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Weed Management Strategies in Direct Seeded Rice: A Review

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ABSTRACT: Integrated Weed Management (IWM) means integrating multiple weed control tactics into a single weed management program, optimizing control of a particular weed problem. The past several decades have seen simplified weed control practices that rely heavily on a few popular herbicides. However, the rapid spread of herbicide-resistant weeds has required farmers to incorporate alternative weed management approaches. While many farmers are incorporating different herbicides, this is likely to have only short-term success. Using non-herbicide approaches in combination with multiple, effective sites of action is needed for long-term success. Direct seeded rice (DSR)[1] is a practice of sowing paddy which involves planting rice seeds directly into the field, instead of the traditional method of growing seedlings in nurseries and then transplanting them into the fields. This method significantly reduces the demand for labor, one of the major costs associated with rice farming. By eliminating the need for transplanting, farmers can cut down on labor costs and effectively manage the workforce during peak periods. It also provides flexibility in timing the planting, helping farmers to adapt to changing climate conditions. Moreover, DSR offers water efficiency. Traditional rice farming involves flooding fields, which is water-intensive and often unsustainable. Direct seeding of rice, on the other hand, requires less water during the establishment period, making it an attractive solution in regions experiencing water scarcity. Reduced water usage in DSR systems can help lower methane emissions, a potent greenhouse gas significantly produced in flooded rice paddies.

KEYWORDS-integrated weed management, direct seeded rice, paddy, water, tradition

I. INTRODUCTION

Rice cultivation always remains significant for food and livelihood security. The predictions of increasing water deficiency under a changing climate and escalating labor shortages in agriculture have brought a paradigm swing in rice cultivation from conventionally flooded transplanting to direct-seeded rice (DSR). DSR cultivation can potentially address the concerns of diminishing natural resources and mounting production costs in the establishment of transplanted rice. The transition towards DSR saves water, reduces duration to maturity as well as labor required, and reduces negative environmental footprints. Despite all these recompenses, the potential yield losses through enormous weed menaces under DSR remains a challenge and may reduce yield by up to 50%. In this review, we examine the extent of weed infestation, weed shift and the losses in dry DSR (DDSR). Various regional and global scientific efforts made under DDSR have been assessed in the present and the smart weed-management strategies suggested can be adopted after scrutiny. Integration of different weed management approaches, namely prevention, cultural, mechanical, and chemical, have been discussed, which can pave the way for worldwide adoption of DDSR, especially in South Asia. In Asia, 22% of the acreage of total rice cultivation is under DSR and the region-specific integration of these weed-management approaches might reduce herbicide use in these areas by up to 50%.[1,2,3]

One of the most significant hurdles is weed control. In flooded paddies, water serves as a natural barrier to weed growth. However, in DSR systems, weeds can grow alongside rice, reducing yield. Thus, effective weed management strategies are critical for the successful application of DSR.

Another concern is the need for precision in seed placement. Unlike transplanting, where seedlings are carefully placed in fields, direct seeding requires accurate equipment to ensure optimal plant density and uniform growth. Technological advancements, such as laser-assisted land leveling and drill seeders, are paving the way for overcoming these challenges, making DSR an increasingly feasible option for farmers.

Globally, out of the total 161 M ha under paddy cultivation, DSR is being practiced on about 33 M ha area [23]. DDSR could be practiced in rain-fed upland, lowland, and also flood-prone areas [24]. Different methods of sowing under

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DDSR include broadcasting of dry seeds directly, either after field preparation (conventional tillage, CT) or zero tillage (ZT), and mixed thereafter with a harrow; dibbling of sprouted seeds after seedbed preparation, especially in hilly terrain or line sowing at the rate of 70–80 kg ha^{-1} through a seed-cum-fertilizer seed drill after ZT, CT, reduced tillage or on raised beds [25]. DDSR in most Asian countries is kept aerobic through alternate wetting and drying under rain-fed upland ecosystems in place of continuous submergence or saturation. Under double DSR, cycling dry and wet tillage is also practiced in Asia [26]; however, exclusive DDSR is practiced in the United States, Latin America, Australia, West Africa and Europe [27].

