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Final report

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1 Acknowledgments

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In Australia the support and encouragement of Twynam Agriculture and its Principal Johnny Khalbetzer is also acknowledged.

We acknowledge permission from the Tasmanian Institute of Agricultural Research and Caring for Our Country, as the funding body, to use extracts from Geoff Deans final report “Increasing the adoption of stubble retention and direct drilling practices by Tasmanian farmers through the use of revolutionary new machinery”, in the preparation of this report

In these drought affected years the opportunity to use experimental sites at DPI Yanco and the help of Harnam Gill was also appreciated.

In 2009 Chairman of Murrumbidgee Irrigation Dick Thompson allowed us access to one of the few channel irrigated rice crops in Australia where we successfully demonstrated the latest "Rocket" seeder, thanks Dick.

All the participating farmers and other institutions in Pakistan and Australia are gratefully acknowledged.

2 Executive summary

The main achievement of the project has been the development of a new generation machine the “FMI Rocket Seeder” based on a new principle of cutting loose residues only in the planting rows, rather than lifting or manipulating the entire residue load as in the FMI Seeder. This new machine is novel and represents a major breakthrough. It is light-weight, compact, requires significantly less power, is suitable for commonly available tractors (50HP), it generates significantly less dust, has improved operator visibility, and is likely to cost significantly less than the FMI Seeder. The project team developed this concept into a viable prototype, which has been used extensively to plant the farmer and on-station trials in the 07/08 season. Results obtained show that the FMI Rocket Seeder technology is out-yielding conventional methods of sowing, (Burning + disking + broadcasting) and the FMI Seeder + partially straw burning seeding methods. However, to date the FMI Rocket Seeder has only been tested for one season, and further testing across a wider spectrum of soil and farm conditions is warranted to consolidate the early positive results.

The Indian Turbo approach (similar in concept to the Rocket seeder), in spite of rendering the chopping and blowing approach redundant, was unsuccessful in heavy Australian rice soils and stubbles (see previous reports). The project decided to import a Pakistani Rocket model to assess the potential for this approach under Australian conditions. The machine performed very well in 11.8t/ha of rice residue on a typical Australian rice soil, with excellent germination and emergence, which result entirely justified the importation of the machine

The FMI Seeder technology was evaluated at the Rice Research Institute farm, KSK and in farmers’ fields, for a range of stubbles, site, sowing and seasonal conditions. The main emphasis was on the establishment of wheat in rice stubbles. Field days were organized to demonstrate the machinery in operation and crop performance to farmers, machinery manufacturers and government officials. A local manufacturer M/S Sayyed Machinery Ltd Lahore is already involved as a collaborative manufacturer.

These significant achievements were attained despite a number of operational problems the project experienced. These included a change of over all Project Leader and commissioned agent and more importantly, cash flow constraints such as lengthy procedure for encashment of the cheques (It took 4-14 months) and delay in releasing funds to the Pakistan project team.

Australian results have been confounded by the prolonged drought resulting in very little rice being grown over the duration of the project. (See previous reports). The Twynam Happy seeder was duly completed and tested successfully but as previously reported was superseded by the development of the Dasmesh Turbo Happy. A Turbo Happy was imported but failed to live up to its Indian ability in trials in Australia in heavy rice stubbles and heavy wet soils. (See previous report.)

On Blackwell's last trip to Pakistan and India he noticed that all manufacturers had now adopted a concept variation of the straight high speed blades closely sweeping each tine which he first saw on the Pakistan Rocket development. This prompted the importation of a Rocket seeder which performed very well under this years Australian conditions in one of the few channel irrigated rice crops in the MIA with a 11.8 t/ha stubble load.

3 Background

Wheat and rice crops are grown in Pakistan on 8.5 and 2.5 million ha, respectively. Late maturing Basmati rice varieties cover more than 55 percent of the rice area. This results in a very short turnaround time between the rice and wheat crops (less than 10 days) and wheat sowing often gets delayed beyond the optimum date.

Used European self-propelled combine harvesters are imported with about 5000 units in operation. More than 50 percent of rice crop is harvested using these combines especially in Punjab Province. These machines cut the paddy crop at a height of 40-80 cm, unless, as is often the case, the crop is lodged which may require cutting at ground level, and leave behind a swath of loose residue,

Lack of suitable machinery is a major constraint to direct drilling into combine harvested heavy rice residues. Consequently, rice stubble burning is widely practiced in the mechanized rice-wheat systems of both Pakistan and Australia. It is a rapid and cheap option, and allows for quick turn around time between crops. Burning results in the loss of organic matter and nutrients and is causing very serious and widespread air pollution in Pakistan, particularly in the Basmati growing areas of the Punjab province.

The Farm Machinery Institute (FMI), NARC, Islamabad has been involved in the design, development and commercialization of Zero Till Drills since 1987 and has developed three different models for wheat sowing into manually harvested paddy fields where the straw is usually removed. To address the straw burning issue, FMI started work in 1997 on the development of a suitable drill to sow wheat in manually as well as combine harvested paddy fields and in 1999 developed the first prototype machine named as FMI Dual Mode zero till drill (Fig.1). The main improvement in the drill was incorporation of a curved tine with cultivator spring to produce vibration to aide tine passage through loose straw lying in front of the openers and fixing of v-notched discs in front of each tine to cut/press the loose straw below semi-circular openers. The semi circular opener and disks were later replaced with Bekker boot inverted-T openers. (Fig.2). This drill performed very well in manually harvested fields, well in partially burnt fields and poorly in heavy rice residue fields (Kalwar et al 2002).

Fig. 1 FMI Dual Mode Zero Till Drill

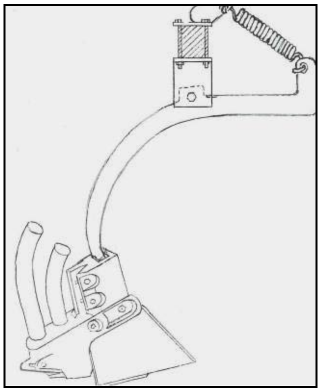


Fig.2 Curved tine with spring

FMI continued its efforts into rice residue handling and developed a paddy stubble chopper with the collaboration of local manufacturer M/S Green Land Engineers Daska. In 2002 the first proto-type unit was tested at farmer's fields near Daska (Fig.3). The prototype was a tractor mounted PTO driven machine with flappers/flails hinged on a rotor that rotates at a speed of 1200rpm; its work capacity was 1 acre an hour. It performed well in evenly distributed heavy residues but subsequent penetration of disc seeders into the chopped residue was a problem (PARC AR2002).

Fig.3. Paddy stubble chopper machine

3.1 Development of the FMI Seeder

After preliminary testing of the stubble chopper and elucidation of the disc penetration problems, FMI started working on the combination of stubble chopper and Dual mode zero till drill for handling rice residue and seeding simultaneously in a single operation. The first prototype unit was developed and tested in farmer fields during 2003 (Fig.4). The design was based on the CSIRO patent design, the first embodiment of which, the Indian Happy Seeder, was exposed to the international Rice wheat Consortium at their meeting in Nepal on the 5th May 2003.

The first prototype was modified to increase its work rate from (0.2 to 0.25 ha/h). The prototype unit was further modified to improve its work rate to 0.3 ha/hr, its weight was reduced from 620 kg to 550 kg, flail weight was increased from 0.8 kg to 1.0 kg for better straw throw and all parts were designed according to PSI standards. This modified machine was named the “FMI Seeder” and is shown in figures 4 and 5.

Fig.4. First prototype unit of FMI Seeder

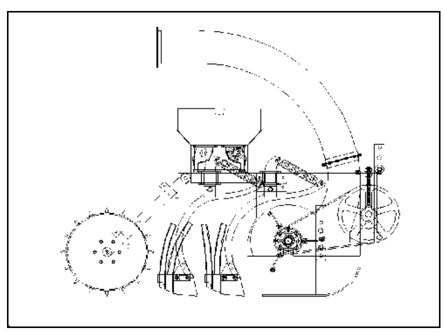


Fig.5 Schematic view of FMI Seeder

The FMI Seeder technology, which combines mulching and direct drilling functions is capable of making a significant contribution to sustainability and air quality issues, and could generate substantial economic benefits in Pakistan. These benefits arise from agricultural production, resource management, environmental and human and animal health improvements. The extent and rate of adoption of this technology is, however, critical to the realization of these benefits.

The prospects of successful operation of FMI Seeder were quite high for direct drilling of wheat in combine-harvested paddy fields. However, there were a number of issues to be resolved to achieve good crop establishment and crop performance. These include;

- Optimal operation required even spreading of the residues,
- Weight of mulch that the machine could handle and the crop can establish through,
- Maintenance of an even sowing depth,
- Soil moisture required at the time of sowing,
- Would all soil types be amenable to the approach and
- What changes would be required of irrigation management.

In addition to the need to develop strategies to reliably achieve good establishment, strategies for agronomic management in the presence of thick mulch, such as time and depth of sowing, N and irrigation management need to be developed. There was clearly need to evaluate and refine the technology for a range of residue, soil, sowing and seasonal conditions. Guidelines need to be developed for achieving good establishment, efficient use of N fertilizer and irrigation water, and high yields in Rice-Wheat and alternative systems.

4 Objectives

The overall goal of this project was to contribute to the development and implementation of profitable and more environmentally sustainable irrigated rice-wheat cropping systems in Pakistan and irrigated cropping systems in Australia.

4.1.1 Objective 1.

To evaluate and refine the FMI Seeder in Pakistan, and to increase the uptake of the new direct drilling technology by farmers in Pakistan and Australia

Objective 1 achieved through:

1.1 Evaluation of the field performance of the machines

1.2 Sharing of experience and ideas among Pakistani, Indian and Australian engineers and agronomists

1.3 Evaluation of the performance of crops sown with the FMI Seeder

1.4 Financial analysis of the technology

1.5 Previous reports have highlighted the decision not to persist with the Twynam seeder approach because of the improvements embodied in the Indian Turbo machine and the subsequent inability of the Turbo seeder in handling Australian rice residue and soil conditions

1.6 The Rocket seeders tine and flail design has proven capable of handling Australian conditions. This tine and flail design is now adopted by all Indian manufacturers; however none of the sub-continent machines lend themselves to scale up to broad acre machines. This challenge still remains.

1.7 The Turbo seeder supplied to TIAR Tasmania was successfully demonstrated on a variety of crops following modifications to bring it into line with the current models from both Pakistan and India.

4.1.2 Objective 2.

To encourage the manufacture of FMI Seeder in Pakistan by extending the new direct drilling technology to farmers in Pakistan and Australia

Objective 2 achieved through:

2.1 Production of technically sound prototypes of the FMI Seeder

2.2 Documentation and distribution of machinery design of the FMI Seeder

2.3 Field demonstrations of the machinery in action in farmers' fields

2.4 Field days to demonstrate crop performance in on-farm trials

2.5 Production and distribution of guidelines on machinery operation and crop management for crops sown with the FMI Seeders

2.6 Presentations to policy makers and influential senior government officials

5 Methodology

5.1.1 Site selection

The objective was to setup a replicated experiment suitable for long-term evaluation of the FMI Seeder when direct drilling wheat into full mechanically harvested rice residues.

In order to study the residue effects on germination of wheat and application of different nitrogen rates, three sites were selected in R-W areas in Zone II near Lahore; one at the Rice Research Institute, Kala Shah Kaku (KSK), and two at farmers' fields namely, Ch. Mushtaq (CM) Farm, village Kot Nazir near KSK and Shahbaz Ali (SA) Farm, Village Ratan Singh near Murid Kay. Wheat was sown with different sowing methods on 3.5 acres at each site for yield comparison. At KSK site, the plots were further divided into two parts for replicated (N rates) and non-replicated plots with the view of continuing these trials on a long term basis i.e. beyond the current project life.

The following map shows the location of the three sites.

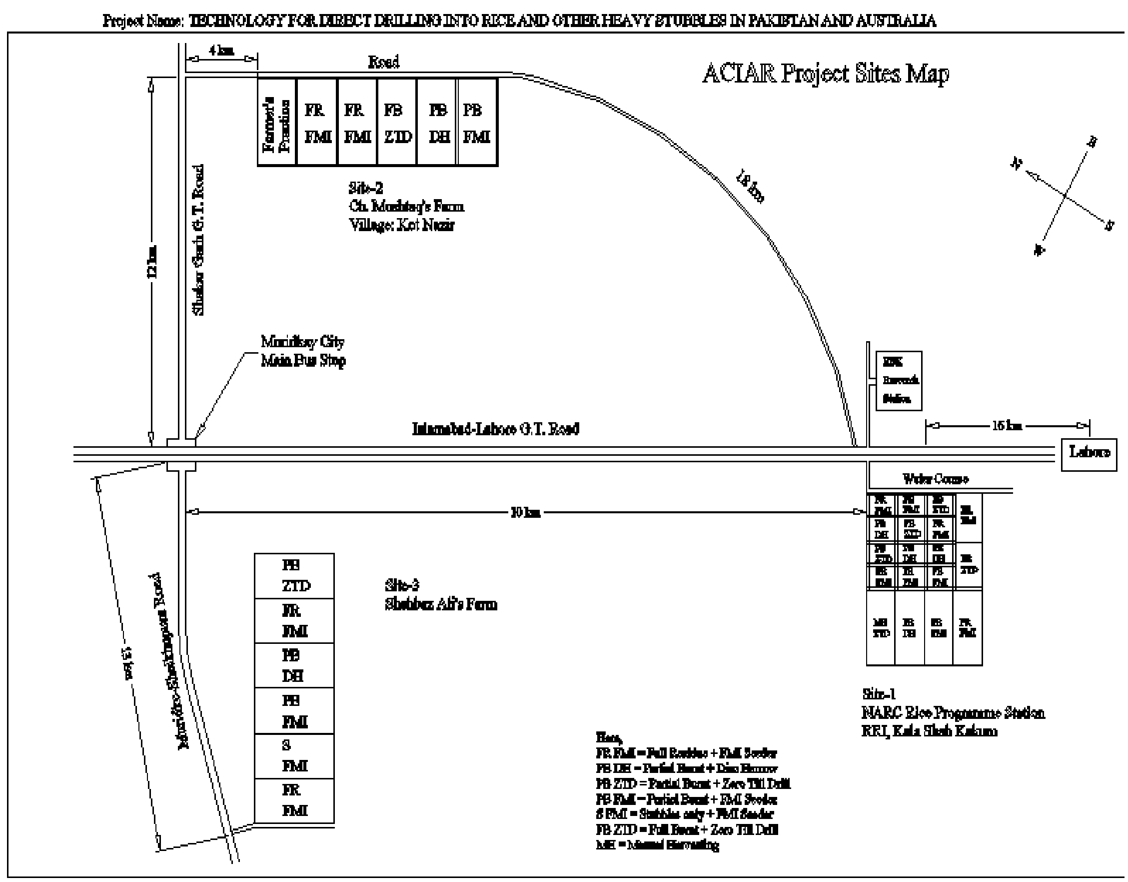


Fig.6 Location map of the project sites

5.1.2 Farmer's field trials

The sites were used for three years to compare the yield under different sowing methods using the FMI Seeder in different soils. These sites were selected within a radius of 20 km of KSK so that they could be managed efficiently by the project agronomist stationed at KSK. Experiments were established at CM and SA farms on six plots, each plot was half an acre, however at KSK five plots were selected and each plot size was about ¼ acre. The following treatments without replication were installed on the farmer's fields for yield comparisons:

(i) FMI Seeder, straw retained (early sowing)

(ii) FMI Seeder, straw retained (one week later sowing)

(iii) FMI Seeder after partial burning

(iv) Zero till drill after manual harvesting (full straw removal)

(v) Conventional (partial burning, discing, broadcast seeding)

(vi) Farmers' practice at CM, and SA only

5.1.3 Long-term replicated experiment at Kala Shah Kaku

Wheat sowing method x N rate

Replicated experiments were established at KSK with application of 4 different Nitrogen fertilizer rates (0.5, 0.75, 1 and 1.25 x the recommended rate of 100Kg/Ha). The main plot treatments (3 replicates) were:

(i) FMI Seeder, straw retained (6.5-8.5 t/ha dry) green in plan

(ii) FMI Seeder after partial burning light green in plan

(iii) Zero till drill in manually harvested field (Complete straw Removal) yellow in plan

(iv) Conventional (partial burning, disking, planking and seed broadcasting) mauve in plan

Fig. 7 Randomized block design of N Fertilizer rates at RRI, Kala Shah Kaku

Rep 3	ZTD partial burn				FMI full residues				Disc partial burn				FMI partial burn			
	75 kg urea/ac	100 kg urea/ac	50 kg urea/ac	125 kg urea/ac	125 kg urea/ac	50 kg urea/ac	100 kg urea/ac	75 kg urea/ac	125 kg urea/ac	100 kg urea/ac	75 kg urea/ac	50 kg urea/ac	75 kg urea/ac	50 kg urea/ac	100 kg urea/ac	125 kg urea/ac
Rep 3	FMI partial burn				ZTD partial burn				Disc partial burn				FMI full residues			
	50 kg urea/ac	125 kg urea/ac	75 kg urea/ac	100 kg urea/ac	50 kg urea/ac	100 kg urea/ac	75 kg urea/ac	125 kg urea/ac	50 kg urea/ac	125 kg urea/ac	75 kg urea/ac	100 kg urea/ac	125 kg urea/ac	100 kg urea/ac	75 kg urea/ac	50 kg urea/ac
Rep 1	FMI full residues				Disc partial burn				ZTD partial burn				FMI partial burn			
	100 kg urea/ac	50 kg urea/ac	125 kg urea/ac	75 kg urea/ac	125 kg urea/ac	50 kg urea/ac	75 kg urea/ac	100 kg urea/ac	100 kg urea/ac	125 kg urea/ac	75 kg urea/ac	50 kg urea/ac	100 kg urea/ac	75 kg urea/ac	50 kg urea/ac	125 kg urea/ac

5.1.4 Machinery performance

Pakistan

Machinery performance was assessed by measuring fuel consumption, tractor speed, ease of operation, accuracy of seed placement, chaff size before and after chopping, distribution of residues on seeded rows and maximum straw load handling capability The performance of the machine with and without spreading of the loose residues, was assessed, as well as measurement of the machines field capacity and efficiency with and without residue.

Australia

Performance of all previous models of the Happy seeder, including the Twynam seeder built with Twynam money has been documented in previous reports. This report will include results of a field demonstration using the imported Pakistan Rocket seeder.

5.1.5 Crop performance

Pakistan

Crop establishment, crop growth, yield and yield components and N uptake was recorded over the three years.

Australia

As reported previously the lack of rice crops due to the drought has precluded the establishment of replicated field trials. The 2009 season wheat crop demonstration on Dick Thompson's farm has proved the techniques ability in very heavy rice stubble (11.8 t/ha)

5.1.6 Soil Sampling and analysis

Soil samples from all sites in Pakistan were collected at different depths before sowing and after harvesting of the wheat crop. Soil analysis was conducted at the NARC laboratories. See Appendix 1

5.1.7 Sharing of experience and ideas among Pakistani, Indian and Australian engineers and agronomists

Engineers, scientists, manufacturers and farmers of India and Pakistan visited each others countries to share their experiences regarding handling of rice residue and machinery development.

The reciprocal visits between the Australian and Pakistani researchers have allowed a good cross fertilisation of ideas, both on concept and machinery development. The Pakistani delegation gained enormous benefit from their visits to Australian Manufacturers and farmers.

5.1.8 Production of technically sound prototypes of the FMI seeder

Production of prototypes of the FMI Seeder, Rocket Seeder and straw spreading kit were supervised by Shabbir Kalwar and his team at the workshop of a collaborative manufacture Sayyed Machinery Ltd, Lahore.

5.1.9 Documentation and distribution of machinery design of the FMI Seeder and FMI Rocket Seeder

Detailed manufacturing drawings of the FMI Seeder and Rocket Seeder have been developed with AutoCAD software at FMI. These as well as production guidelines have been provided to many local machinery manufacturers.

As far as the current project leader can ascertain 5 Rocket seeders have been manufactured. 3 by Sayyed machinery and 2 by United Agro a manufacturer from Daskar

5.1.10 Field demonstrations of the machinery in action and field days to demonstrate crop performance in farmers fields

Five major Machine demonstrations and three field days on crop performance have been conducted at farmers' fields to demonstrate the machinery in action, as well as subsequent crop performance. These demonstrations were attended by farmers, agricultural machinery manufacturers and dealers, machinery contractors, rental companies, and the media, including the daily one hour State TV programme "Kissan times" ("Farmers Time")

Extension workers from Provincial departments and from PARC's Provincial Technology Transfer Institutes were also present.

Provincial Ministers, from the Government of Punjab, secretaries of government agencies responsible for environmental management and NGO's attended the field days.

5.1.11 Presentations to policy makers and influential senior government officials

Papers were presented at national level workshops, conferences and the machines exhibited on the occasion of a visit by the President and Prime Minister, and the Federal Agricultural Minister.

