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Impact of Rice Cultivation Methods on Insect Pest Incidence and Their Management

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Abstract

Under the influence of fluctuating global climate scenario and limited resources of water availability, different methods of rice cultivation like System of rice intensification (SRI), Direct seeded rice (DSR), Alternate wetting and drying (AWD) and Aerobic rice have become popular as alternatives to conventional transplanting method. Due to these shifting cultivation situations, insect pest profiles have also undergone changes with associated influence on beneficial insects and other natural enemies. Multi-location studies carried out under All India Coordinated Rice Improvement Project (AICRIP) have revealed significantly less incidence of major pests like stem borers, planthoppers in SRI compared to normal rice transplanting method. Overall, the SRI method leads to more robust plant health with enhanced capacity to resist pest attacks. In case of DSR, AICRIP studies have consistently revealed higher incidence of all the insect pests in the normal transplanted method compared to DSR. However, few reports have indicated association of insect pest outbreaks with higher seed rate and plant densities. Limited studies have shown that AWD also has the potential to minimize the incidence of insect pests and diseases compared to irrigated rice. However, soil borne pests, particularly root-knot nematode can be more damaging under aerobic conditions. Field cum laboratory studies carried out at ICAR – IIRR on impact of cultivation systems on the rich insect biodiversity in rice have revealed association of higher total abundance and greater richness of beneficial insect species with SRI management.

Keywords: Insect pests, Prevalence, Establishment methods, Arthropod diversity, IPM

Introduction

Rice is the world's most important food crop, providing a major source of food energy for more than half of the human population. Rice cultivation methods are continuously evolving to meet the challenge of sustaining rice production under changing global climate scenario. With limited resources of water and other inputs, different methods of rice cultivation have emerged, of which, System of Rice Intensification (SRI), Direct seeded rice (wet direct-seeded rice -wet DSR) and dry direct-seeded rice -dry DSR)), Alternate wetting & drying (AWD) method of rice cultivation and Aerobic rice have been potentially promising. These methods provide potential alternatives to the conventional transplanting method of rice cultivation under limited sources of water, land, and other inputs.

Since the onset of the green revolution in rice in the country, insect pests have been the prime biotic stresses exerting considerable pressure limiting rice production. In India, the rapid increase in rice area under high-yielding varieties, mono and continuous culture of rice accompanied by enhanced use of inorganic fertilizers has led to increased incidence of insect pests and diseases. The number of insect pests considered important in paddy cultivation increased from three in 1965 to more than 15 in 2009 (Gururaj katti *et al.,* 2009). Among these, six major insect pests are prevalent in different rice cultivation systems in India. Of them, stem borers have been recorded to cause consistently more damage to the rice crop. Three species, yellow stem borer (YSB), *Scirpophaga incertulas* Wlk. followed by pink stem borer (PSB), *Sesamia inferens* and White stem (WSB) borer, *Scirpophaga innotata* are widespread across rice cultivation systems and regions. Planthoppers are also key pests and are widely distributed across all the rice ecosystems. Two types of planthoppers are commonly observed in India with brown planthopper (BPH) being more dominant than white-backed planthopper (WBPH) in occurrence and distribution. Gall midge (*Orseolia oryzae* Wood-Mason) is another important pest confined mainly to irrigated or rainfed rice including shallow upland and deep-water rice. Similar to stem borer, gall midge is also one of the important hidden pests of rice as most of the pest life cycle is completed within the rice plant. Among the foliage pests of rice, leaf folder (*Cnaphalocrocis medinalis* Guenee) is an important one having the ability to cause severe defoliation. Leaf folder infestation can result in yield loss when the flag leaf is severely affected during the early reproductive stage of the rice crop. In addition to the above, there are a few pests of regional significance such as rice hispa, whorl maggot, case worm, and cutworm/swarming caterpillar which are sporadic but can cause considerable losses depending upon time and place of occurrence.

Rice cultivation methods vary depending on the availability of water resources (**Figure 1**). In recent times due to limited water resources, improved rice cultivation methods like SRI, DSR, AWD and Aerobic rice have become popular (Kumar *et al*., 2009 & 2013). Under these changing cultivation scenarios, insect pest patterns have also altered over time and space with concomitant influence on beneficial insects and other natural enemies.