The aerobic soil environment in DDSR saves water, but with the absence of stagnating water and the lack of a 'head start' in rice seedlings over germinating weed seedlings; the weed menace in DSR is aggravated. The critical period of weed competition in DDSR remains up to 41 days after sowing (DAS), yet a weed-free situation until 70 DAS remains desirable for higher productivity [28]. Weeds, when not controlled during this period, may reduce yields from 15–100% [29]. The intense competition for water, nutrients and solar radiation posed by weeds reduces yield and grain quality. Poor weed control is the second major yield barrier after an inadequate water supply in DDSR worldwide, the range of maximum and minimum yield losses, however, differ under varying ecologies as illustrated in Figure 1. The yield losses remain higher under DDSR over TPR. An approximate 35% yield loss has been reported in TPR [30], however, under DDSR it may reach as high as 100% [14]. Out of the total 40% yield loss in rice caused by various pests, weeds create nearly 10% of the yield loss, which under DSR may go up to 32%. Thus, weed management shares a very high relative importance, ranking among different agronomic management options for higher productivity in DDSR [31].

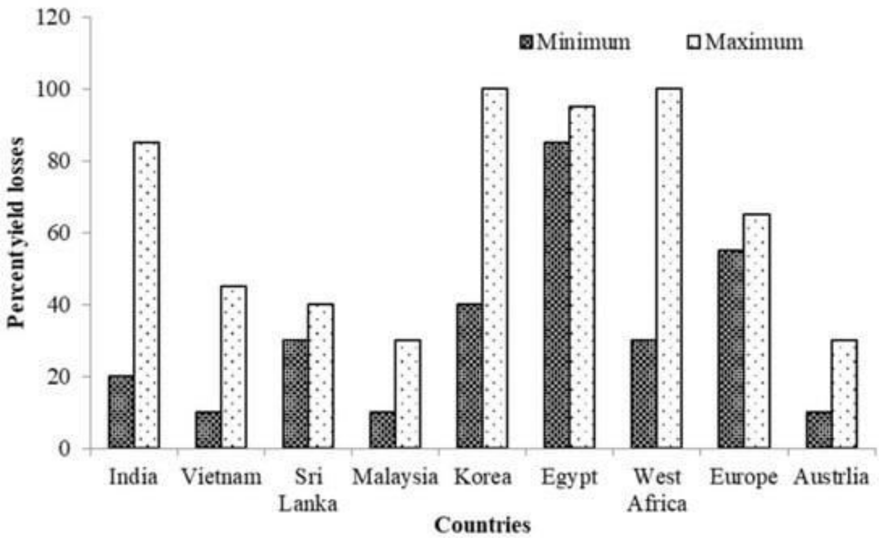

Figure 1. The extent of yield losses due to weeds in major dry direct-seeded rice (DDSR) growing ecologies of the world

II. DISCUSSION

Rice is an integral part of life as it is the staple food for over half of the world's population. And to meet the global rice demand, about 114 million tons of additional milled rice needs to be produced by 2035. The need of the hour is to solve the world's food problem through innovations in agriculture backed by technology, while putting our people first – farmers, consumers and the future generations.

Currently, rice is grown in more than 158 million ha in over 110 countries. Asia being the biggest consumer, the consumption per capita varies from 186 kg per year in Myanmar to a low of 4 kg per year in USA. Asia has more than 200 million rice farms, most of which are smaller than 1 hectare. In India, we grow rice on 43.2 million ha, with an annual production of about 110 million tons of paddy. (Source: www.ricepedia.org)

Rice is cultivated under diverse growing environments in India. It is primarily grown as a tropical and subtropical crop and can be cultivated at an altitude from sea level to about 3,000 meters. Depending on geography, soil type, rainfall distribution, irrigation facility, and labor availability, the crop is established either by direct sowing (broadcast or drilled) or by transplanting.