6 Achievements against activities and outputs/milestones

Objective 1: To evaluate and refine the FMI Seeder in Pakistan, and to extend the uptake of the new direct drilling technology by farmers in Pakistan and Australia

no.	activity	outputs/ milestones	completion date	comments
1.1	Evaluation of the field performance of the machines	Two different versions of machine namely FMI Seeder and FMI Rocket Seeder were designed, and developed and tested in farmers field	Dec 2008	The Rocket Seeder performed well in terms of fuel consumption, field capacity and efficiency - is light weight (425 kg) and requires less power than the FMI Seeder. The Twynam seeder was superseded by the Turbo/Rocket approach. The imported turbo was not capable of handling Australian conditions. The imported Rocket did and all Indian machines now incorporate the same improvements to the cutting blade/tine relationship. (See previous reports)
1.2	Sharing of experience and ideas among Pakistani, Indian and Australian engineers and agronomists		April 2008	All key representatives from Government, NGO's, Extension departments, manufacturers and farmers participated. Also the new version of the FMI Rocket Seeder was exhibited during the occasion. An Indian delegation visited Pakistan twice and a Pakistani Delegation including engineers, scientists, manufacturers and farmers crossed the border into India Australian engineers/partners visited Pakistan many times. The Pakistani team visited Australia twice over the life of the project These visits provided good opportunities for the participants to share their experiences. A field seminar was organized at the KSK site, where Christian Roth also participated.
1.3	Evaluation of the performance of crops sown with the FMI Seeder	Three permanent experimental sites were selected one at Rice Research Institute, Kala Shah Kaku and two at farmers fields and used for the entire project life. Six different sowing methods were tested on an area of 1/2 acre. At	June 2010	The over all performance of crop sown in full residue plots was good however performance with FMI Rocket Seeder was better than FMI Seeder in terms of germination due to lower load of straw on seeded rows In Australia we were not able to establish replicated trials. (See

		KSK also replicated trials on different N rates were conducted and continued to the 4th year		previous reports) One farm demonstration into the 2009 harvested rice crop proved the efficacy of the approach under Australian conditions
1.4	Financial analysis of the technology	The performance of both machines were measured and analysed in terms of fuel consumption, working capacity and efficiency and overall operational cost under different field conditions	Dec.2008	The over all benefits to the farmers was calculated at Pk R. 4500/ha using first year data of one site using FMI Seeder **compared** with farmers practi**ce** Mirani's thesis shows a cost saving of 26% over conventional farmers practice (Rs 13,924/ha)

PC = partner country, A = Australia

Objective 2: To enable the manufacture of FMI Seeder in Pakistan, and to extend the uptake of the new direct drilling technology by farmers in Pakistan and Australia

no.	activity	outputs/ milestones	completion date	comments
2.1	Production of technically sound prototypes of the FMI Seeder	Ist Batch of Five units of FMI Seeder and Five units of FMI Rocket Seeder have been fabricated at Sayyed Machinery Ltd (A collaborative manufacturer)	Feb.2009	The FMI Seeders heavy weight, expense, dust generation and poor germination under thick residue load (>7 tons/ha) and also poor workmanship militated against its adoption. The later Rocket model has been included under Government of Punjab 50% subsidy programme but has been delayed due to funding constraints Development of the FMI and Twynam models were discontinued in favour of the Rocket and Turbo models
2.2	Documentation and distribution of machinery design of FMI Seeder	Complete manufacturing drawings of the ten rows Rocket Seeder has been completed and distributed to three more local manufacturers	Feb.2009	The training of these manufacturers will be conducted in Sep.2009. and at least one unit each will be fabricated in the coming wheat sowing season

2.3	Field demonstrations of the machinery in action in farmers' field	Three major machinery demonstrations of FMI Rocket Seeder were organized in the month of Nov.2008 one at KSK where more than 300 government officials, business community, scientists, extension workers, manufacturers and farmers participated and 2nd demonstration organized at Daska (local manufacturers hub) where only agric machinery people were invited and more than fifty manufacturers participated and a third one at Gujranwala area (main hub of combine harvesters) where combine importers, distributors, repairing work shop owners, and rental companies were invited. More than 50 people participated	Nov,2008	These demonstrations were designed with specific targeted people to spread this new technology very quickly and efficiently to the farmers. Australian extension is documented later in this report
2.4	Field days to demonstrate crop performance in on-farm trials	Three field days so far organized at two locations where most of the farmers were invited. Field seminar organized at Rice Research Institute Kala Shah Kaku more than 60 scientists/ engineers, manufacturers, farmers, government officials and delegations from India and Christian Roth RPM of ACIAR attended.	Feb2008	Most of the time due to heavy rains in the months of Feb. and March, field days could not arranged and funds availability was also a limitation See Roth's correspondence with PARC. (JB 05/2010)
2.5	Production and distribution of guidelines on machinery operation and crop management for crops sown with the FMI Seeders	The two page pamphlet (handout) was published in English and Urdu in bulk quantity. The operation manual in Urdu language compiled with the help of the Institute of training and technology	Feb.2009	The operation manual of FMI Rocket Seeder will be distributed to the local manufacturers in the 2009 wheat sowing season

		transfer,(ITTT), NARC has been finalized		
2.6	Presentations to policy makers and influential senior government officials	The FMI Seeder technology has been exhibited at high level Government level at Federal as well as provincial level. President of Pakistan visited the stall of FMI Seeder during silver jubilee of PARC from 12–14 December 2006. Twice the Prime minister of Pakistan visited the stall of FMI Seeder one on 12 Nov.2008 at the time of inauguration of wheat sowing season ceremony at Kala Shah Kaku and 2nd time at Islamabad during Kissan (farmer) Convention held on 27 May 2009. One time Chief Minister of Punjab visited the FMI Seeder stall at the occasion of wheat sowing ceremony in the month of Nov.2008 at Barani (Rain fed) Agricultural Research Institute Chakwal. Provincial excise and taxation Minister inaugurated, as chief guest, the field demonstration of FMI Rocket Seeder on 20 Nov.2008 at KSK.	Dec.2008	The FMI Rocket Seeder has been demonstrated to policy makers and influential government officials.

PC = partner country, A = Australia

7 Key results and discussion

7.1.1 To evaluate and refine the FMI Seeder in Pakistan, and to extend the uptake of the new direct drilling technology to farmers in Pakistan and Australia

7.1.2 Evaluation of the field performance of the machines

A second prototype unit of FMI Seeder with major modifications to the earlier model was fabricated at the workshop of collaborative manufacturer M/S Sayyed Machinery Ltd. Lahore. This machine at first cuts the stubbles as well as picks up the loose straw lying in front of each opener of the Zero Till Drill and chops them into small pieces and spreads them uniformly over the seeded rows in a single operation.

FIG. 8 Fabrication of FMI Seeder at SML factory. Fig.9. Field testing of FMI Seeder

The machine was preliminary tested near SML factory in the farmer field The overall performance of the 2nd prototypes of FMI Seeder was satisfactory The main advantages for using FMI Seeder were;

- Timely sowing of wheat soon after rice harvesting (Without any delay)
- Substantial savings in its operating cost
- Soil moisture conservation
- Early decomposition of crop residue
- Non- chemical weed control
- Reduced environmental pollution
- Improvement in soil aeration and fertility
- Suppress weeds

After preliminary testing it was further modified and a 3rd prototype unit was manufactured at the collaborative manufactures' SML workshop near Raiwind, Lahore. A set of engineering drawings for this model was developed on Auto Cad at FMI. The main modifications in comparison with 2nd prototype unit included:

7.1.3

Reduction in weight from 680kg to 550kg to make them suitable for commonly available 50 hp tractors. Reshaping the chute for improved operator visibility, uniform straw spreading and dropping of the straw closer to machine to reduce dust, Reduction in row spacing from 20 cm to 18 cm to make more closely comply with recommended practice i.e. 15 cm and Increased width of the outer side flails to improve straw removal in front of outside openers.

7.1.4 Field performance of FMI Seeder

The machine cut a strip of anchored stubbles (10 cm width) in front of each opener, picked all loose straw lying on the ground, chopped it into small pieces and threw it behind the machine spread uniformly across the sowing with as mulch

The FMI Seeder was field tested in 2005 wheat sowing season at Village Shergarh, Disst. Okara. The machine was tested in a combine harvested paddy field with heavy residue (10.8 t/ha. The loose straw of one plot was uniformly distributed manually and the straw of another plot remained undisturbed in windrows. The measured parameters and their values are shown in the Table-1.

Table 1. Test results of FMI Seeder

7.1.5 Parameters	Values
Tractor MF-35	35kW (47 hp)
Number of rows	8
Row to row distance	18cm
Working width	1.35m
Number of tests	Two
Average size of test plot	0.48ha
Average rice stubble height (Combine harvested field)	40 cm
Soil type	silt loam
Average soil cone index values	2365 kpa
Soil moisture content at 10cm depth	16.6%
Crop & Variety	Wheat, Inqilab
Average travel speed (km/h)	
(Full residue evenly distributed 10.8t/ha)	4.6
(Full residue in undisturbed windrow)	4.8

Effective capacity (ha/h) (Full residue evenly distributed 10.8t/ha) (Full residue in original windrow)	 0.35 0.29
Average field efficiency (Full residue evenly distributed 10.8t/ha) (Full residue undisturbed windrow)	 59% 57%
Fuel consumption (35kW)	5.1 L/h
Average depth of seed placement	4 cm

Fig.10. Residue coverage over seeded rows

Fig.11 Crop emergence in heavy rice residue

The overall performance of FMI Seeder in the manually distributed rice straw was increased compared to the undistributed straw plot. Dust was also a problem for the tractor operator particularly with a following wind. The effective field capacity and field efficiency were low due to wastage of time during turning of the machine at both ends; this downtime is exacerbated in small fields

7.1.6 Economic analysis of Using FMI Seeder

Table 2 shows the operational cost analysis of the FMI Seeder, in full residue, compared with the conventional Pakistan wheat sowing method in a "partial burn" paddy field. The tractor and machine costs were worked at present market prices (August, 2006). The total life of tractor and machines were assumed as 10 and 5 years respectively. Annual use of tractors and machines were assumed as 1000 and 240 h respectively with a 35kW tractor.

Table 2. Operational cost of FMI Seeder vs traditional sowing method (Pak. Rs)

ITEM	TRACTOR	FMI	CONVENTIONAL

	(50hp)	SEEDER	
Purchase price	340,000	80,000	70,000
Useful life (hrs)	10,000	1,200	1,200
Useful life (years)	10	5	5
Salvage value (10%)	34,000	8,000	7,500
Fixed Costs (Rs/hr)			
Depreciation	31	60	56
Interest 10% on initial investment	4	7	7
Taxes/Insurance 2.5% of initial invest	19	2	2
Repairs and maintenance	34	60	56
Total Fixed Cost (Tractor machine)	88	129	121
Field work rate (ha/hour)		0.3	0.4
Labour input (man hours/ha)		5	8
Fuel consumption (l/ha)		17	15
Cost Rs/ha			
Fixed and Repairs (Tractor and machine)		723	522
Fuel, diesel @ Rs 36/l + lubricants		704	621
Labour @ Rs 25/hr		125	200**
Cultivation 2*discing, 1 planking			2500
Cost of one pass seeding		1552	1464
Total Cost Rs/ha		3104	5307
Cost saving with FMI		**2203**	
Financial benefit of using the FMI Seeder (Rs./ha) (1 years data) of Shahbaz farm			
Average Yield (t/ha)		3.332	3.027
Yield increases return @Rs.1050/quintal		**3200**	
One irrigation Savings (Tube well charges)		**1300**	
Total benefit using FMI Seeder (Rs./ha)		**6703**	

* Cost of Disk harrow14 discs

** Cost of burning + broadcasting

Note: Conventional means drying of straw for good burning(one Week) + three disc harrow for mixing stubbles with soil +one cultivator with planking + broadcasting of fertilizer & seed + one cultivator with planking

- Suitable for more than 50 hp tractors

- Effective field capacity is around 3.5 hr/ha
- Fuel consumption was 17 litre/ha
- Cost of operation was Rs.1800/ha as compared to conventional method Rs.5750/ha
- It saves one irrigation (Ist irrigation applied after 40 days)

However there were some problems in germination in uneven straw thrown by combines especially at corners and in heavy residue more than 7 tons/ha although manually distributed, the main problems were;

Fig.12 Dust generation during sowing Fig. 13 Effect of heavy residue on germination

- Fuel consumption was high
- Poor germination under thick layer of straw (above 7ton/ha) in some places,
- Dust generated by blowing dry straw from the chute @ 8 m/s and up to 6m distance (fig 12)
- Heavy weight machine difficult for older tractor (hydraulic lift problem)
- Require more power for cutting of anchored stubbles as well as picking up loose straw all of which is then cut into small pieces and thrown up to 6m behind the drill
- Due to reduction in weight; and smaller components which failed during trials, the reliability of the machine was poor

During the mid term review conducted by Christian Roth, ACIAR Regional Manager for Asia and Prof. John Blackwell of Charles Sturt University, Australia it was agreed to terminate any further work on the original design and shift the project focus onto a new machine based on the successful demonstration of the Indian Turbo design in Pakistan and incorporating the novel ides of Shabbir Kalwar.

In the rotor flail design of the **FMI Seeder**:

- The machine cuts the stubble in 10 cm wide strips close to ground level in front of each opener,

- Picks-up all the loose straw lying un-evenly on the ground left by combines,
- Chops any encountered straw in to small pieces,
- Straw thrown above the drill
- Straw blowing velocity ranges between 8-10m/sec
- Uniformly Spread straw over the sown area in one pass.
- These actions consumed more energy (Fuel and power) but suppress the weeds efficiently and conserved moisture.

In the case of the **Rocket Seeder** knives on the rotor only cross the anchored stubbles and removes/cut the loose straw rising up on the front edge of the tines. The machine can sow across windrows, this approach saves half the fuel and power required by the FMI Seeder but to get good control of weeds and moisture conservation the uniform distribution of straw is a precondition of good seeding,

7.1.7 Development of the FMI Rocket Seeder

Following the review committee decision to stop further work on the original deign of FMI Seeder (major problems of poor wheat germination under thick layer of straw over the seed and dust generated during throwing of dry straw), the team started work in 2006 on a new idea based on the straw chopper kit of New Holland combine harvesters and building on the Pakistan experience with the Indian Turbo Happy Seeder.

Many changes were made in the rotor configuration to improve its performance in terms of passing of material between the tines. Seed furrow opening, quantity of straw above the opening, safety factors, improved work rate and overall efficiency of the machine were also worked on. The major modifications were:

- Flails replaced with knife blades on the rotor,
- Chute removed,
- Straw retainer added between the tines to reduce re-cutting of straw
- The shape of openers changed
- Straw strikers fixed on tines to divert straw flow and improve placement between the seeded rows to avoid covering the seed

Fig.14 Knife configuration on new rotor

Fig.15 View of straw retainers

A new prototype version of FMI Seeder named the 'FMI Rocket Seeder' was designed and fabricated with the collaboration of Sayyed Machinery Ltd, Lahore. This machine is novel and represents a major breakthrough. The resulting machine is superior to the original FMI Seeder. The main features of this new machine include;

- It is light-weight
- Compact
- Requires significantly less power
- Suitable for low-HP tractors
- Generates significantly less dust
- Improved operator visibility generally, and for lining up subsequent passes
- It is likely to cost significantly less than the original FMI machine.

Fig. 16. 2nd prototype unit of FMI Rocket Seeder

Fig.17. FMI Rocket Seeder working in heavy rice residues

The tractor mounted FMI Rocket Seeder was tested at Ch. Mushtaqs farm during the month of November 2008. The overall performance of the machine was excellent. The test results are as follows:

- Field capacity 2.5 hr/ha
- Fuel consumption in full residue 5.5 litre/hr
- Fuel consumption without residue 4.5 litre/hr
- Total machine weight 425 kg
- Row –row spacing 20cm
- Power Requirement 35hp (8 row machine, 50hp 10 row)
- Material handling capacity (loose residue) 10 ton/ha

–

7.1.8 Benefits of using the FMI Rocket Seeder

- Timeliness in sowing wheat even after long duration basmati rice varieties
- The possibility of sowing the wheat crop immediately after rice harvesting thus using the residual moisture and avoiding the pre sowing irrigation.
- Huge reduction in primary tillage cost
- Crop residue as mulch helps in moisture and temperature conservation
- Less weed growth (weeds suppressed in the inter row due to mulching)
- Can save one irrigation (1st irrigation applied after 40 days instead 20 days)
- Fertilizer efficiency improvement
- Conservation of nutrients like N & S which otherwise are lost during burning and improvement in soil organic matter content and soil physical & biological properties
- High yield (+ 4 tons/ha)
- Environment friendly technology reducing air pollution by reduced fuel usage and obviation of burning
- Increased opportunities for double cropping

Fig.18 Testing of 1st prototype Rocket unit in field

Fig. 19 Excellent emergence in heavy rice residue

7.1.9 Development of Straw spreading kit for combine harvesters

Reasons for its development

There are now more than 5000 combine harvesters are used for harvesting of rice and wheat crops in Pakistan. Most of them are second hand and imported from western countries especially from Germany and UK 80%. The main share of these combines are New Holland Company., Combine harvested rice fields are left with windrows of loose chaff and straw from straw walkers and sieves of the combine harvesters. The majority of these combines have no straw spreading attachment, those that do have straw spreaders require extra power (25hp). All rental companies and owners removed these attachments to conserve power on the second hand machines.

Manually straw spreading (7 tons/ha) requires around 8-13 man-h/ha. It was also observed that it is very difficult to manually spread the entangled dry loose rice straw due to its light weight. Evenly spread loose straw is a precondition for the smooth operations of both the FMI and Rocket seeders. A simple low power requirement straw spreader was required for all existing second hand combine harvesters.

7.1.10 Functional requirements of straw spreader:

It should be able to handle the straw flow coming from the straw walkers and sieves of the harvester without affecting harvesting performance. It should be supplied as a kit and be easily detached the power requirement and cost should be low. A new straw spreading kit was designed and fabricated at the FMI workshop (Fig. 21). The proper test stand developed to finalize all technical parameters under lab conditions (Fig.22). The kit was then sent to Lahore and installed in a commonly available combine harvester at the workshop of collaborative manufacturer Sayyed Machinery Ltd, Lahore (Fig.23)

Fig.20 Harvesting of lodged rice crop

Fig.21 Straw spreading kit

Fig.22 Testing of kit at Laboratory

Detailed field testing of the straw spreading kit was conducted near Nankana, Dist. Faisalabad during the 2007 paddy harvesting season (Fig.24), in the presence of harvesting contractors and combine owners. Results were encouraging.

This kit spreads straw uniformly at 350 rpm (Fig.25).

It is simple in design and construction, can easily be attached to the available combine harvesters in the country. Its estimated cost is less than Rs.10,000

Power requirement is 2.5hp

This kind of kit is in demand from many rental companies and farmers as it will help them to mulch residue evenly in the field easily rather than burning.

Fig.23 Straw spreading kit attachment

Fig.24 Straw spreading with kit

Fig.25. Uniformly distributed rice straw

7.1.11 Results of residue management experiments

Experiments were initiated at the two farmers' field and at the Rice Research Institute KSK in Rabi season 2005 to evaluate the effect of various residue management options and nitrogen levels on crop performance as well as on the soil properties. The treatments included six residue management practices:

Retention of full crop residues (Stubble + loose straw),

Half crop residue incorporation (Stubbles only),

Removal (Manually harvesting),

Partial burning

Farmers practices. The summary of management practices carried-out at three sites is shown in table 3.

Table 3. Over all management details of the three sites (2005-06 to 2008-09)

Activity	KSK rep expt	KSK large plots	Ch. Mushtaq Farm	Shahbaz Ali Farm
Soil	Grey silty clay	Grey silty clay	Brown clay loam	Grey silty clay
RICE Transplanting				
variety	Supper Basmati	Supper Basmati	Supper Basmati	Supper Basmati
Paddy Yield (Avg) kg/ha	3100	3100	3300	3400
Transplanting dates	Ist Week of July	Ist Week of July	Ist Week of July	Ist Week of July
harvest date	2nd week of Nov.	2nd week of Nov	2nd week of Nov	2nd week of Nov
Harvesting methods	Manual/ Combine	Manual/ Combine	Combine Harvester	Combine Harvester
stubble load (dry) ton/ha @ 20% moisture	5-6	5-6	6-6.5	7-7.5
WHEAT - SOWING				
Varieties 2005-06	Inqilab	Inqilab	Inqilab	Inqilab
2006-07	AS2000	AS2000	AS2000	AS2000
2007-08	Bakhar	Bakhar	Bakhar	Bakhar
2008-09	Shafaq	Shafaq	Sahar/Inqilab	NA
Date	3rd week of Nov	3rd week of Nov	3rd week of Nov	3rd week of Nov
Seed Rate Kg/ha	120	120	120	120
fertilizer type Kg/ha	DAP	DAP	DAP	DAP
fertilizer rate Kg/ha	120	120	120	120
fertilizer appl. method	Mechanical	Mechanical	Mechanical	Mechanical
WHEAT – TOPDRESSING				

1. date	Ist Week of Jan	Ist Week of Jan	Ist Week of Jan	Ist Week of Jan
1. type	Urea	Urea	Urea	Urea
1. rate Kg/ha	50, 75, 100 & 120	120	120	120
2. date	3rd week 0f Feb	3rd week 0f Feb	3rd week 0f Feb	3rd week 0f Feb
2. type	Urea	Urea	Urea	Urea
2. rate Kg/ha	50, 75, 100 & 120	120	120	120
WHEAT - IRRIGATIONS				
1. Start date	Ist Week of Jan	Ist Week of Jan	Ist Week of Jan	Ist Week of Jan
1. duration of ponding	Not Recorded	Not Recorded	Not Recorded	Not Recorded
2. start date	3rd week 0f Feb	3rd week 0f Feb	3rd week 0f Feb	3rd week 0f Feb
2. duration of ponding	Not Recorded	Not Recorded	Not Recorded	Not Recorded
3. start date	3rd week of March	3rd week of March	3rd week of March	3rd week of March
3. duration of ponding	Not Recorded	Not Recorded	Not Recorded	Not Recorded
WHEAT- HERBICIDES				
Date	After Ist irrigation	After Ist irrigation	After Ist irrigation	After Ist irrigation
Type 2.5 litre/ha				
WHEAT – HARVEST DATE	End of April	End of April	End of April	End of April

7.1.12 Yield comparison of different sowing methods

The combine ejected rice straw was manually distributed in plots 1 and 2 at farmer's fields after harvesting of the crop. In plot 3 loose straw was removed, standing stubble was retained and in plots 4 and 5 the straw was burnt partially, while in plot 6 all stubble was removed to make ideal conditions for zero till drilling. The seventh plot was left for the farmer to use his conventional method at both sites. The uniformly distributed residue was measured by quadrat samples and soil samples were collected from all plots. Plot 1, & 5 were sown on the same day at each site and all other plots left for one week to dry the straw to achieve good partial burn, a common practice in this area.

