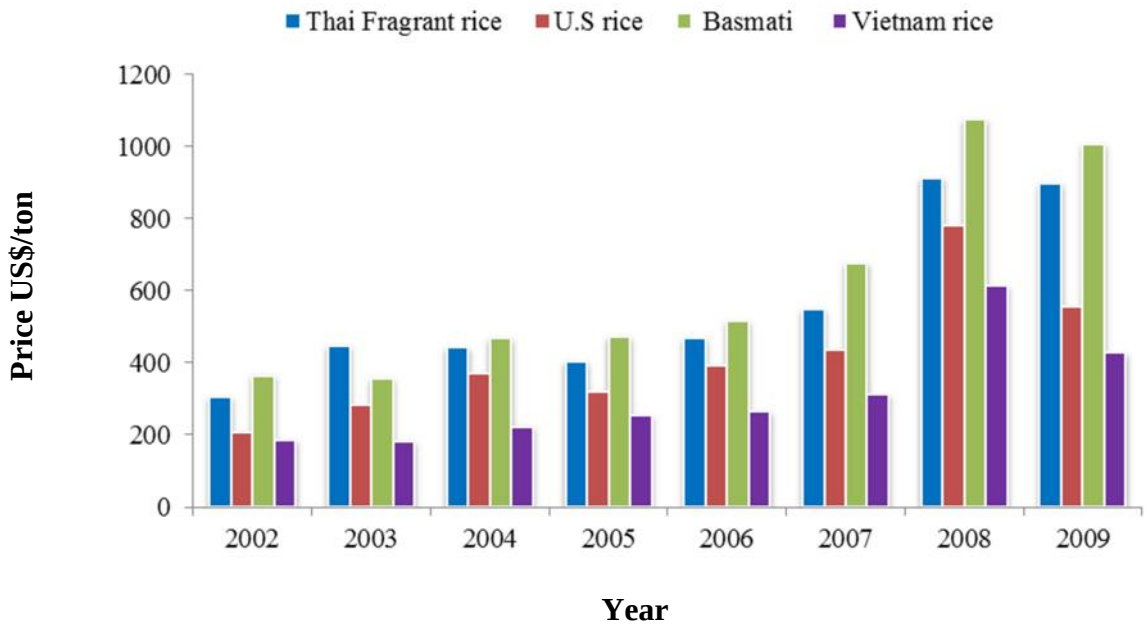

Fig. 1: A comparison of price for rice grains in the world market; Source: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1229

Issues

Several of the issues restrict the successful rice production by DDS method. Many of the crop management issues still require solution to successfully exploit potential of DDS method. For example, a poor crop stand may be witnessed if the rice seed is of poor quality and has not been treated with some suitable treatment to improve germination. Similarly, limited information is available regarding the nutrient in DDS method of rice growing. Moreover, severe spikelet sterility, high weeds and diseases intensity are among the serious issues being faced by DDS method of rice cultivation. However, high weed proliferation carries extreme gravity which results many times in failure of rice crop when grown by DDS method. *Dactyloctenium aegyptium* (L.) Willd., *Echinochloa crus-galli* (L.) Beauv., *Echinochloa colona* (L.) Link, *Cyperus rotundus* L., *Cyperus iria* L., and *Trianthema portulacastarus* L. are among the most important weeds which are infesting the DDS rice (Tindall *et al.*, 2005; Sanusan *et al.*, 2010; Chauhan and Opeña, 2013). On the other hand, huge quantity of rice grains in DDS method is lost due to weed-crop competition. For example, a study from Pakistan reported that the weeds such as *C. rotundus*, *T. portulacastrum*, *Eclipta prostrata* L., *E. crus-galli* and *D. aegyptium* caused a nearly 75% decline in the productivity of rice grown by DDS method (Jabran *et al.*, 2012a). Hence, weeds are the most serious issue faced while growing rice as DDS.

Integrated weed management (IWM)

IWM is the scientific and smart way of controlling weeds where more than one methods are practiced in integration. Use of multiple methods to control the weeds makes the control techniques to work in harmony. Hence, the antagonistic effects of few practiced weed suppression methods improve the reliability of weed control. IWM is particularly desired for the DDS rice owing to hardy weeds, shifts in weed flora and the appearance of repeated flushes of weed flora. For IWM in DDS rice, the different techniques can be integrated to have improved weed control and higher paddy yields. Several techniques such as field sanitation, crop rotation, brown mulching, chemical control, mechanical control and spotted hand weeding are elaborated here.

Field sanitation

Field sanitation comprise of a complex of sanitary practice which are aimed to prevent the weed propagation in the agricultural fields (Norris *et al.*, 2003). Field sanitation is important for maintaining weed free fields as the hygienic conditions are important for avoiding illnesses in humans, and enjoying a healthy life. Although, a number of field sanitation practices can be listed we will briefly discuss those which are important in relevance with the weed management in DDS rice. Irrigation canals, rice farm areas, rice farm roads and field bunds can be listed as the places which should be free from weeds to avoid the weed propagation in DDS rice (Rao *et al.*, 2007). More importantly, the entire crop inputs like seed, fertilizer, water, compost and mulches should no contain weed seeds. Similarly, the equipment like tractor, cultivator, sowing drills, sprayers and others, which are used for different farm operations must be hygiene from weed seeds to avoid weeds proliferation in DDS rice. Adopting such cares to practices field sanitation will help to reduce weed intensity, in order to improve the weed suppression through IWM.