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| Volume 11, Issue 3, March 2024 |

Rice also grows under diverse water regimes. It is an upland crop, where there is no standing water and mostly rains are the sole source of moisture, hence irrigation availability is very limited. It is also a lowland crop, in which water, derived either from rain or irrigation systems, remains standing in the fields. Shortage of water, soil health and climate change are challenges that are threatening the productivity and sustainability of rice-based systems. The emerging energy crisis and rising fuel prices exacerbate the issues.

Direct seeding, still not so prevalent in India, it is the process of growing crops under a dry seeding environment. It involves sowing rice seeds directly into the soil rather than transplanting seedlings from a nursery. The process has several advantages - saves labor, requires less water, less drudgery, early crop maturity, low production cost, better soil physical conditions for following crops and less methane emission. [4,5,6]

There are two types of Direct Seeded Rice (DSR). One is dry DSR where rice is grown like any other upland crop, with dry seed placed in dry soil by a seed drill as found mostly in North India or broadcasting followed by ploughing, as is done in Tamil Nadu. The other type is wet DSR under which sprouted seeds are broadcast or placed with a drum seeder under puddled or wet soil conditions.

Though growing of crop under a dry seeding environment has several advantages – most important being water conservation - it also has challenges, particularly that of efficient weed management for sustainable rice production.

Land preparation by precision land leveling and summer season plowing is an important part of weed management. Sowing time must be kept in mind based on rainfall pattern, temperature and duration of variety/hybrid and the crop's adaptability and maturity period under dry conditions. Understanding the period of crop weed competition is critical because in dry DSR condition, from day one, weed starts converging with crop, posing a threat. The first 4 – 6 weeks period is very critical for weed management as controlling the weed at this stage will result in better yield. The weed flora in dry direct seeded rice as against wet seeded rice is more of aerobic weeds particularly grasses. An herbicide program-based approach to cover all the stages - pre planting, pre-emergence, post-emergence, and spot application – is the right approach.

Rinskor TM active(to be launched in India), a new systemic, broad spectrum post-emergence herbicides provides an alternative solution to the farmers for managing weeds effectively under different rice growing environments for control of economically important grass, broadleaf, and sedges. These herbicides contain no petroleum distillates and have low use rate.

Farmers expect reduced input costs and better return on their investments. Water and labour saving will lower input costs. Alternate planting methods such as DSR or mechanized drilling will reduce labour requirement thus achieving cost and production efficiencies. A farmer-centric approach to arrive at solutions for direct seeding and transplanting environments will hold the key to sustainable rice cultivation. Integrated weed management will be the key to success in the dry seeding environment.

III. RESULTS

The demand for rice is on the rise. Projections by the International Rice Research Institute (IRRI) anticipate rice production needs to increase by 25% in the next 25 years in order to meet global demand. To achieve this challenge in a sustainable way, we have to produce this extra rice more efficiently with less labor, water, energy, and agro-chemicals to reduce the environmental footprint of rice production.

In traditional rice cultivation methods, 40% of the world's irrigation water is applied for rice production. Increasing water scarcity due to climate change and competition from urbanization is making this traditional method of rice production unsustainable in the long term. Combined with other factors like shortage of labor and decreasing arable land, new ideas and innovations in rice cultivation are critically needed to meet rising demand and ensure food security.

One of the potential solutions to address these challenges is direct seeded rice (DSR). Direct seeding is a crop establishment system wherein rice seeds are sown directly into the field, as opposed to the traditional method of growing seedlings in a nursery, then transplanting into flooded fields.[7,8,9]

Direct seeded rice is seen to be one of the most efficient, sustainable, and economically-viable rice production systems used today. Compared to the conventional puddled transplanted rice (PTR) method prevalent in Asia, DSR delivers faster planting and maturing, conserves scarce resources like water and labor, is more conducive to mechanization, and reduces emissions of greenhouse gases that contribute to climate change. Mechanized DSR also creates avenues for employment through new service provisions and is less labor intensive and free from drudgery, hence more attractive to youth and women farmers.