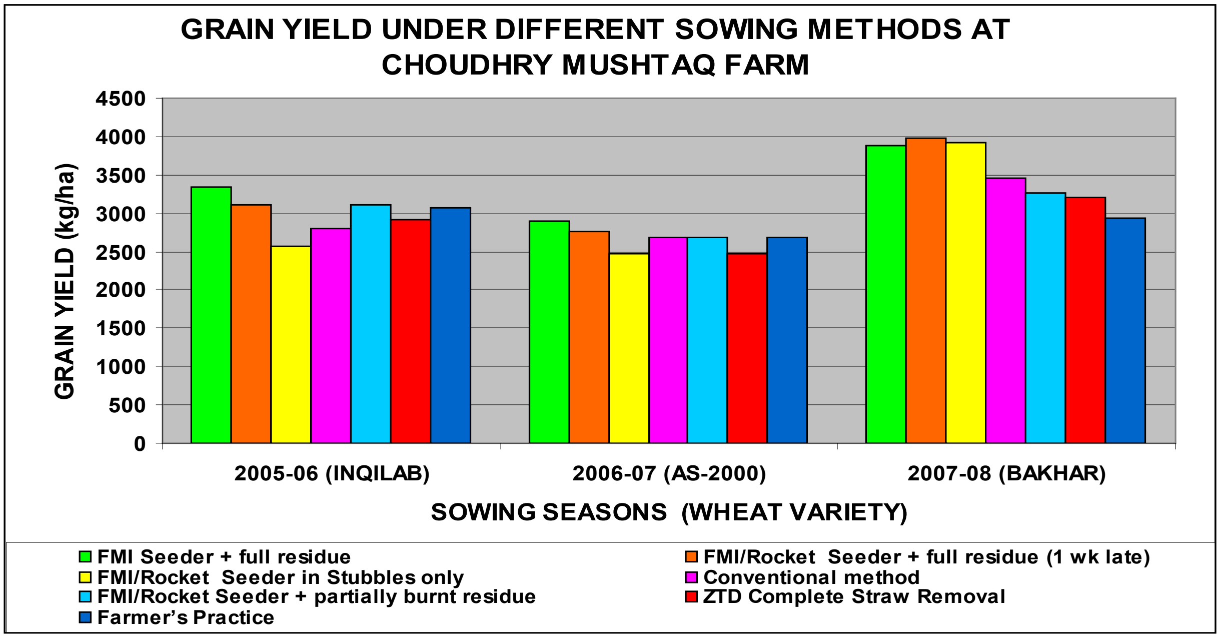
Irrigation at all sites was applied as flood irrigation from local tubewells.

The recommended fertilizer rate of 100 Kg/ha was applied at the three sites.

Grain yield was determined by harvesting the whole plot, threshing at all sites was with a stationary thresher and grain weighed and moisture content recorded on site.

. The yield data of each site for three years are shown in the following 3 figures:

Figure 26.



The use of different varieties each year confounds the comparisons.

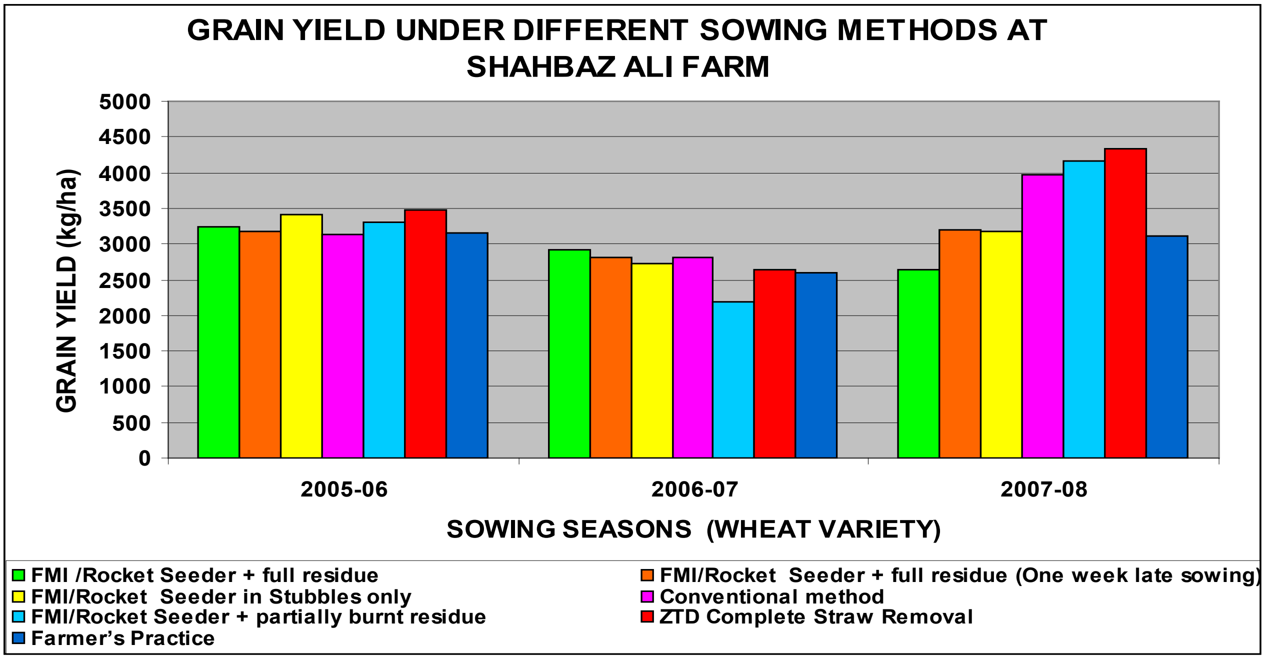


Figure 27

Shahbaz Ali used the same varieties of wheat as Mushtaq in all years

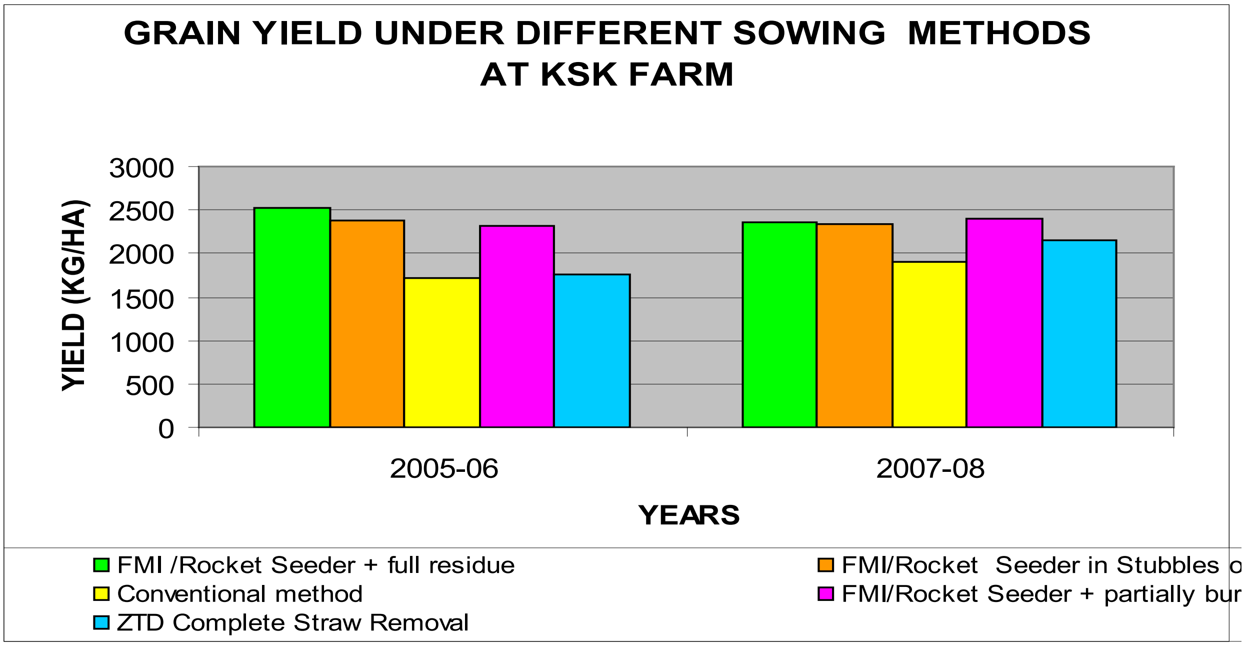


Figure 28

All the agronomic data recorded at each site for the last three years such as thousand grain weight, plant height, number of spikes per sq. meter, number of grains per spike, grain weight per spikes, number of weeds per sq. meter and yield is shown in the tables in Appendix 2

Australia 2009

The project imported a Rocket Seeder from Sayyed Machinery, specifically to demonstrate that the new rotor-flail and tine arrangement, now adopted by all manufacturers in India and Pakistan, would overcome the problems encountered with the original Turbo design (see report "Australian experience with the Turbo happy seeder").

We were lucky to obtain access to one of the few channel irrigated rice crops in Australia in 2009, thanks to Murrumbidgee Irrigation Chairman, Dick Thompson.

The rice sown yielded 10t/ha of paddy and the straw load in our plots was 11.8t/ha, the cut straw had been spread by the header. The crop had not lodged and much of the stripped straw was still standing and well anchored.

We were given access to two 1 hectare bays at the exit from the field, this meant that a track of multiple passes with the snigging bin had really rolled the stubble into the ground and presented a veritable mat to the seeder.

We sowed the wheat variety "Chara" at 100kg/ha with 100kg/ha single super on the 22/05/09. The seed was placed into reasonable moisture at 30 to 35mm depth.

The machine performed very well except where the straw had been rolled by the header and the snigging bin, fig 29.It was possible to get through the rolled straw with minimal blockage but only at "Creep" speed. (Fig. 29)

Figure. 29 Poor wheat emergence through the heavily rolled laneway area

This would not be acceptable for any farmer and remains an aspect of the technique that needs to be worked on.

The machine worked very well in the standing stubble with minimal blockage, a great improvement on the Turbo's effort the previous season.

As mentioned previously all machines currently manufactured in the subcontinent now incorporate similar flail tine configuration first seen by Blackwell on the Pakistan FMI Rocket Seeder. Any further development of a wide line broad acre Happy Seeder for Australian conditions must incorporate this approach. In addition work will have to be done to improve any machines effectiveness in flat, rolled straw, conditions as shown in Figure 29 above and 29a below.

Figure 29a. The imported Rocket Seeder at normal speed in the totally rolled “laneway” of Dick Thompson’s 11.8t/ha rice straw crop.

Figure.30 Good emergence in the standing stubble areas.

To attempt to overcome the problem of the rolled straw we slashed the second hectare. This turned out to be a complete mistake as again the only way to get through the straw without frequent blockage was at creep speed. This was a valuable lesson teaching us to retain as much standing stubble as possible. This of course will be difficult in lodged crops which require cutting the straw at ground level.

Progress in this slashed paddock was too slow to be worth continuing to sow it, although we persevered for 4 rounds of the hectare experiencing multiple blockages at normal speed. This attempt showed an interesting result, see fig 30, establishment was excellent and the yield from this section was higher than the standing stubble plot. This poses another conundrum for the future.

Figure 31. Establishment in the standing stubble left and slashed stubble on the right

In spite of the difficulty in sowing the rolled straw did not affect the emergence just the speed of travel across the ground. The average emergence per metre of row was 39 plants with the minimum of 19 being found in standing straw.

This average number of plants established per metre of row was greater than that established by the farmer, 28/m of row, in a burnt paddock. As we were both aiming for the 100kg/ha sown, this discrepancy almost certainly reflects the inability of all the subcontinent machines tried to date, to hold their calibration while sowing. (see previous report).

The field was topped dressed with 90kg of urea from the air at the 3 leaf stage

The weather in Griffith over the growing season shows reasonable rainfall, see figure 31a. In spite of this the yield of the FMI sown plots was only half the farmers average (3t/ha), see table 3. Neither the farmer's field nor our trial received any irrigation, relying on antecedent moisture and rainfall.

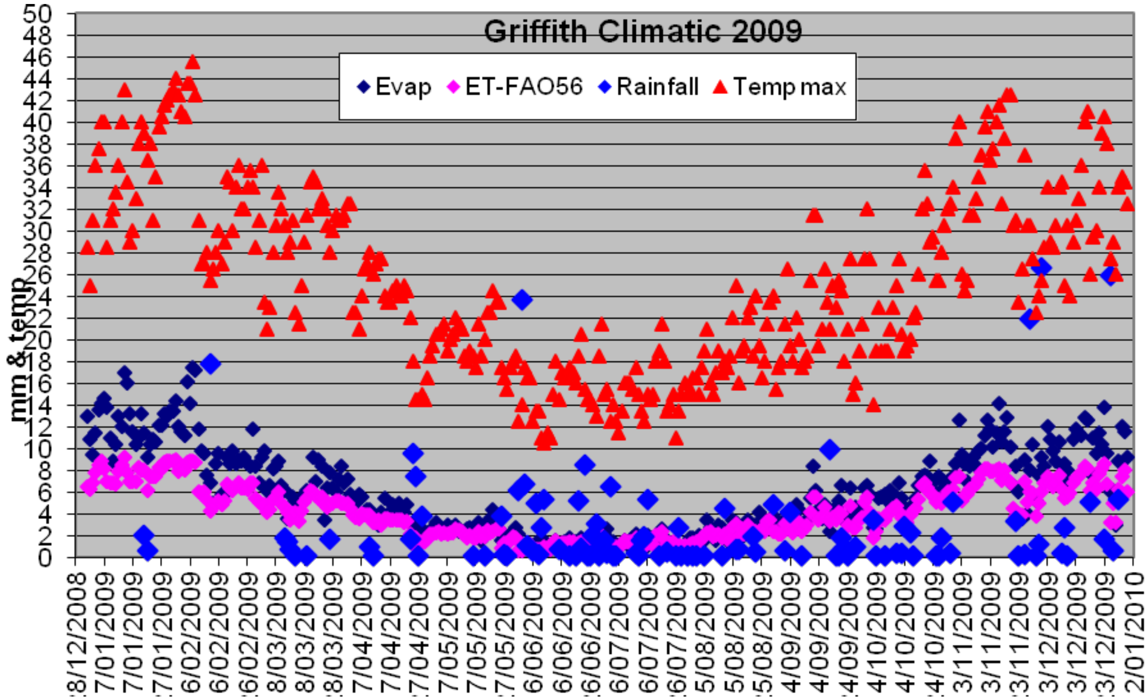


Figure 31a. Griffith weather data 2009.

Sample	Wheat Straw weight grms/m^2	Plants per m^2	Tillers per m^2	Avg plant height mm	Full heads per m^2	Empty heads per m^2	Grains per head	Seed weight grms per m^2	1000 grain weight grms	Yield t/ha
A1	441	221	313	569	211	102	16	101	30	1.01
A2	517	227	322	607	233	89	12	85	30	0.85
A3	281	228	255	564	143	112	12	95	30	0.95
A4	426	235	260	534	188	72	14	78	30	0.78
B1	432	280	337	674	313	37	19	211	36	2.1
B2	384	254	285	593	178	107	14	79	32	0.78
B3	356	286	357	588	311	46	14	157	36	1.56
B4	438	244	280	563	235	45	16	134	36	1.39

Table 3. Yield and yield components from Dick Thompson's demo site. Plot A standing stubble, plot B stubble slashed prior to sowing

Whilst these yield results are disappointing we have at least proved the current flail/tine configuration can operate in our heavy conditions.

One of the most disturbing factors in all the Australian attempts at sowing wheat into rice straw has been the lack of breakdown of the rice straw over the wheat growing season, perhaps due to our relatively dry and cold winters compared to Pakistan and India.

From a rice straw weight of 11.8 t/ha at wheat sowing the average rice residue left at wheat harvest was 8.25 t/ha. In Pakistan and India there is very little rice straw left by the time the wheat is harvested. The little that does remain is so broken down as to pose no problem to subsequent field operations.

The Tasmanian Experience

As explained before, the Irrigation Research and Extension Committee purchased a Dasmesh Turbo Happy, which performed poorly in Rice in the Murrumbidgee Irrigation Area (see previous reports), this was sold to the Tasmanian Institute of Agricultural Research (TIAR)

Geoff Dean had secured a Caring for our Country grant of $39,900 for 1 year titled: “Increasing adoption of stubble retention and direct drilling practices by Tasmanian farmers through the use of revolutionary new technology “

The objectives of the project were to:

- Address the knowledge gap of what sowing equipment can be used to reliably sow directly into high crop stubble loads, specifically through evaluation and construction of a novel direct drill.
- Communicate project outcomes to the wider rural community through newsletter, newspaper and radio media.
- Improve adoption of stubble retention practices by increasing awareness and capacity development of primary producers.
- Increase sustainable cropping practices and reduce the need to burn crop stubbles.
- Increase soil organic matter levels, improve soil structure and water infiltration and reduce soil erosion.

The Dasmesh Turbo Happy seeder was modified by making the flail and tine configuration as similar to the current Indian and Pakistani designs as possible

Press wheel assemblies were also added to improve evenness of sowing depth and seed soil contact, see figure 32

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Figure 32. The press wheel and depth wheel assembly

There have been a number of successful outcomes from this project but the most important were:

- Developing a means of sowing seed with a tine drill into high volume stubbles in particular wheat and poppy stubbles, see figures 33, 34 and 35. The outcome is reduced need to burn crop stubbles with resulting improvements in soil structure and reduced green house gas emissions. There has also been increased awareness of alternatives to disc drills in high stubble loads. The Happy Seeder uses mulcher blades to cut a narrow strip of stubble in front of each tine and the cut straw acts as an effective mulch between rows and inhibits weed growth as well as conserving soil moisture.
- Farmer engagement with the project has been high and the Happy Seeder has become a talking point in cropping discussion. This has increased awareness of direct drilling, minimum tillage and alternatives to burning of stubbles. The flow on from this has been increased awareness of the Caring for our Country program.
- With the interest in the Happy Seeder generated by this project a nationally leading company which specializes in agricultural tillage has stated that it is interested in further developing the machine. Funding to assist with this is currently being sought.

Figure 33. The modified Turbo Happy sowing into heavy Buckwheat

While disc drills can handle much higher stubble loads they are restricted to where conditions are damp/wet and/or soils are hard setting. The major restriction to use of the Happy Seeder is the presence of rocks, which don’t mix well with mulcher blades. At one demonstration the Happy Seeder also struggled to sow into buckwheat with its stringy stubble and in addition the straw was wet.

Figure 34. Blackwell on the right, and keenly interested farmers examining the results of the Buckwheat demonstration

Figure 35. A full windrow of Poppy stubble poses no obstacle to the machine. Poppy capsule destruction was satisfactory, according to Poppy growers present.

The field days were a great success with good attendances, lots of discussion and considerable media attention.

The success of the project can be attributed to:

- The field days being run by Southern farming Systems, a farmer group which is recognised as delivering relevant and practical sessions. The skills and communication of the organising group running the field days and demonstration were also instrumental.
- Working displays of equipment and commentary on each drill were invaluable for those wanting to compare different drills under working conditions.
- Good practical skills of staff involved in the project allowed the design of the Happy Seeder to be improved.

Close links with other organisations and grower and industry groups. For example the Agricultural Contractors Association of Tasmania assisted with technical issues and the Coal Valley Cropping Group and Serve-Ag helped organise the southern field day.

The Happy Seeder has enormous application across large regions of Australia, in particular the high rainfall zone, where large volumes of stubble are a problem for tine drills to sow into.

For many farmers and agribusiness representatives the activities of this project have contributed to a substantial improvement in knowledge about direct drilling and minimum tillage and how to go about it. In particular the field day presentations by Dr Jack Desboilles were very informative. For other growers with a general awareness of the benefits of minimal soil disturbance, the Happy Seeder has led farmers to consider alternatives to standard sowing equipment.

Improving adoption of stubble retention is a win/win situation as removal of stubble results in a net loss from the soil through removal of carbon and nutrients. By retaining stubble, natural resource management is improved and profitability potentially increased.

- The success of the project has stimulated grower discussion on tackling modifications to existing drills to enable direct drilling. The project steering committee considers the best approach would be to run small hands-on workshops focussing on drill modifications and adaptations for existing drills. Additional funding would be sought for this work.
- With the success of the Happy Seeder there has been renewed interest in the Happy Seeder nationally with a leading agricultural tillage company interested in further developing the machine. Discussions between the original Happy Seeder designer Prof. John Blackwell, and this company to seek additional funding are continuing.

1. What other lessons have been learnt to inform future directions of initiatives such as this project?

- One critical aspect to this project has been the involvement farmers and other agribusiness groups such as the Agricultural Contractors Association of Tasmania and Tasmanian Alkaloids. This ensures that the project and program are relevant and stay on track. Working displays of equipment are also very useful.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The development of the tine and rotor relationship first seen by Blackwell in the Rocket seeder has now been adopted by all Indian and Pakistani manufacturers. It is not clear who in fact "invented" this but it has been a breakthrough and enabled the machines to sow into heavy rice stubble under Australian conditions.

The agronomic work in Pakistan has given the team a better understanding of nitrogen and water management under direct drilling whilst retaining straw as a surface mulch.

The development of the simple straw spreader might lead to wider adoption on Pakistani harvesters. Windrow spreading is seen as a prerequisite to use and adoption of the FMI Rocket seeder

Shabbir Kalwar and Nadeem Amjad, along with Quasim Raja, at his own expense, visited Australia from July 16-29, 2006 . With Blackwell they visited agricultural machinery suppliers and manufactures in Australia to share their experiences and understand first hand the possibilities for mechanization in all aspects such as seed drills, laser levelling, combine harvesters, bed farming and precision agriculture.

The Pakistani team of scientists/engineers, manufacturers and farmers visited India from 7-20 April 2008 to share their experiences gained in the two ACIAR projects both continuing the development and management understanding of the "Happy" technique in the Indian and Pakistani Punjab

The Government of Punjab had included FMI Rocket Seeder in the 50% subsidy program on Agric. Machinery to farmers

The Federal government through its ministry of Food and Agriculture is also launching a subsidy program for Agricultural Machinery to benefit farmers the FMI Rocket Seeder is included in this program, to which more than 20 manufacturers responded asking to be included in the tender These included Sayyed Machinery Ltd and United Agro Engineers Daska.

The teams in Pakistan and Australia have gained increased understanding of the interactions between mulching and crop performance.

The development of the Rocket seeder has spawned two new projects promoting direct seeding technology; one is funded by the Punjab Development Board and is being conducted by Agric. Univ. of Faisal Abad and FMI. The other is funded under Agricultural Linkage Program (ALP), at PARC and is being conducted by different programs at NARC and lead by FMI.

Engr; Asif Ali Mira's MSc thesis "Investigation of water productivity and economic efficiency of a wheat crop under different sowing methods in a combine harvested parry field" submitted to the Dept; of agricultural Engineering NWFP University of engineering and Technology Peshawar Pakistan December 2009, has lent good support to the efficiency and water saving aspect of the technique.