Experiments have been carried out at ICAR-IIRR farm and multi-locations under the All India Coordinated Rice Improvement Project (AICRIP) since 2005 to know the influence of the cultivation systems on insect pest incidence as well as insect biodiversity. This paper highlights the salient findings of these studies with a view to provide significant leads for successful insect pest management in these diverse scenarios of rice cultivation. Results of a case study to assess farmers' experiences in pest incidence and pest management practices adopted in SRI compared to conventional practices have also been described to focus the efforts towards the development of need-based location-specific IPM.

Waterlogged / low lying	Normal Transplanted rice	Direct seeding/ AWD	Saturated / SRI	Aerobic
Stem borer, Case worm, Swarming caterpillar	Stem borer, Gall midge, Leaf folder, BPH, WBPH, GLH Gundhi bug, Whorl maggot, Hispa, Caseworm	Stem borer, Leaf folder, GLH, BPH, WBPH, rodents	Hispa, thrips, defoliators like leaf folder, stem borer, leaf mite	Soil borne pests like nematodes, root aphids
MORE WATER →				LESS WATER

Figure 1. Insect pest incidence vis-à-vis rice cultivation methods influenced by water resources

Insect pest scenario in different rice cultivation systems *vis a vis* conventional method of cultivation

System of Rice Intensification (SRI)

System of rice intensification (SRI) developed in Madagascar in 1980's has gained wider acceptance in many countries including India due to its advantages over conventional method *viz.*, water and seed saving, high yield and less dependent on chemicals (Uphoff, 2003). The components of SRI include the use of young seedlings, careful transplanting of single seedling per hill, wide spacing, controlled irrigation, aerated soil conditions and enrichment of soil through *in situ* incorporation of weeds and the use of organic manures (Gopalakrishnan *et al.,* 2014; Surekha *et al.,* 2015).

Multi-location studies have revealed the incidence of YSB, leaf folder, gall midge, case worm, BPH, WBPH, whorl maggot, and thrips in both SRI and normal methods of rice cultivation (Padmavathi *et al.,* 2009). The incidence of dead hearts (DH) and white earheads (WEH) caused by stem borer has been relatively lower in the SRI method compared to the normal transplanting method at various locations. However, leaf folder incidence was found higher in SRI method at few locations, whereas the incidence of caseworm and gall midge has been at par in both the methods of rice cultivation. In case of planthoppers, BPH and WBPH numbers have been higher in normal cultivation than SRI method (**Table 1**).

Table 1. Insect Pest incidence in Normal and SRI methods of rice cultivation

Method/Treatment*	Per cent damage						Number per hill	
	SBDH	SBWE	LFDL	WMDL	GMSS	CWDL	BPH	WBPH
SRI	9.8	15.5	21.0	12.5	2.7	7.1	9	15
Conventional/ Normal	12.6	25.5	12.9	5.6	4.5	7.8	249	28
Locations	6	6	2	5	3	2	3	3

* Replications - 7

Among various cultivars grown in both methods of rice cultivation, white earheads were found significantly low in IR 64 grown under the SRI method followed by Swarna, Annada, and Krishnahamsa varieties. Scented varieties like Sugandhamathi and Vasumathi were infested more than non-scented varieties (**Figure 2**).

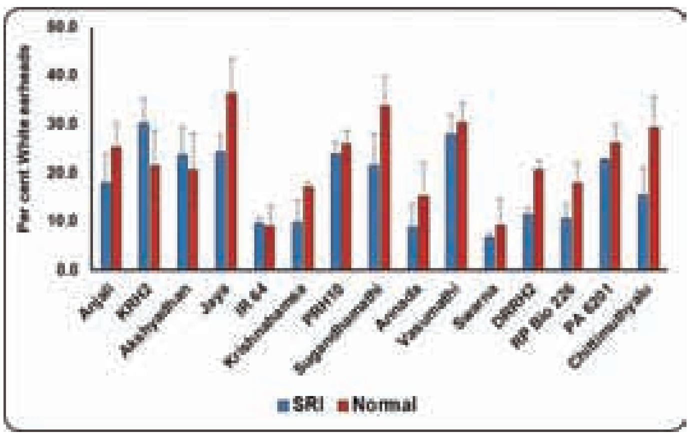

Figure 2. Incidence of YSB in different cultivars grown under SRI and Normal methods of rice cultivation

