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INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Consortia Research Platform
On
Conservation Agriculture

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Background

Agriculture is the most important sector in India; accounting for 13.7 per cent of the countryĝs GDP and employs more than 60 per cent of the labour force. Food grain production of the country has reached a record 257 million tons during 2012-13, under favourable weather conditions those prevailed throughout the year. The mission of increasing food grain production, though somehow realized at present, but under risk due to climatic aberrations and reduced availability of land, water, nutrients along with poor and continuous degradation of the resources to cope up with the demands of increasing population. Although the country had attained self sufficiency in food grain production through intensification of agriculture with high yielding varieties and fertilizer application during the green revolution, productivity is still low and is stagnating. Conservation agriculture permits management of soils for sustainable agricultural production without excessively disturbing the soils, while protecting it from the processes of soil degradation like erosion, compaction, aggregate breakdown, loss of organic matter, leaching of nutrients, and processes that are accentuating by anthropogenic interactionsin the presence of extremes of weather and management practices**.** The organic materials conserved through this practice are decomposed slowly, and much of it is incorporated into the surface layer, thus reduces the liberation rate of carbon into the atmosphere. In the total balance, carbon is sequestered in the soil, and turns the soil into a net sink of carbon. This could have profound consequences in our fight to reduce green house gas emissions into the atmosphere from agricultural operations and thereby help to forestall the calamitous impacts of global warming.

Conservation agricultural systems are gaining increased attention worldwide as a way to reduce the water footprint of crops by improving soil water infiltration, increasing soil water retention and reducing runoff and contamination of surface and ground water. South American countries (e.g. Brazil, Argentina, Colombia etc) practicing conservation agriculture reported to have a remarkable positive effects on water footprints of crops.

Conservation Agriculture – Indian Scenario

Unlike, in the rest of the world, CA technologies in India are spreading mostly in the irrigated areas of the Indo-Gangetic plains where rice-wheat cropping system dominates. CA systems have not been extensively tried or promoted in other major agro-ecoregions like rainfed semi-arid tropics, the arid regions and the mountain agro-ecosystems.

In India, efforts to adopt and promote resource conservation technologies have been underway for more than a decade, but it is only in the past 6-8 years that technologies are finding acceptance by the farmers particularly in the Indo-Gangetic irrigated plains under the aegis of the Rice-Wheat Consortium. Concerns about stagnating productivity, increasing production costs, declining resource quality, declining water tables and increasing environmental problems are the major factors forcing to look for alternative technologies, particularly in the northwest regions of India encompassing Punjab, Haryana and western Uttar Pradesh (UP). In the eastern region covering eastern UP, Bihar and West Bengal, developing and promoting strategies to overcome constraints to continued low cropping system productivity have been the chief concerns. The primary focus of developing and promoting CA practices in India has been the development and adoption of zero tillage cum fertilizer drill for sowing wheat crop in the riceï wheat system. Other interventions being tested and promoted in the Indo-Gangetic plains include raised-bed planting, laser-aided land-leveling, residue management alternatives, and alternatives to riceï wheat cropping system in relation to CA technologies. The area planted with wheat adopting zero-tillage drill has been rapidly increasing in the last few years. It is estimated that over the past few years, adoption of zero-tillage has expanded to cover about 2 m ha. The rapid adoption and spread of zero tillage is attributed to benefits resulting from reduction in cost of production, reduced incidence of weeds in long-run and therefore savings on account of herbicide costs, savings in water and nutrients and environmental benefits. Adopting CA systems further offers opportunities for achieving greater crop diversification. Direct seeded rice has been evaluated as an alternative to transplanted rice in view of increasing water and labour crisis and the adverse effect of green house gas emissions like methane and nitrous oxide. The work on system rice intensification in rice based production systems is also being worked out for saving water, chemical fertilizers and plant protection chemicals, and reducing green house gas emissions and also improving soil health. Information on efficient alternatives to rice-wheat cropping system, FIRB system, BBF and BBSF systems, laser-aided land-leveling, residue friendly happy and turbo seeding is available. Apart from improved soil health, up to 3 fold increase in productivity through diversification and 20% reduction in cost of production through tillage management have been achieved.