The few trials we have managed to conduct in NSW and Tasmania have created scientific interest in the technique.

The size and quality of the imported machines have mitigated against this interest and the superseding of the large area Twynam machine did not help. In-spite of this, great interest has been shown in the technique by many farmers, both rain fed and irrigated, and two manufactures. This interest does encourage us to continue to seek funds for the development of an Australian model of the successful FMI/Turbo machines.

8.2 Capacity impacts – now and in 5 years

This project has enhanced the capacity of Pakistani team to work with multinational teams, exchanging views and conducting research

This project provided the opportunity for scientists, agricultural machinery manufacturers and farmers to share their views and problems facing the farming community and specifically rice residue handling after combine harvesting

Mr Shabbir Ahmad Kalwar and Dr Tariq Sultan Soil scientist have been elected as committee members for residue management at Punjab Development Board

Mr Asif Ali Mirani an. Engineer with FMI has completed his MSc. thesis research at the PARC-ACIAR funded project site at KSK on "Investigation of water productivity and economic efficiency of a wheat crop under different sowing methods using FMI Rocket Seeder in combine harvested paddy field

Machine designing, development and manufacturing skills of the team have been improved through prototype fabrication.

Team building of related disciplines for technology development

Improvement in technical ability of the manufacturers through local and foreign visits

Awareness and capacity building of the participating farmers in direct drilling into heavy crop residue, this has happened in Australia as well as Pakistan

Improved crop husbandry skills of the participating farmers

Enhanced tractor operating skills of the public and private sector tractor operators

The current Australian project leader has improved his patience and frustration tolerance over the life of this project

8.3 Community impacts – now and in 5 years

- Because of the difficulty in extending any novel technique involving machinery purchase, in Pakistan, without Government subsidy, the community impact has been restricted to farm level associated with the participating farmers. None the less great interest and understanding has been generated wherever the technique has been demonstrated both by farmers and manufacturers in both Pakistan and Australia
- The Governments of Pakistan and the Punjab are establishing machinery purchase subsidy programs which will cover the FMI Rocket seeder. This should encourage the uptake of the new technology
- In Australia lack of rice crops and the poor performance of wheat in those we did sow has not been promising, the interest generated by the success of the

technique in other crops has had a positive impact on farmer attitudes, particularly in Tasmania

8.3.1 Economic impacts

The widespread adoption of this technique would create the following economic impacts:

Reduction in fertiliser costs (no loss of nutrients in straw by burning).

Reduction in land preparation costs Rs. 2,203/ha

Saving one irrigation due to mulching Rs.3,208/ha

Total net benefits to farmers adopting FMI Seeder technology as compared to conventional method (farmers practice) are Rs. /ha 6703 (Shabbir findings), Rs/ha 13924 (from Mirani's thesis)

Adoption of the FMI Rocket Seeder concept has the potential to reduce smoke related health problems

It will reduce motorway/high way closures and accidents and airport closures through reduction of smog problems.

Adoption of the FMI Seeder technology may reduce demand of irrigation water in the Rabi season The Pakistan Punjab is facing a 20-30% shortage of river water every year

The economics of the technology are being investigated in detail by economists in Industry and Investment NSW and PAU in India in two ACIAR sister projects LWR-2006-124 and CSE/2006/132, the outputs of these two projects will be entirely applicable to this project, after substitution of Pakistani costs and returns.

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8.3.2 Social impacts

Improvement in living standards of the users of the FMI Seeder technology/machinery due to improved income with less drudgery

Improvements in general human and animal health of the community due to the elimination of crop residue burning

Reduction in chances of road and air accidents due to improved visibility

Opening of employment opportunities for production and service of the machines

8.3.3 Environmental impacts

Improvement in air quality through elimination of crop residue burning

Improvement of soil health through mulching, saving nutrient and water loss and improving soil biota activity

Large scale adoption of FMI Seeder technology has the potential to reduce weed infestation and hence herbicide use.

In both Pakistan and Australia, retention of stubbles will also reduce emissions of greenhouse gases, especially nitrous oxide, a very potent greenhouse gas, while direct drilling will contribute to increased sequestration of carbon in the soil. Soil “fertility” (physical, chemical and biological properties) will also improve with retention of stubbles

The Ministry of Environment, Government of Pakistan is moving to ban rice residue burning in the near future, .as the FMI Rocket seeder now offers a viable alternative

8.4 Communication and dissemination activities

8.4.1 Workshop/Field days Organized

April 11 2008, one day International seminar organized on Residue handling machinery at Rice Research Institute, Kala Shah Kaku, Lahore, included presentations from, India, Australia and Pakistan

On 30th Nov. 05 Demonstration of field operation at Shahbaz Ali’s farm (~20 farmers)

Three major machinery demonstrations of FMI Rocket Seeder were conducted in the month of Nov.2008

The Turbo Happy was demonstrated at the Rice field days at Cooree Station NSW in February 2007

Junee Agronomist Phil Bowden presented the technique and machinery to a farmers field day in Junee 21/06/07

First demonstration jointly organized by PARC and Guard Rice Group at ACIAR project site RRI, KSK on 20 Nov.2008, where more than 300 government officials, business community, scientists, extension workers, manufacturers and farmers participated and Provincial Minister for Excise and Taxation Mr Shuja ur- Rehman was the chief guest.

The Second demonstration organized at Daska especially for the agric. Machinery manufacturers on 23 rd Nov.2008. More than 50 local manufacturers and 20 farmers attended and witnessed machine operation and four manufacturers have shown interest to sign a MoU with PARC.

The third demonstration was organized in Gujranwala on 30th No.2008 especially for combine harvester traders, importers, rental companies and farmers. There were more than 50 participants in attendance.27/02/08 Address to 2008 International Nuffield Scholars in Werribee, Victoria

. 13/08/08 Disclosure of Happy seeder and discussions with Primary Sales Australia, Alan Fisher, at the CTF conference in Dubbo

25/09/08 Discussions with IREC Executive re sale of Turbo Seeder to TIAR Tasmania for Tasmanian trials

31/03/09 The Happy Seeder was evaluated in wheat, poppy, fababean and buckwheat stubbles. The drill performed well in cereal, poppy and fababean stubbles but less well in buckwheat. The latter evaluation was conducted when the stubble was wet and buckwheat straw is by nature also very stringy.

Field demonstrations displaying the Happy Seeder were conducted at 3 sites: Sassafras (North West), Symmons Plains (Northern Midlands) and Cambridge (South East). The latter two sites were conducted as field days. North West (24/02/09), N. Midlands (12/03/09), South East (13/03/09. These major field days comparing 8 commercial drills with the Happy Seeder were conducted at Symmons Plains (Northern Midlands) and Cambridge (South East). In the higher stubble loads at Symmons Plains the disc seeders and Happy Seeder outperformed the standard tine drills. Attendances were 85 and 55 respectively. A further 15 people attended the Sassafras demonstration, a total of over 150 people.

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8.4.2 Presentations at workshops/conferences

T. Ahmad, S. A. Kalwar, M. Ahmad, N. Amjad (2006). “Mechanization technologies for wheat planting and seed processing”, Paper presented at National Seminar on Wheat Production Technology (Sep.18, 2006), At Ayoob Agricultural Research Institute, Faisal Abad.

Kalwar S.A, Amjad N, Mahmood.H.S, J. Blackwell, E.Humphreys (2006) “The FMI Seeder and its Performance” Paper presented on final review workshop on Permanent Bed Rice–Wheat Cropping Systems and Direct Drilling into Rice Residues in the North-West Indo-Gangetic Plains 5-7, Sep.2006 at Punjab University Ludhiana, India

S.A.Kalwar & N.Amjad (2007). Development of Rice Residue handling machinery. Paper presented at Annual Rice meeting March 11-12, 2007 qt NARC, Islamabad.

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T. Ahmad, S. A. Kalwar, M. Ahmad, N. Amjad (2006). “Mechanization technologies for wheat planting and seed processing”, Paper presented at the National Seminar on Wheat Production Technology (Sep.18, 2006), at Ayoob Agricultural Research Institute, Faisal Abad.

S.A.Kalwar & N.Amjad 2007. Development of Rice Residue handling machinery. A paper presented at the Annual Rice meeting March 11-12, 2007 qt NARC, Islamabad.

A presentation on the Happy Seeder concept was made at the Cootamundra DPI field days 21/06/2007

A seminar was conducted on the Happy approach in Launceston on Nov; 17 2007

27/02/08 Address to 2008 International Nuffield Scholars in Werribee, Victoria

Blackwell has made many presentations to farmers, service clubs and other Institutions throughout the life of this project

11 April 2008 Shabbir – Presentation at an International Field Seminar at RRI, KSK 'Machinery for crop residue handling'

18 April 2008 Shabbir – Video presentation to farmers at M/S Kamboj Mechanical Works ltd. Ramdas, Amritsar during the visit to India

29-30 April 2008 Shabbir & Nadeem – Presentation at Annual Rice Meeting held at RRI, KSK on Paddy Residue Handling Machinery

8.4.3 High level delegates visit

The President of Pakistan visited the stall of FMI Seeder during the silver jubilee of PARC from 12–14 December 2006.

The Prime minister of Pakistan visited the stall of FMI Seeder once on 12 Nov.2008 at the time of inauguration of wheat sowing season ceremony at Kala Shah Kaku and the second at Islamabad during the Kisan (farmer) Convention held on 27

May 2009. the Chief Minister of Punjab visited the FMI Seeder stall on the occasion of a wheat sowing ceremony in Nov.2008 at Barani (Rain fed) Agricultural Research Institute Chakwal.

A USAID and Egyptian high level delegation witnessed the new development on residue handling machinery as shown in the photo graphs.

8.4.4 Visitor to Project/Experimental Sites

07 December 2007 DG NARC, DDG IBGR NARC, National Coordinator RW, Dir PMRC, NARC

08 April 2008 the Indian delegation headed by Dr Harminder Singh Sidhu, PAU (PI ACIAR Project), India

31/03/09 The Happy Seeder was evaluated in wheat, poppy, fababean and buckwheat stubbles. The drill performed well in cereal, poppy and fababean stubbles but less well in buckwheat. The latter evaluation was conducted when the stubble was wet and buckwheat straw is by nature also very stringy.

Field demonstrations displaying the Happy Seeder were conducted at 3 sites: Sassafras (North West), Symmons Plains (Northern Midlands) and Cambridge (South East). The latter two sites were conducted as field days. North West (24/02/09), N. Midlands (12/03/09), South East (13/03/09. These major field days comparing 8 commercial drills with the Happy Seeder were conducted at Symmons Plains (Northern Midlands) and Cambridge (South East). In the higher stubble loads at Symmons Plains the disc seeders and Happy Seeder outperformed the standard tine drills. Attendances were 85 and 55 respectively. A further 15 people attended the Sassafras demonstration, a total of over 150 people.

8.4.5 Presentation/ Displays

8.4.6 Dr. Christian Roth, RPM of ACIAR visited the field sites along with Dir. FMI, DG Field, Dir. RRI KSK and Representatives of DG OFWM Government of Punjab and SML on 4 December 2006**.**

The Prime Minister of Pakistan Shaukat Aziz at a prize distribution ceremony at NARC on 16 Aug 2005. The FMI Seeder was displayed at the machinery stall.

Presentation and display of the FMI Seeder at village 18, Shergarh, Okara during the visit of scientists, delegates farmers from many countries at the time of the annual review meeting of the ADB/IRRI RW project

8.4.7 Media

24 April 2008 Agha Qasim Raza, MD of Sayyed Machinery Ltd Live Interview with Business Plus TV Channel on ‘Development of machinery for handling of heavy crop residue’

Interview by Shabbir on TV Channel GEO regarding RCT technologies and residue handling machinery 25 Nov. 2007

In Tasmania Considerable media interest was created with an interview appearing in the Jan-Feb 2009 edition of Ground Cover, the Grains Research and Development Corporation newsletter with over 40 000 readers.

The Tasmanian field days also generated extensive media coverage with an article appearing in the Tasmanian Country on 20/03/09 and ABC radio conducting a live cross to the Symmons Plains field day (12/03/09) plus interviews played back on air 13/03/09 and 16/03/09.

9 Conclusions and recommendations

9.1 Conclusions

The overall project aim was to refine and demonstrate the FMI Seeder with a view to its commercialization The FMI seeder was superseded by the FMI Rocket seeder which was superior in performance and similar in action to its Indian counterpart the Turbo Happy seeder.

The FMI Rocket Seeder has been evaluated in farmer's field, however it needs to be tested over time at larger scale (>200 ha) to check its reliability and durability.

The Rocket imported into Australia whilst successfully demonstrating the designs ability to sow into heavy rice stubble (11.8t/ha) under Australian conditions, required much tender love and attention to nurse it through the 2 ha trial

Steel, fabrication and construction will have to be greatly improved to satisfy farmer's requirement for durability if commercialisation is to be successful in Pakistan.

Neither the Pakistan Rocket nor the Indian Turbo models lend themselves to a scale up for broad acre Australian conditions.

The project demonstrated that wheat can be successfully grown by direct drilling into heavy rice residues (>7 tons/ha straw load in Pakistan and 11.7t/ha in Australia) without burning, in combine harvested paddy fields.

In Pakistan plots sown with either the FMI Seeder or the Rocket Seeder under heavy residue yielded consistently higher than conventional methods (Partial burning + 3 Disk harrow + 2 Cultivator +2 Planking + Broadcasting fertilizer and seed).

Three years results in Pakistan show that the mulch could save one irrigation per year.

The approach has proved successful at sowing a range of crops into a range of stubbles in Australia

The one wheat crop established in Rice straw at Griffith yielded disappointingly, attaining only half the yield of the farmers field, established into burnt rice stubble

More work is needed to perfect the wheat husbandry when sowing into heavy rice stubbles in Australia.

The cold and often dry Australian winters militate against breakdown of the rice straw with subsequent difficulties for any following field operations

In Pakistan the OM contents were increased in the upper layer as 15, 15, 12 and 5% respectively among the plots where nitrogen was applied @ 50, 75, 100 and 125 kg urea per acre

I Pakistan plots sown with either the FMI Seeder or the Rocket Seeder under heavy residue yielded consistently higher than conventional methods (Partial burning + 3 Disk harrow + 2 Cultivator +2 Planking + Broadcasting fertilizer and seed) during the project period and net benefit to farmers adopting this technology could be Rs. 2,203 cost savings per ha and an increased return of Rs 4,500 per ha compared to conventional method .

9.2 Recommendations

9.2.1 Promotion of the Rocket Seeder technology

Coordinated extension of the technology must be continued in Pakistan if the Technique has any hope of widespread adoption

Machinery fabrication and design will have to be improved to produce a more robust machine. Farmers will not tolerate breakdowns particularly at demonstrations.

A scale up or redesign of the current tine/flail relationship into a broad acre machine suitable for Australian rain fed and irrigated condition, in wide range of crops, is a prerequisite for adoption in Australia.

Large scale trials are needed in both Australia and Pakistan to demonstrate the machines reliability and durability.

More local Pakistani manufacturers should be involved in the manufacturing to develop healthy competition in the hope of reducing escalating costs and improve quality

Loan facilities through the Zarai Tarqiati Bank ltd (ZTBL) should be extended to farmers who are interested in purchasing an FMI Rocket Seeder.

Development of a policy environment and enforcement to prohibit burning of rice stubble to promote uptake of the technology

The Government of Punjab and the National Ministry of Food and Agriculture subsidies of 50% must be continued to help farmers afford the initial high cost of the machines.

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10.2 List of publications produced by project

1. A full set of working drawings have been produced for the FMI Rocket Seeder, these are available in hard copy only. Copies are available from The Farm machinery Institute, NARC, Islamabad, Pakistan.
2. A two page handout on the technique in Urdu and English has been prepared and distributed.(Not sighted by Blackwell)

3. An operational manual in Urdu has been compiled in conjunction with the Institute of Training and technology Transfer (not sighted by Blackwell)

4. A report published by TIAR Tasmania for Caring for Our Country, has been extensively quoted in this report

11 Appendixes

11.1 Appendix 1: Details of soil analysis of Pakistan project sites

The following soil sampling and analysis protocol was followed:

Pre-Sowing Soil Sampling

Before the start of the study, soil samples were collected from the experimental sites by a core sampler (ten sub-samples and composite) from 0-15 and 15-30 cm depth. The soil samples were air dried, ground and analyzed for physical and chemical properties i.e., soil texture, pH, electrical conductivity, available phosphorus, nitrate nitrogen, organic carbon of the composite soil samples were determined

Soil Sampling at Harvest of Crop

Soil samples were collected from the experimental area from depth of 0–15, 15-30 cm using a sampling tube after harvesting of each crop. The soil samples were air dried, ground with pestle and mortar and passed through 2 mm sieve (Peterson and Calvin, 1986).

Particle Size Analysis.

To a 40 g soil sample, 200 ml of water and 40 ml of 1% sodium hexametaphosphate solution were added while stirring with glass rod. The soil-water mixture was allowed to stand for at least 18 hrs. The suspension was dispersed in a dispersion cup for 15 minutes. The readings were recorded with Buyoucus hydrometer. Soil texture class was determined by ISSS Triangle (Gee and Bauder, 1986).

Soil Reaction (pH)

Soil pH was determined by preparing a saturated soil paste. Electrode of pH meter was inserted in the paste and the reading was recorded (Mc Lean, 1984).

Saturation Percentage

A 100 g of air dried soil was taken in 500 ml beaker. Then the soil saturated paste was prepared by adding little volume of distilled water from the 100 ml cylinder while stirring with spatula. At saturation point checked, the amount of distilled water used in preparing the paste by subtracting the amount of water left from 100 ml in a cylinder and calculated on % age basis (U.S. Salinity Lab. Staff, 1954).

Electrical Conductivity

A saturated soil paste was prepared and the extract was collected with the help of vacuum pump. The electrical conductivity of the extract was measured by using conductivity meter after calibrating the instrument at the temperature of the solution (Page et al. 1982).

Total Nitrogen

Ten g of soil was taken in a macrokjeldahl flask and 20 ml of concentrated sulfuric acid (H_2SO_4) was added to it. Then 10 g of digestion mixture was added and heated continuously for 30 minutes in digestion block. After digestion, the flasks were allowed to cool. The contents were transferred to 250 ml flask. 10 ml of solution was taken and placed it in distillation apparatus. The volume was made up to 50 ml with distilled water. The distillation was carried out in the presence of 20 ml of 40% NaOH and distillate was collected in 5 ml boric acid. The distillate was titrated against 0.1N H_2SO_4. The colour changed from green to pink.

Nitrate–Nitrogen (NO_3-N)

Salicylic acid method was used for the determination of NO_3– N in the soil. A 25 g soil sample was taken in a 250 ml bottle and 50 ml distilled water was added. The contents were shaken for an hour and filtered through Whatman No.42 filter paper. A sample of 0.5 ml was taken in test tube and 1 ml of 5% salicylic acid reagent was added and mixed thoroughly. The tubes were left for thirty minutes. Then 10 ml of 4 M NaOH reagent was added to each tube. The contents were mixed again and were left for an hour for full color development. Standards were also prepared and readings for standards and samples were recorded using spectronic 21 at 410 nm. (Vendrell and Zupanic, 1990).

Available Phosphorus (P)

Five g of air dried soil was extracted with 100 ml of 0.5 M $NaHCO_3$ (adjusted at pH 6.5) after shaking for 30 minutes in a mechanical shaker. The suspension was filtered through whatman filter paper No.42. Ten ml of clear filtrate was taken in to 50 ml volumetric flask. Then 10 ml of color developing reagent (ascorbic acid, ammonium molybdate, antimony potassium tartrate and sulphuric acid) was added into the flask and the volume was made up to the mark with distilled water. After 15 minutes of color development reading was recorded on spectronic 20 at 880 nm wavelength. (Olsen and Sommers, 1982).

Available Potassium

The extraction was carried out by AB-DTPA extraction method and potassium determined by Flame Photometer (Ryan et al., 1996)

Lime ($CaCO_3$) contents of Soil

A 5 g of air dried, sieved soil sample was taken in a conical flask and 30 mL of 0.5 N HCl was added to it. The suspension was heated on hot plate for 5 minutes, after boiling started; it was removed and allowed to cool down. The suspension was then filtered and filtrate was titrated against 0.25 N NaOH. Note the mL of NaOH used and calculations were performed to obtain percent lime content of soil was calculated as under.

$$CaCO_3\ \% = \frac{[(\text{mL of HCl} \times \text{N of HCl}) - (\text{mL of NaOH} \times \text{N of NaOH}) \times 0.05]}{\text{Weight of soil}} \times 100$$

Soil Organic matter

One g of air-dried soil was taken in a conical flask and 10 mL of 0.5 N K2Cr2O7 and 20 mL of conc. H2SO4 was added to it. Allowed to stand for 30 minutes to complete the reaction, 200 mL of distilled water was added and suspension was filtered. Indicator, 2-3 drops of orthophenonthrolein was added to the filtrate and titrated against 0.5 N FeSO4.7H2O until the colour changed to dark drown at last (Nelson and Sommers, 1996).

$$\text{SOM \%} = \frac{[(\text{mL of K2Cr2O7} \times \text{N}) - (\text{mL of FeSO4.7H2O} \times \text{N}) \times 0.69]}{\text{Weight of soil}} \times 100$$

Statistical Analysis

LSD was compare the data collected for various characteristics was analyzed statistically by Analysis of Variance technique and the mean values at 5% level of significance (Steel and Torrie, 1980).

The aim of the project studies were to analyse the different soil properties to assess; is there any improvement in soil health by managing the residues on soil surface and to discourage the practice of residue burning to avoid the environmental problems. The main emphasis was to study the effects of different residue management practices on soil properties and to compare the different rate of N fertilizer on residue management practices and its effects on soil health. The physico-chemical properties of soil were presented in the following Tables.

