

Innovations in weed management in rice

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Rice is cultivated over an extensively divergent environment, such as irrigated uplands, rainfed lowlands, and rainfed upland ecosystems. The challenges and constraints in rice cultivation vary from environment to environment. With direct seeding, rice seed is sown and sprouted directly into the field, eliminating the laborious process of planting seedlings by hand and greatly reducing the crop's water requirements. Weeds are the major pests that affect the rice yields to the greatest extent. In a survey of upland rice-producing countries covering 80% of the total production area, weeds were the most widely reported biological constraint to yield. 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.

Key words: Herbicide, Integrated weed management, Rice, Weeds

Rice (*Oryza sativa*) is the principal food for more than 50% people and contributes about one-fifth to the total calories consumption of the world. The statistics showed that during the crop year, 2016-17 India produced 110.15 million metric tonne of milled rice from 43.19 million ha area, making the country the world's second largest producer of rice. To meet the food and nutritional requirements, India alone would need about 156 metric tonne of rice by 2030 at an annual increment of 3 metric tonne in the current rice production. Rice is cultivated over an extensively divergent environment, such as irrigated uplands, rainfed lowlands, and rainfed upland ecosystems. The challenges and constraints in rice cultivation vary from environment to environment. Weeds are the major pests that affect the rice yields to the greatest extent. In a survey of upland rice-producing countries covering 80% of the total production area, weeds were the most widely reported biological constraint to yield. The average yield losses in rice due to weed competition are estimated to

vary between 40 and 60% which may go up from 94 to 96% with uncontrolled weed growth. The studies revealed that unchecked weed growth reduced crop yield up to 57% in puddle transplanted rice and 82% in direct-seeded rice.

Direct seeded rice has received much attention because of its low-input demand. It involves sowing pre-germinated seed into a puddled soil surface (wet seeding), standing water (water seeding) or dry seeding into a prepared seedbed (dry seeding). Burgeoning rice cultivation expenses, primarily for human-labour and irrigation water and increasing paucity water needed for rice cultivation, particularly in South and South-east Asia, have led to a shift from transplanting to direct seeded rice. The elimination of practice of maintaining about a 5 cm depth of standing water that would otherwise keep a check on weed growth, and the emergence of weed seedlings earlier or together with crop seedlings under direct seeded rice cultivation method has seriously mounted the risk of severe crop-weed competition ultimately culminating

into heavy losses in yield.

Technologies used to manage weeds in different rice systems

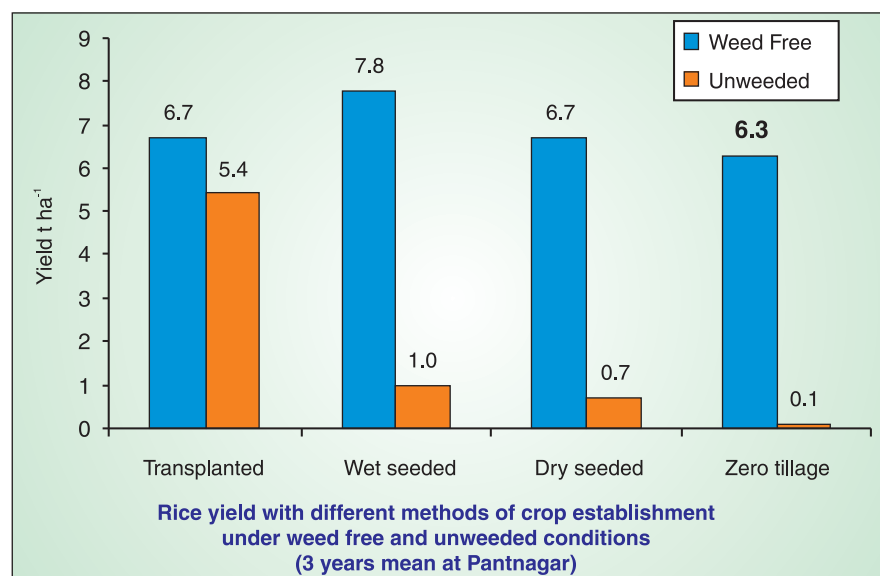
Effective weed management is serious challenge for weed management in different ecosystem of rice. The cultivation practices associated with rice crop establishment methods affects weed flora emerging in the rice crop. The effective period of competition occurred in two phases: between 15 and 30 days, and 45 and 60 days after seeding. The competition in direct-seeded rice beyond 15 days after seeding may cause a significant reduction in grain yield. However, competition for the first 15 days only may not have much adverse effect on the grain yield. The effect of soil moisture and water depth in rice on weed emergence and suppression was long back recognized. Weed density with standing water in the early stages may be reduced but, once the weeds are established, their stand is not affected. The response of weed species to soil moisture levels and depth of standing water is variable crop. At Pantnagar, studies

comparing crop establishment and weed management options over a four year period showed that changing from transplanting to direct seeding resulted in marked changes in weed populations in the rice-wheat system. In general, with direct seeding, three annual grasses, *Echinochloa crus-galli*, *E. colona*, and *Leptochloa chinensis*, the perennial sedge *Cyperus rotundus*, and certain broad leaf weeds such as *Commelina diffusa* and *Caesulia axillaris* increased. Species responded differently, however, to the various options. The *C. rotundus* decreased with wet seeding, whereas, in contrast, *C. axillaris* decreased with dry seeding.

