

Importance of Herbicides for Zero-Till Wheat and Rice on the Indo-Gangetic Plains

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INTRODUCTION

The Indo-Gangetic Plains (IGP) consists of the Indus and Ganges River systems covering parts of India, Pakistan, Nepal and Bangladesh. The climate of the IGP consists of a wet monsoon summer and a dry, cool winter. This allows short-duration rice and wheat cultivars to be grown in a double cropping pattern in one calendar year: rice in the summer and wheat in the winter. The rice-wheat rotation is primarily irrigated and occupies about 13.5 million hectares on the IGP. The rice-wheat systems produce more than 30% of the rice and 40% of the wheat in the four countries.⁵

In the 1990s, evidence accumulated that the rice-wheat system was showing signs of fatigue with yields at a plateau or in decline.¹ The main causes of yield stagnation were identified as land degradation (deteriorating soil structure and fertility) associated with tillage and the tendency for farmers to plant wheat too late to achieve the highest possible yields. Traditionally, farmers grow rice after intensive dry and wet tillage followed by wheat after intensive dry tillage. High intensity of tillage in the rice-wheat system has led to degradation of soil and water resources threatening the sustainability of the system. Resource conservation technology in the form of zero tillage was introduced in the region in 1996-97.

WHEAT

Late planting of wheat was identified as a major cause of reduced yields. In Pakistan, about 80% of the wheat is planted late.⁹ Because of the shorter growing period coupled with delayed planting, wheat grain filling stage coincides with high temperature leading to a large yield penalty, whereas timely planted wheat has a longer growing period.¹¹ To improve productivity, the wheat crop must be planted at the optimal time at the end of



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November followed by a decline in yield of 1 to 1.5%/day after that date. Farmers plant wheat late because of multiple tillage operations (6-12) after the rice harvest. Farmers believed the tillage was necessary for good germination, weed control, proper aeration and moisture conservation.²

Research demonstrated that zero-tillage in which wheat is directly seeded into undisturbed soil after rice harvest enhanced farm income by about US\$100 per hectare as a result of increased wheat yield (5-7% higher) and savings in fuel costs (36 L less diesel per hectare).³ Zero-tillage allows reduction in tractor trips from 6-12 to 1. The result is a 15-16% savings on operational costs. Zero-tilled wheat enabled farmers to sow wheat earlier. It was determined that zero-tillage helps to reverse soil degradation and leads to improved soil structure and higher soil organic matter. Zero-tillage takes immediate advantage of residual moisture from the previous rice crop, as well as cutting down on irrigation requirements, so it reduces water use by about one million liters per hectare.³ The yield effect is closely associated with enhanced timeliness of wheat establishment after rice.³ In Pakistan if the sowing time would be advanced by two weeks, an additional two million tons of wheat could be produced.⁹

The area under ZT wheat was negligible until it slowly increased to .2 million hectares in 2001-2. Thereafter, the increase was very fast. By 2008, the zero/reduced tillage wheat area amounted to 1.76 million hectares and was used by 620,000 farmers.³ Zero tillage in wheat is now practiced on about 5 million hectares in the IGP.¹⁴ The cost savings effect is the main driver behind its spread. Studies have reported the benefits of zero tillage wheat to be relatively scale neutral with both large and small landholders adopting zero tillage. This is facilitated by the ability of smallholders to contract zero-tillage drill services.

Herbicides are an essential component of the zero-till wheat system. In zero-till wheat, herbicides are sprayed to kill all weeds that emerge following rice harvest and before wheat seed planting.^{4,5,1} Weeds that emerge in the wheat crop are effectively controlled with a single herbicide application.^{5,1} Surveys have shown that farmers practicing zero-till in wheat fields rely exclusively on herbicides for weed control.⁶ Research has shown that zero tillage in combination with herbicides led to doubling of wheat yield in comparison with zero tillage and no herbicides.¹²

In wheat, *Phalaris minor* (littleseed canarygrass) is the most dominant and problematic weed. Introduced in India with wheat seed from Mexico in the 1960s, *P. minor* soon became a major weed. The herbicide isoproturon provided almost complete control of *P. minor* for two decades. However, repeated use of isoproturon eventually resulted in the evolution of biotypes of *P. minor* resistant to isoproturon. Yield reductions of 30 to 80% were observed. Severe infestations led to complete crop failure.¹ The problem of *P. minor* was a major reason for the stagnation of wheat yields in the IGP in the 1990s.¹ A major reason for the rapid adoption of NT wheat was the effect on *P. minor*. *P. minor* emergence is greater at lower temperatures. Therefore, early planting of wheat at higher temperatures with ZT reduces the intensity of *P. minor* by 30-40% giving wheat a competitive advantage.¹

The introduction of effective new herbicides for control of *P. minor* led to confidence of wheat growers in the zero-till wheat system.¹ ZT in combination with the new herbicides have been the key to effective management of *P. minor* in the IGP.¹