Table 4: Physico-Chemical analysis of soil samples from experimental sites before sowing of wheat crop at Kala Shah Kaku Farm during 2005-08 (Replicated Trial)

Parameter	Unit	Amount/Class		
		2005/06	2006/07	2007/08
EC (1:1)	dS m-1	0.43	0.48	0.46
pH		8.4	8.3	8.5
Organic matter	%	0.75	0.87	0.88
CaCO3 Content	%	3.65	3.75	3.02
Phosphorus (Olson)	mg kg-1	3.62	3.31	3.51
NH4OAC extractable K	mg kg-1	73	82	79
Zn	mg kg-1	0.61	0.77	0.85
B	mg kg-1	0.29	0.35	0.27
Sand	%	41.5	40.5	41.21
Silt	%	37.5	38.2	39.58
Clay	%	21	21.3	19.21
Texture		loam	loam	loam
Bulk density	g cm-3	1.62	1.52	1.47
Saturation Percentage	%	20.67	23.50%	24.36%
Nitrate-N (mg kg-1)	mg kg-1	1.27	2.35	2.75
Total N	%	0.027	0.036	0.042

Table 5: Physico-Chemical analysis of soil samples from experimental sites before sowing of wheat crop at Kala Shah Kaku Farm during 2005-08 (Non-replicated Trial)

Parameter	Unit	Amount /Class		
		2005/06	2006/07	2007/08
EC (1:1)	dS m-1	0.36	0.48	0.48
pH		8.3	8.3	8.3
Organic matter	%	0.65	0.87	0.87
CaCO3 Content	%	3.65	2.75	2.75
Phosphorus (Olson)	mg kg-1	3.85	3.31	3.31
NH4OAC extractable K	mg kg-1	75	82	82
Zn	mg kg-1	0.52	0.77	0.77
B	mg kg-1	0.35	0.35	0.35
Sand	%	44.2	40.5	40.5
Silt	%	33.8	38.2	38.2
Clay	%	22	21.3	21.3
Texture		loam	loam	loam
Bulk density	g cm-3	1.57	1.52	1.52
Saturation Percentage	%	23.5	23.50%	23.50%
Nitrate-N (mg kg-1)	mg kg-1	1.73	2.35	2.35
Total N	%	0.023	0.036	0.036

Table 6: Physico-Chemical analysis of soil samples from experimental sites before sowing of wheat crop at Ch. Mushtaq Farm during 2005-08 (Non-replicated Trial)

Parameter	Unit	Amount Class		
		2005/06	2006/07	2007/08
EC (1:1)	dS m-1	0.68	0.67	0.67
pH		8.5	8.2	8.2
Organic matter	%	0.72	0.68	0.68
CaCO3 Content	%	3.45	2.9	2.9
Phosphorus (Olson)	mg kg-1	4.32	4.65	4.65
NH4OAC extractable K	mg kg-1	85	96	96
Zn	mg kg-1	0.63	0.67	0.67
B	mg kg-1	0.47	0.49	0.49
Sand	%	50.34	50.5	50.5

Silt	%	22.16	26	26
Clay	%	23.5	23.5	23.5
Texture		Sandy–clay loam	Sandy–clay loam	Sandy–clay loam
Bulk density	g cm-3	1.55	1.47	1.47
Saturation Percentage	%	24.5		
Nitrate-N (mg kg-1)	mg kg-1	2.05	2.78	2.78
Total N	%	0.037	0.042	0.042

Table 7: Physico-Chemical analysis of soil samples from experimental sites before sowing of wheat crop at Ch. Shahbaz Farm during 2005-08 (Non-replicated Trial)

Parameter	Unit	Amount /Class		
		2005/06	2006/07	2007/08
EC (1:1)	dS m-1	0.68	0.35	0.35
pH		8.5	7.9	7.9
Organic matter	%	0.72	0.71	0.71
CaCO3 Content	%	3.45	3.05	3.05
Phosphorus (Olson)	mg kg-1	4.32	2.7	2.7
NH4OAC extractable K	mg kg-1	85	105	105
Zn	mg kg-1	0.63	0.83	0.83
B	mg kg-1	0.47	0.46	0.46
Sand	%	50.34	41.3	41.3
Silt	%	22.16	37	37
Clay	%	23.5	21.7	21.7
Texture		loam	loam	loam
Bulk density	g cm-3	1.55	1.42	1.42
Saturation Percentage	%	24.5		
Nitrate-N (mg kg-1)	mg kg-1	2.05	3.3	3.3
Total N	%	0.037	0.49	0.49

11.1.1 Effect of rice residue management on soil properties after harvest of wheat crop at different levels of nitrogen during 2005-06 at Replicated plots at KSK

Organic Matter

The organic matter (OM) content was increased significantly ($P < 0.05$) in upper depth (0-15 cm) where full residue was mulched with FMI Seeder and nitrogen was applied @ 125 kg urea per acre. The minimum OM contents (0.57%) were observed in the upper layer (0-15 cm), in the plot where wheat was sown after manual harvesting of rice, the residues were burned and nitrogen was applied @ 50 kg urea per acre (Fig. 26, Appendix 1 Table 1). The OM contents were significantly ($P < 0.05$) increased 19% higher in the upper layer of soil (0-15 cm), in the plot where wheat was sown after manual harvesting of rice, the residues were burned, nitrogen was applied at 75, 100 and 125 kg urea per acre respectively compared with plot where nitrogen was applied @ 50 kg urea per acre with same sowing method. The organic matter contents in the upper layer (0-15 cm), were observed statistically (P < 0.05) similar among the plots of all nitrogen levels where wheat was sown with disc plough after manual harvesting of rice. The OM contents were increased 10, 6, 3 and 5% respectively among the plots where nitrogen was applied @ 50, 75, 100 and 125 kg urea per acre and wheat was sown with full rice residue mulched with FMI Seeder compared with residue burned. The OM contents were observed similar in the upper layer where residue was burned and wheat was sown with FMI Seeder.

The OM contents were statistically (P < 0.05) similar in lower depth (15-30 cm) at all nitrogen levels among all treatments and highest increased was 2.5% in the treatment where wheat was sown with mulching of full rice residue compared with manual harvesting of rice the stubbles were burned and wheat was sown with zero till drill.

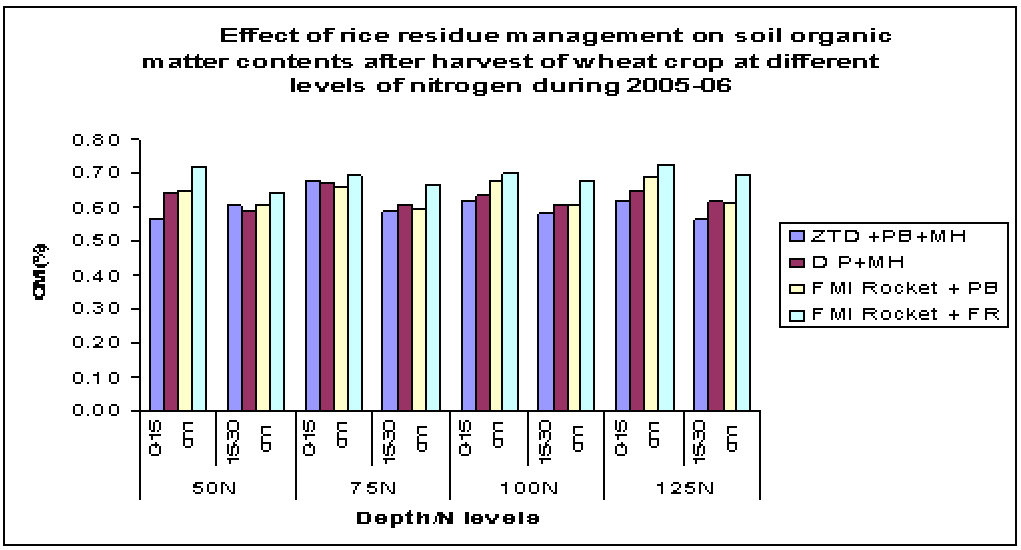


Fig.26. Effect of rice residue management on soil organic matter contents after harvest of wheat crop at different levels of nitrogen during 2005-06

The organic matter (OM) contents (0.95%) was increased significantly (P < 0.05) in upper depth (0-15 cm) where full residue was mulched with FMI Seeder and nitrogen was applied @ 100 kg urea per acre. The minimum OM contents (0.72%) were observed in the upper layer (0-15 cm), in the plot where wheat was sown after manual harvesting of rice, the residues were burned and nitrogen was applied @ 100 kg urea per acre (Fig. 26,)

The OM contents were statistically (P < 0.05) similar in the upper layer of soil (0-15 cm), in the plot where wheat was sown after manual harvesting of rice, the residues were burned, nitrogen was applied at 75, 100 and 125 kg urea per acre respectively.

The organic matter contents in the upper layer (0-15 cm), were observed statistically (P < 0.05) similar among the plots of all nitrogen levels where wheat was sown with disc plough after manual harvesting of rice. The organic matter contents in the upper layer (0-15 cm), were observed statistically (P < 0.05) similar among the plots of all nitrogen levels where wheat was sown with FMI Seeder after partial burning of rice residues. The organic matter contents in the upper layer (0-15 cm), were observed statistically (P <

0.05) similar among the plots of all nitrogen levels where wheat was sown with FMI Seeder after partial burning of rice residues. The OM contents were statistically (P < 0.05) significantly higher in the upper layer (0-15 cm) where wheat was sown with mulching of rice residues with by using FMI Seeder at all nitrogen levels compared with plots where wheat was sown either by zero till or disc plough and rice residues after manual harvesting either burned or removed.

The OM contents were increased in the upper layer as 15, 15, 12 and 5% respectively among the plots where nitrogen was applied @ 50, 75, 100 and 125 kg urea per acre and wheat was sown with full rice residue mulched with FMI Seeder compared with residue burned. The OM contents were observed statistically (P < 0.05) similar but 10% increased in the upper layer (0-15 cm) of the plot where residue was burned and wheat was sown with FMI Seeder and nitrogen was applied @ 100 kg urea per acre compared with plot where nitrogen was applied @ 50 kg urea per acre.

The OM contents were statistically (P < 0.05) similar in lower depth (15-30 cm) at all nitrogen levels among plots where residue was either removed or burned and wheat was sown either with disc or zero till drill, but its slightly higher in the plots where wheat was sown with mulching of full rice residue compared with other sowing methods.

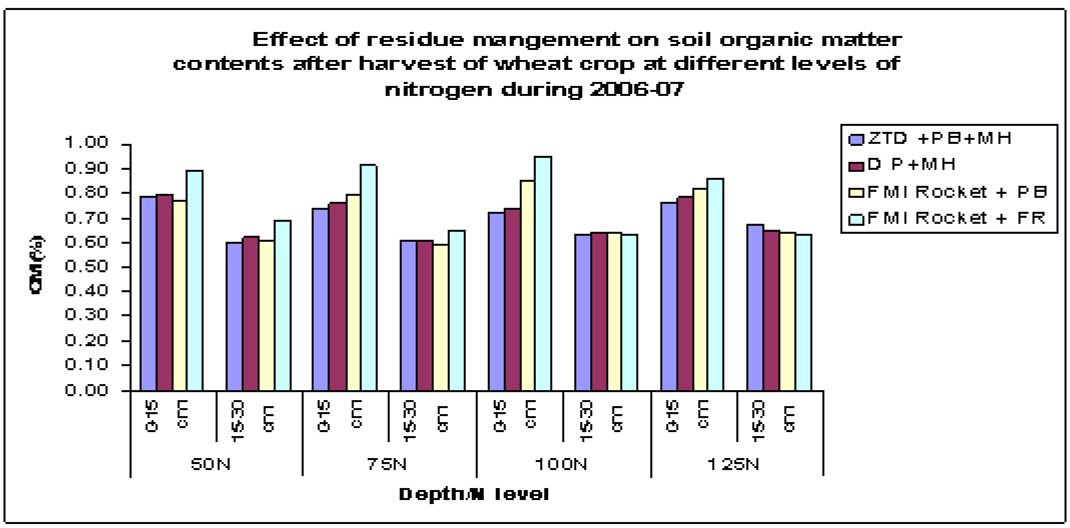


Fig.27. Effect of rice residue management on soil organic matter contents after harvest of wheat crop at different levels of nitrogen during 2006-07

The maximum OM contents (0.96%) was observed significantly (P < 0.05) higher in upper depth (0-15 cm) where full residue was mulched with FMI Seeder and nitrogen was applied @ 100 kg urea per acre. The minimum OM contents (0.62%) were observed in the lower layer (15 -30 cm), in the plot where wheat was sown FMI Seeder after burning of rice residues, nitrogen was applied @ 75 kg urea per acre (Fig. 27).

The OM contents was increased significantly (P < 0.05) in upper depth (0-15 cm) where full residue was mulched with FMI Seeder all nitrogen levels compared with rest of the sowing methods. The OM contents in the upper layer (0-15 cm), were observed statistically (P < 0.05) similar among the plots of all nitrogen levels where wheat was sown with disc plough after manual harvesting of rice but in this sowing method values are slightly lower than other sowing methods like manually harvesting, the rice residues were burned and wheat was sown with zero till and the residue was partially burned and wheat was sown with FMI Seeder.

The OM contents in the upper layer (0-15 cm) were increased as 14, 15, 10 and 12% respectively among the plots where nitrogen was applied @ 50, 75, 100 and 125 kg urea per acre and wheat was sown with full rice residue mulched with FMI Seeder compared with sowing method where rice residue were burned and wheat with FMI Seeder.

The OM contents were statistically ($P < 0.05$) similar in lower depth (15-30 cm) at all nitrogen levels among plots where residue was either removed or burned and wheat was sown either with disc or zero till drill, but its slightly higher in the plots where wheat was sown with mulching of full rice residue.

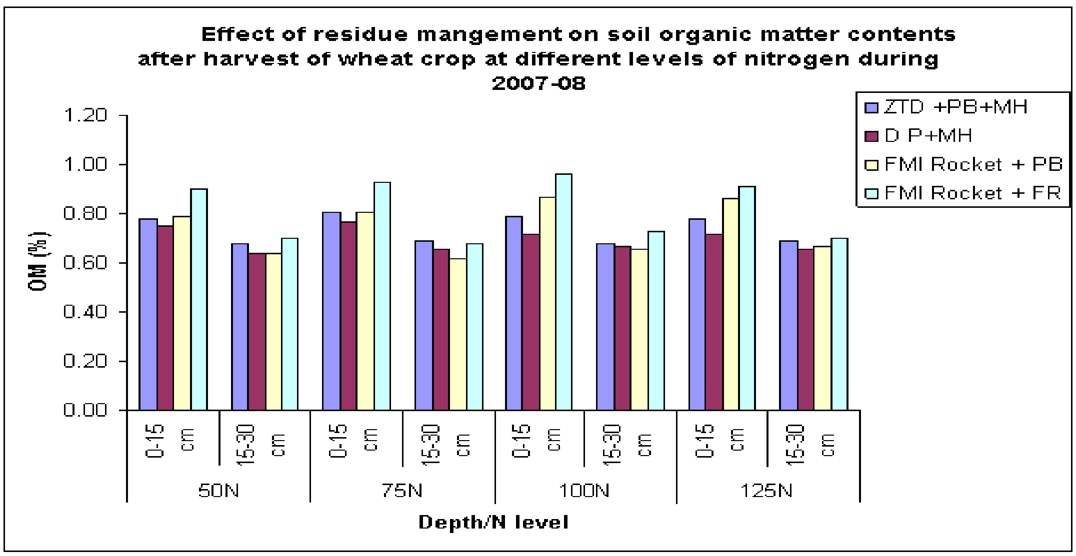


Fig.28. Effect of rice residue management on soil nitrate nitrogen contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2007-08

Soil Nitrogen

The maximum soil nitrate nitrogen (NO3-N) content (2.73 mg kg-1) was observed statistically significantly ($P < 0.05$) in upper depth (0-15 cm) where full residue was mulched with FMI Rocket seeder and nitrogen was applied @ 125 kg urea per acre. The minimum NO3-N content (2.08 mg kg-1) was observed in the lower depth (15-30 cm), in the plot where wheat was sown after manual harvesting, the rice residues were burned and nitrogen was applied @ 100 kg urea per acre (Fig. 28).

The NO3-N contents in the upper layer (0-15 cm), were observed statistically ($P < 0.05$) similar among the plots of all nitrogen levels where wheat was sown with disc plough after manual harvesting of rice. The NO3-N contents were increased 11, 9 and 10% respectively among the plots where nitrogen was applied @ 75, 100 and 125 kg urea per acre and wheat was sown with full rice residue mulched with FMI Rocket seeder compared with the wheat sown with FMI Rocket seeder after residue burning.

The NO3-N contents were observed similar in the upper soil depth where residue was burned and wheat was sown with FMI Rocket seeder at all nitrogen levels. But NO3-N contents were increased significantly (P < 0.05) in the upper soil depth where full rice residue was mulched with FMI Rocket seeder where nitrogen was applied @ 125 kg per acre compared with plots having same sowing method and nitrogen levels were 50, 75 and 100 kg urea per acre.

The NO3-N contents were statistically (P < 0.05) similar in lower depth (15-30 cm) at all nitrogen levels among all treatments at all nitrogen levels.

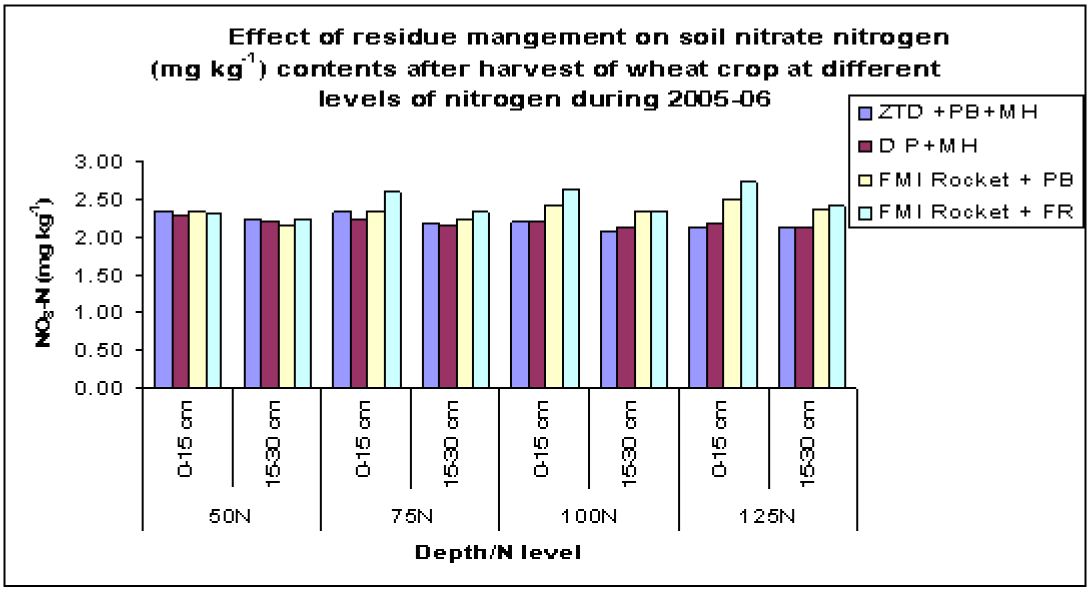


Fig.29. Effect of rice residue management on soil nitrate nitrogen contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2005-06

The maximum soil nitrate nitrogen (NO3-N) content (4.76 mg kg-1) was observed significantly (P < 0.05) higher in upper depth (0-15 cm) where full residue was mulched with FMI Seeder and nitrogen was applied @ 125 kg urea per acre. The minimum NO3-N content (2.48 mg kg-1) was observed in the lower depth (15-30 cm), in the plot where wheat was sown after manual harvesting, the rice residues were burned and nitrogen was applied @ 100 kg urea per acre (Fig. 29).

The NO3-N contents in the upper layer (0-15 cm), were observed significantly (P < 0.05) higher (3.56 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI Seeder and nitrogen was applied @ 50 kg urea per acre compared with rest of the sowing methods i.e., it was 20% higher than plot where wheat was sown with FMI Seeder after burning rice residues, 30% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 53% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the upper layer (0-15 cm), were observed significantly (P < 0.05) higher (4.52 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI Seeder and nitrogen was applied @ 75 kg urea per acre compared with rest of the sowing methods i.e., it was 13% higher than plot where wheat was sown with FMI Seeder after burning rice residues, 47% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 74% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the upper layer (0-15 cm), were observed significantly ($P < 0.05$) higher (4.64 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI Seeder and nitrogen was applied @ 100 kg urea per acre compared with rest of the sowing methods i.e., it was 42% higher than plot where wheat was sown with FMI Seeder after burning rice residues, 50% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 76% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the upper layer (0-15 cm), were observed significantly ($P < 0.05$) higher (4.76 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI Seeder and nitrogen was applied @ 125 kg urea per acre compared with rest of the sowing methods i.e., it was 41% higher than plot where wheat was sown with FMI Seeder after burning rice residues, 32% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 78% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents were statistically ($P < 0.05$) similar in lower depth (15-30 cm) at all nitrogen levels where wheat was sown with FMI Seeder and mulching of rice residues with this drill but the contents were significantly ($P < 0.05$) higher than rest of the sowing methods. The NO3-N contents were statistically ($P < 0.05$) similar in lower depth (15-30 cm) of the plots crop was sown with all the sowing methods except with FMI Seeder and mulching of rice residues with this drill.

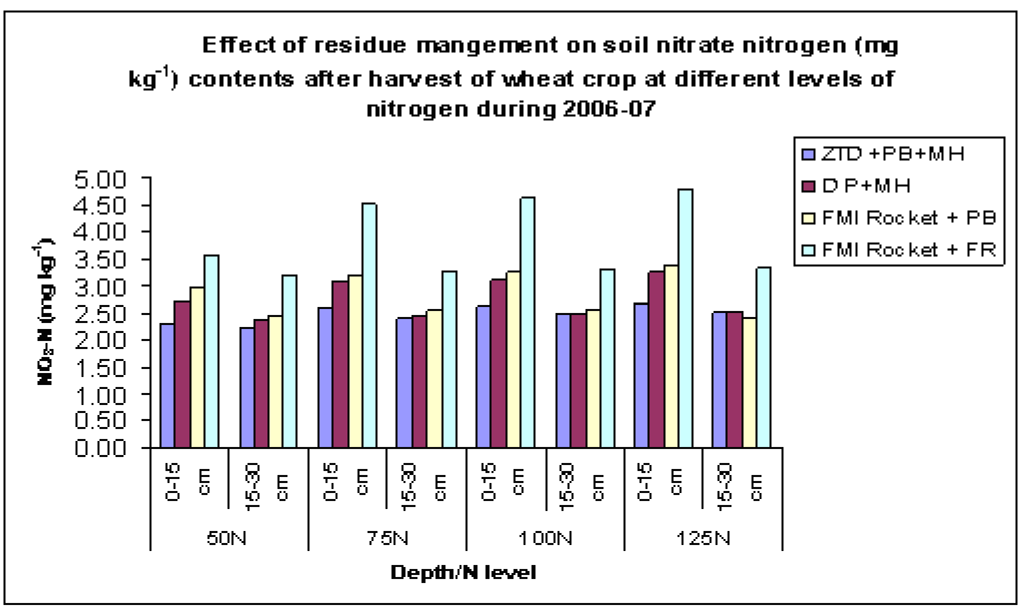


Fig.30. Effect of rice residue management on soil nitrate nitrogen contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2006-07

The maximum soil nitrate nitrogen (NO3-N) content (4.76 mg kg-1) was observed significantly ($P < 0.05$) higher in upper depth (0-15 cm) where full residue was mulched with FMI Seeder and nitrogen was applied @ 125 kg urea per acre. The minimum NO3-N content (2.46 mg kg-1) was observed in the lower depth (15-30 cm), in the plot where wheat was sown with zero till drill after manual harvesting of rice crop, the rice residues were removed and nitrogen was applied @ 50 kg urea per acre (Fig. 30).

