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Current status of zero tillage in weed management

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ABSTRACT

Rice and wheat are the major cereals in India hence rice-wheat system provides the staple grain supply for a large portion of the world's population and mainly this system is critically important for global food security. Twenty five per cent of the total rice area of the country is grown in rotation involving wheat, whereas 40% of wheat is grown in rotation with rice. The rice-wheat cropping system with zero tillage is the best cropping system with lower risk as it has major benefits such as improving water use efficiency, reduced cost due to saving in the fuel and labour, timely planting of crops, results in higher yield, reduced weed density and has a positive environmental impact. Hence, zero tillage are divisible nature and flexible in operation allowing farmers to benefit from than under driver situation. Tillage influences weed infestation, and thus interaction between tillage and weed control practices are commonly observed in crop production. Adequate tillage checks and delays emergence of weeds and provides a more favourable environment for early crop establishment. This paper presents current status of zero tillage in context to weed management in India.

Key words : Zero tillage, Weeds

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Rice-wheat system provides the staple grain supply for a large portion of the world's population and mainly this system is critically important for global food security. In south Asia, ricewheat system produce more than 30% of the rice and 42% of wheat consumed and cover about 14 m/ha of cultivated land, with most of the area located in India and the Indo-Gangetic Plain (IGP). In India, these two major cereals are grown in an area of about 43 and 26 m/ha. Twenty five per cent of the total rice area of the country is grown in rotation involving wheat, whereas 40% of wheat is grown in rotation with rice. In India, the maximum area under zero till is recorded in Punjab state (46.6%). As on recent estimates, average area under zero till situation was 7.60 mha (Table 1).

Brief history of zero tillage (ZT) in India

In India, research on zero tillage (ZT) for wheat started almost three decades ago (Ekboir 2002). Several state agricultural universities tried ZT in the 1970s but their efforts failed due to technical difficulties such as the lack of adequate planting equipment and the difficulty in controlling the weeds chemically. This line of research was soon abandoned by all except a handful of researchers working in isolation. In 1990, Centro International de Mejoramiento de Maizy Trigo [International Maize of Improvement Center] (CIMMYT) regional wheat agronomist introduced inverted-T openers to Indian researchers. In 1991, a first prototype of the Indian ZT seed drill was developed at GB Pant University of Agriculture and Technology, Pantnagar. After considerable investment of resources and several design changes, the first ZT seed drill was made available for field testing within 12 months. Rice-Wheat Consortium (RWC) for the Indo-Gangetic Plains, and CIMMYT contributed significant impact for the widespread adoption of zero tillage at the turn of this century. Zero tillage technology is now turning into a great success story and looks set to become one of the best technologies after green revolution.

Table 1. Zero-till coverage area under different states in India (2009-10)

State	Area under zero till (ha)	Coverage (%)
Punjab	3,54,324	46.6
Haryana	2,60,020	34.2
Eastern Uttar Pradesh	662	0.08
Bihar	45,800	6.01
Andhra Pradesh	1,00,000	13.1
Tamil Nadu/ Karnataka	40	0.005
Total	760846	

Major causes of lower yield production

Recent studies indicated a slow down in the productivity of growth in the rice-wheat system in India. Delayed sowing and weeds are the main constraint besides many others. In general, season long competition from major weeds culminates in yield reduction to an extent of 15-40% (Singh *et al.* 1997). In this context, one of the most serious incidences was associated with isoproturon-resistant grass, *Phalaris minor* in North India. The entire rice-wheat area of 10 million ha is affected by the resistant biotype of *Phalaris minor* in the Indo-Gangetic plains. The problem is more serious in a 5 million ha area. To overcome the problem of lower yield and weed infestation, zero tillage and modified crop establishment practices are being suggested with the availability of new machinery and application of herbicides in rotation for weed control to improve the crop yield.

Zero till cultivation is sustainable way of crop production

To overcome the problems, Indian specialists have suggested an integrated approach for cropping wheat in zero till condition. There is already some area under wheat planted with the zero till system in India. The zero till wheat in rice-wheat cropping system has been addressing in the several issues of sustainability and its success has encouraged the farmers to adopt the double no till practice for long term sustainability of the system.