Although direct seeding is widely practiced in the United States and South America, productivity challenges have limited its wide-scale adoption in Asia, where 90% of the global rice is produced and consumed. This underscores the need for an integrated and scientific approach to make direct seeded rice socioeconomically and environmentally sustainable.

Advantages of direct seeding

- No significant reduction of yield under optimal conditions
- Savings on irrigation water by 12-35% under efficient water management practices
- Reduces labor and drudgery by eliminating seedling uprooting and transplanting
- Reduces cultivation time, energy, and cost
- No plant stress from transplanting
- Faster maturation of crops
- Lower GHG emissions
- Mechanized DSR provides employment opportunities for youth through service provision business model
- Increases total income by reducing cost of cultivation

Current constraints

- Higher seed rates
- Seeds exposed to birds and pests
- Weed management
- Higher risk of lodging
- Risk of poor or non-uniform crop establishment

It has become a major challenge to meet food demand for the burgeoning population now than ever before. Agriculture is at the forefront of national and international agenda to assume food security and sound management of natural resources. Rice (*Oryza sativa* L.) is the second most important staple food crop, just after wheat, for more than half of the world's population, including regions of high population density and rapid growth. Globally, India ranks first in rice in terms of area and second in terms of production next to China. India occupies 21% of global rice production from 28% of rice area. Among all the states, West Bengal is the leading state contributing 13.8% of India's total rice production, which occupies the first position in terms of production and second in terms of area.

There are several factors for its low productivity and out of that, losses due to weeds are the most critical one. In recent years, rice production has increased with the introduction of high-yielding varieties, but their maximum yield potential has not been fully realized owing to improper weed management. Weeds are the most severe and widespread biological constraints that compete with rice plants for natural resources *viz.*, light, nutrients, moisture, and space and thus reducing the yield significantly. Mukherjee and Singh (2005) opined that uncontrolled weeds compete with the rice and cause grain yield losses up to 76% under transplanted conditions. Thus, effective weed management at the initial stages [0-40 days after transplanting (DAT)] is an important key factor for obtaining higher crop productivity.

Weed flora in rice field

The weed flora in lowland rice is very much diverse and dynamic over times and places. Depending on the types of rice culture and season, rice field is colonized by terrestrial, semi aquatic or aquatic weeds. Weeds belonging to various species of grasses, sedges and broad-leaved weeds are found to be associated with rice culture. The dominant grassy

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| Volume 11, Issue 3, March 2024 |

weeds are *Echinochloa sp.* and *Cynodon dactylon*; sedges are *Cyperus sp*. and *Fimbristylis miliacea and* broad-leaved weed species are *Ammania baccifera*, *Marsilia quadrifolia, Monochoria vaginalis* and *Ipomea aquatic* etc. under puddle condition of sandy clay loam soil during *kharif* season. According to Singh *et al*. (2007), the broad leaved constituted 34.1 %, grasses 42.2 % and sedges 23.6 % of the total weed population under weedy conditions. The wet seeded rice infested with composite weed flora comprising of 51.5 % grasses, 30.9 % sedges and 17.5 % broad leaved weeds (Ravisankar *et al*., 2008). The detail of predominant weeds has been depicted in the Table1.