With the introduction of the System of Rice Intensification (SRI), a new dimension has been added to the changing pest scenario. Ideally, the SRI method leads to healthier and more vigorous plants having better capacity to resist pest attacks. However, the initial management of pests immediately after planting can pose a problem for the farmers. The freshly planted and tender seedlings may not be able to withstand severe hispa and thrips damage as it may severely affect the plant growth. Stem borer is another pest that may create havoc at this stage, if not properly managed. Similarly, wider spacing adopted in SRI cultivation may favour increased hispa but reduce gall midge incidence in the early stages. In the tillering stage, vigorous plant growth with a cluster of tillers may attract defoliators such as cutworms, ear-cutting caterpillars, and leaf folders (Padmavathi *et al*., 2009). However, a significant increase in the number of tillers and leaves should be able to compensate for the loss due to defoliation. In later stages, SRI cultivation may reduce BPH incidence due to increased aeration resulting from wider spacing.

Direct-seeded rice (DSR)

Direct seeding is done in two ways *viz.,* wet-seeded rice and dry-seeded rice. In general, direct-seeded rice is affected by similar pests and diseases as transplanted normal rice. Multi-location studies revealed the incidence of stem borer, leaf folder, gall midge, whorl maggot, hispa, BPH, and WBPH at many locations in both the methods of cultivation, *viz*., normal method and DSR. However, under some conditions, a high seed rate (80-120 kg ha-1) is being recommended for the establishment of DSR and studies have indicated association of an outbreak of insect pests with high rice plant densities. High seed rate causes nitrogen deficiency, reduces tillering, and increases proportions of ineffective tillers, leading to a greater chance of crop lodging accentuated by attack due to planthoppers. Higher pest incidence has also been reported because of dense canopy and less ventilation around plants (especially in broadcast-sown rice with a high seed rate). In another related scenario, higher population densities of leafhopper, *Nephotettix cincticeps* and leaf folder have been reported in machine-transplanted rice than in DSR.

AICRIP studies have consistently revealed higher incidence of all the insect pests in the normal transplanted method as compared to DSR (**Figure 3**).

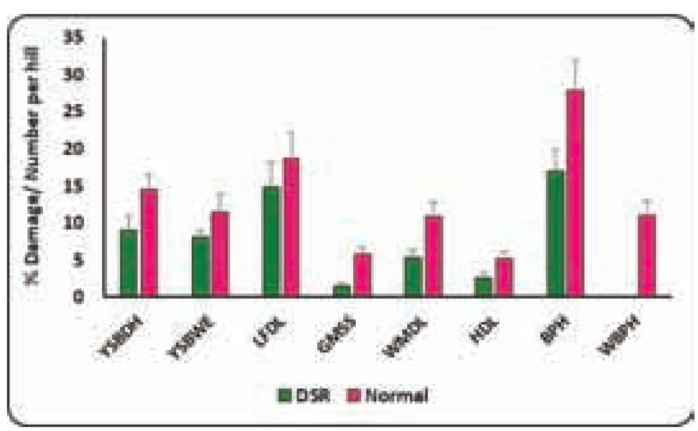

Figure 3. Insect pest incidence in DSR and normal methods of rice cultivati on

Alternate wetting & drying (AWD) method of rice cultivation

Alternate wetting and drying (AWD) is a water-saving technology that lowland (paddy) rice farmers can follow to reduce their water use in irrigated fields. In AWD, irrigation water is applied to flood the field a certain number of days after the disappearance of ponded water. Hence, the field is alternately flooded and non-flooded. The number of days of non-flooded soil in AWD between irrigations can vary from one day to more than 10 days depending on the soil type. AWD also has the potential to minimize the incidence of insect pests and diseases compared to the conventional method.

