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Different approaches of weed management in aerobic rice production

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Abstract

The production of rice is always important for the security of food and everyday life. Rice cultivation has changed from traditionally flooded transplanting to aerobic rice due to expectations of increased water limitations under a changing climate and growing manpower shortages in agriculture. Because there is less standing water, aerobic rice becomes more affected by weeds, which puts crop plants in competition for the same resources. According to research, in order to minimize crop losses, weeds should be managed 20–60 days after seeding. Aerobic rice may become widely used if integrated weed management strategies, namely, i.e. cultural, mechanical, chemical, and preventive, are adopted globally.

Key words : aerobic rice, weed management, prevention

Introduction

Rice (*Oryza sativa* L.) is a major food crop that supports two-thirds of the global population Kahani et al. (2015). Rice agriculture accounts for nearly one-fifth of all cereal land area. This plant thrives in diverse environments, including rainy places and arid deserts. Rice is farmed in 112 nations stretching from 53 degrees north to 35 degrees south, with Asia accounting for over 95% of production and consumption. It is semi-aquatic and occurs annually. Rice fields are usually flooded for prolonged periods of time, which increases seepage, percolation, transpiration, and evaporation. One kilogram of rice requires 3000 to 5000 liters of water to produce. Though it makes only 25% of the total production, rainfed rice accounts for 45% of the rice acreage worldwide (Pandey et al., 2000). Rice serves as the prime source which contains carbohydrate/energy for more than half of the world's population. It is the second most cultivated cereal crop in the world which is significantly higher than that of wheat and maize. Widely practiced across varied topographies and climatic conditions. Exposure to a variety of climatic conditions has made rice adapt to the respective climatic conditions. The rice cultivated area in Asia alone contributes 89%, and 90% of them are produced and

consumed here (<http://www.fao.org>).

There has to be a reduction in the amount of water used to grow rice. In Asia, puddled paddy fields are usually cultivated with irrigated rice. Saturated soil is soaked, then plowed and harrowed as part of the land preparation process. Following crop establishment, 5–10 cm of water is maintained in the fields. Lowland rice production uses a lot of water due to the wet land preparation process and significant losses from seepage, percolation, and evaporation when the soil gets flooded (Bouman and Tuong, 2001). If rice could be cultivated in aerobic soil conditions like wheat and maize, irrigation water savings and increased water productivity may be attained. But if the idea of "aerobic rice" is to succeed, new cultivars need to be developed. There is such a thing as upland rice, but it is grown in difficult conditions with minimal external inputs, limited irrigation, and a low prospective yield. According to Liu et al. (2021) the aerobic rice system may reduce methane emissions by up to 70% and water use by up to 30%. Furthermore, aerobic rice farming can increase crop yields by as much as 30%, which is a promising idea for small-scale farmers (Ishfaq et al., 2020).

The primary obstacle to the success of aerobic rice growth has been determined to be a high weed infestation rate, which is higher than that of the traditional way of producing rice under flooded conditions. Weeds have been reported to cause 70–80% of yield losses in aerobic rice systems (Hussain et al., 2008). Furthermore, using effective weed control techniques has been observed to increase rice yield in aerobic scenarios by 27–300%. Further, it is important to note that the use of less water and avoiding standing water reduces the methane emissions from the rice fields. Thus, shifting from transplanted rice systems to aerobic conditions would also help in lowering greenhouse gas emissions and the approach proves to be more eco friendly. Besides, the labor requirement is also reduced in DSR under aerobic conditions thus lowering the total production cost. Unlike in a traditional transplanted system, where rice is sown in the nursery, aerobic rice cultivation is being sown directly in the non puddled field. It has been claimed that unmanaged weeds in the field might affect yield in DDSR by up to 75%. For successful IWM implementation, a systematic weed-monitoring program is needed. Various weed-management techniques, such as cultural weed management using crop residue mulch and stale seedbed, can be used, as can cultivating cultivars that are crop-competitive and adjusting seed rate, row spacing, nutrient, and water management to improve crop competitiveness. Chemical weed control depending on needs, using herbicides, herbicide mixtures, and novel herbicides that are effective against a variety of weeds. In DSR, weeding at 60 DAS (20.4%) resulted in the greatest grain production losses from weeds, followed by 45 DAS (15.8%). Therefore, early weeding in DSR is crucial to achieving improved yields of rice and reducing crop loss from weeds. Because aerobic soil conditions and dry plowing make aerobic rice more susceptible to weed infestation, weed management remains a major concern.