The NO3-N contents in the upper layer (0-15 cm), were observed significantly ($P < 0.05$) higher (3.70 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI Seeder and nitrogen was applied @ 50 kg urea per acre compared with rest of the sowing methods i.e., it was 17% higher than plot where wheat was sown with FMI Seeder after burning rice residues, 28% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 21% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the upper layer (0-15 cm), were observed significantly ($P < 0.05$) higher (4.30 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI rocket seeder and nitrogen was applied @ 75 kg urea per acre compared with rest of the sowing methods i.e., it was 33% higher than plot where wheat was sown with FMI rocket seeder after burning rice residues, 38% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 34% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the upper layer (0-15 cm), were observed significantly ($P < 0.05$) higher (4.55 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI rocket seeder and nitrogen was applied @ 100 kg urea per acre compared with rest of the sowing methods i.e., it was 37% higher than plot where wheat was sown with FMI rocket seeder after burning rice residues, 44% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 37% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the upper layer (0-15 cm), were observed significantly ($P < 0.05$) higher (4.71 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI rocket seeder and nitrogen was applied @ 125 kg urea per acre compared with rest of the sowing methods i.e., it was 32% higher than plot where wheat was sown with FMI rocket seeder after burning rice residues, 41% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 34% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the lower layer (15-30 cm), were observed significantly (P < 0.05) higher (3.12 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI rocket seeder and nitrogen was applied @ 50 kg urea per acre compared with rest of the sowing methods i.e., it was 20% higher than plot where wheat was sown with FMI rocket seeder after burning rice residues, 31% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 27% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the lower layer (15-30 cm), were observed significantly (P < 0.05) higher (3.24 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI rocket seeder and nitrogen was applied @ 75 kg urea per acre compared with rest of the sowing methods i.e., it was 22% higher than plot where wheat was sown with FMI rocket seeder after burning rice residues, 20% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 28% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the lower layer (15-30 cm), were observed significantly (P < 0.05) higher (3.35 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI rocket seeder and nitrogen was applied @ 100 kg urea per acre compared with rest of the sowing methods i.e., it was 17% higher than plot where wheat was sown with FMI rocket seeder after burning rice residues, 23% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 24% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents in the lower layer (15-30 cm), were observed significantly (P < 0.05) higher (3.42 mg kg-1) in the pots where wheat was sown by mulching of rice residues with FMI rocket seeder and nitrogen was applied @ 125 kg urea per acre compared with rest of the sowing methods i.e., it was 18% higher than plot where wheat was sown with FMI rocket seeder after burning rice residues, 19% higher than the plot where wheat was sown with disc plough after manual harvesting of rice and 20% higher than plots where wheat was sown with zero till drill after manual harvesting and residues were burned.

The NO3-N contents were statistically (P < 0.05) similar in lower depth (15-30 cm) at all nitrogen levels where wheat was sown with FMI rocket seeder and mulching of rice residues with this drill but the contents were significantly (P < 0.05) higher than rest of the sowing methods. The NO3-N contents were statistically (P < 0.05) similar in lower depth (15-30 cm) of the plots where crop was sown with all the sowing methods except with FMI rocket seeder and mulching of rice residues with this drill. The maximum soil phosphorus content (3.54 mg kg-1) was observed significantly (P < 0.05) higher in upper depth (0-15 cm) where full residues were mulched with FMI

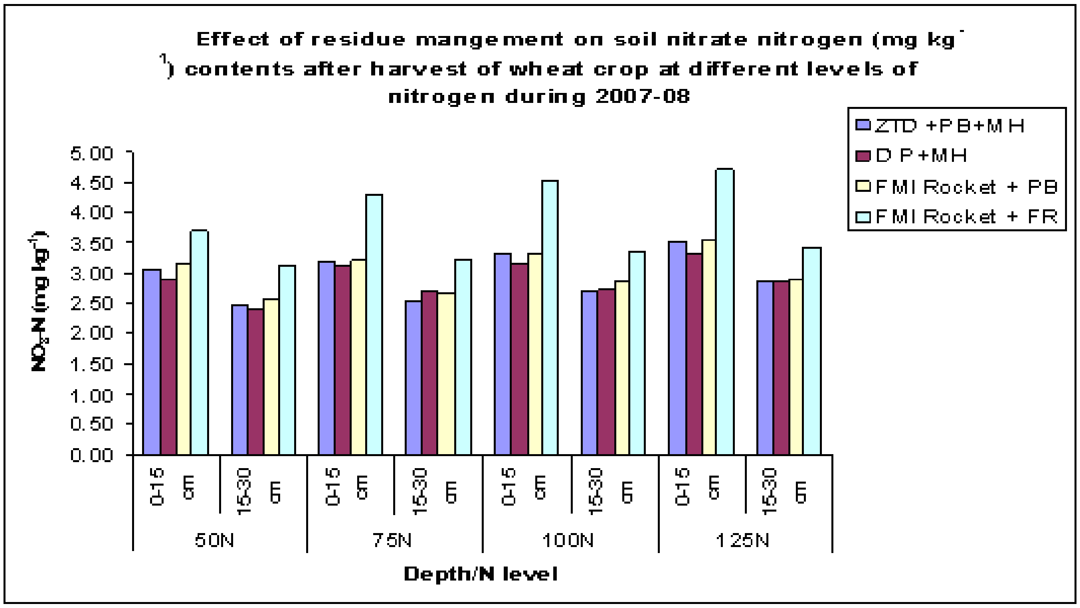
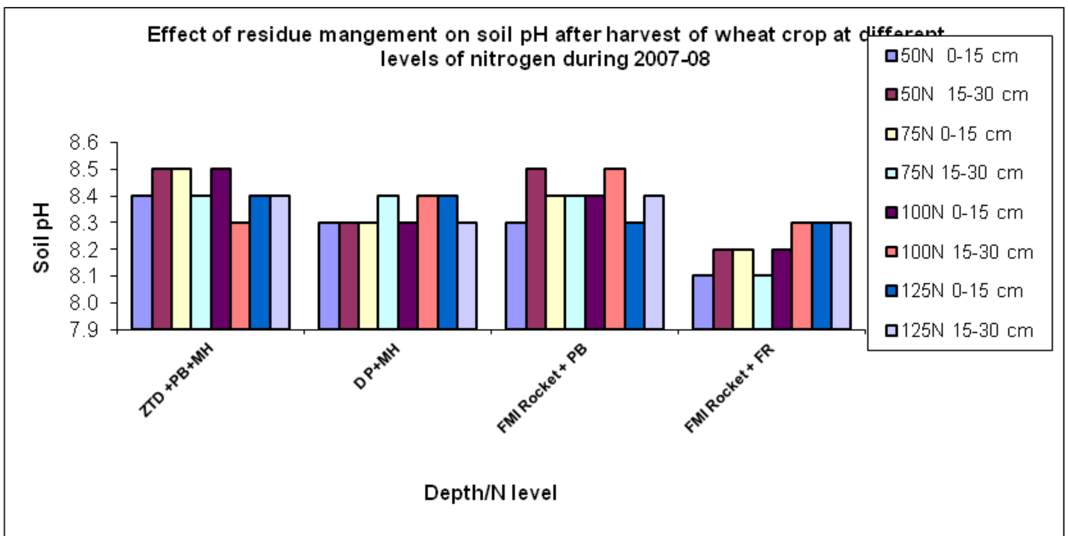


Fig.31. Effect of rice residue management on soil nitrogen contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2007-08



11.2 Appendix 2: Agronomic data

11.2.1 A. Soil Analysis after Harvesting of Wheat Crop (2005-06) at KSK (Replicated Trial)

Effect of residue management on organic matter (%) contents after harvest of wheat crop during 2005-06								
N level	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								

R1	0.67	0.54	0.73	0.54	0.73	0.65	0.68	0.65
R2	0.53	0.67	0.66	0.65	0.62	0.54	0.51	0.60
R3	0.56	0.53	0.64	0.52	0.53	0.63	0.72	0.53
R4	0.51	0.69	0.68	0.65	0.58	0.51	0.55	0.55
Mean	0.57	0.61	0.68	0.59	0.62	0.58	0.62	0.58
D P+MH								
R1	0.64	0.65	0.69	0.58	0.75	0.68	0.58	0.71
R2	0.73	0.66	0.58	0.63	0.55	0.65	0.72	0.66
R3	0.68	0.54	0.76	0.55	0.71	0.59	0.66	0.59
R4	0.52	0.51	0.65	0.68	0.53	0.52	0.64	0.51
Mean	0.64	0.59	0.67	0.61	0.64	0.61	0.65	0.62
FMI SEEDER + PB								
R1	0.57	0.67	0.67	0.64	0.57	0.57	0.76	0.58
R2	0.73	0.52	0.65	0.57	0.78	0.64	0.61	0.69
R3	0.61	0.69	0.62	0.51	0.67	0.68	0.64	0.63
R4	0.69	0.55	0.71	0.66	0.68	0.55	0.75	0.55
Mean	0.65	0.61	0.66	0.60	0.68	0.61	0.69	0.61
FMI SEEDER + FR								
R1	0.74	0.68	0.81	0.65	0.66	0.66	0.79	0.68
R2	0.75	0.72	0.62	0.75	0.79	0.56	0.73	0.62
R3	0.62	0.65	0.71	0.59	0.62	0.78	0.61	0.77
R4	0.77	0.53	0.64	0.67	0.73	0.72	0.77	0.71
Mean	0.72	0.65	0.70	0.67	0.70	0.68	0.73	0.70

Effect of residue management on NO3-N (mg kg-1) contents after harvest of wheat crop during 2005-06								
N level	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	2.31	2.45	2.24	2.31	2.26	1.85	2.33	2.27
R2	2.05	2.17	2.35	2.17	2.08	2.05	2.04	2.14
R3	2.78	2.38	2.48	2.28	2.32	2.29	2.23	1.86
R4	2.28	2.01	2.25	2.01	2.13	2.13	1.95	2.25
Mean	2.35	2.25	2.33	2.19	2.19	2.08	2.14	2.13
D P+MH								
R1	2.56	2.33	2.45	2.15	2.12	1.87	2.31	1.91
R2	2.22	2.16	1.97	2.07	2.36	2.23	2.17	2.33

R3	2.23	2.07	2.27	2.35	2.1	2.31	1.99	2.12
R4	2.15	2.25	2.28	2.13	2.26	2.19	2.24	2.06
Mean	2.29	2.20	2.24	2.17	2.21	2.15	2.17	2.11
FMI Seeder + PB								
R1	2.23	2.17	2.41	2.28	2.35	2.45	2.67	2.52
R2	2.34	2.32	2.23	2.33	2.57	2.33	2.48	2.17
R3	2.28	2.06	2.48	2.16	2.25	2.31	2.55	2.38
R4	2.41	2.14	2.29	2.21	2.48	2.23	2.25	2.41
Mean	2.32	2.17	2.35	2.24	2.41	2.33	2.48	2.37
FMI Seeder + FR								
R1	2.44	2.56	2.32	2.16	2.87	2.33	2.71	2.26
R2	2.25	1.82	2.51	2.38	2.44	2.52	2.58	2.59
R3	2.37	2.36	2.75	2.48	2.71	2.18	2.85	2.32
R4	2.15	2.23	2.81	2.25	2.55	2.35	2.77	2.45
Mean	2.30	2.24	2.59	2.32	2.64	2.34	2.73	2.41

Effect of residue management on phosphorus (mg kg-1) contents after harvest of wheat crop during 2005-06

N levels	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	2.87	2.56	3.47	2.34	2.89	2.54	3.48	2.26
R2	3.15	2.43	3.52	2.44	3.58	2.45	3.22	2.34
R3	3.55	2.64	2.78	2.18	3.73	2.28	2.81	2.47
R4	3.29	2.32	3.38	2.36	2.51	2.31	3.86	2.71
Mean	3.215	2.4875	3.2875	2.33	3.1775	2.395	3.3425	2.445
D P+MH								
R1	3.12	2.07	3.44	2.45	3.34	2.51	3.31	2.78
R2	3.55	2.28	3.61	2.37	3.16	2.34	3.64	2.27
R3	3.41	2.72	3.54	2.28	3.49	2.46	3.41	2.52
R4	3.32	2.18	3.21	2.63	2.85	2.17	3.77	2.34
Mean	3.35	2.3125	3.45	2.4325	3.21	2.37	3.5325	2.4775
FMI Seeder + PB								
R1	3.25	2.47	3.53	2.38	3.45	3.01	3.54	2.61
R2	3.31	2.73	3.68	2.29	3.23	2.62	3.25	2.37
R3	3.61	2.35	3.23	2.56	3.67	2.79	3.88	2.55
R4	3.59	2.65	3.75	2.91	3.54	2.42	3.79	2.85
Mean	3.44	2.55	3.5475	2.535	3.4725	2.71	3.615	2.595
FMI Seeder + FR								
R1	3.71	2.56	3.55	2.71	3.48	2.34	3.69	2.38

R2	3.31	2.33	3.86	3.32	3.81	2.65	3.45	2.67
R3	3.27	2.51	3.17	2.88	3.36	2.88	3.57	2.78
R4	3.81	2.21	3.26	2.95	3.67	2.73	3.95	2.93
Mean	3.525	2.4025	3.46	2.965	3.58	2.65	3.665	2.69

Effect of residue management on soil potassium contents (mg kg-1) after harvest of wheat crop during 2005-06

N level	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	55.34	70.32	46.38	53.27	77.94	47.39	53.28	63.35
R2	67.29	65.23	87.35	73.68	80.23	55.35	84.34	74.67
R3	73.45	55.15	67.45	46.32	55.42	63.78	75.36	59.25
R4	63.21	46.27	76.79	55.21	67.25	73.75	80.85	51.63
Mean	64.82	59.24	69.49	57.12	70.21	60.06	73.45	62.23
D P+MH								
R1	79.45	56.49	65.85	78.39	82.46	56.87	76.38	72.67
R2	53.58	78.95	84.36	63.48	74.34	69.35	85.85	60.54
R3	71.37	52.47	67.39	58.21	55.57	51.74	75.44	58.71
R4	76.29	56.38	65.81	61.75	77.45	79.62	65.78	59.34
Mean	70.17	61.07	70.85	65.46	72.45	64.39	75.86	62.82
FMI Seeder + PB								
R1	69.27	74.36	66.52	57.42	56.34	71.24	66.67	83.45
R2	79.51	59.47	73.55	73.26	78.28	60.25	84.24	61.36
R3	68.45	65.49	59.37	76.5	70.52	73.68	53.27	47.28
R4	81.56	67.28	79.23	65.63	63.61	53.51	79.11	56.55
Mean	74.69	66.65	69.67	68.20	67.19	64.67	70.82	62.16
FMI Seeder + FR								
R1	85.42	65.48	68.45	68.25	74.37	57.43	87.73	67.54
R2	75.76	74.66	71.75	59.81	67.75	65.39	74.58	73.75
R3	79.45	59.25	58.37	77.75	75.38	71.72	71.35	65.52
R4	63.27	69.35	82.15	56.39	68.95	75.75	55.65	59.75
Mean	75.97	67.18	70.18	65.55	71.61	67.57	72.33	66.64

Effect of residue management on soil bulk density (g cm-3) after harvest of wheat crop during 2005-06

N level	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	1.63	1.67	1.54	1.67	1.56	1.64	1.55	1.66

R2	1.54	1.65	1.61	1.62	1.59	1.63	1.53	1.6
R3	1.67	1.66	1.57	1.66	1.62	1.67	1.59	1.67
R4	1.58	1.63	1.65	1.61	1.53	1.65	1.56	1.62
Mean	1.61	1.65	1.59	1.64	1.57	1.65	1.56	1.63
D P+MH								
R1	1.52	1.64	1.44	1.56	1.52	1.65	1.45	1.59
R2	1.46	1.56	1.49	1.62	1.47	1.52	1.52	1.66
R3	1.58	1.63	1.47	1.64	1.43	1.59	1.46	1.69
R4	1.37	1.61	1.53	1.55	1.41	1.68	1.44	1.57
Mean	1.48	1.61	1.48	1.59	1.45	1.61	1.47	1.63
FMI Seeder + PB								
R1	1.53	1.71	1.43	1.67	1.62	1.66	1.47	1.64
R2	1.57	1.57	1.57	1.65	1.56	1.69	1.56	1.68
R3	1.64	1.53	1.53	1.61	1.52	1.62	1.55	1.58
R4	1.45	1.68	1.58	1.67	1.55	1.57	1.51	1.69
Mean	1.55	1.62	1.53	1.65	1.56	1.64	1.52	1.65
FMI Seeder + FR								
R1	1.46	1.61	1.58	1.69	1.56	1.65	1.47	1.67
R2	1.53	1.66	1.55	1.62	1.53	1.64	1.58	1.65
R3	1.59	1.65	1.51	1.66	1.51	1.69	1.55	1.61
R4	1.44	1.54	1.53	1.68	1.48	1.57	1.54	1.69
Mean	1.51	1.62	1.54	1.66	1.52	1.64	1.54	1.65

Effect of residue management on soil pH after harvest of wheat crop during 2005-06								
N level	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	8.3	8.7	8.5	8.7	8.6	8.5	8.6	8.5
R2	8.5	8.5	8.3	7.8	8.7	8.4	8.4	8.7
R3	8.7	8.3	8.6	8.7	8.8	8.6	8.3	8.3
R4	8.4	8.2	8.8	8.6	8.5	8.6	8.5	8.8
Mean	8.5	8.4	8.5	8.5	8.6	8.5	8.5	8.6
D P+MH								
R1	8.7	8.4	8.5	8.1	8.5	8.5	8.6	8.5
R2	8.5	8.5	8.6	8.3	8.6	8.4	. 8.4	8.6
R3	8.6	8.7	8.6	8.7	8.7	8.5	8.3	8.4

R4	8.4	8.6	8.3	8.4	8.7	8.3	8.5	8.3
Mean	8.5	8.6	8.5	8.4	8.6	8.4	8.5	8.4
FMI Seedert + PB								
R1	8.5	8.2	8.2	8.6	8.5	8.5	8.8	8.3
R2	8.4	8.1	7.9	8.5	8.6	8.4	8.5	8.7
R3	8.2	8.7	8.2	8.8	8.3	8.6	8.1	8.3
R4	8.7	8.5	8.6	8.3	8.5	8.2	8.6	8.5
Mean	8.4	8.4	8.2	8.5	8.4	8.4	8.5	8.4
FMI Seeder + FR								
R1	8.5	8.7	8.2	8.4	8.4	8.6	8.2	8.5
R2	8.3	8.5	8.6	8.5	8.3	8.5	8.3	8.2
R3	8.1	8.4	8.5	8.9	8.7	8.2	8.7	8.1
R4	8.6	8.6	8.7	8.5	8.5	8.7	7.8	8.7
Mean	8.4	8.6	8.5	8.5	8.4	8.5	8.3	8.4

11.2.2 B. Soil Analysis after Harvesting of Wheat Crop (2006-07) at KSK (Replicated Trial)

Effect of residue management on organic matter contents (%) after harvest of wheat crop during 2006-07								
N levels	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	0.87	0.76	0.82	0.67	0.79	0.63	0.71	0.68
R2	0.63	0.56	0.76	0.72	0.76	0.56	0.78	0.73
R3	0.82	0.64	0.66	0.56	0.64	0.69	0.81	0.61
R4	0.79	0.45	0.71	0.50	0.69	0.62	0.75	0.66
Mean	0.78	0.60	0.74	0.61	0.72	0.63	0.76	0.67
D P+MH								
R1	0.88	0.72	0.87	0.58	0.75	0.68	0.86	0.71
R2	0.85	0.54	0.67	0.63	0.68	0.65	0.72	0.66
R3	0.76	0.68	0.74	0.55	0.71	0.71	0.66	0.73
R4	0.65	0.53	0.77	0.68	0.82	0.52	0.87	0.51
Mean	0.79	0.62	0.76	0.61	0.74	0.64	0.78	0.65
FMI Seeder+ PB								
R1	0.76	0.68	0.86	0.62	0.95	0.58	0.72	0.66
R2	0.75	0.55	0.75	0.51	0.88	0.67	0.91	0.67
R3	0.68	0.61	0.68	0.57	0.75	0.71	0.78	0.69
R4	0.87	0.58	0.87	0.65	0.83	0.59	0.85	0.54

Mean	0.77	0.61	0.79	0.59	0.85	0.64	0.82	0.64
FMI Seeder + FR								
R1	0.89	0.70	1.05	0.59	1.05	0.59	0.87	0.60
R2	0.93	0.67	0.87	0.62	0.87	0.61	0.87	0.72
R3	0.93	0.72	0.91	0.61	0.93	)	0.93	0.56
R4	0.80	0.65	0.81	0.78	0.95	0.70	0.77	0.63
Mean	0.89	0.69	0.91	0.65	0.95	0.63	0.86	0.63

Effect of residue management on NO3-N (mg kg-1) after harvest of wheat crop during 2006-07