The intermittent irrigation with AWD in rice has been effective in decreasing insect pest (92 %) and disease (100%) infestation (Bouman, 2007; Bouman *et al.,* 2007; Chapagain and Yamaji, 2010). In a study from Bangladesh, the incidence of stem borer, rice bug, and brown planthopper was reported in the AWD method of rice cultivation (Hasan *et al.,* 2016). Out of 108 farmers who practiced the AWD method, no occurrence of insect pests was reported by 63% of farmers compared to the conventional method. It was found that the stem borer infestation in the AWD method was less (5.6%) compared to the conventional method (27.8%). However, further studies are needed to unravel the relationship between the paddy water environment and insect pests/diseases.

Aerobic rice system (ARS)

ARS is a new production system in which rice is grown under non-puddled, non-flooded, and non-saturated soil conditions. Few studies carried out so far have indicated that the incidence of pests and diseases in the aerobic rice production system is less than in irrigated rice. However, soil-borne pests, particularly root-knot nematode can be more damaging under aerobic conditions (Arayarungsarit, 1987; Nishizawa *et al.,* 1971; Padgham *et al.*, 2004; Soriano and Reversat, 2003).

Factors contributing to change in pest scenario

A number of factors have contributed to the continuing changes in the pest scenario, of which major ones are: a) planting modern varieties over an extensive area, b) growing varieties that do not possess resistance to major pests, c) cultivating rice throughout the year providing a permanent food source to the pests, d) imbalanced use of fertilizers, particularly the application of high levels of nitrogen and e) increased and misplaced emphasis on insecticides use resulting in their indiscriminate application leading to pest resistance, resurgence, secondary pest outbreaks, and other detrimental side effects.

Impact of cultivation methods on insect biodiversity

Earlier studies have revealed that cultivation systems have an enormous impact on insect biodiversity measured by the guild composition of insects captured in the rice field plots subjected to varying cultivation systems including the conventional normal transplanting method. The guild composition includes the proportion of insects that feed on plants (phytophages) as well as natural enemies like predators, parasitoids and other insects that prey upon and regulate the phytophages. The extent of the impact of any cultivation system on the natural interplay of these beneficial agents determines the suitability of cultivation practice to protect the ecological, economic and ultimately the social interests of rice farmers. Earlier studies, are few, scattered and provide only a limited view of the impact of alternative rice cultivation systems such as SRI and DSR.

The present study encompassing the field cum laboratory studies carried out at ICAR – IIRR involved detailed investigations into guild composition associated with changing pest profiles under differing rice cultivation scenarios with special reference to the SRI method.

Under these studies, the guild composition of captured insects revealed that the proportion of insects that feed on plants (phytophages) was higher where conventional cultivation methods had been used, while predator, parasitoid and other insects that prey upon and control phytophages were more in numbers in SRI-method plots. This indicated that there was a higher total abundance and greater richness of beneficial insect species associated with SRI management. The phytophages counted included yellow stem borer, spotted stem borer, two species of leaf folders, stink bugs, hispa, skipper, leaf and plant hoppers. The predators included spiders, coccinellids, staphylinid beetles, predatory bugs, carabid beetles, damsel, and dragon flies. Parasitoids included braconids, ichneumonids, and chalcids (**Figure 4**). Not surprisingly, conventional methods, which include continuous flooding of plots, showed more aquatic arthropods compared to SRI-