Table 1. Weed flora prevalent in the field of transplanted winter rice

Sl. No.	Common Name	English Name	Scientific Name	Family
A. Grasses				
1.	Durba Ghash	Bermuda grass	*Cynodon dactylon*	Poaceae
2.	Shyama Ghash	Jungle grass	*Echinochloa colona*	Poaceae
3.	Shyama Ghash	Barnyard grass	*Echinochloa crusgalli*	Poaceae
4.	Ram durba	Southern cutgrass	*Leersia hexandra*	Poaceae
B. Sedges				
5.	Mutha	Rice flat sedge	*Cyperus iria*	Cyperaceae
6.	Javani	Tall fringe rush	*Fimbristylis miliacea*	Cyperaceae
7.	Murak	Soft stem bulrush	*Scirpus juncoides*	Cyperaceae
C. Broad leaved weeds				
8.	Dadmari	Blistering ammania	*Ammania baccifera*	Lythraceae
9.	Kolmi sak	water spinach	*Ipomea aquatica*	Convolvulaceae
10.	Chhota shapla	Banana plant	*Nymphoides indica*	Menyanthaceae
11.	Panee kochu	Pickerelweed	*Pontederia cordata*	Pontederiaceae

Crop - weed competition

Weeds possess antagonistic effect on rice crop for several growth factors such as space, light, water and nutrients. Competition begins when crop and weeds grow in close proximity to each other and supply of a single necessary factor falls below the demand as both the crops as well as weeds have the same requirement for their growth and development. Once this occurs, the factors necessary for plant growth cannot be used effectively even though they may be present in abundance and the overall effect would be a reduction in the biomass and reproductive potential of the competitors. Sharma *et al.* (2003) found that the outcome of the competition would depend on the type of competing species, their population, duration and the level of fertility. The competitive advantage of weeds over rice is attributed to some being C_4 plants and more aggressive unlike rice which is a C_3 plant. Weeds have high photosynthetic rates and correspondingly high growth rates, high potential to acclimatize to changing environment and more efficient in seed production.

Critical period of rice-weed competition

The critical period for crop weed competition indicates the critical crop growth stage or the periods during which the field must be kept weed free and weeding results in highest economic return. Critical period of competition between rice and weeds is when the rice is in the vegetative phase and the yield components of rice are being differentiated. According to Thapa and Jha, (2002), critical period for crop weed competition in rice is up to 40 days after transplanting. In rain fed lowland rice, 30-60 days after sowing period is considered as critical period for crop weed competition to avoid grain yield losses (Moorthy and Saha, 2005). The yield obtained by weeding at this duration is almost similar to that obtained by full season weed free condition.

Effect of weed competition on rice growth

In a particular environmental condition, a unit area of land can produce a certain amount of total vegetative dry matter. In order to maximize the crop yield, all of this growth should be in the form of crop. The competition between rice and weeds is severe during early growth of rice when yield components like tillers, panicles, grains etc. are being formed. Limited crop growth at this stages ultimately possess negative effect on yield of rice. Crop yield loss and population of weeds is linearly correlated, however, above certain population limits, yield reduction becomes nearly constant due to self-competition among weed plants. Crop yield losses due to weeds are mainly influenced by their intensity as well as type of weed flora present in the field. Any weed growing in association with the crop will reduce the vegetative potential of the crop and ultimately result in loss of yield. Grassy weeds are the heavy competitors of rice crop which is followed by sedges and broad leaved weeds.

Methods of weed control

A sound weed management system involves utilization of all feasible methods of prevention and control in a harmonious combination including the maximization of mortality factors to keep weed population below threshold level and at the same time keep the cost and harmful effects at minimum. Weeds must be kept under check with the use of any of the weed control measures in order to achieve higher benefits from applied inputs. Methods of controlling weeds vary from situation to situation and season to season. These methods are grouped into cultural, manual, mechanical, chemical, and biological. Each of them has their own advantage and disadvantage, any single method is rarely found adequate and effective in controlling weeds. The integrated weed management is very effective and low cost it includes use of weed control methods in combination with each other to check weed population.