Why are farmers not adopting this technology?

Since weeds emerge along with rice in aerobic rice systems and there is no water layer to inhibit weed growth, direct-seeded aerobic rice is more susceptible to weed infestation than transplanted lowland rice. Weeds can reduce rice productivity by 50–100% (Mishra and Singh, 2007), which is a significant barrier to the widespread usage of aerobic rice. Under such circumstances, the most useful and economical way to lessen weed competition is through integrated weed control.

The majority of Asian upland and aerobic rice farmers mechanically remove weeds from their fields twice or three times a season, requiring up to 190 labor days per hectare for manual weeding (Roder, 2001). Adoption of water-saving aerobic rice and raising production of crops in aerobic rice-based cropping systems are significantly hampered by the labor-intensive weeding process.

Given that weed prevalence is higher than in the traditional way of producing rice under flooded environments, heavy weed infestation has been found to be the main obstacle to the success of aerobic rice systems (Farooq et al., 2011). Weeds have been found to cause 70–80% of yield losses in aerobic rice systems (Mahajan et al., 2009). Furthermore, it has been found that using appropriate weed control techniques can increase rice yield in aerobic scenarios by 27–300% (Mishra and Singh, 2012).

Rice farming facing the difficulty of implementing a more environmentally conscious weed management strategy in response to the above mentioned issues. Because aerobic soil conditions and dry plowing make aerobic rice more susceptible to weed infestation, weed management remains a major concern.

One of the most crucial requirements for ensuring a sufficient production of rice is thought to be effective weed control (Juraimi 2013). In direct seeded rice, high weed pressure reduces the yield and, in the worst situations, makes rice farming unprofitable. (Jabran 2012). This requires the return of biological, cultural, and physical weed control in addition to the smart application of herbicides based on an extensive understanding of the crop-weed ecology, a practice called as integrated weed management (IWM).

Important Weed flora associated with aerobic rice

The association of aerobic rice weed seems to be a sophisticated ecological system. Along with aerobic rice, about 51 species have been reported, of which 34 species (66.7%) were broad-leaved weeds, 12 species (23.5%) were narrow-leaved weeds, and 5 species (9.8%) were sedges. 18 of the 75 weed species that were studied are regarded as major weed species. These include “*Phyllanthus niruri*, *Ageratum conyzoides*, *Celosia argentea* L., *Mimosa pudica*, *Protulaca oleracea* L., *Aeschynomene indica*, *Spilanthus acmella* Murray not (L.) L., *Alternanthera sessilis* L., *Emilia sonchifolia* (L.) DC. ExWight and *Eclipta prostrata* (L.) L. among broad leaved weeds, *Echinochloa colonum* L., *Dactyloctenium aegyptium* (L.) Willd., *Panicum repens* L., *Eleusine indica* (L.) Gaertn., *Cynodon dactylon* (L.) Pers. and *Digitaria marginata* L. among narrow leaved weeds and *Cyperus rotundus* L., *Cyperus iria* L. and *Fimbristylis miliacea* (L.) Vahl” among sedges .

Importance of crop rotation and diversification to disrupt weed life cycles

Between 10% and 15% of potential yield is considered to be lost as a result of weed competition in rice cultivation (Baltazar 1994). However, the introduction of new crops in areas under rice monoculture was encouraged by the widespread distribution of imidazolinone-resistant weedy rice. This approach attempts to prevent weed interference from reducing rice grain yield and quality and from increasing the seed bank of problematic weed species. This effect can be connected to a wide range of processes, such as disturbance patterns, allelopathy, and faunal changes, which may diversify selection pressures through their effects on seed bank dynamics. According to certain investigations, when monoculture is abandoned in rice farming, the seed bank of problematic species is significantly reduced (Avila 2002). By regulating the frequency of tillage and the consequences of farming practices like pesticide programs, crop seed rate, and sowing timing, rotation also has an impact on biodiversity.