In contrast to the homogenous growing environment of the IGP, the production systems in semi-arid and arid regions are quite heterogeneous in terms of land and water management and cropping systems. These include the core rainfed areas which cover up to 60-70% of the net sown area and the remaining irrigated production systems. The rainfed cropping systems are mostly single cropped in the Alfisols while in Vertisols, a second crop is generally taken on the residual moisture. In *rabi* black soils, farmers keep lands fallow during *kharif* and grow *rabi* crop on conserved moisture. Sealing, crusting, sub-surface hard pans and cracking are the key constraints which cause high erosion and impede infiltration of rainfall. The choice and type of tillage largely depend on the soil type and rainfall. Leaving crop residue on the surface in CA is a major concern in these rainfed areas due to its competing uses as fodder, leaving very little or no residues available for surface application. Agroforestry and alley cropping systems are other options for CA practices. This indicates that the concept of CA has to be adopted in a broader perspective in the arid and semi-arid areas. Experience at IISS showed that reduced tillage in soybean-wheat system is a suitable option for growing soybean and wheat crops in Vertisols with saving of energy and labour. This also improves soil organic carbon, physical and biological properties.

Due to less biomass production and competing uses of crop residues, the scope of using crop residues for conservation agriculture is limited in dryland ecosystems. The Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, has shown that in dryland ecosystems, it is possible to raise a second crop with residual soil moisture by covering the soil with crop residues. In a network project on tillage conducted since 1999 at various centers of the All India Coordinated Research Project for Dryland Agriculture, it was found that rainfall and soil type had a strong influence on the performance of reduced tillage. In arid regions (<500 mm rainfall), low tillage was found on par with conventional tillage and weed problem was controllable in arid Inceptisols and Aridisols. In semi arid (500-1000 mm) region, conventional tillage was superior. However, low tillage + interculture were superior in semi-arid Vertisols and low tillage + herbicide was superior in Aridisols. In sub-humid (>1000 mm) regions, weed problem was severe due to rainfall and thus, there is a possibility of reducing the weed population by using herbicide in reduced tillage condition.

Challenges in adoption of Conservation Agriculture:

The CA system constitutes a major departure from the past ways of doing things. This implies that the whole range of agricultural practices, including handling crop residues, sowing and harvesting, water and nutrient management, disease and pest control, etc. need to be evolved and evaluated. The key challenges relate to the development, standardization and adoption of farm machinery for seeding amidst of crop residues with minimum soil disturbance; developing crop harvesting and management systems with residues maintained on soil surface; and developing and continuously improving site specific crop, soil and pest management strategies that will optimize the benefits of the new systems.

Residue burning:Residue burning is a quick, labour-saving practice to remove residue that is viewed as a nuisance by farmers. Burning residues facilitates seeding, reduces crop disease infestation and improves weed control. Residue burning, however, causes considerable loss of organic C, N and other nutrients by volatilization, which may affect soil microorganisms detrimentally. However, residue burning has several adverse environmental and ecological impacts. The burning of dead plant material adds a considerable amount of CO_2 and particulate matter to the atmosphere and can reduce the return of much needed C and other nutrients to the soil. The lack of a soil surface cover may also increase the loss of soil minerals via runoff. Crop residues returned to the soil maintain OM levels, and crop residues also provide substrates for soil microorganisms. In comparison to burning, residue retention increases soil carbon and nitrogen stocks, provides organic matter necessary for soil macro-aggregate formation and fosters celluloseï decomposing fungi and thereby carbon cycling.

Lack of appropriate machinery: Permanent crop cover with recycling of crop residues is a prerequisite and an integral part of conservation agriculture. However, sowing of a crop in the presence of residues of preceding crop is a problem. But new variants of zero-till seed-cum-fertilizer drill/planters such as Happy Seeder, Turbo Seeder and Rotary-disc drill have been developed for direct drilling of seeds even in the presence of surface residues (loose and anchored up to 10 t ha^{-1}). These machines are found to be very useful for managing crop residues for conserving moisture and nutrients as well as controlling weeds. In addition to moderating soil temperature, these machines are also adopted in the Indo-Gangetic plains under the rice-wheat system. There is an increasing awareness and concern for affordable and energy efficient equipment and technology for cost-effective production of crops. This more emphasis is on increased yield, reduced cost of cultivation, and efficient utilization of input resources to raise farm income. Agricultural Machinery or tools, which support conservation agriculture generally refer to the cultivation systems with minimum or zero tillage and *in-situ* management of crop residues. Different designs of direct drilling machines *viz.,* zero till drill, no till plant drill, strip till drill, roto till drill and rotary slit no till drill have been developed with controlled traffic measures for energy efficient and cost-effective seeding of crops without tillage.