Cultural innovations

Crop establishment: Spatially uniform establishment of healthy and vigorous rice seedlings increased crop competitive ability and suppresses weed growth. Well leveled, preferably laser leveled seed bed with fine soil tilth, placement of seeds/seedlings at required depth (2-3 m), good seed soil contact and optimum moisture availability are all important for good crop establishment.

Direct drilling: Good germination and establishment of rice seedlings are pre-requisite for the success of direct seeded rice that offered a good opportunity to conserve irrigation water by avoiding water used in puddling. For field preparation in direct seeded rice, pre-sowing irrigation should be done in the first half of June followed by field preparation with cultivator/disc harrow. Fine seed bed should be prepared for sowing with drill or seeds may be broadcast during first half of June. For weed management, pendimethalin may be applied at 1.00 kg ai/ha as pre-emergence spray using 500-600 litre water. Pendimethalin spray should be done as early as possible just after sowing (within two days, better results were obtained at the application on same day) when soil moisture is adequate. To control broad leaf weeds and annual sedges apply 2, 4-D at 0.4 kg ai/ ha or Almix at 20 g product/ ha at 30 days after sowing. One-or two-hand weeding or spot-weeding may be done as per



need. If the infestations of grassy weeds like *Echinochloa* or *Leptochloa* are more apply cyhalofop butyl 10% EC @ 75-80 a.i/ha at 15-20 days after sowing to control annual grasses.

Wet seeding: Wet seeding is a successful crop establishment and water management require level field, hence fields must be properly leveled. Laser leveling makes perfect field. Fields must be harrowed and sowing can be done by drum seeder in well puddled field in first fortnight of June. If drum seeder is not available, seeds can be broad-cast over the puddled beds. At the sowing time, there should not be standing water on the puddled bed or else the seeds float and move. The field should remain wet till seedlings are well establishment but it should not be flooded till rice seedlings have grown sufficiently to anchor themselves to

the soil. Subsequently irrigation may be applied as per need and avoid cracking of the soil.

For weed management, herbicide application must be required when rice seedlings are 2-3 leaf stage, spray anilofos at 0.4 kg ai/ ha in 500-600 litre water. One or two hand weeding or spot-weeding may be done as per need. Timely weeding is crucial.

Sesbania brown manuring: In brown manuring practice, rice and *Sesbania* crops are planted together and allowed to grow for 25 to 30 days, before knocking down *Sesbania* crop with 2,4-D (Na/amine/ ester) at 0.4 to 0.5 kg/ha. *Sesbania* surface mulch conserves the soil moisture and supplies 10 to 15 kg N/ha on decomposition. Residues, when retained on surface, reduce the emergence of weeds, add organic matter and improve nutrient water



interaction. Considering discussed above, *Sesbania* co-culture was used at University, Pantnagar between 2005 and 2006 in direct seeded rice. Significant reduction in the weed density was observed with pre-emergence application of pendimethalin at 1.0 kg/ha along with 2, 4-D (0.5 kg/ha) and hand weeding at 30 day after seeding. It recorded 81% lower weed density compared to no spray of pendimethalin. Average data of two years revealed that weed dry weight was reduced when *Sesbania* was used as brown manure. Broadcasting of *Sesbania* seeds with direct seeded rice proved better compared to intercropping both in reducing weed dry weight as well as enhancing grain yield. Hand weeding at 30 days after seeded increased the grain yield during both the years. direct seeded rice + *Sesbania* (row) + pendimethalin + 2, 4-D (0.3 kg) 25 day after seeded + HW recorded the highest yield (6.0 tonne/ha) mainly due to better control of weeds. Application of 2, 4-D at 0.5 kg/ha at 25 day after seeded had some setback on the crop. *Sesbania* co-culture technology reduced the weed population by nearly half without any adverse effect on rice yield.