Prevention of Crop Seed Contamination with Weed Seeds

The adoption of clean, weed-seed-free crop seeds is still the most important and feasible preventive approach for lowering the weed intensity in aerobic rice. Several weeds, such as *E. colona*, mature together with rice and frequently mix in during the harvesting and threshing process (Dubey 2004). In addition to bringing in new species, the contaminated weed seeds will also develop herbicide resistance (Pratley 1995). According to reports, contaminated seeds

may have brought *L. chinensis*, a significant rice weed, to northern Italy (Benvenuti 2004). Since a larger seeding rate is required per unit of area under aerobic DSR, preventing weed seed contamination becomes more crucial in this situation than it does in TPR.

Prevention of Weed Seed Dispersal

In order to prevent more infestation, preventive weed-management techniques focus more on reducing weed seed banks and preventing new weeds from entering agricultural fields. Large weed seed banks develop in crop fields as a result of poor agronomic practices that allow new weed seeds to enter the field. Preventive techniques, which limit weed distribution and minimize weed seed bank buildup, are an excellent addition to curative strategies like the use of pesticides. The main rice weed species spread via natural ways (human, animal, mechanical, etc.). Compared to control measures, the zero weed seed rain strategy is more practical and affordable.(Gallandt, 2006).Crop-weed competition is more severe due to prolific seed production, dormancy in weed seeds, and varied maturation times. For example, *Caesulia axillaris* Roxb., a common rice weed, can continue to produce mature seeds even after the crop has been removed. The current seed banks of weeds run out as a result of preventive measures such induced predation, lethal germination, and decay from tillage and submersion. (Rao, 2017) Weeds have numerous devices from nature that aid in their widespread dispersal. Animals, including humans, as well as the elements of wind and water help weed seeds spread far.The proverb "one year of seeding is seven years of weeding" encompasses the problems of weeds cause for crops, soil, and water. It would be advisable to go by the adage "prevention is better than cure" in order preventing such an occurrence. The use of manure and irrigation water free of weed seeds, the enforcing of weed control legislation, and seed certification procedures are examples of preventive strategies. Crop seeds should also not be sown with weed seeds incorporated(Walia, 2010)

Eradication

A weed species' total eradication eliminates both the expensive ongoing control of the weed and its negative impacts, making it a desirable choice. Eradication is the final and total elimination of all wild populations through a time-limited campaign from a designated area. An eradication campaign must be "time-limited," meaning that it must be completed by a specific date; else, it essentially amounts to continued control. The most effective method of preventing establishment of newly imported weeds is early discovery and elimination. Programs for early detection should identify weeds, map areas, and identify high-priority locations. Certain places need to be given top importance since they can be more susceptible to disruption or weed invasion. These locations needs to be noted on maps with clarity, and whenever feasible, an inventory should be taken of each. It is recommended that you map and identify every weed you have during the blossoming period. At this point, they stand out the most. Options for control can change based on the type of weed and its location.This makes it possible to identify the weeds you have and where they are located, giving you an advantage on them in the spring. Marker flags with colors work well as visual aids. Collaborate with neighboring landowners and other organizations to plan early detection initiatives in high-priority regions. Go meet your neighbors if you also have weed infestations, and work to find a solution together.

Mechanical control

Mechanical management techniques physically impede the growth of weeds. Mechanical weed management techniques include hand pulling, burning, and mowing. These are effective methods of control, dependent on the kind of weed and extent of the infestation. To prevent further multiplication, as well it is strongly advised to mow and pull by hand at the flowering

stage, prior planting to prevent further propagation.

Biological control

Biological control techniques aim to prevent weed development by utilizing living organisms. The organism is frequently a plant pathogen or insect that is the weed's natural competitor. Biological control works best when used in combination with other management strategies, never as a stand-alone remedy. Not all noxious weeds can be controlled with biological agents since they are host specific. Depending on the kind of weed, grazing may be beneficial. Sheep and goats are capable of controlling and eating a wide range of exotic species that are hard to eradicate.