1.Cultural method:

Transplanting, the oldest and most widely used method of growing rice, is effective in lowering weed density. Under transplanting, puddling and submerged conditions inhibit weed germination. If flooding happens soon after crop establishment, a better weed control could be achieved. It was also noted that if weed infestation is severe during the early stages of crop growth and is not managed, later submergence will not be successful in weed management. Under transplanted rice, continuous submergence of the crop successfully reduced weed population and weed seed germination. As both the weeds and rice usually emerge simultaneously and farmers are not generally able to use standing water to suppress weeds at the early growth phases of rice, the risks of crop yield loss due to competition from weeds in direct-seeded rice were higher than in transplanted rice. Reducing the row-to-row and plant-to-plant spacing, weeds can also be suppressed. The closely spaced crop do not provide enough space for weed growth and prevents sunlight from entering downward thus effectively buried the weeds growing beneath its canopy.

2.Manual method:

Weed management through manual methods i.e. hand weeding, is very effective. It was found that the maximum grain yield and weed control efficiency were achieved when two manual or hand weeding were given in rice field (Tripathi *et al*., 2000). According to Pal *et al*. (2009), the highest grain yield of 5.08 t ha^{-1} in Gangetic alluvial soil was obtained by hand weeding at 20 and 40 DAT, since it left limited space for weeds to grow and compete with the crop, preferably at the crucial stage of crop weed competition. But in large-scale cultivation, it is tedious, expensive, and time-consuming. Also in rainy season, Continuous rains and unavailability of man power make manual weeding difficult.

3. Mechanical method:

Interculture with different implements or machines *viz., khurpi*; *kassola/ kodal*; wheel hoe, rotary weeder; *cono* weeder; Japanese paddy weeder; rotating hoe etc., can be used for controlling weeds from different crops. This method can be adopted by unskilled labour and are invariably economical, non-polluting, without residue problems, and relatively safe for operator. The incorporation of weeds in situ through mechanical weeding may aid in the efficient recycling of nutrients that have been depleted. These implements helped to save labour, time and reduce man days required for weeding from 30 to 10 as they become more experienced in handling the weeding implements. In comparison to using a conventional weeding approach, using a *cono* weeder increased grain yield by 10% during the wet season but only by 3% during the dry (Thiyagarajan *et al*., 2002). The weeds in the inter-row space were successfully controlled by the rotary weeder, but those in the intra-row space and those near the crop were not. The mechanical weeding using rotating hoe having small toothed wheels, increase the soil pores thus roots and microbes gain access to oxygen more easily and also significantly increase the tiller production. There are some problems encountered with mechanical weeding that incorporation of some weeds like *Cynodon sp.* and sedges with underground stolon and rhizomes which result in faster regeneration. Beside this, driving of heavy machinery on field leads to soil compaction which is not desirable for plant growth.

4. Chemical method

In general, cultural and mechanical methods of weed control are time-consuming, cumbersome, and laborious apart from being less effective because of a chance of escape and or regeneration of weeds from roots or rhizomes that are left behind. Hand weeding is difficult due to the crop's morphological resemblance to some grassy weeds. Thus, it looks like the only other option is to apply herbicides. Chemical weed control under puddled planted rice culture is an effective way to get rid of grasses, sedges, and broad-leaved weeds by reducing labour costs and increasing grain output. Higher weed control efficiency and crop yield depend on judicious herbicide selection, appropriate timing, dosage and application technique. Herbicide application techniques such spraying, sand mixing and urea mixing need to be made more efficient. Method of sowing, water management, fertilizer management etc. are greatly influence the time of application of herbicides. In transplanted rice, pre-emergence herbicides should be applied at 2-3 DAT whereas in case of direct seeded rice it is 1 DAT under sufficient moisture condition.