Stale seed bed technique: Stale seed bed (SSB) technique is another important cultural management strategy that can be used before any crop to reduce the weed seed bank in particular from upper soil layer. In stale seed bed, weeds are allowed to germinate by giving a irrigation or after a rainfall and after that emerged weed seedlings are killed using a non-selective herbicide like glyphosate or paraquat or shallow tillage or flooding. This technique not only reduced weed emergence but also reduced the number of weed seeds in the soil seed bank. The stale seedbed technique in combination with mechanical control of emerging weeds can reduce the weed population during crop growth as effectively as chemical control. Stale seed bed reduced weed density from 43% to 53% in Dry-direct seeded rice a stale seed bed than without this

practice. Adopting stale seedbed technique either for 7 or 14 days significantly reduced the population of grassy weeds. It gave successful control of broadleaf weeds too. Stale seedbed preparation significantly improved grain and straw yields of wet seeded rice compared to normal seedbed. An increase in stale seedbed period contributed to corresponding increase in yields as evident by higher grain and straw yields in plots with stale seed bed for 14 days.

Surface mulch and cover crops

Surface retention of crop residues provides a physical barrier to emerging weeds, thereby delaying weed emergence. It also moderates the soil temperature, conserve soil moisture, add organic matter and improve nutrient- water interactions. For precise seeding rice should be drilled with a multi-crop planter fitted with inclined plates seed metering systems and inverted T-type tynes. For zero tillage rice, when only anchored residues are retained, then same multi- crop planter can be used for seeding. However, when loose crop residues are present on the soil surface, specialized machines are needed for drilling the rice as turbo happy seeder, rotary disc drill and double disc coulters. The cover crops like *Sesbania rostrata*, *Phaseolus radiatus* and *Vigna unguiculata* can also suppress weed growth, irrigation to these cover crops stimulate weed seed germination which can be killed during the field bed preparation of the main crop. Study at Pantnagar showed that mulching with 5 tonne/ha straw of wheat followed by application of penoxsulum at 22.5 g/ha at 20 day after seeded followed by one hand weeding at 45 day after seeded in direct seeded rice crop recorded about 80% weed control efficiency at 60 days stage of crop.

Mechanical innovations

Rising labour scarcity, pessimistic impact of unsystematic herbicide use, weed management approach needs to be diverted towards mechanical way for satisfactory economic benefits. In mechanical method of weed control, implements are used to destroy weeds or make environment less favourable



for weed seed germination and weed survival. It is most commonly practised on row-seeded rice since, inter row cultivation with either hand tools/animal traction equipment reduces time in weeding and minimizes crop damage. Mechanical weeding using hand pushed weeders is feasible only where rice is planted in rows; however, weeds emerging within rows are difficult to remove with these weeders.

Cono-weeder can reduce man-days required for weeding from 30 to 10, thus saves labour and time. The cost of weeding for labours could be reduced by 7.6 times by using cono-weeder than hand weeding. Mechanical weeding (20 days after seeded) followed by hand weeding showed lower weed population and dry matter production of weeds in direct-seeded rice. Weeding by machine involves the use of hand-pushed or power operated weeders, which is feasible only where rice is planted in straight rows. However, hand weeders such as conventional push-pull rotary weeder and cono-weeder are not effective if land is too dry or in standing water. The pushed weeders are most commonly used in many tropical Asian countries. To achieve the best result in transplanted rice, the weeder should be run in both the directions at right angles to each other. Mechanical weeding needs to be supplements by hand pulling the weeds that are close to the rice plant.

Mechanical weeding is effective but expensive, time consuming and cumbersome and the efficiency varies depending on the row space. While the weeds growing in the inter-row area get effectively controlled. But the intra-row weeds remain unaffected because of the inaccessibility of the weeders in the narrow intra-row area.

Chemical method

Herbicides are important tool of weed management in the lowlands and in upland rice grown. Herbicides-based weed management is economical, more effective and requires less time for weeding and to adopt time and labor saving planting methods such as direct (broadcast) seeding. Herbicide options with their rate of application are discussed in Table 1.

Integrated weed management

The herbicides in combination resulted significantly better than the sole application due to their broad spectrum and long lasting weed control. Combination of two or more weeding methods must be evaluated for widening the weed control spectrum and efficacy to achieve effective and economical weed management in direct-seeded rice. The sequential application of pre-emergence herbicides such as pendimethalin in dry-seeded rice or early post-emergence application of anilofos/thiobencarb for the control of annual grasses in wet-seeded rice and post-emergence application of 2, 4-D against sedges and non-grassy weeds in wet- and dry-seeded rice may be a better option than the use of one herbicide.