The major benefits (Gupta and Sayre 2007a, Gupta and Seth 2007b, Saharawat *et al*. 2010) of zero till technology include :

- Reduced costs due to savings in the fuel and labour.
- Timely planting of *kharif* and winter season (*rabi*) crops, resulting in higher yields.
- Saving of irrigation water (up to 15-20%).
- Improved input use efficiency because of better crop stands due to good seed and fertilizer nutrients placements.
- Reduced weed density

In zero till system residues, when retained on the soil surface, serve as physical barrier for emergence of weeds, moderate the soil temperature, conserve soil moisture, add organic matter and improve the nutrient-water interactions. The innovation of zero tillage devices advances the wheat sowing 15 to 20 days and also cuts the production cost of wheat in rice-wheat cropping system. Farmers adopting zero-tillage can saves Rs 2000 to 2500 per hectare compared to conventional tillage, which can make savings and stabilize profits for farming community (Singh *et al.* 2007).The success of zero tillage technology will greatly improve the chances of increasing cropping intensity in Indo-Gangetic plains. Zero tillage of wheat may also lead to early emergence of wheat and no or less soil disturbance in cropped area resulting in less and late emergence of weeds (especially *P. minor*).

Zero tillage in cereal systems have helped in saving fuel, water, reduce cost of production, improve system productivity and soil health (Malik *et al.* 2005, Gupta and Sayre 2007a, Gupta and Seth 2007b, Saharawat *et al*. 2010). Residue management in zero till systems (surface retention) helps in improving soil health (Sharma *et al.* 2008) reducing GHG emission equivalent nearly 13 t/ha (Mandal *et al.* 2004) and also regulates canopy temperature at grain filling stage to mitigate terminal heat effects in wheat (Jat *et al.* 2009, Gupta *et al.* 2010). Verma and Srivastava (1989) conducted an experiment to study the effects of tillage and weed control methods on energy output (MJ/ha) and water use efficiency (WUE) of wheat grown after puddled rice. Energy output and water use in wheat grown with optimum tillage were higher than with zero tillage. However, energy use efficiency (EUE; energy output: energy input ratio), energy productivity (g/MJ) and WUE were not affected by tillage methods. Cultural (2 hand hoeings) and chemical (1kg 2,4-D/ha post-emergence) methods of weed control were superior to the unweeded control in terms of energy use efficiency (EUE), energy productivity and water use efficiency (WUE). There are several hypotheses for this.

Zero till and weed management

Reluctance on the part of farming community in adoption of zero tillage sowing of wheat in a large area is mainly associated with management of weeds. In zero tillage, herbicides functions are extended and the herbicides use for weed control in conventional tillage is not expected to be essentially suitable for zero tillage also in view of varying weed intensity and flora. Hence, it is of paramount importance to work out weed management technology in zero tilled wheat. Mukhopadhyay and Rooj (1971) were the first to conduct the work on zero tillage in West Bengal (India) by using the non selective herbicide paraquat and reported that zero tillage +3.75 l/ha of

Table 2. Treatments effect on total weed population at 45 days after sowing and paddy yield

Treatment	Weed population		Paddy yield (kg/ha)
	Number (m^2)	% mortality over control	
Non cultivation+ paraquat 1.25 lit/ha	82	65.1	1380
Non cultivation+ paraquat 2.50 lit/ha	51	78.5	2250
Non cultivation+ paraquat 3.75 lit/ha	42	82.3	2400
Non cultivation+ paraquat 5.00 lit/ha	34	85.3	2390
Preparatory cultivations (two) + hand weeding at 3 weeks	64	72.0	2380
Control (no ploughing and no weeding)	238	-	1330
LSD (P=0.05)	20	-	287

Sources Mukhopadhyay and Rooj (1971)

paraquat application produced more rice yield as compared to conventional tillage supplemented with one hand weeding (Table 2). Wheat crop grown as succeeding crop in same field also obtained more grain yield in zero tillage as compared to conventional tillage. Hence, it was realized that chemical weeding with application of non selective herbicide along with more residual toxicity would be a key factor for success of zero tillage.

For the past 10 years, the evolution and acceleration of zero tillage in Haryana have been one of the few big ideas in introducing conservation agriculture. In India, the rapid and widespread adoption of ZT started in the Haryana state. In Haryana, many farmers grow late-maturing fine-grained rice varieties (e.g., basmati) causing late sowing of wheat and the widespread incidence of the weed *P. minor*. Therefore, ZT was found helpful not only in reducing the cost of tillage but also in increasing the wheat yield. The demand for zero tillage is driven not only because it assists in better weed control but also it will replace the lengthy procedure of wheat sowing.