Package of equipment and technology for residue-incorporation and bed planters have been developed for higher productivity with reduced irrigation water requirements. Recent development and performance of agricultural machinery have concentrated both on biological and mechanical parameters. Selection of most appropriate equipment for a specific situation is essential for maintaining soil physical environment. Besides the chosen equipment should be fuel efficient. Tractor operated/self propelled machinery/technologies used in conservation agriculture (CA) have the potential to meet the challenges encountered in CA under field conditions. Zero tillage farming on 1.2 million ha Indo-Gangetic plains reportedly saved 360 million m3 water. It also reduces the number of operating hours of the pumps, thus reducing CO_2 emission and consumption of electrical energy.

Weed Management:Weed control is the other main bottleneck, especially in the rice-wheat system. Excessive use of chemical herbicides may not be a desirable option for a healthy environment. Continuous and high intensity rainfall during the rainy season also creates a problem in effective weed management through herbicides. Thus, increased use of herbicides is pre-requisite for adopting conservation agriculture. Countries that use relatively higher amounts of herbicides are already facing such problems of pollution and environmental hazards. Nutrient management may become complex because of higher residue levels in surface layers and reduced options for application of nutrients, particularly through manure. Application of fertilizers, especially N entirely as basal dose at the time of seeding may result in a loss in its efficiency and environmental pollution. Sometimes, increased application of specific nutrients may be necessary and specialized equipments are required for proper fertilizer placement, which contributes to higher costs.

Difficulty in input use: There are difficulties in sowing and application of fertilizer, water and pesticides under residue retained conditions. The conservation agriculture with higher levels of crop residuesusually requires more attention on the timing and placement of nutrients, and application of pesticides and irrigations.

Farmers' perception: *L*imiting factor in adoption of residue incorporation systems in conservation agriculture by farmers include additional management skills, apprehension of lower crop yields and/or economic returns, negative attitudes or perceptions, and institutional constraints. In addition, farmers have strong preferences for clean and good looking tilled fields vis-à-vis untilled shabby looking fields.

Technological Gaps

In India, efforts to adopt and promote CA practices are in increasing demand among stakeholders in intensively copped areas as in IGP. There is also limited use in other parts of India due to inappropriate knowledge about CA technologies. Concerns about stagnating productivity, increasing production costs, declining resource quality, depleting water tables and increasing environmental problems are the major factors to look for alternative technologies for improving production potential in diverse agro-ecological regions of the country. The Northern and Eastern IGP, black soil belts of central plateau, Odisha-upland systems, Coastal high rainfall regions and rainfed regions are the areas where there is a potential to improve crop productivity through CA technologies. In IGP, some of the CA components have gone to field implementation whereas in other parts of India efforts are made to popularize such technologies. Developing location specific CA practices in these regions are urgently required.

Mission

Mainstreaming conservation agriculture for sustainable use and management of natural resources to improve productivity and ensuring food security

Objectives

- Adapt and mainstream available best bet location specific CA practices for enhanced productivity and profitability in rainfed and irrigated eco-systems.

- Develop and validate location specific CA technologies for sustainable intensification of cropping systems across agro-ecologies.
- Quantify impact of CA on soil health, input use efficiency, carbon sequestration and greenhouse gas emissions.
- Capacity building, knowledge management, institutional arrangement and enabling policies for accelerated adoption of CA.

Thrust areas of Research

- Developing low cost, energy efficient and environment friendly CA technologies for major cropping systems both under rainfed and irrigated conditions.
- Validation and up-scaling location specific CA packages in farmersô participatory mode involving all stakeholders.
- Assessing the impact of CA practices on soil health, carbon sequestration, soil microbial biodiversity, resource use efficiency and mitigation of climate change.

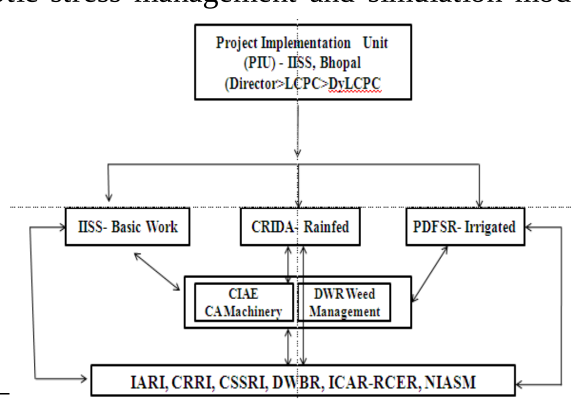
Approach

1. Adaptive (Action) Research for CA Knowledge dissemination: To organize on-station and on-farm adaptive trials on CA and front line demonstrations in irrigated and rainfed cropping systems.