No Till Wheat

RICE

Unlike wheat, rice continues to be almost entirely grown on the IGP by the practice of conventional wet tillage.¹⁶ To harness the full potential of Conservation Agriculture, rice will have to be brought under zero tillage.¹⁶ The environmental and soil health benefits of ZT wheat for the rice-wheat system as a whole remain short-lived (i.e. seasonal) with no cumulative gains in terms of enhanced soil and water productivity as long as the subsequent rice crop remains intensively tilled. To realize the full benefits of zero tillage, which otherwise are lost by doing puddling in rice, serious efforts are being made to develop zero-tillage rice followed by zero-tillage wheat.¹³

The traditional technique of rice culture on the IGP involves continuous submergence and puddling the soil by repeated intensive tillage. The main reason for flooding and transplanting of rice is the control of weeds. Puddling involves two to three dry tillages and two to three wet tillage operations. Puddling produces a soft mud and forms a saturated root zone for the establishment of transplanted seedlings above a compacted subsoil layer that reduces seepage of standing water. Wheat cannot tolerate the anaerobic

conditions to which rice is well adapted, however, so the dominating feature of current rice-wheat systems becomes the annual conversion of soil from aerobic to anaerobic and then back to aerobic. These conversions have significant effects on the physical, chemical, and biological status of soils.¹⁵ Puddling breaks capillary pores, destroys soil aggregates, disperses fine clay particles, and lowers soil strength.¹⁵ With repeated puddling over years, the clay particles clog the macropores and settle into a dense zone at the base of the tilled layer.¹⁵ Subsurface compaction caused by puddling reduces root growth of wheat which cause decrease in nutrient and water uptake lowering wheat yield.¹⁵ A yield decline of 8-9% has been observed in wheat when grown after puddled rice compared with non-puddled rice.¹⁶ Research in India demonstrated a 15% increase in wheat yield with continuous zero tillage in rice-wheat in comparison with continuous tillage.⁷

Recently, interest has been rapidly increasing in non-puddled direct seeded-rice due to increasing labor scarcity, water shortage, and rising input costs.¹⁶ Puddling and transplanting operations require a huge amount of water and labor. In the future, many rice farmers on the IGP may have limited access to irrigation water. In addition, there is also a concern about labor shortage for transplanting and weeding because of the increasing wage rate resulting from the migration of rural labor to the cities.¹⁰

Weeds are the main constraint to the production of dry-seeded rice. The main reason for the weed problem in dry-seeded rice systems are the absence of standing water at crop emergence to suppress weeds and the absence of a seedling size advantage between rice and weed seedlings as both emerge simultaneously in these production systems.¹⁰ The weed spectrum changes without puddling and flooding. Research in India showed that the number of species of grasses and broadleaves were 6 and 4 respectively under conventional tillage whereas in dry-seeded rice, it increases to 15 grass species and 19 broadleaf species.¹³



Puddling

Some weed species that are not adapted to conventional tillage appear in the dry-seeded systems. Yield losses caused by uncontrolled weeds in rice were up to 98% in zero-till.⁷

Research has shown that rice under direct-seed conditions with effective weed control can be as productive as puddled transplanted rice.¹⁶ Successful cultivation of direct-seeded rice requires intensive use of herbicides.¹ A variety of herbicides have been screened and found effective for preplant/burndown, preemergence, and postemergence weed control in dry direct drill-seeded rice systems, including under zero-tillage conditions.¹³ Because of their high dormancy, the weeds of some weed species keep germinating throughout the growing season. For such weed species, broad spectrum late POST herbicides are needed that can be applied 4-6 weeks after sowing.⁸ Through the use of suitable herbicides, rice yields without tillage can produce higher yields than conventional puddled transplanted systems.¹¹ In research in India continuous zero tillage rice-wheat resulted in an increase in rice yields of 25%.⁷ The use of herbicides gives selective and effective control of weeds and allows the crop to emerge in a relatively weed-free environment.¹⁷ PRE and POST emergence herbicides are imperative to keep weeds under check in direct-seeded rice.¹⁸

CONCLUSIONS

Zero-till rice-wheat production systems is a key pathway for improving productivity , income and food security while sustaining natural resources in smallholder production systems of the IGP.¹¹ Currently-registered

herbicides for rice in the region have been developed for transplanted rice. Development of new herbicides for dry seeded rice is needed. There is a need to register and make available effective herbicides for weed control in rice and wheat under zero-till in the IGP.⁸ Research is needed to evaluate the performance of different herbicides which can provide effective weed control under zero-till systems.¹⁷ There is a need to enhance the accessibility of smallholders to zero-till knowledge, herbicides, and zero-till planters. There is also need for more field days, farmer exchanges and capacity building of extension agents with information on herbicides for weed management. The benefits of ZT systems for the rice-wheat system on the IGP can be fully exploited only if effective herbicides that are suitable for use in these systems can be identified, registered and used.¹⁰

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