Gill and Kumar (1975) recorded that the differences in maize grain yield due to different tillage treatments were significant during 1971 but not in 1972. In 1971, one cultivation before sowing reinforced by paraquat application gave a maximum yield of 3700 kg/ha compared with 3550 kg/ha for normal tillage. Both treatments gave significantly higher yields than zero tillage and cultivation without application of paraquat. Rivera *et al.* (1982) while studying the effect of broad leaf herbicide (applied after harvest), prior to sowing zero tillage soyabeans, observed weed control in the soybeans with application of oryzalin 1-1.5 lb/ac did not adversely affect the yield. Mandal *et al*. (1994) conducted an experiment to compare the performance of winter oil seed crops under two tillage treatments, zero and conventional tillage and observed that in zero tillage, weeds were suppressed by the application of herbicide (paraquat) before sowing. Greater seed yields (27%) were achieved with conventional tillage as compared with zero tillage. However, safflower and *Linum usitatissimum* showed no significant difference in seed yields between two tillage systems in the 2nd year. Moorthy *et al.* (2002) observed that both the tillage practices (zero tillage and conventional tillage) have similar weed control efficiency with application of butachlor or supplemented with hand weeding resulted in better crop performance. Tomar *et al*. (2003) observed that in wheat crop conventional tillage and application of pre and post-emergence herbicides (pendimethalin 50 EC at 2.0 litres/ha and isoproturon 2.0 kg/ha), *Fumaria parviflora* was the dominant weed species (53.4%) followed by *Cyperus rotundus* (18.0%), while in zero tillage, *C. rotundus* was the dominant (81.1%) weed species followed by *F. parviflora* (11.1%). Weed growth (biomass and population) was significantly affected by weed management practices.

Malik *et al*. (1998) reported that in fields infested with problematic weeds, the saved time in ZT could be used for stimulating weed emergence followed by effective control with a non-selective or selective herbicide. The success of zero tillage technology will greatly improve the chances of increasing cropping

Table 3. Interaction effect of crop establishment method and weed control treatments on rice grain yield (kg/ha)

Weed control treatment	Zero till transplanting yield (kg/ha)
Ethoxysulfuron 15 g/ha	9050
Ethoxysulfuron 30 g/ha	8940
Ethoxysulfuron 60 g/ha	9260
Anilofos 400 g/ha	7900
Ethoxsysulfuron 30+anilofos 375 g/ha	9260
Weedy	7590
Weed free	967

Sources Godara *et al.* (2003)

intensity. Godara *et al*. (2003) among the herbicidal treatment reported higher grain yield of zero till transplanted rice with application of ethoxysulfuron 60 g/ha followed by ethoxysulfuron 15 g/ha (Table 3). The above findings suggest that zero tillage are 'divisible' nature and flexible in operation allowing farmers to benefit from them under drivers situations.

Zero till reduce the weed population

Tillage influences weed infestation, and thus interaction between tillage and weed control practices are commonly observed in crop production. Adequate tillage checks and delays the emergence of weeds and provides a more favourable environment for early crop establishment. In addition to this, decomposition of crop residues kept on the soil surface possibly release allelo-chemicals which further strengthen the inhibitory effects on weed seed germination and early growth and development of weed plant. The studies on long-term trials on zero till have shown that *Phalaris minor* stand decreased over the three-year period because of the combined effect of the herbicides and zero tillage (Rice-Wheat Consortium and CIMMYT 2003). High input use without any significant yield gains and without compensating in the form of increased price of wheat have drained farmers of cash and squeezed them into financial difficulties. Zero tillage, therefore, can help farmers to pay for new herbicides.

Weed shifting in zero tillage

With traditional tillage, seed bank of the weeds buried in sub-surface soil layers comes to the surface. When rice is established as a puddled transplanted crop, lighter seeds float on water and get deposited on the soil surface. Main reason for change of weed flora seems to be the use of herbicides for control of grassy weeds and non-adoption of any measure to control broad leaf weeds in wheat over the time. This increases population of perennial and broad leaf weeds in the zero-tillage system. Also control of *Phalaris minor* reduces competition for other weeds. Thus it seems that several factors have contributed to shifts in weed composition. The long term site where ZT has been practiced for many years has seen no major shift in weed flora. Malik *et al*. (1998) found a change in the weed spectrum in ZT wheat fields particularly an increase in the population of broad leaved weeds (Table 4). Bayan *et al*. (1999) found that weeds were the major problem of rice crop and with the help of tillage practices, weed growth can be reduced. Minimum and zero tillage techniques can replace conventional tillage operations under widely varying conditions of climate, weeds and soils without causing reductions in rice yield.