2. Basic & Strategic Research: To carry out research to evolve CA technologies (including suitable machinery) and its impact on soil health, input use efficiencies and GHG emissions both for irrigated and rainfed cropping systems.

3. Capacity Building and Knowledge Management: Capacity building of scientists/trainers/extension staff/students/farmers r for effective dissemination of CA programme.

4. **Competitive Grant Projects:** Innovative and cutting edge project proposal will be invited particularly in the areas of residue management, machinery development, nutrient & weed dynamics, abiotic and biotic stress management and simulation modelling etc. to facilitate CA practices.



Structure of CRP on CA

Research Highlights of Irrigated and RainfedEco-systems (2015–16)

Research highlights on the effect of conservation agriculture on crop productivity under rainfed region and irrigated ecosystem have been presented under this section. Various ICAR-institutes namely, IISS, Bhopal, CRIDA, Hyderabad, IARI, New Delhi, IIFSR, Modipuram, CIAE, Bhopal, DWR, Jabalpur, NRRI, Cuttack, CSSRI,Karnal, IIWBR, Karnal, ICAR-RCER, Patna and NIASM, Baramati have conducted multi-location on-farm and on-station experiments to fulfill the following objectives and objective-wise research highlights are presented here.

- Adapt and mainstream available best bet location specific CA practices for enhanced productivity and profitability in rainfed and irrigated eco-systems.
- Develop and validate location specific CA technologies for sustainable intensification of cropping systems across agro-ecologies.

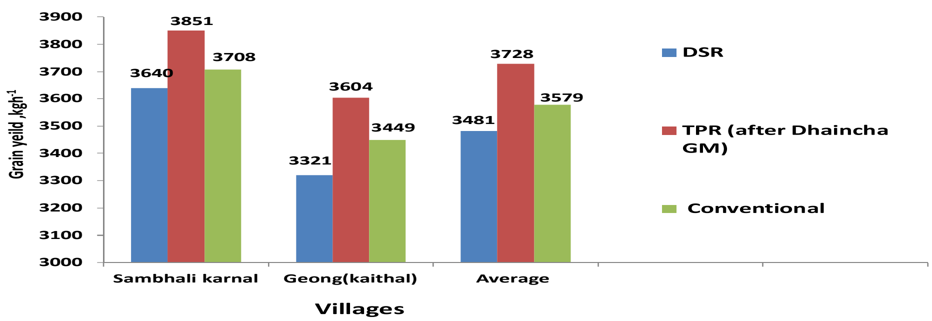
1. ADAPTING AND MAINSTREAMING AVAILABLE BEST BET LOCATION SPECIFIC CONSERVATION AGRICULTURE PRACTICES

1.1Rice based cropping systems

1.1.1 Rice –wheat

In kharif 2015, rice crop was grown in direct seeded (DSR) and transplanted (TPR) conditions under farmersô fields by ***CSSRI***, Karnal. DSR with 50% tillage with CSR 30 basmati rice was compared with the farmer practice. A fertilizer dose of 90:60:40 kg NPK ha^{-1} with Zinc (24 kg $ZnSO_4$ ha^{-1}) was used with surface irrigation. In DSR, irrigation was scheduled when soil surface dried with small cracking, irrigation was made at 4/5 days interval during the crop season. A grain yield of 3.48 t ha^{-1} in DSR with 50% tillage comparable to the yield under farmersô practices was obtained. DSR techniques saved labour, diesel, irrigation water, electricity etc. Salt tolerant variety (CSR 30 basmati) performed well under 5.2 RSC yielded up to 3.38 t ha^{-1} in DSR. Dhaincha before transplanting yielded more in comparison to DSR & TPR technique but no resource saving was observed (Plate 1).

Plate 1. Performance of rice under different crop establishment techniques



Water quality	Sambhali(karnal)	Geong(kaithal)
pH iw	8.13	8.66
EC(ds/m)	1.06	1.32
RSC(me/l)	0.9	5.2

Fig. 1. Rice grain yield in different villages under improved conservation practices

Wheat (cv KRL-210) was sown at four sites in rice ï wheat cropping system on one acre land adopting three techniques, e.g. farmers practice, zero tillage wheat with crop residue and zero tillage wheat with residue under sprinkler irrigation system (system installed in March-2016). A fertilizer dose of 150:60:40 kg NPK ha^{-1} with Zinc (24 kg $ZnSO_4$ ha^{-1}) was used with surface irrigation. Wheat in zero tillage with rice crop residue yielded 4.75t ha^{-1} which was 12.60% higher than farmers practice. The average wheat grain yield was 4.66 t ha^{-1}, in TPR (after dhainchagreenmanuring) which was 10.15 % higher than farmers practice (Fig. 2). In Shambhali village yielded higher (where fresh water given for irrigation) in comparison to saline and alkali irrigation water.