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	2.35	2.01	2.56	2.51	2.95	2.05	2.82	2.85
R2	2.28	2.31	2.34	2.31	2.74	2.37	2.58	2.26
R3	2.55	2.15	2.58	2.45	2.45	2.61	2.45	2.71
R4	2.11	2.45	2.86	2.35	2.37	2.89	2.85	2.21
Mean	2.32	2.23	2.59	2.41	2.63	2.48	2.68	2.51
D P+MH								
R1	2.53	2.56	3.52	2.14	3.33	2.67	3.94	2.76
R2	2.75	2.26	2.75	2.31	2.81	2.21	3.43	2.57
R3	2.93	2.11	2.88	2.62	2.79	2.35	2.75	2.16
R4	2.65	2.56	3.12	2.75	3.45	2.74	2.84	2.58
Mean	2.72	2.37	3.07	2.46	3.10	2.49	3.24	2.52
FMI Seeder + PB								
R1	3.01	2.75	3.73	2.53	3.43	2.42	3.60	2.00
R2	2.76	2.46	3.35	2.31	3.33	2.43	3.46	2.95
R3	3.35	2.37	2.91	2.51	2.85	2.57	3.74	2.32
R4	2.71	2.21	2.73	2.76	3.41	2.88	2.63	2.27
Mean	2.96	2.45	3.18	2.53	3.26	2.58	3.36	2.39
FMI Seeder + FR								
R1	3.74	3.48	5.16	3.20	4.07	3.12	4.49	3.35
R2	3.66	2.79	4.33	3.45	4.44	3.76	4.36	3.85
R3	3.37	3.12	4.79	3.70	5.36	2.92	4.93	2.72
R4	3.45	3.33	3.81	2.71	4.69	3.42	5.24	3.42
Mean	3.56	3.18	4.52	3.27	4.64	3.31	4.76	3.34

Effect of residue management on Phosphorus (mg kg-1) after harvest of wheat crop during 2006-07

N levels	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	3.45	2.63	3.58	2.15	4.17	2.51	4.65	2.33
R2	3.21	2.55	3.62	2.36	3.65	2.47	4.42	2.15
R3	3.78	2.71	3.39	2.22	3.82	2.23	2.54	2.47
R4	3.33	2.43	3.47	2.72	2.21	2.34	3.69	2.71
Mean	3.44	2.58	3.52	2.36	3.46	2.39	3.83	2.42
D P+MH								
R1	3.02	2.00	3.43	2.51	3.78	2.64	3.59	2.01
R2	3.65	2.21	3.25	2.32	3.26	2.14	3.78	2.27
R3	3.49	2.64	3.78	2.16	3.22	2.53	3.41	2.68
R4	2.71	2.43	3.46	2.37	3.25	2.21	3.45	2.34
Mean	3.22	2.32	3.48	2.34	3.38	2.38	3.56	2.33
FMI Seeder + PB								
R1	3.67	2.56	3.43	2.27	3.79	2.71	3.56	2.50
R2	3.33	2.67	3.77	2.16	3.41	2.63	3.43	2.24
R3	3.56	2.43	2.92	2.42	3.37	2.87	3.78	2.60
R4	3.41	2.71	3.81	2.85	3.26	2.32	3.62	2.31
Mean	3.49	2.59	3.48	2.43	3.46	2.63	3.60	2.41
FMI Seeder + FR								
R1	3.95	2.53	4.72	2.48	4.81	2.06	5.50	2.37
R2	3.56	2.66	3.73	3.67	3.78	2.57	4.63	2.35
R3	3.43	2.79	4.21	4.51	4.50	3.33	4.83	2.72
R4	3.78	2.47	3.45	2.44	4.25	2.85	4.30	2.46
Mean	3.68	2.61	4.03	3.28	4.34	2.70	4.82	2.48

Effect of residue management on potassium contents (mg kg-1) after harvest of wheat crop during 2006-07

N levels	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	76.3	69.4	81.4	72.3	68.8	63.2	75.6	75.8
R2	91.3	75.5	93.5	67.3	72.5	57.5	71.3	67.3
R3	89.4	62.4	78.8	56.7	75.8	76.3	68.4	60.9
R4	84.5	64.6	84.4	77.0	84.2	68.3	72.1	55.3
Mean	85.4	68.0	84.5	68.4	75.3	66.3	71.9	64.8
D P+MH								

R1	83.0	58.5	93.4	73.9	94.7	61.7	86.4	64.3
R2	97.4	74.8	83.4	69.9	83.3	47.3	79.3	57.5
R3	76.6	69.8	88.7	66.2	63.3	65.4	58.7	47.2
R4	88.9	60.1	64.8	77.0	61.2	75.2	52.8	65.6
Mean	86.5	65.8	82.6	71.8	75.6	62.4	69.3	58.6
FMI Seedert + PB								
R1	89.7	72.2	90.1	67.6	81.6	62.5	73.1	70.3
R2	84.2	63.6	87.5	77.5	83.2	85.3	80.4	81.3
R3	64.7	57.3	60.5	89.3	67.3	77.5	63.4	65.8
R4	90.9	80.2	79.2	62.4	71.6	60.2	81.3	60.4
Mean	82.4	68.3	79.3	74.2	75.9	71.4	74.5	69.4
FMI Seedert + FR								
R1	90.4	71.4	79.5	55.1	85.7	73.8	91.4	64.2
R2	76.2	72.4	83.3	76.3	90.7	69.4	75.3	75.3
R3	85.8	64.7	87.7	96.8	74.9	78.1	80.7	70.8
R4	70.6	68.7	78.3	82.5	72.3	69.1	68.5	61.5
Mean	80.7	69.3	82.2	77.6	80.9	72.6	79.0	68.0

Effect of residue management on soil bulk density (g cm-3) after harvest of wheat crop during 2006-07

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	1.52	1.65	1.48	1.67	1.51	1.69	1.48	1.65
R2	1.56	1.61	1.54	1.58	1.57	1.63	1.55	1.68
R3	1.53	1.67	1.58	1.62	1.45	1.64	1.56	1.62
R4	1.56	1.69	1.53	1.65	1.52	1.57	1.52	1.66
Mean	1.54	1.66	1.53	1.63	1.51	1.63	1.53	1.65
D P+MH								
R1	1.47	1.60	1.52	1.56	1.45	1.57	1.55	1.61
R2	1.43	1.57	1.46	1.62	1.67	1.59	1.46	1.58
R3	1.52	1.64	1.41	1.53	1.58	1.65	1.47	1.67
R4	1.45	1.67	1.47	1.60	1.49	1.64	1.49	1.62
Mean	1.47	1.62	1.47	1.58	1.55	1.61	1.49	1.62
FMI Seeder + PB								
R1	1.56	1.63	1.47	1.68	1.53	1.65	1.54	1.69
R2	1.54	1.67	1.56	1.67	1.54	1.64	1.58	1.62
R3	1.59	1.65	1.57	1.64	1.58	1.57	1.55	1.66

R4	1.48	1.62	1.53	1.61	1.53	1.60	1.56	1.65
Mean	1.54	1.64	1.53	1.65	1.55	1.62	1.56	1.66
FMI Seeder + FR								
R1	1.54	1.65	1.55	1.66	1.58	1.62	1.53	1.68
R2	1.47	1.64	1.52	1.61	1.51	1.63	1.55	1.61
R3	1.53	1.66	1.50	1.63	1.55	1.69	1.59	1.65
R4	1.46	1.69	1.48	1.68	1.57	1.61	1.49	1.67
Mean	1.50	1.66	1.51	1.65	1.55	1.64	1.54	1.65

Effect of residue management on soil pH after harvest of wheat crop during 2006-07

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	8.1	8.6	8.2	8.7	8.4	8.1	8.6	8.3
R2	8.4	8.7	8.3	8.5	8.6	8.7	8.5	8.6
R3	8.6	8.5	8.6	8.5	8.5	8.4	8.2	8.6
R4	8.3	8.4	8.5	8.2	8.3	8.5	8.5	8.4
Mean	8.4	8.6	8.4	8.5	8.5	8.4	8.5	8.5
D P+MH								
R1	8.5	8.6	8.7	8.6	8.4	8.3	8.4	8.6
R2	8.3	8.7	8.6	8.4	8.6	8.2	8.2	8.3
R3	8.4	8.5	8.5	8.5	8.4	8.5	8.5	8.5
R4	8.7	8.2	8.4	8.3	8.5	8.6	8.4	8.2
Mean	8.5	8.5	8.6	8.5	8.5	8.4	8.4	8.4
FMI Seeder+ PB								
R1	8.7	8.4	8.0	8.3	8.4	8.2	8.5	8.2
R2	8.3	8.5	8.5	8.7	8.5	8.3	8.4	8.3
R3	8.4	8.5	8.3	8.5	8.4	8. 6	8.3	8.5
R4	8.5	8.2	8.3	8.1	8.2	8.1	8.3	8.2
Mean	8.5	8.4	8.3	8.4	8.4	8.2	8.4	8.3
FMI Seeder+ FR								
R1	8.6	8.3	8.1	8.2	8.5	8.4	8.4	8.6
R2	8.4	8.5	8.0	8.3	8.5	8.5	8.2	8.5
R3	8.6	8.2	8.4	8.4	8.2	8.6	8.5	8.3
R4	8.1	8.5	8.6	8.7	8.3	8.2	8.6	8.2
Mean	8.4	8.4	8.3	8.4	8.4	8.4	8.4	8.4

C. Soil Analysis after Harvest of Wheat Crop (2007- 08) at KSK (Replicated Trial)

Effect of residue management on organic matter contents (%) after harvest of wheat crop during 2007-08

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	0.74	0.73	0.78	0.74	0.78	0.69	0.78	0.71
R2	0.86	0.67	0.74	0.63	0.85	0.63	0.81	0.68
R3	0.77	0.64	0.85	0.71	0.73	0.74	0.77	0.74
R4	0.76	0.68	0.86	0.68	0.81	0.65	0.75	0.62
Mean	0.78	0.68	0.81	0.69	0.79	0.68	0.78	0.69
D P+MH								
R1	0.74	0.65	0.76	0.68	0.73	0.64	0.76	0.64
R2	0.88	0.75	0.83	0.59	0.65	0.73	0.63	0.77
R3	0.71	0.62	0.68	0.65	0.77	0.67	0.69	0.65
R4	0.68	0.55	0.81	0.71	0.72	0.65	0.81	0.58
Mean	0.75	0.64	0.77	0.66	0.72	0.67	0.72	0.66
FMI Rocket + PB								
R1	0.79	0.65	0.85	0.67	0.91	0.65	0.77	0.75
R2	0.78	0.63	0.82	0.55	0.86	0.66	0.87	0.69
R3	0.82	0.57	0.73	0.64	0.81	0.73	0.92	0.56
R4	0.75	0.69	0.84	0.61	0.89	0.61	0.86	0.66
Mean	0.79	0.64	0.81	0.62	0.87	0.66	0.86	0.67
FMI Rocket + FR								
R1	0.95	0.76	0.96	0.62	0.97	0.75	0.89	0.64
R2	0.87	0.69	0.93	0.7	0.87	0.68	0.83	0.77
R3	0.86	0.75	0.86	0.65	0.86	0.79	0.95	0.71
R4	0.9	0.61	0.97	0.73	1.12	0.68	0.96	0.68
Mean	0.90	0.70	0.93	0.68	0.96	0.73	0.91	0.70

Effect of residue management on NO3-N (mg kg-1) after harvest of wheat crop during 2007-08

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	2.97	2.13	2.85	2.56	3.48	2.73	3.34	2.91
R2	3.45	2.67	3.28	2.33	2.85	2.59	3.78	3.16
R3	3.58	2.24	3.41	2.47	3.52	2.58	3.51	2.88

R4	2.25	2.81	3.26	2.76	3.38	2.94	3.46	2.43
Mean	3.06	2.46	3.20	2.53	3.31	2.71	3.52	2.85
D P+MH								
R1	2.63	2.33	2.65	2.77	3.22	2.84	3.29	2.65
R2	3.21	2.64	3.19	2.85	3.18	2.75	3.45	3.16
R3	2.77	2.29	3.23	2.91	2.93	2.85	3.37	2.89
R4	2.96	2.25	3.38	2.26	3.27	2.47	3.22	2.78
Mean	2.89	2.38	3.11	2.70	3.15	2.73	3.33	2.87
FMI Rocket + PB								
R1	3.35	2.82	3.51	2.73	3.57	2.56	3.75	2.65
R2	2.76	2.96	3.36	2.58	3.46	2.93	3.55	2.77
R3	3.31	2.21	3.18	2.61	2.71	3.17	3.32	2.95
R4	3.24	2.35	2.84	2.67	3.52	2.78	3.61	3.25
Mean	3.17	2.59	3.22	2.65	3.32	2.86	3.56	2.91
FMI Rocket + FR								
R1	3.73	3.27	4.68	3.25	4.67	2.93	4.51	3.55
R2	3.42	2.82	4.55	3.56	4.53	3.22	4.29	3.64
R3	3.98	3.12	4.23	3.21	4.62	3.28	4.87	3.17
R4	3.65	3.25	3.75	2.95	4.36	3.97	5.15	3.32
Mean	3.70	3.12	4.30	3.24	4.55	3.35	4.71	3.42

Effect of residue management on Phosphorus (mg kg-1) after harvest of wheat crop during 2007-08

N levels	50		75		100		125	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	3.37	2.75	3.85	2.41	3.88	2.72	3.85	3.21
R2	3.68	2.43	3.42	2.54	3.61	2.61	4.55	2.75
R3	3.77	2.84	3.78	2.67	4.32	2.59	3.73	2.67
R4	3.45	2.77	3.54	2.92	3.33	2.93	3.67	2.78
Mean	3.57	2.70	3.65	2.64	3.79	2.71	3.95	2.85
D P+MH								
R1	3.51	2.53	3.64	2.65	3.61	2.54	3.62	2.37
R2	3.72	2.64	3.73	2.36	3.86	2.37	4.17	2.89
R3	3.38	2.73	3.59	2.84	3.69	2.78	3.59	2.61
R4	3.86	2.38	3.35	2.62	3.52	2.91	3.81	3.25
Mean	3.62	2.57	3.58	2.62	3.67	2.65	3.80	2.78
FMI Rocket + PB								

R1	3.87	2.76	3.66	2.42	3.77	2.85	3.64	2.81
R2	3.42	2.71	3.45	2.87	3.63	2.55	3.87	2.69
R3	3.39	2.33	3.83	2.76	3.48	2.61	3.51	3.18
R4	3.61	2.64	3.79	2.53	3.99	2.49	4.04	2.38
Mean	3.57	2.61	3.68	2.65	3.72	2.63	3.77	2.77
FMI Rocket + FR								
R1	4.22	2.83	3.91	2.55	4.26	2.71	4.45	3.13
R2	3.76	2.75	3.86	2.86	4.33	2.65	4.37	2.76
R3	3.39	2.51	4.32	3.56	3.88	3.42	4.74	2.81
R4	3.65	2.98	3.55	2.35	4.03	2.38	4.59	2.78
Mean	3.76	2.77	3.91	2.83	4.13	2.79	4.54	2.87

Effect of residue management on potassium (mg kg-1) contents after harvest of wheat crop during 2007-08

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	81.2	58.2	112.4	92.4	80.6	71.2	82.4	67.3
R2	92.3	84.7	87.7	79.6	91.2	68.3	75.3	71.8
R3	102.6	69.6	93.9	70.3	79.8	85.7	91.7	75.5
R4	96.5	74.8	66.4	61.2	107.3	62.5	88.5	63.5
Mean	93.1	71.8	90.1	75.9	89.7	72.0	84.5	69.5
D P+MH								
R1	91.3	88.3	81.4	89.3	87.3	71.5	77.8	74.4
R2	86.5	56.4	75.4	61.6	75.6	81.2	64.7	87.0
R3	105.8	71.5	121.5	76.5	81.3	77.3	94.3	60.8
R4	72.8	60.8	99.9	65.2	97.5	70.8	76.5	62.4
Mean	89.1	69.2	94.5	73.1	85.4	75.2	78.3	71.1
FMI Rocket + PB								
R1	111.2	77.7	92.4	73.3	108.4	65.6	85.4	69.6
R2	98.7	58.3	78.4	96.5	80.7	73.5	71.6	83.5
R3	87.4	70.3	118.7	64.9	93.5	88.8	76.2	75.6
R4	108.7	86.5	97.8	71.3	76.5	68.8	102.4	66.1
Mean	101.5	73.2	96.8	76.5	89.8	74.2	83.9	73.7
FMI Rocket + FR								
R1	103.3	87.3	122.3	68.8	97.7	67.3	84.5	58.8
R2	118.2	66.7	106.4	81.5	89.5	79.2	98.5	73.2

R3	92.5	74.8	92.7	79.7	116.5	80.2	79.4	80.2
R4	104.6	78.6	103.6	91.7	91.3	75.8	92.4	60.7
Mean	104.6	76.9	106.2	80.4	98.7	75.6	88.7	68.2

Effect of residue management on soil bulk density (g cm-3) after harvest of wheat crop during 2007-08

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
ZTD +PB+MH								
R1	1.49	1.57	1.55	1.64	1.54	1.56	1.48	1.61
R2	1.55	1.63	1.51	1.56	1.53	1.65	1.55	1.65
R3	1.54	1.65	1.47	1.65	1.59	1.61	1.56	1.67
R4	1.51	1.58	1.53	1.59	1.49	1.55	1.52	1.63
Mean	1.52	1.61	1.52	1.61	1.54	1.59	1.53	1.64
D P+MH								
R1	1.44	1.65	1.54	1.57	1.56	1.63	1.55	1.56
R2	1.45	1.56	1.48	1.61	1.43	1.57	1.46	1.60
R3	1.50	1.57	1.45	1.53	1.55	1.62	1.47	1.64
R4	1.41	1.60	1.47	1.62	1.51	1.59	1.49	1.57
Mean	1.45	1.60	1.49	1.58	1.51	1.60	1.49	1.59
FMI Rocket + PB								
R1	1.48	1.68	1.55	1.64	1.51	1.65	1.57	1.62
R2	1.52	1.63	1.46	1.57	1.48	1.62	1.46	1.65
R3	1.51	1.65	1.44	1.65	1.53	1.54	1.58	1.55
R4	1.46	1.57	1.46	1.63	1.57	1.67	1.45	1.61
Mean	1.49	1.63	1.48	1.62	1.52	1.62	1.52	1.61
FMI Rocket + FR								
R1	1.48	1.56	1.54	1.61	1.44	1.57	1.51	1.63
R2	1.52	1.62	1.45	1.57	1.53	1.68	1.54	1.53
R3	1.47	1.58	1.46	1.64	1.59	1.60	1.57	1.57
R4	1.46	1.59	1.48	1.56	1.45	1.61	1.46	1.61
Mean	1.48	1.59	1.48	1.60	1.50	1.62	1.52	1.59

Effect of residue management on soil pH after harvest of wheat crop during 2007-08

N levels	**50**		**75**		**100**		**125**	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30

ZTD +PB+MH								
R1	8.1	8.5	8.3	8.6	8.2	8.4	8.1	8.4
R2	8.5	8.6	8.5	8.5	8.5	8.3	8.4	8.5
R3	8.3	8.2	8.7	8.1	8.5	8.1	8.6	8.2
R4	8.6	8.5	8.5	8.4	8.7	8.5	8.3	8.6
Mean	8.4	8.5	8.5	8.4	8.5	8.3	8.4	8.4
D P+MH								
R1	8.2	8.6	8.4	8.5	8.3	8.6	8.3	8.2
R2	8.2	8.2	8.5	8.3	8.6	8.5	8.4	8.1
R3	8.1	8.1	8.2	8.6	8.3	8.1	8.6	8.6
R4	8.5	8.2	8.1	8.1	8.1	8.2	8.2	8.4
Mean	8.3	8.3	8.3	8.4	8.3	8.4	8.4	8.3
FMI Rocket + PB								
R1	8.6	8.3	8.1	8.1	8.1	8.4	8.6	8.4
R2	8.4	8.5	8.7	8.5	8.6	8.5	8.2	8.2
R3	8.1	8.7	8.6	8.3	8.3	8.7	8.3	8.5
R4	8.2	8.4	8.3	8.6	8.6	8.3	8.2	8.6
Mean	8.3	8.5	8.4	8.4	8.4	8.5	8.3	8.4
FMI Rocket + FR								
R1	8.5	8.1	8.3	7.8	8.5	8.5	8.1	8.1
R2	8.0	8.5	7.9	8.4	8.1	8.2	8.5	8.4
R3	7.9	7.8	8.2	8.2	8.2	8.3	8.4	8.5
R4	8.1	8.4	8.3	8.0	8.0	8.0	8.1	8.3
Mean	8.1	8.2	8.2	8.1	8.2	8.3	8.3	8.3

Effect of residue management on soil organic matter contents (%) after harvest of wheat crop at different levels of nitrogen during 2005-06

Sowing Method	Nitrogen Level							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	0.57 f	0.61 cdef	0.68 abcde	0.59 def	0.62 cdef	0.58 ef	0.62 bcdef	0.56 ef
D P+MH	0.64 abcdef	0.59 def	0.67 abcdef	0.61 cdef	0.64 abcdef	0.61 cdef	0.65 abcdef	0.62 abcdef
FMI Seeder t + PB	0.65 abcdef	0.61 cdef	0.66 abcdef	0.60 cdef	0.68 abcdef	0.61 cdef	0.69 abcde	0.61 bcdef

FMI Seeder t + FR	0.72 ab	0.65 abcdef	0.70 abcd	0.67 abcdef	0.70 abc	0.68 abcde	0.73 a	0.70 abcd

LSD = 0.1088 at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.028	0.009	1.6985	0.1727
2	Factor A	3	0.127	0.042	7.5945	0.0001
4	Factor B	3	0.007	0.002	0.4444	
6	AB	9	0.012	0.001	0.2483	
8	Factor C	1	0.060	0.060	10.7127	0.0015
10	AC	3	0.005	0.002	0.3094	
12	BC	3	0.004	0.001	0.2389	
14	ABC	9	0.019	0.002	0.3800	
15	Error	93	0.517	0.006		
	Total	127	0.779			

Coefficient of Variation: 11.64%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil organic matter contents (%) after harvest of wheat crop at different levels of nitrogen during 2006-07

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	0.78 defg	0.60 j	0.74 efgh	0.61 ij	0.72 efghi	0.63 ij	0.76 defg	0.67 ghij
D P+MH	0.79 cdef	0.62 ij	0.76 defg	0.61 j	0.74 efgh	0.64 hij	0.78 defg	0.65 hij
FMI Seeder t + PB	0.77 defg	0.61 j	0.79 cdef	0.59 j	0.85 abcd	0.64 hij	0.82 bcde	0.64 hij