Singh *et al.* (2002b) found in his long term experiment in Karnal (Haryana) that the intensity of *P. minor* decreased by 30-40% in ZT when compared to conventional tillage, while the intensity of broad leaf weeds increased. Laxmi *et al*. (2003), reported that 51% of farmers in Haryana and 85% of farmers in Bihar perceived that weed infestation had decreased due to adoption of ZT in wheat. The lower *P. minor* population and dry weight was recorded under ZT and higher under conventional tillage system of wheat cultivation. The less weed problem under ZT may be due to less soil disturbance helping in keeping the weed seeds at depth from where it could not germinate. Unchecked weed growth during crop season caused maximum yield loss in conventional tillage. In Pantnagar, average of ten year data revealed that there is less intensity of weeds specially *P. minor, Melilotus* spp. and *Polygonum* spp. in ZT wheat as compared to wheat sown by conventional practice at 30 DAS, resulting less infestation of weeds and less competition with crop. The grain yield obtained was also higher in zero tillage wheat over the conventional (Table 4).

Singh *et al*. (2005), recorded highest weed dry matter in zero tillage rice (ZTR) than in direct seeded rice (DSR)

Table 4. Effect of different establishment methods in rice-wheat system on weeds situation in wheat crop at 30 DAS at Pantnagar (average of 10 years)

Establishment systems	Weed density (no./m^2)							
	ZTW	CTW	ZTW	CTW	ZTW	CTW	ZTW	CTW
	P. minor		*Melilotus* spp.		*Polygonum* spp.		Grain yield (kg/ha)	
TPR	34	34	7	13	30	48	3600	3700
WSR	11	15	5	15	35	126	3700	3700
DSR	14	27	6	8	23	117	3900	3800
DSRAF	10	21	4	11	34	69	3800	3700
ZTR	8	8	9	6	20	147	3800	3800
Average	15	21	6	11	28	101	3800	3700

Sources TPR-Transplanted rice, WSR-Wet seeded rice, DSR-Direct seeded rice, DSRAF-Direct seeded rice after flood irrigation, ZTR- Zero tillage rice, ZTW - Zero tillage wheat, CTW - Conventional tillage wheat

Table 5. Interaction effect of rice establishment and weed management on total dry matter of weeds (g/m^2) and grain *yield* (kg/ha) of rice

Rice Establishment	Weed management									
	Weed dry matter (g/m^2)					Grain yield of rice (kg/ha)				
	WC_1	WC_2	WC_3	WC_4	Mean	WC_1	WC_2	WC_3	WC_4	Mean
DSR	16.8(2.8)	0.8(0.6)	0.4(0.3)	1.2(0.7)	4.8(1.1)	1447	3618	3614	3138	2663
WSR	11.8(2.4)	1.5(0.9)	0.4(0.4)	2.3 (0.0)	4.0(1.2)	2655	3896	3926	4222	3675
ZTR	15.9(2.8)	1.5(0.9)	0.3(0.3)	3.6(1.5)	5.3(1.3)	1400	3207	3688	2939	2789
TPR	1.90(0.9)	0.9(0.7)	0.0 (0.0)	1.0(0.8)	1.0(0.6)	3876	4224	4623	4496	43.5
Mean	11.6(1.0)	0.1(0.8)	0.3(0.2)	2.1	3.8(0.1)	2344	3736	3929	3708	-

	LSD (P=0.05)	
	Weed dry matter	Grain yield of rice
Rice Establishment	0.32	127.94
Weed management	0.28	92.97
Weed management at same level of rice establishment	0.56	185.94
Rice Establishment at same level of weed management	0.58	205.39

WC_1-Weedy check, WC_2- Anilofos 1.5 kg/ha + one hand weeding at 30 DAS, WC_3-Pendimethalin 1 kg/ha + two hand weeding at 30 DAS, WC_4- two hand weeding at 30 and 60 DAS, DSR: Direct seeded rice, TPR: Transplanted rice, WSR: Wet seeded rice, ZTR: Zero tillage rice.