Delay in the application of herbicide beyond the date of sowing decreases the phytotoxicity to the crop but increases resistance of germinating weeds. So the complexity of our rice farming system, soil and environmental conditions, as also the farmers' ignorance of the herbicide technology' necessitates development of relative safe, economic and easily acceptable herbicides. The co-ordinated research effort of several years helped to identify pretilachlor, pyrazosulfuron ethyl, butachlor, thiobencarb, anilofos, pendimethalin, oxadiazon, 2, 4-DEE, bispyribac sodium, oxyflurofen and sulfonylurea etc. herbicides are of promising herbicides for rice.

Herbicide mixtures:

Herbicide residue or herbicide resistance to weeds may result from the repeated application of the same herbicide or chemical belonging to the same family. In contrast to using a single herbicide, the usage of herbicide mixtures (both ready and tank) enabled broad spectrum weed control with a minimal dose. Some herbicide combinations used in transplanted rice are Arozine (Anilofos 24% + 2.4 –DEE 32EC); londax power (Bensulfuron methyl 0.06 % + Pretilachlor 0.60 %); Almix (Metsulfuron methyl 10% and Chlorimuron ethyl 10%); Swachh (Pretilachlor 6% + pyrazosulfuron ethyl 0.15%) etc.

Herbicides that are most commonly used in transplanted rice field are given presented in Table 2.

Table 2. Details of some herbicides

Herbicide name	Trade name	Dose ha^{-1}	Time of application	Types of weed control
Bentazon	Basagran	1.2 kg	Post-emergence	Sedge and broad-leaved
Pyrazosulfuron-ethyl	Saathi	25 g	Pre-emergence	Grass, sedge and broad-leaved.
Bispyribac sodium	Nominee Gold	25 g	Post-emergence	Grass, sedge and broad-leaved.
2, 4-D ethyl ester (2,4- DEE)	Weednil	750 g	Post-emergence	Broad-leaved
Pendimethalin	Stomp	1-1.5 kg	Pre-emergence	Grass, sedge and broad-leaved.
Pretilachlor 6% + pyrazosulfuron ethyl 0.15%	Swachh	(600+15) g	Pre-emergence	Grass, sedge and broad-leaved.
Metsulfuron methyl 10% and Chlorimuron ethyl 10%	Almix	4 g	Pre and post emergence	Grass, sedge and broad-leaved.
Anilofos 24% + 2.4 –DEE 32EC	Arozine	(0.24 + 0.32) kg	Pre-emergence	Grass, sedge and broad-leaved.
Bensulfuron methyl 0.06 % + Pretilachlor 0.60 %	Londax power, Eraze strong, Rizal	(60+600) g	Pre-emergence	Grass, sedge and broad-leaved.

5. Biological method

It includes the deliberate use of living organisms to suppress the population of the targeted weeds and has produced numerous remarkable achievements against weeds. Biotic agents such as insects, mites, nematodes, and plant infections have been utilized to suppress weeds. As far as rice weed concerns, biological weed control has not yet received much attention. To effectively utilise it and assist the farmer community, extensive study and innovative technology are needed in this field. The concept of "bio-herbicides," which contain microorganisms as their active ingredient, has gained momentum. In this approach, only minute fungal spores have been employed thus the resulting compounds are frequently referred to as mycoherbicides. Currently, scientists are using Collego, Devine, Biomal, Dr. Bio Sedge etc. commercially available bio-herbicides, to manage weeds in rice fields, but there has been no success documented to yet. Geese and ducks are used in the case of deep-water rice cultivation to pick weeds and insects. In China, grass carp, a herbivore fish, has attracted a lot of attention, particularly for its ability to eliminate submerged weeds like duckweed, *Amaranthus viridis*, *Corchorus acutangulus*, and filamentous algae.

Integrated weed management

An integrated weed management system is the coordinated control of the weed population using reliable, effective, and practical management strategies that are both economically sound and environmentally safe in order to increase and maintain the yield of the rice crop. In rice and rice-rice cropping systems, integrated weed management encompasses using well-accepted high-yielding crop cultivars that resist weed competition, pre-sowing seedbed tillage for effective seed bed preparation, seeding techniques that enhance crop growth and minimise weed growth, optimal plant population, including closer spacing in and between rows, use of cultivars that form a good canopy structure over weeds, precision placement/timing of fertiliser application, judicious use of irrigation water, sound crop rotation use of effective herbicides. Thus, integrated weed management combines all appropriate management strategies with the environment's own natural controlling and limiting factors.