FMI Seeder + FR	0.89 abc	0.69 fghi	0.91 ab	0.65 hij	0.95 a	0.63 hij	0.86 abcd	0.63 ij

LSD = 0.1088 at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.058	0.019	3.3453	0.0225
2	Factor A	3	0.148	0.049	8.5020	0.0000
4	Factor B	3	0.007	0.002	0.4081	
6	AB	9	0.039	0.004	0.7427	
8	Factor C	1	0.977	0.977	168.0977	0.0000
10	AC	3	0.084	0.028	4.8209	0.0036
12	BC	3	0.004	0.001	0.2258	
14	ABC	9	0.028	0.003	0.5312	
15	Error	93	0.540	0.006		
	Total	127	1.885			

Coefficient of Variation: 10.61%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil organic matter contents (%) after harvest of wheat crop at different levels of nitrogen during 2007-08

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	0.78 defgh	0.68 klmn	0.81 cdef	0.69 ijklmn	0.79 Defg	0.68 klmn	0.78 efghi	0.69 jklmn
D P+MH	0.75 fghijk	0.64 lmn	0.77 efghij	0.66 lmn	0.72 ghijklm	0.67 klmn	0.72 fghijklm	0.66 lmn

FMI Rocket + PB	0.79 defgh	0.64 mn	0.81 cdef	0.62 mn	0.87 Cdef	0.66 n	0.86 lmn	0.67 lmn
FMI Rocket + FR	0.90 abc	0.70 hijklmn	0.93 ab	0.68 klmn	0.96 A	0.73 fghijkl	0.91 ab	0.70 hijklmn

LSD = 0.1088 at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.004	0.001	0.4006	
2	Factor A	3	0.211	0.070	19.1404	0.0000
4	Factor B	3	0.010	0.003	0.8713	
6	AB	9	0.024	0.003	0.7231	
8	Factor C	1	0.707	0.707	192.3267	0.0000
10	AC	3	0.102	0.034	9.2335	0.0000
12	BC	3	0.005	0.002	0.4732	
14	ABC	9	0.011	0.001	0.3189	
15	Error	93	0.342	0.004		
	Total	127	1.415			

Coefficient of Variation: 8.12%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil nitrate nitrogen contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2005-06

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	2.36 defgh	2.25 efghij	2.33 defghi	2.19 efghij	2.20 efghij	2.08 j	2.14 hij	2.13 hij
D P+MH	2.29 defghij	2.20 efghij	2.24 efghij	2.16 fghij	2.21 efghij	2.15 ghij	2.18 fghij	2.11 ij

FMI Seeder + PB	2.32 defghi	2.17 ghij	2.35 defgh	2.25 efghij	2.41 bcde	2.33 defghi	2.49 bcd	2.37 cdefg
FMI Seeder + FR	2.30 defghij	2.24 efghij	2.60 abc	2.32 defgdi	2.64 ab	2.35 defgh	2.73 a	2.41 cdef

LSD = 0.1088 at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.127	0.042	1.5887	0.1974
2	Factor A	3	1.357	0.452	16.9385	0.0000
4	Factor B	3	0.046	0.015	0.5746	
6	AB	9	0.713	0.079	2.9679	0.0038
8	Factor C	1	0.532	0.532	19.9075	0.0000
10	AC	3	0.138	0.046	1.7253	0.1672
12	BC	3	0.011	0.004	0.1425	
14	ABC	9	0.101	0.011	0.4212	
15	Error	93	2.484	0.027		
	Total	127	5.511			

Coefficient of Variation: 7.12%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil nitrate nitrogen contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2006-07

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	2.32 gh	2.23 h	2.59 fgh	2.41 gh	2.63 efgh	2.48 Gh	2.68 efgh	2.51 fgh
D P+MH	2.72 defg	2.37 gh	3.07 cde	2.46 gh	3.10 bcde	2.49 Fgh	3.24 bc	2.52 fgh
FMI Seeder + PB	2.96 cdef	2.45 gh	3.18 bcd	2.53 fgh	3.26 bc	2.58 Fgh	3.36 bc	2.39 gh
FMI Seeder + FR	3.56 b	3.18 bcd	4.52 a	3.27 bc	4.64 a	3.31 bc	4.76 a	3.34 bc

LSD = 0.4741 at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.286	0.095	0.8320	
2	Factor A	3	33.022	11.007	96.1702	0.0000
4	Factor B	3	2.755	0.918	8.0246	0.0001
6	AB	9	0.687	0.076	0.6667	
8	Factor C	1	12.676	12.676	110.7443	0.0000
10	AC	3	3.683	1.228	10.7269	0.0000
12	BC	3	1.057	0.352	3.0793	0.0313
14	ABC	9	0.749	0.083	0.7274	
15	Error	93	10.645	0.114		
	Total	127	65.561			

Coefficient of Variation: 11.39%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	3.06 defghijk	2.46 n	3.20 cdefg	2.53 lmn	3.31 Bcdef	2.71 ijklm	3.52 bc	2.85 ghijkl
D P+MH	2.89 efghijkl	2.38 mn	3.11 cdefghij	2.70 jklm	3.15 Cdefghi	2.73 hihjlm	3.33 bcde	2.87 fghijkl
FMI Rocket + PB	3.17 cdefgh	2.59 lmn	3.22 cdefg	2.65 klmn	3.32 Bcde	2.86 ghijkl	3.56 bcdef	2.91 efghijkl
FMI Rocket + FR	3.70 b	3.12 cdefghij	4.30 a	3.24 cdefg	4.55 a	3.35 bcd	4.71 a	3.42 bcd

LSD = 0.4741 at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	3	0.257	0.086	0.8627	
2	Factor A	3	17.777	5.926	9.6633	0.0000
4	Factor B	3	3.967	1.322	13.3131	0.0000
6	AB	9	0.492	0.055	0.5505	
8	Factor C	1	14.365	14.365	144.6360	0.0000
10	AC	3	1.638	0.546	5.4974	0.0016
12	BC	3	0.023	0.008	0.0775	
14	ABC	9	0.700	0.078	0.7831	
15	Error	93	9.236	0.099		
	Total	127	48.455			

Coefficient of Variation: 9.99%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil phosphorus contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2005-06

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	3.22 bc	2.49 fg	3.28 bc	2.33 g	3.18 bcde	2.40 g	3.34 bc	2.45 g
D P+MH	3.35 bc	2.31 g	3.45 bc	2.43 g	3.21 bcd	2.37 g	3.53 b	2.48 fg
FMI Seeder + PB	3.44 b	2.55 fg	3.54 g	2.53 fg	3.47 b	2.71 fefg	3.62 b	2.60 fg
FMI Seeder + FR	3.53 b	2.40 g	3.46 bc	2.97 cdef	3.58 b	2.65 fg	3.67 b	2.69 efg

LSD = 0.5004 at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.304	0.101	0.7960	
2	Factor A	3	1.425	0.475	3.7371	0.0138
4	Factor B	3	0.971	0.324	2.5453	0.0608
6	AB	9	1.191	0.132	1.0410	0.4140
8	Factor C	1	29.156	29.156	229.3477	0.0000
10	AC	3	0.544	0.181	1.4266	0.2400
12	BC	3	0.570	0.190	1.4955	0.2209
14	ABC	9	1.127	0.125	0.9851	
15	Error	93	11.823	0.127		
	Total	127	47.111			

Coefficient of Variation: 11.89%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil phosphorus contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2006-07

Sowing Method	Nitrogen Level							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	3.44 efgh	2.58 ijklm	3.52 cdef	2.36 m	3.46 efg	2.39 klm	3.83 bcde	2.42 klm
D P+MH	3.22 efghijkl	2.32 m	3.48 efg	2.34 m	3.38 efghi	2.38 lm	3.56 cde	2.33 m
FMI Seeder + PB	3.49 def	2.56 efghi	3.48 efghijk	2.43 fghijklm	3.46 efgh	2.63 ghijklm	3.60 abc	2.41 klm
FMI Seeder t + FR	3.68 ab	2.61 hijklm	4.03 abcde	3.28 efghij	4.34 abcd	2.70 fghijklm	4.82 a	2.48 jklm

LSD = 0.8483, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	1.116	0.372	1.0182	0.3883
2	Factor A	3	9.238	3.079	8.4292	0.0001
4	Factor B	3	0.626	0.209	0.5715	
6	AB	9	1.147	0.127	0.3487	
8	Factor C	1	44.074	44.074	120.6453	0.0000
10	AC	3	2.570	0.857	2.3453	0.0779
12	BC	3	3.548	1.183	3.2375	0.0257
14	ABC	9	3.014	0.335	0.9167	
15	Error	93	33.975	0.365		
	Total	127	99.309			

Coefficient of Variation: 19.10%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil phosphorus contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2007-08

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	3.57 cd	2.70 e	3.65 cd	2.64 e	3.79 bcd	2.71 e	3.95 bc	2.85 e
D P+MH	3.62 cd	2.57 e	3.58 cd	2.62 e	3.67 cd	2.65 e	3.80 bcd	2.78 e
FMI Rocket + PB	3.57 cd	2.61 e	3.68 cd	2.65 e	3.72 cd	2.63 e	3.77 bcd	2.77 e
FMI Rocket + FR	3.76 bcd	2.77 e	3.91 bc	2.83 e	4.13 b	2.79 e	4.54 a	2.87 e

LSD = 0.3922, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.104	0.035	0.4428	
2	Factor A	3	1.902	0.634	8.1106	0.0001
4	Factor B	3	1.341	0.447	5.7170	0.0012
6	AB	9	0.307	0.034	0.4358	
8	Factor C	1	36.178	36.178	462.8343	0.0000
10	AC	3	0.459	0.153	1.9583	0.1257
12	BC	3	0.227	0.076	0.9678	
14	ABC	9	0.443	0.049	0.6295	
15	Error	93	7.269	0.078		
	Total		1278.230			

Coefficient of Variation: 8.62%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil potassium contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2005-06

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	64.82 abcd	59.24 cd	69.49 abcd	57.12 d	70.21 abcd	60.07 bcd	73.46 abc	62.26 abcd
D P+MH	70.17 abcd	61.07 bcd	70.85 abcd	65.46 abcd	72.45 abc	64.39 abcd	75.86 a	62.82 abcd
FMI Seeder t + PB	74.70 ab	66.65 abcd	69.67 abcd	68.20 abcd	67.19 abcd	64.67 abcd	70.82 abcd	62.16 abcd
FMI Seeder t + FR	75.97 a	67.19 abcd	70.18 abcd	65.55 abcd	71.61 abcd	67.57 abcd	72.33 abc	66.64 abcd

LSD = 14.69, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	886.128	295.376	2.6992	0.0502
2	Factor A	3	275.407	91.802	0.8389	
4	Factor B	3	94.707	31.569	0.2885	
6	AB	9	570.584	63.398	0.5793	
8	Factor C	1	1547.001	1547.001	14.1368	0.0003
10	AC	3	74.791	24.930	0.2278	
12	BC	3	24.752	8.251	0.0754	
14	ABC	9	240.256	26.695	0.2439	
15	Error	93	10177.037	109.431		
	Total	127	13890.664			

Coefficient of Variation: 15.44%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil potassium contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2006-07

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	85.40 ab	68.00 ghijk	84.50 abc	68.40 ghijk	75.30 abcdefghij	66.30 hijk	71.90 cdefgh ij	64.80 ijk
D P+MH	86.50 a	65.80 ijk	82.60 abcd	71.80 cdefghij	75.60 abcdefghi	62.40 jk	69.30 ijk	58.60 k
FMI Seeder t + PB	82.40 abcde	68.30 ghijk	79.30 abcdefgh	74.20 abcdefghij	75.90 abcdefghi	71.40 defghijk	74.50 abcdefghij	69.40 efghijk
FMI Seeder + FR	80.70 abcdefg	69.30 fghijk	82.20 abcdef	77.60 abcdefghi	80.90 abcdefg	72.60 bcdefghij	79.00 abcdefgh	68.00 ghijk

LSD = 13.02,   at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	597.684	199.228	2.3174	0.0807
2	Factor A	3	477.374	159.125	1.8509	0.1434
4	Factor B	3	1405.109	468.370	5.4480	0.0017
6	AB	9	530.450	58.939	0.6856	
8	Factor C	1	3387.674	3387.674	39.4050	0.0000
10	AC	3	176.265	58.755	0.6834	
12	BC	3	350.117	116.706	1.3575	0.2607
14	ABC	9	216.563	24.063	0.2799	
15	Error	93	7995.274	85.971		
	Total	127	15136.509			

Coefficient of Variation: 12.58%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil potassium contents (mg kg-1) after harvest of wheat crop at different levels of nitrogen during 2007-08

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	93.1 abcdefg	71.8 jk	90.1 abcdefgh	75.9 hijk	89.7 abcdefghi	72.0 jk	84.5 defghijk	69.5 jk
D P+MH	89.1 bcdefghi	69.2 jk	94.5 abcdef	73.1 ijk	85.4 cdefghij	75.2 hijk	78.3 fghijk	71.1 jk
FMI Rocket + PB	101.5 abc	73.2 ijk	96.8 abcde	76.5 ghijk	89.8 abcdefghi	74.2 hijk	83.9 defghijk	73.7 hijk
FMI Rocket + FR	104.6 ab	76.9 ghijk	106.2 a	80.4 efghijk	98.7 abcd	75.6 hijk	88.7 bcdefghi	68.2 k

LSD = 13.02, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	395.346	131.782	0.9275	
2	Factor A	3	1175.999	392.000	2.7589	0.0466
4	Factor B	3	1611.873	537.291	3.7814	0.0131
6	AB	9	299.092	33.232	0.2339	
8	Factor C	1	11125.472	1125.472	78.3009	0.0000
10	AC	3	406.686	135.562	0.9541	
12	BC	3	556.700	185.567	1.3060	0.2772
14	ABC	9	223.823	24.869	0.1750	
15	Error	93	13214.018	42.086		
	Total	127	29009.009			

Coefficient of Variation: 14.38%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil bulk density (g cm-3) after harvest of wheat crop at different levels of nitrogen during 2005-06

	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	1.61 abcdefg	1.65 ab	1.59 bcdefgh	1.64 ab	1.57 cdefghi	1.65 ab	1.56 efghij	1.63 abc
D P+MH	1.48 klm	1.61 abcdef	1.48 klm	1.59 bcdefgh	1.46 m	1.61 abcdef	1.47 lm	1.62 abc
FMI Seeder + PB	1.55 fghij	1.62 abcd	1.53 ijkl	1.65 ab	1.56 defghij	1.64 abc	1.52 ijkl	1.65 ab
FMI Seeder t + FR	1.50 jklm	1.61 abcde	1.54 ghijk	1.66 a	1.52 ijklm	1.64 abc	1.54 hijk	1.65 ab

LSD = 0.06280, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.010	0.003	1.4184	0.2424
2	Factor A	3	0.087	0.029	11.8413	0.0000
4	Factor B	3	0.001	0.000	0.1072	
6	AB	9	0.014	0.002	0.6308	
8	Factor C	1	0.344	0.344	141.2291	0.0000
10	AC	3	0.025	0.008	3.3783	0.0216
12	BC	3	0.004	0.001	0.5569	
14	ABC	9	0.006	0.001	0.2713	
15	Error	93	0.227	0.002		
	Total	127	0.718			

Coefficient of Variation: 3.12%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil bulk density (g cm-3) after harvest of wheat crop at different levels of nitrogen during 2006-07

Sowing Method	Nitrogen Level							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	1.54 b	1.66 b	1.53 b	1.63 b	1.51 b	1.63 b	1.53 b	1.65 b
D P+MH	1.47 b	1.62 b	1.47 b	1.58 b	1.55 b	1.61 b	1.49 b	1.62 b
FMI Seeder t + PB	1.54 b	1.64 b	1.53 b	1.65 b	1.55 b	1.62 b	1.56 b	1.66 b
FMI Seeder t + FR	1.50 b	1.66 b	1.51 b	1.65 b	1.55 a	1.64 b	1.54 b	1.65 b

LSD = 0.3688, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.205	0.068	0.9877	
2	Factor A	3	0.284	0.095	1.3667	0.2579
4	Factor B	3	0.239	0.080	1.1501	0.3332
6	AB	9	0.691	0.077	1.1091	0.3643
8	Factor C	1	0.140	0.140	2.0282	0.1577
10	AC	3	0.170	0.057	0.8185	
12	BC	3	0.306	0.102	1.4741	0.2267
14	ABC	9	0.688	0.076	1.1045	0.3675
15	Error	93	6.440	0.069		
	Total	127	9.164			

Coefficient of Variation: 16.43%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil bulk density (g cm-3) after harvest of wheat crop at different levels of nitrogen during 2007-08

Sowing Method	Nitrogen Level							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	1.52 def	1.61 a	1.52 f	1.61 a	1.54 bcdef	1.59 ab	1.53 cdef	1.64 a
D P+MH	1.45 g	1.60 ab	1.49 fg	1.58 abcde	1.51 fg	1.60 a	1.49 fg	1.59 ab
FMI Rocket + PB	1.49 fg	1.63 a	1.48 fg	1.62 a	1.52 def	1.62 a	1.52 f	1.61 a
FMI Rocket + FR	1.48 fg	1.59 abc	1.48 fg	1.60 ab	1.50 fg	1.62 a	1.52 ef	1.59 abcd

LSD = 0.0628, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.010	0.003	1.9675	0.1243
2	Factor A	3	0.018	0.006	3.4110	0.0207
4	Factor B	3	0.008	0.003	1.4512	0.2330
6	AB	9	0.005	0.001	0.3006	
8	Factor C	1	0.340	0.340	193.4355	0.0000
10	AC	3	0.004	0.001	0.8372	
12	BC	3	0.005	0.002	0.9876	
14	ABC	9	0.010	0.001	0.6114	
15	Error	93	0.164	0.002		
	Total	127	0.564			

Coefficient of Variation: 2.70%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil pH after harvest of wheat crop at different levels of nitrogen during 2005-06

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	8.48 abc	8.43 abc	8.55 a	8.45 abc	8.65 a	8.53 ab	8.45 abc	8.57 a
D P+MH	8.55 a	8.55 a	8.50 abc	8.37 abc	8.63 a	8.43 abc	8.47 abc	8.45 abc
FMI Seeder + PB	8.45 abc	8.37 abc	8.22 c	8.55 a	8.47 abc	8.42 abc	8.50 abc	8.45 abc
FMI Seeder + FR	8.37 abc	8.55 a	8.50 abc	8.56 a	8.48 abc	8.50 abc	8.25 bc	8.38 abc

LSD = 0.2979, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.109	0.036	0.8057	
2	Factor A	3	0.132	0.044	0.9766	0.0000
4	Factor B	3	0.092	0.031	0.6809	0.0000
6	AB	9	0.320	0.036	0.7887	
8	Factor C	1	0.001	0.001	0.0156	
10	AC	3	0.155	0.052	1.1429	0.3360
12	BC	3	0.097	0.032	0.7179	
14	ABC	9	0.284	0.032	0.6994	
15	Error	93	4.194	0.045		
	Total	127	5.383			

Coefficient of Variation: 2.51%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil pH after harvest of wheat crop at different levels of nitrogen during 2006-07

Sowing Method	Nitrogen Level							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	8.4 ab	8.6 a	8.4 ab	8.5 ab	8.5 ab	8.4 ab	8.5 ab	8.5 ab
D P+MH	8.5 ab	8.5 ab	8.6 a	8.5 ab	8.5 ab	8.4 ab	8.4 ab	8.4 ab
FMI Seeder + PB	8.5 ab	8.4 ab	8.3 b	8.4 ab	8.4 ab	8.2 ab	8.2 ab	8.3 ab
FMI Seeder t + FR	8.4 ab	8.4 ab	8.3 b	8.4 ab	8.4 ab	8.4 ab	8.4 ab	8.4 ab

LSD = 0.,   at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.158	0.053	1.6662	0.1797
2	Factor A	3	0.191	0.064	2.0087	0.1181
4	Factor B	3	0.042	0.014	0.4413	
6	AB	9	0.112	0.012	0.3952	
8	Factor C	1	0.003	0.003	0.0889	
10	AC	3	0.053	0.018	0.5565	
12	BC	3	0.037	0.012	0.3853	
14	ABC	9	0.143	0.016	0.5016	
15	Error	93	2.942	0.032		
	Total	127	3.680			

Coefficient of Variation: 2.11%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths

Effect of residue management on soil pH after harvest of wheat crop at different levels of nitrogen during 2007-08

Sowing Method	**Nitrogen Level**							
	50N		75N		100N		125N	
	Soil depth (cm)							
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTD +PB+MH	8.4 abcde	8.5 abcd	8.5 ab	8.4 abcde	8.5 abc	8.3 abcde	8.4 abcde	8.4 abcd
D P+MH	8.3 bcde	8.3 abcde	8.3 abcde	8.4 abcde	8.3 abcde	8.4 abcde	8.4 abcde	8.3 abcde
FMI Rocket + PB	8.3 abcde	8.5 abc	8.4 abcd	8.4 abcde	8.4 abcde	8.5 a	8.3 abcde	8.4 abcde
FMI Rocket + FR	8.1 bcde	8.2 e	8.2 cde	8.1 de	8.2 de	8.3 bcde	8.3 abcde	8.3 abcde

LSD = 0.2979, at alpha = 0.050

ZTD + PB + MH = Zero till drill, Partial burning and manual harvesting

DP + MH = Disc ploughing, Manual harvesting

FMI Rocket + PB = FMI Rocket Seeder, Partial burning

FMI Rocket + FR = FMI Rocket seeder, Full Residue

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
1	Replication	3	0.050	0.017	0.3701	
2	Factor A	3	0.725	0.242	5.3348	0.0020
4	Factor B	3	0.028	0.009	0.2046	0.0000
6	AB	9	0.182	0.020	0.4451	
8	Factor C	1	0.000	0.000	0.0069	0.0000
10	AC	3	0.014	0.005	0.1034	
12	BC	3	0.039	0.013	0.2873	
14	ABC	9	0.232	0.026	0.5677	
15	Error	93	4.215	0.045		
	Total	127	5.485			

Coefficient of Variation: 2.55%

Factor A = Sowing Methods, Factor B = Nitrogen levels, Factor C = Soil depths