(Table 5). The higher grain yield (4304 kg/ha) was obtained by transplanting (TPR) than wet seeding (WSR), zero till (ZTR) as direct seeded rice (DSR). The maximum yield of rice was achieved by the application of herbicides supplemented with two hand weeding at 30 and 60 DAS gave significantly higher yield of rice than the pre emergence application of herbicides supplemented with one hand and two hand weeding. They also found changing in weed spp. composition depending on the establishment method with wet direct dry seeding *Fimbristylis milliacea* and *Ischaemum rugosum,* with zero tillage, *Echinochloa colona* and *Cyperus rotundus* and with dry drill seeded rice, *Echinochloa crusgalli*, *Cyperus iria* and *Cyanotis axillaris* were increased.

Herbicides used in zero tillage (ZT)

In zero tillage, herbicides functions are extended and the herbicides use for weed control in conventional tillage is not expected to be essentially suitable for zero tillage also in view of varying weed intensity and flora. Hence, it is of paramount importance to work out weed management technology in zero tilled wheat.

Bio-efficacy of different herbicides was tested under ZT condition (Table 6). Recommended herbicide, isoproturon 1.0 kg/ha was compared with its higher rates and other herbicides *viz.*, clodinafop, sulfosulfuron and manual weeding. Application of any of the herbicides, isoproturon, clodinafop or sulfosulfuron effectively controlled the weeds. Wheat yield was obtained at par with application of isoproturon 1.0 kg/ha, clodinafop 60 g/ha and sulfosulfuron 25 g/ha. Thus weed management in ZT sown wheat was same as crop sown after conventional tillage. The weeds can be effectively controlled by the application of isoproturon (1 kg/ha), sulfosulfuron (25 g/ha) or clodinafop (60 g/ha). All the herbicides are recommended for the application in zero tillage wheat at

Table 6. Effect of different herbicidal treatments on density, dry weight of weeds and yield in ZT sown wheat

Treatment	Dose (g/ha)	Stage of application (DAS)	Weed density at 60 DAS (no./m^2)	Weed dry wt. at 60 DAS (g/m^2)	Yield (kg/ha)
Weedy	-	-	263	265.6	1909
Isoproturon	1000	30	28	12.1	4521
Paraquat *fb* isoproturon	500 *fb* 1000	BS *fb* 30	13	7.3	4606
Isoproturon	1500	30	5	9.7	4870
Isoproturon *fb* isoproturon	1000 *fb* 1000	20 *fb* 35	7	3.4	4394
Isoproturon + 2,4-D	1000 + 500	30	12	2.5	4876
Clodinafop	60	30	58	13.6	4594
Clodinafop *fb* 2,4-D	60 *fb*500	30 *fb* 40	27	5.2	4846
Sulfosulfuron	25	30	11	4.2	4921
Hand weeding	2	30 and 45	37	6.1	4636
LSD (P=0.05)	-	-	17	5.2	381

Source: NATP, 2001, *fb* - Followed by, BS- 7- days before sowing,

Zero till effect on yield

Bhardwaj *et al.* (2004), found that the potential yield of wheat was increased up to 8% at Pantnagar. Zero tillage (ZT) and conventional tillage (CT) have been compared in number of field experiments over the years. When the crop under the two systems was sown on same date, yield was at par or slightly higher under ZT. In Pantnagar, the different establishment methods used in a long term rice wheat cropping system (10 years) showed that wheat grain yield was higher in zero tillage practice over the conventional practice (Fig. 1).

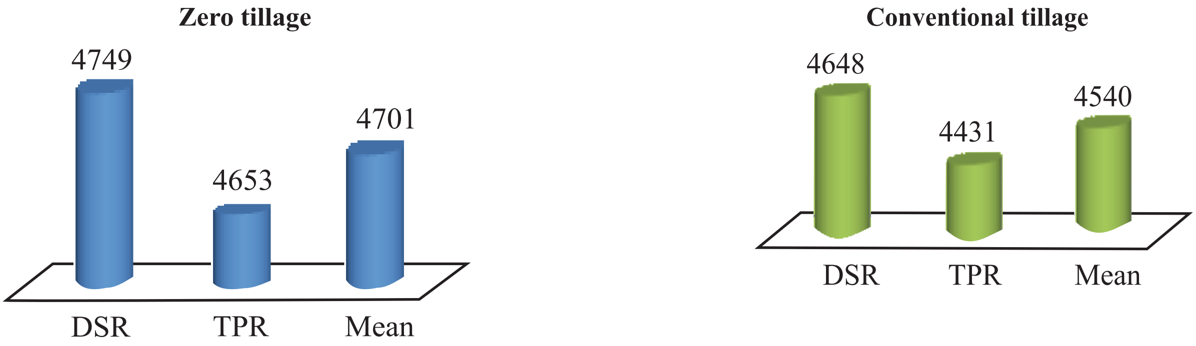

Fig. 1. Effect of rice wheat establishment methods on wheat grain yield (kg/ha) at farmers field (average of 10 yrs.)