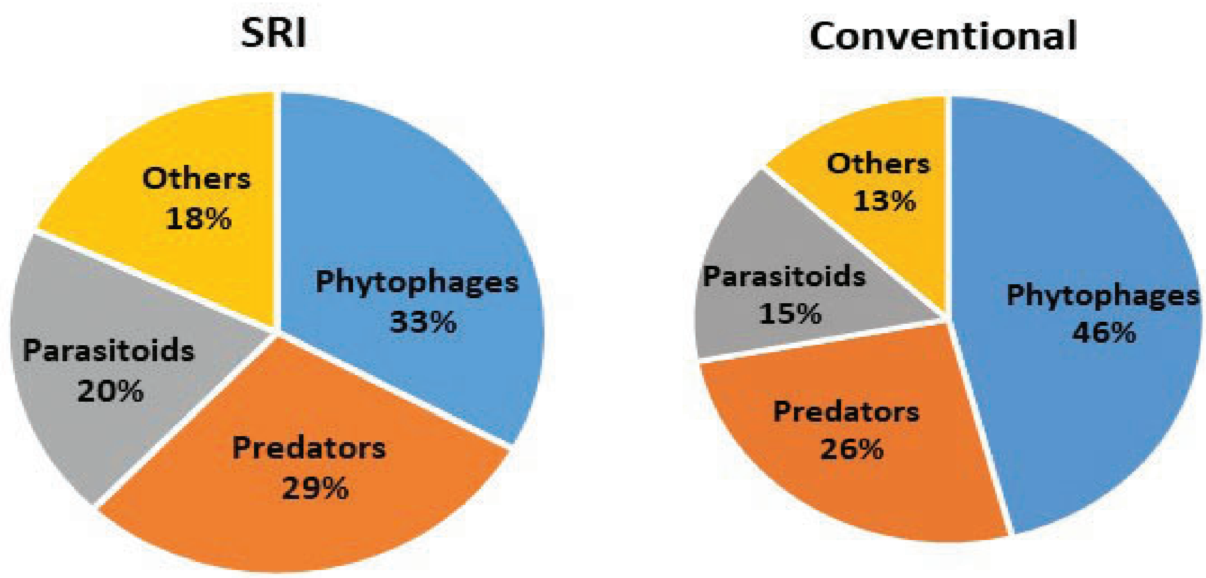

Figure 4: Guild composition in SRI and Conventional method of rice cultivation

method plots. Karthikeyan *et al.,* (2010) and Jayakumar and Sankari (2010) have also reported high spider populations with SRI, while Devi and Singh (2015) have reported higher species diversity and greater Shannon Index with SRI compared to conventional methods.

Integrated Pest Management (IPM)

Rice farmers have been mostly relying on a single tactic of chemical control for managing pest problems, hence it has become imperative to develop an effective and holistic system of tackling pests to make it more environment-friendly, economically viable, and socially acceptable for the farmers. This can be achieved through integrated pest management (IPM), which is an approach to promote natural, economic and social farming techniques through the effective blending of appropriate tactics like growing pest-resistant cultivars (host plant resistance), suitable cultural practices (cultural control), use of eco-friendly pesticides (chemical control), conservation of in situ natural biological control (biological control) and other novel pest control techniques like the use of pheromones, etc. Under the changing cultivation scenarios coupled with global climate alteration patterns, IPM technology development strategies have also evolved to address the twin challenges of altered pest profiles and transforming cultivation systems. This has been made possible by the concerted multi-location research efforts under AICRIP to develop holistic pest management modules appropriate for each cultivation system.

Farmers Experiential Learning study on pest incidence and management under SRI method compared to conventional practices – A Case Study

As a case study to highlight the ecological, economic and social implications involved in carrying out such studies under farmer situations, a field survey was conducted with the aim of assessing farmers' experiences in pest incidence and pest management practices adopted in SRI compared to conventional practices.

Among the insect pests of rice, whorl maggot, rice hispa, stem borer, green leaf hopper and leaf folder were recorded in both methods. Around 70% of farmers did not take up any control measure in SRI whereas, in the normal method, they undertook at least one spraying of chemical pesticide. These included endosulfan, monocrotophos, and quinalphos. Among the SRI adopters, 35% of farmers used indigenously prepared mixtures such as Pancha kavya, Amrita jalam, Pancha jalamrutam, and neem for protection against insect pests.

In the SRI method, the benefit-cost ratio was 1.77 and 1.76 in Katkur and Bonakallur villages, respectively. In conventional paddy cultivation, insecticides accounted for 5% of the cost of cultivation (Padmavathi *et al.,*2008). In the SRI method, this cost is reduced. Moreover, reduction in the usage of pesticides helps in the conservation of natural enemies in the rice ecosystem, protects human and animal health, and reduces environmental pollution.

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