The post-emergence herbicides can be substituted with manual weeding, which may have an added advantage of controlling escapes and reducing herbicide load. This will also help in managing herbicide-resistant biotypes. Pendimethalin at 1.0 kg/ha followed by 2, 4-D 1.0 kg/ha or 0.50 kg/ha at 25 day after seeded hand weeding 45 day after seeded found to be the best way for obtaining maximum reduction in weed density and weed dry matter accumulation and the maximum weed control efficiency and higher yield in direct seeded rice. Stale seed bed *fb* pendimethalin 1.0 kg /ha *fb* bispyribac at 25 g/ha at 20 days of seeding was also found best alternative for manual hand weeding practices. At Pantnagar, good success with dry-seeded rice production technology in large-scale farmer participatory trials in the *Tarai* of Uttarakhand, was observed when the

Table 1. Different crops treated with herbicides

Rice nursery
• Apply Pretilachlor 50 EC @ 0.75-1.0 kg a.i/ha within 3 days after sowing • Apply Thiobencarb @ 1.0 kg a.i/ha or Anilofos 30 % EC @ 0.4 kg a.i/ha within 6 days after sowing. • Apply Bispyribac sodium 10% SC @ 0.02 kg a.i/ha at 10-15 days after sowing. • Summer ploughing of main field to destroy weeds and expose soil and wet bed method for raising rice nursery.
Transplanted rice
• Apply Butachlor 50 % EC @ 1.5 kg a.i/ha or Pretilachlor 50 % EC @ 0.5-0.75 kg a.i/ha or Oxadiargyl 80%WP @ 0.1 kg a.i/ha Bensulfuron Methyl 0.6%+ Pretilachlor 6% @ 0.66 kg a.i/ha within 3 days after transplanting. • Apply Anilofos 30 % EC @ 0.4 kg a.i/ha or Penoxsulam 24% SC @c 0.020-0.022 kg a.i/ha within 8 days after transplanting. • Apply Pyrazosulfuron Ethyl 10 % WP @ 0.010-0.015 kg a.i/ha within 4-5 days after transplanting. • Apply 2,4-D Ethyl Ester 38 % EC @ 0.85 kg a.i/ha or Chlorimuron+ Metsulfuron methyl 20%WG @ 0.004 kg a.i/ha within 20-25 days after transplanting to control broad leaf weeds • Apply Fenoxaprop-p-ethyl 9.3 % EC @ 56.5 g a.i/ha within 25-30 days after transplanting or Cyhalofop butyl 10 % EC @ 75-80 g a.i/ha at 10-15 days after transplanting to control annual grasses. • Apply Azimsulfuron 50 % DF @ 0.035 kg a.i/ha or Bispyribac sodium 10%SC @ 0.02 kg a.i/ha within 15-20 days after transplanting to control grasses and non grassy weeds. • Apply Ethoxysulfuron 15 WDG @ 15 g a.i/ha at 10-15 days after transplanting to control broad leaf weeds and sedges.
Direct Seeded Rice
• Apply Pendimethalin 30 % EC @ 1.0-1.5 kg a.i/ha or Oxyflourfen 23.5 EC @ 0.150 to 0.240 kg a.i/ha within 3 days after sowing. • Apply Chlorimuron+ Metsulfuron methyl 20%WG @ 0.004 kg a.i/ha or Bispyribac sodium 10%SC @ 0.02 kg a.i /ha at 15-20 days after sowing to control annual broad leaf weeds and grasses. • Apply Cyhalofop butyl 10% EC @ 75-80 a.i/ha at 15-20 days after sowing to control annual grasses. • Apply Fenoxaprop-p-ethyl 10% EC @ 60.0 g a.i/ha at 25-30 days after sowing to control annual grasses. • Apply Azimsulfuron 50% WG @ 0.035 kg a.i/ha at 15-20 days after sowing to control annual grasses and sedges. • Pendimethalin 1.0 kg /ha within 0-3 days after seeding <i>fb</i> metsulfuron methyl 4.0 g/ha at 25-30 days after seeding and one hand weeding (40-45 days after seeding) if needed in Direct Seeded Rice.

stale-seed bed technique was combined with the application of pre-emergence herbicide, pendimethalin within 2 days after seeding direct seeded rice.

SUMMARY

Conventional herbicidal weed management strategy has occupied an important place both in direct seeded rice and transplanted rice, this approach has also brought many challenges and production vulnerabilities in crop production systems in general and rice ecologies in particular. These challenges included high crop production costs due to escalating herbicide prices, rising environmental pollution, deterioration in food quality and

soil- health due to herbicidal residues, and emerging risk of herbicide resistance in weeds. Thus, under aforesaid circumstances, there is a dire need to evolve and adopt potential alternative ecological approaches like enhanced competitiveness of rice through use of weed-competitive cultivars, increased seed rates, narrowed row spacing and allelopathy, all of which are greatly important, viable, and sustainable strategies to suppress the weeds at large.

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