Both long-term trial and farmers' field surveys suggest a change in the weed spectrum in ZT wheat fields. Trials conducted at 5 locations in Indo-Gangatic plain (IGP) under National Agriculture Technology Project (NATP) showed higher grain yield of wheat in zero tillage practice in four locations *viz.,* Pantnagar, Faizabad, Varanasi and Patna and it was at par with conventional practice of wheat growing at Ludhiana location (Fig. 2).

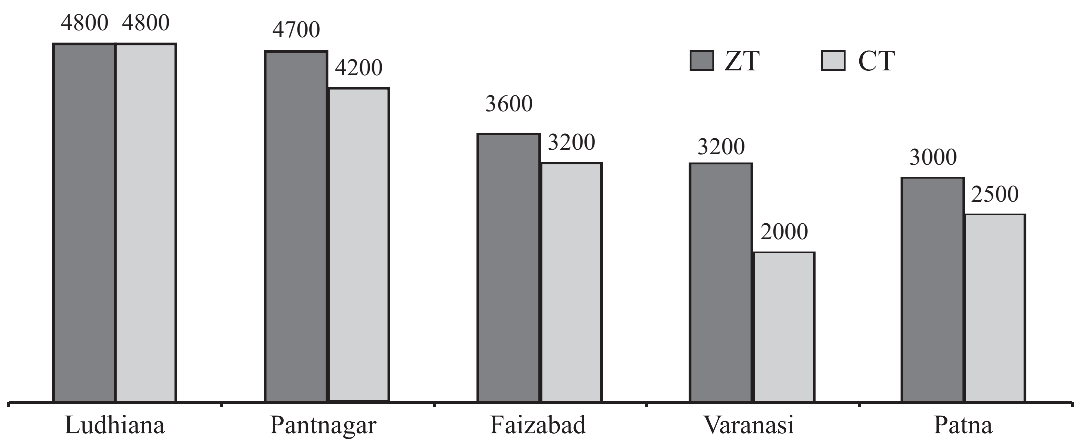

Fig. 2. Wheat yield (kg/ha) under two tillage systems *viz.*, zero tillage (ZT) and conventional tillage (CT) at five different locations

Singh *et al.* (2004), also reported that the minimum weed population was recorded in ZT sown crop which was significantly less than CT sown wheat (Fig. 3). Rahaman and Mukherjee (2006), while studying the effect of different tillage practices and herbicides observed that CT+ pendimethalin have more weed control efficiency and higher grain yield than zero tillage with application of different herbicides (Table 7), Moorthy *et al.* 2002 found significantly higher grain yield of wheat with summer deep tillage and conventional tillage in direct seeded rice followed by conventional tillage in succeeding wheat (4590 kg/ha) compared with zero tillage (4110 kg/ha). Maximum grain yield (4720kg/ha) was obtained with two hand weedings, which was significantly higher than herbicides alone (4070 kg/ha).

Table 7. Effect of treatments on weed dry matter, weed control efficiency and grain yield of wheat

Treatment	Weed dry wt. (g/m^2) at 60 DAS	Weed control efficiency (%) at 60 DAS	Grain yield (kg/ha)
ZT	51.6	-	1033
ZT+2,4-D	29.8	42.2	1383
ZT+glyphosate+2,4-D	14.8	71.1	1893
CT+2,4-D	12.5	71.3	2180
CT+isoproturon	26.5	37.5	1940
CT+pendimethalin	6.8	83.9	2240
CT+weedy plot	42.4	-	1366
CT+weed free plot	-	-	2306
LSD (P=0.05)	1.7	-	211