Chemical weed management

Chemical weed control methods include the use of herbicides. Herbicides could be used to manage weeds in a timely manner, prevent weed growth from starting, or monitor weed growth during the key period and crop growing season. (J. Ogborn, 1969) Because of the severity of the weed problem, labor shortages for weeding, and high costs associated with weeding, chemical weed control has become increasingly important in aerobic rice farming. Herbicide may be seen as a potential substitute or addition to manual weeding, according to the findings of numerous researchers who have worked and are still working on weed management in aerobic rice. Pre-emergence, post-emergence, and combination herbicide applications "Penoxsulam @15 g a.i. ha¹, Bensulfuron methyl @ 60 g + pretilachlor at 600 g a.i ha¹, Pendimethalin (30EC)@1.00 kg/ha fb Bispyribac sodium (10% SC) @35 g/ha, Pendimethalin 1.0 kg/ha fb Almix 4.0 g/ha, and Bispyribac sodium + metamifop 14% SE at 70 g ha¹ +wetter" have all been applied before and after emergence, respectively, with minimal yield reduction (Jabran 2012).

Cultural practices

In order to effectively manage weeds in aerobic rice, cultural methods such as competitive cultivars, tillage, seed rate, seeding technique, spacing and priming of seeds, water management, fertilizer management, crop rotation, intercropping, and mulching are also essential.

Stale Seedbed

Stale seedbed (SSB) is a cultural weed management technique that is often combined with tillage; however, in ZT-DDSR, the emergent weed seedlings are killed by applying a nonselective post-emergence herbicide, such as glyphosate (Riemens 2007) or paraquat (Renu 2007). Under DDSR, most weed seeds stay on or near the soil surface, which increases the percentage of weed seeds that germinate when irrigation is applied (Chauhan 2010). SSB can reduce weedy rice by up to 53%, making it an extremely efficient weed management strategy against weedy rice (Delouche 2010). (Singh 2007). Following rice harvest, there was a notable decrease of 25–30% in the viable seed bank of *E. colona* and *Dactyloctenium aegyptium* L. (Willd), and an overall reduction of 13–33% in the seed bank as entirety.

Tillage

Stale seedbed (SSB) is a cultural approach of controlling weeds. Changes in the mechanical properties (bulk density, penetration resistance, aggregate mean weight diameter, and surface roughness) of the seedbed and the vertical seed dispersion in the soil brought about by tillage affect the appearance of weeds (Carman, 1996) (Chauhan, 2009). Primary tillage lowers the

populations of annual weeds by deeply planting weed seeds, and it also lowers the populations of perennial weeds such as *Cyperus rotundus* and *Cynodon dactylon* by exposing their vegetative propagation materials (Buhler 1996). Secondary tillage is necessary for aerobic rice in order to prepare the seed bed finely, improve rice seed germination, and lessen weed infestation (Shahidhar 2010).and also it improved root growth into deeper levels, which in turn improved nutrient and water intake and improved grain production (Sunil 2014).

Mulching

The use of mulches, such as Polythene sheet mulch, sugarcane waste, maize stover rice straw, and biological mulch, greatly decreased the density and dry weight of weeds. However, in aerobic rice grown in sub-tropical soil and climate, mulching with black polythene cover demonstrated good potential for exhaustive weed control.

The type of weed and level of residue used determine how much weed suppression results from residue application. Crop residues have no effect on the emergence and growth of weed species like "*Trianthema portulacastrum* L., *Amaranthus viridis* L., and *Ipomoea tribola* L., but weed species like *Echinochloa crus-galli*, *Echinochloa colona*, *D. aegyptium*, *I. rugosum*, *Eleusine indica*, *Euphorbia prostrata* Aiton, and *Murdannia nudiflora* L". Brener may require 4-6 t ha⁻¹ of residues carry for significant weed suppression. The relative position and shape of weed seeds and residues, the extent of residue, the crop from which it is derived, and environmental conditions all affect how successful and effective agricultural residue utilization is for controlling weeds.