Rice has a dynamic weed flora that changes from place to place and condition to condition which competes with the crop and lowers grain output. In places where labour is expensive and limited, chemical weed management is becoming more important. In order to manage weeds in rice fields, some herbicides, either individually or in combination, have been shown to be an economically feasible alternative to hand weeding. However, an innovative idea called integrated weed management is now emerging. In this case, all efficient management techniques are used in a way that is compatible with maintaining environmental quality while lowering weed populations below economic threshold levels.

IV. CONCLUSION

Due to labour shortage in two granary states of Punjab and Haryana, farmers are now being encouraged to adopt 'Direct Seeding of Rice' (DSR) in place of conventional transplanting.

Covid-19 pandemic has led the labourers to reverse migrate to their villages, which has created a shortage of labourers.

Normal Transplanting of Paddy vs Direct Seeding of Rice

Transplanting Paddy:

In transplanting paddy, farmers prepare nurseries where the paddy seeds are first sown and raised into young plants.

The nursery seed bed is 5-10% of the area to be transplanted.

These seedlings are then uprooted and replanted 25-35 days later in the puddled field.

Direct Seeding of Rice (DSR):

In DSR, the pre-germinated seeds are directly drilled into the field by a tractor-powered machine.

There is no nursery preparation or transplantation involved in this method.

Farmers have to only level their land and give one pre-sowing irrigation.

Protection against the weeds[10,11,12]

Transplanting Method: In transplanting for the first three weeks or so, the plants have to be irrigated almost daily to maintain a water depth of 4-5 cm.

Water prevents growth of weeds by denying them oxygen in the submerged stage, whereas the soft 'aerenchyma tissues' in paddy plants allow air to penetrate through their roots. Water, thus, acts as a herbicide for paddy.

DSR Method: In DSR as flooding of fields is not done during sowing, chemical herbicides are used to kill weeds.

Advantage with Direct Seeding of Rice

Water savings.

Less numbers of labourers required.

Saves labour cost.

Reduce methane emissions due to a shorter flooding period and decreased soil disturbance compared to transplanting rice seedlings.

Drawbacks of Direct Seeding of Rice[16,17,18]

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Non-availability of herbicides.

The seed requirement for DSR is also high, 8-10 kg/acre, compared to 4-5 kg/acre in transplanting.

Further, laser land levelling is compulsory in DSR. This is not so in transplanting.

The sowing needs to be done timely so that the plants have come out properly before the monsoon rains arrive.

Rice

Rice is a staple food for the overwhelming majority of the population in India.

It is a kharif crop which requires high temperature, (above 25°C) and high humidity with annual rainfall above 100 cm.[19]

In the areas of less rainfall, it is grown with the help of irrigation.

In southern states and West Bengal the climatic conditions allow the cultivation of two or three crops of rice in an agricultural year.

In West Bengal farmers grow three crops of rice called 'aus', 'aman' and 'boro'.

About one-fourth of the total cropped area in India is under rice cultivation.

Leading producer states: West Bengal, Uttar Pradesh, and Punjab.

High Yielding States: Punjab, Tamil Nadu, Haryana, Andhra Pradesh, Telangana, West Bengal and Kerala.[13,14,15]

Punjab and Haryana are not traditional rice growing areas.

Rice Cultivation in the irrigated areas of Punjab and Haryana was introduced in the 1970s following the Green Revolution.

Almost the entire land under rice cultivation in Punjab and Haryana is irrigated.

India contributes 21.6% of rice production in the world and ranked second after China in 2016.[20,21,22]

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