Crop rotation

Crop rotation is the phenomenon where a definite crop sequence is disturbed by introducing an out-of-routine crop. It is the weed control techniques which reduces the weed intensity without any extra expenses. Crop rotation can be used to reduce weed intensity in DDS rice (Rao *et al.*, 2007). Hence, the rice fields with DDS having abundant uncontrolled weeds can be vacated from rice for one season, and sown with another crop, such as a legume crop like *Vigna mungo* (L.) Hepper, or *Vigna radiata* (L.) R.Wilczek. This crop rotation will help to break the weeds' life cycle by depriving them from their specific ecology. Further, rotating rice with a legume crop will also improve the soil health in addition to reducing the weed intensity. Therefore, crop rotation can be helpful in managing the weeds in DDS rice. More precisely, the crop rotation can help to improve weed control under the auspices of IWM

Brown mulching

Recently, the technique of brown mulching has been found effective for managing weeds in dry-seeded rice. In this technique, the plants from *Sesbania* spp. are sown (as intercrop) along with the dry-seeded rice. Both the rice and *Sesbania* spp. plants are allowed to grow together four to six weeks after crop sowing. Thirty to forty days later, herbicide (usually 2, 4-D) is sprayed to kill the *Sesbania* spp. The applied herbicide kills not only the *Sesbani* spp. plants, but also the susceptible weeds. The *Sesbania* spp. turning brown, hence, the technique is named brown mulching. The weeds in the dry-seeded rice crop are first suppressed by the shading of the intercropped *Sesbania* spp., while the weeds are suppressed by the brown mulch through physical effect and shading. Therefore, the technique of brown mulching can play an important role for weed control in DDS rice.

Chemical control

Herbicides have done a remarkable job for agriculture by suppressing weeds efficiently. Weed control through herbicides gains more significance if the existing weed flora is tough. Although, some literature indicate that applying an herbicide can suppress weeds in DDS, contradictory reports indicate the failure only of herbicides to control the hardy weed flora in DDS rice (Mahajan *et al.*, 2009). Application of a single herbicide may be suitable for keeping down the weeds if the weed flora is not complex (Jabran *et al.*, 2012a). However, if the weeds are hardy and complex, a combination of herbicides would probably be desired to quash the weeds (Bhurer *et al.*, 2013). A study was conducted for evaluating the effect of three herbicides for controlling weeds in DDS basmati rice (Akbar *et al.*, 2011). The

herbicides such as pretilachlor (1250 g a.i. ha^{-1}), pendimethalin (1650 g a.i. ha^{-1}) and butachlor (1800 g a.i. ha^{-1}) decreased the weed dry weight by 74-87% and the weed density by 81-87%, and improved paddy yield by 6-19% over the control treatment (Akbar *et al.*, 2011). Bispyribac sodium (30 g a.i. ha^{-1}), 2,4-D (500 g a.i. ha^{-1}), ethoxysulfuron (38 g a.i. ha^{-1}) and penoxsulam (15 g a.i. ha^{-1}) are among the most important herbicides which can be applied for chemical weed control in DDS rice (Singh *et al.*, 2006; Hussain *et al.*, 2008; Jabran *et al.*, 2012b).

Mechanical control

Mechanical weed control has particular importance for DDS rice owing to repeated appearance of flushes of weed. Hence, controlling weeds gets impossible while using a single method of control. Hand tools are important for mechanical weed control at small farms. Tractor drawn mechanical weeders can be used in integration with other techniques for IWM in DDS rice. Modern weeders can improve the precision of mechanical weed control in DDS rice.

Spotted hand-weeding

Hand-weeding is among the oldest methods of managing weeds in crops, vegetables, fruit crops and other places. However, only hand-weeding is insufficient to control all the weeds in DDS rice. Hand-weeding can be performed in the DDS rice setting some special objectives. Hence, performing targeted hand-weeding would strengthen the integrated weed control in DDS rice. For instance, the hand-weeding can be combined with a pre-emergence or early post-emergence herbicide to improve the weed control (Singh *et al.*, 2008). In this case, the hand-weeding is done 3-5 weeks after the herbicide application. Similarly, the other way is to perform hand-weeding a few days after the herbicide application (Mahajan *et al.*, 2009). In this way, the spotted hand-weeding is done to pull the weeds which are left uncontrolled after the herbicide application. In another way, the weeds which attain the reproductive growth stage after completing the vegetative stage (i.e. these weeds were not controlled by any of the applied methods) can be cut by a sickle. The cut weeds can be put in the soil to add organic matter to soil. Therefore, the spotted hand-weeding can be employed for achieving specific target in order to improve integrated weed control.

Conclusions

Basmati rice grains outstanding quality conventionally grown by the puddled flooded method requiring high labor and water inputs. DDS is the method which can reduce water input and labor use for cultivating the basmati rice. Weeds are most important among the constraints which reduce productivity of basmati rice under DDS method. High weed infestation in DDS rice stresses to adopt IWM for

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