Intercropping

In both industrialized and developing nations, intercropping is a widespread practice. Because intercropping inhibits weeds more effectively than solo cropping, it offers the chance to use crops as biological weed management methods. Because of their wider leaves and early, fast growth, which prevented light from reaching the ground, smother crops like amaranthus and Indian till were shown to be far more successful at reducing weed growth without affecting the production of aerobic rice (Venkatesha 2014). It was discovered that intercropping sesbania with aerobic rice for 40 days effectively controlled weeds (Mohitsham 2013).

Brown manuring

Compared to break crops (Roper et al., 2012), the use of green and brown manure crops to disrupt pest cycles and enhance nutrition is less well-documented and has not received thorough trendy evaluations. The method known as "brown manuring" involves growing extra crop in standing field crops and using herbicide to kill them so that the residue can be used as manure. Brown manuring is the term for the residue that results from killing excess crop, as it turns brown. A "no-till" variation of green manuring, brown manuring involves applying a non-selective herbicide to dry toward the crop (as well as any weeds) during the flowering period rather than tilling the soil to get rid of the vegetation (Preston, 2019).When plant remains are left in place, soil organic matter increases and surface cover and soil structure are preserved.A crop or pasture is mowed, sliced, or cut with a knife roller and left on the soil's surface in mulching, also known as brown manuring. This technique lowers soil evaporation. Because mulched leftovers have more interaction with soil and fragments, they decompose more quickly than regular brown manuring (Edwards, 2020).

Brown manuring in Rice

Brown manuring is similar to green manuring, with the exception that rice and *Sesbania* spp. are cultivated together. After about 25 days of co-culture, when the height of the dhaincha plants reaches that of the rice plants, a weedicide called 2, 4-D is used to kill the *Sesbania* plants.

Allelopathy in rice fields

Root exudation affects the microbial population, the growth of other competitive plant species in the soil, and the chemical and physical characteristics of the soil, all of which are significant in the field of agriculture. There are very few data on the physiological system that plants use to exude various chemicals from their root cells. On the other hand, other scientists proposed that plants use proton-pumping processes and plasmalemma or endoplasmic derived exudation to release a wide variety of chemicals (Bais et al., 2004).

The origin and type of rice can control allelopathic behavior; for instance, hybrids of indica and japonica rice are less allelopathic than japonica rice (Khanh et al., 2007). Different allelochemicals that rice produces and secretes into the surrounding environment have a range of biological consequences. Thus, in order to make better use of rice's allelopathic properties and enhance both cultivation and harvest, it would be imperative to understand the various interactions that persist in rice fields.

Residual allelopathy

After harvest, farmers typically leave the rice residue in the soil because they think it will increase the soil's organic matter and nitrogen content, which will help the next crop thrive. However, because rice straw decomposition is known to release phytotoxic compounds, this technique has suppressed a number of succeeding harvests (Inderjit and Dakshini, 1999). It has been discovered that when rice is continuously monocropped, the yield in the second year is much less than in the first. This may be the result of an autotoxic process brought on by rice straw breakdown that is left in the soil after harvest (Chou, 1995). Due to the waterlogged conditions and the presence of decomposing rice residue, which produces a negative redox potential in the soil, the soil in paddy fields is oxygen-deficient. Rice plants have developed a survival mechanism to capture necessary oxygen by enlarging their root cells, despite the negative rice-rice residue interaction impeding rice root growth (Chou, 1995).

Competitive Varieties

Crop tolerance and suppression of weeds is known as weed competitiveness. In an agricultural field, weed infestation is related to the crop plants' root and shoot growth patterns. One can increase weed-suppressive abilities or induce tolerance in cultivars to increase weed competitiveness. For weed competitiveness, any rice cultivar that has substantial early growth, quick soil cover, or greater specific leaf area is still preferred. Weeds provide competition for crop growth from both roots and shoots, although rice growth is more inhibited by root rivalry than by shoot competition; in fact, root competition can account for as much as 55% of the yield reduction in rice.