ZT - Zero tillage, CT - Conventional tillage

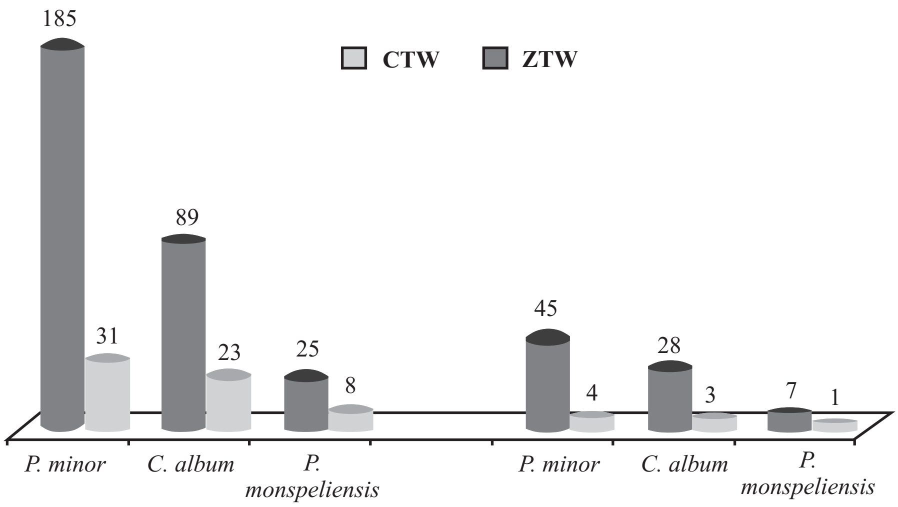

Fig. 3. Effect of establishment methods on weed density in conventional tillage wheat (CTW) and zero tillage wheat (ZTW) in wheat at 30 DAS

Conclusion

Zero tillage primarily has a positive environmental impact (savings of fossil fuel, reduced emissions of greenhouse gas, water savings), and this would enhance the social returns to the research and development investment. The water savings in the wheat crop are particularly interesting in view of excessive groundwater exploitation in intensive rice-wheat growing areas. Further research to substantiate and value the environmental impacts is needed. There is also significant scope for enhancing the environmental impact of ZT in rice-wheat systems. Two areas that merit particular attention in this respect are management of crop residue and shifting towards direct-seeded aerobic rice. Permanent practicing zero tillage reduced weed seed bank as compared to disturbed soils, and less weeds emerged succeeding year if, further multiplication of weeds seeds is checked. Residue retention or inclusion of cover crops (Sesbania, cowpea, moongbean *etc*) have added the advantage of suppressing weeds in zero tillage. Crop residue and cover crops reduces weed germination and emergence by altering the soil temperature, release of the phytototoxins, soil pH and sun light (intensity and quality). Weed seed predation due to increased population of beneficial insects that consume weed seeds have been reported by Brust and House (1988), Kjellson (1985), Manley (1992), Westerman *et al*. (2003). Time and resources saved through ZT are variously used by the adopting farm households for productive and social, purposes. The challenge remains to extend these gains to the less-endowed areas of the IGP, where it has significant potential and can contribute to poverty alleviation. The combined yield increase with cost savings implies that returns to ZT adoption is pretty robust, thereby significantly reducing the risk of adoption. Most studies report on the technical and private financial gains of ZT at plot level with limited documentation of socioeconomic, livelihood, and environmental impacts. Zero tillage therefore offers high potential economic, environmental, and social gains in the Indo-Gangatic plain (IGP). This implies moving beyond mere production cost savings to natural resources savings and using ZT as a stepping stone to conservation agriculture. Zero tillage is also no panacea, and complementary resource conserving technologies that are privately and socially attractive are needed. However, further research, some of it already initiated, is needed to substantiate these impacts more rigorously. At the same time, the current use of ZT only for wheat limits the extent of some of the potential environmental gains. Environmental gains are likely when the whole rice-wheat system converts to year round conservation agriculture.

Future thrusts

- Development and adoption of zero tillage and modified crop establishment practices aimed that at resource conservation have a long term and broader perspective, which go beyond yield improvement.
- Successful adoption of conservation technologies call for greatly accelerated effort In development suitable machinery along with water, nutrient and weed management techniques for a wide range of crops and cropping system.
- Zero tillage practices set in processes which initiate changes in soil physical, chemical and biological properties, which in turn, affect root growth and crop yield. Understanding the dynamics of these changes and interactions is basic to developing improved soil, water, nutrient and weed management strategies.

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