Seed Priming

By shortening the germination period and enhancing overall crop performance in the DDSR, seed priming combined with accurate planting technology increases the rate and synchronicity of seed germination (Mahajan 2011). According to Jurumi (2012), seed priming produces a 50% increase in seed vigor, a greater seedling dry weight of 35–60%, and resilience to a variety of abiotic stressors. It has been observed that spermidine, hydro-priming (Goswami 2013), solid matrix priming (Zheng 2016), osmo-hardening with KCl, pre-treating

polyethylene and polyamines (Rehman 2012), and nutri-priming with phosphorus and boron are all highly advantageous. The process of seed priming, which involves soaking seeds in Zappa® solution for 24 hours and then letting them air dry for 12 hours, has enhanced rice's efficiency to suppress weeds by 22–27%.

Water management

It is commonly known that managing water is crucial for controlling weeds in aerobic rice (Rao 2007). Drought stress has no effect on rice emergence or seedling growth; therefore, preserving a dry soil surface for as long as feasible will significantly inhibit weed emergence and give rice a "head start" over weeds. Water management has a significant impact on the emergence, population, growth, maturation period, and seed production of weeds. Micro-irrigation, particularly surface or subsurface drip irrigation systems, can significantly lessen the weed threat in DDSR after early establishment. It has been stated that drip-irrigated DDSR results in greater grain yields and up to 42% water savings.

Fertilizer management

Plants that receive an appropriate amount of nutrients according to their needs are better able to fend off weeds. Effective management of fertilizer is essential for boosting crop vigor, enabling it to tolerate weed competition, and perhaps aiding in long-term weed control (Blackshaw 2004). The goal of managing fertilizer should be to prevent weeds from absorbing nutrients and vice versa. Subsurface band distribution of N rather than broadcast N resulted in reduced uptake of N and attainment of weed biomass (Blackshaw 2005).

The findings indicate that N has an impact on the emergence, germination, and competitiveness of several weeds. According to a study, the total biomass of weeds increased as the rate of N application increased (Guza 2008). Application rates should be determined by the needs of the crop and the environment; otherwise, a significant weed infestation may result. Major, 2005. Furthermore, scheduling fertilizer applications differently may result in weeds absorbing less nutrients since weeds may find an unfavorable environment regardless of when crop stands are established. Ahmad (1981).

Why we have to adopt aerobic rice cultivation

It is becoming more and more necessary to modify the aerobic rice system in order to solve the issues of sustainable agriculture and global food security. The misuse of natural resources, industrialization and urbanization, population growth at a rapid pace, and a lack of innovative adaptation strategies to climatic stresses are among the main human-caused factors contributing to natural disasters in developing nations (Carter et al., 2015; Padli et al., 2018). It is imperative to boost food production while lowering agriculture's environmental effect because it is predicted that there will be 9.7 billion people on the entire globe by 2050 (Kumar et al., 2022). The conventional method of growing rice uses a lot of water, and its flooded paddy fields greatly increase greenhouse gas emissions. The aerobic rice system, on the other hand, may reduce methane emissions by up to 70% and water use by up to 30% (Liu et al., 2021). Benefits of this rice production technique using saturated soil culture on permanent beds have been noted, including reduced soil compaction, energy savings, improved timeliness of field activities, and economies of water, nitrogen, and phosphorus (Borrell and Garside, 2005).

Conclusion

Rice grown aerobically is a more advanced method that uses less water. When cultivating rice aerobically, the crop is directly sown in non-puddle aerobic soil, supplemented with fertilizer and irrigation, and high-yielding rice types that are suitable. When combined with the right agronomic practices, aerobic rice may produce yields that are comparable to TPR and can be

an attractive alternative to TPR in situations when labour and water are scarce. It has been observed that unmanaged weeds in the field can reduce aerobic rice production by up to 75%. In order for rice to thrive, weed management techniques that suppress all weed species must be adopted. Furthermore, aerobic rice farming can increase crop yields by as much as 30%, which is a convincing reason to grow aerobic rice for small-scale farmers.

Future aspects

According to Nature scientific reports, Ground water storage levels have been declining by 2.6 centimetres per year in the Ganga basin, according to new estimates. Then we need to adopt this technology to save water along with more production for the vast population in India from hunger. And need to improve crop ideotypes that sustain in all climatic conditions with short duration, less biomass, and high yield production.

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