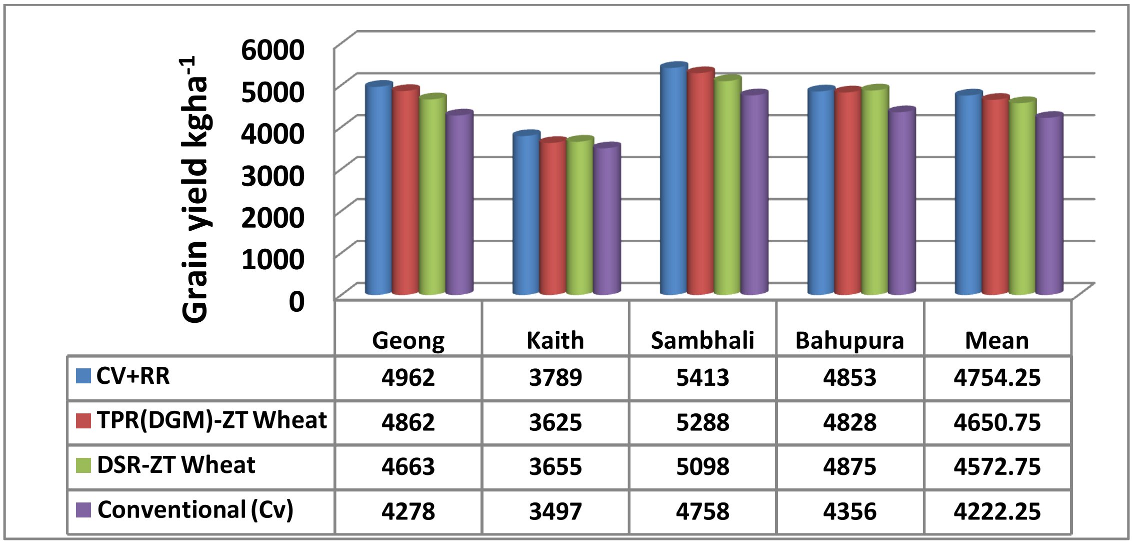


Fig. 2. Wheat grain yield in different villages under improved conservation practices

Field demonstrations were carried out by ICAR-IARI, New Delhi involving 15 selected farmers (District: Gurgaon in Haryana: Villages: Turkapur and HedaHedi). It was observed that zero-tillage with improved varieties of IARI enhanced yield up to 11%. Farmers saved 4-5 tillage costing Rs 6000 ï Rs 9000 per ha and fuel; HD 2967 gave highest yield (5.93 t/ha), followed by HD 2894 (5.48 t/ha), HD 733 (5.33 t/ha) and HD 2895 (5.15 t/ha).

Table 1. Demonstration of zero-tillage in wheat and comparative assessment with conventional system

Practice	Yield (t/ha)	Cost (Rs/ha)	Net income (Rs/ha)	BCR
Zero tillage	5.93	27,170.0	52,858.0	2.95
Conventional tillage	5.31	37,050.0	34,642.0	1.94

Plate 2. Zero-till wheat in farmer's field

Comparative performance of two CA machines for seeding in to loose rice residue at farmers' field under rice-wheat cropping systems

In Village Taraori, wheat was sown in rice residue using Rotary Disc Drill (RDD) and Turbo Happy Seeder (THS) by ***IIWBR***, Karnal. Wheat *cv* HD 2987 was sown using a seed rate of 100 kg/ha. The row to row spacing was 22.5 cm for THS and 20 cm for RDD. The wheat yield was similar in CT and ZT without loose residue when sown either using RDD or THS. In the presence of rice residue, the wheat yield was slightly lower in RDD sown as there was less cutting effect due to lesser moisture. Moreover, with THS also some dragging of residue was observed due to wet and heavy residue load. The CA wheat yield was 4848 and 5370 kg/ha under RDD and THS, respectively. The respective wheat yield under RDD and THS was 5585 and 5132 kg/ha under ZT and 5367 and 5203 kg/ha under CT.

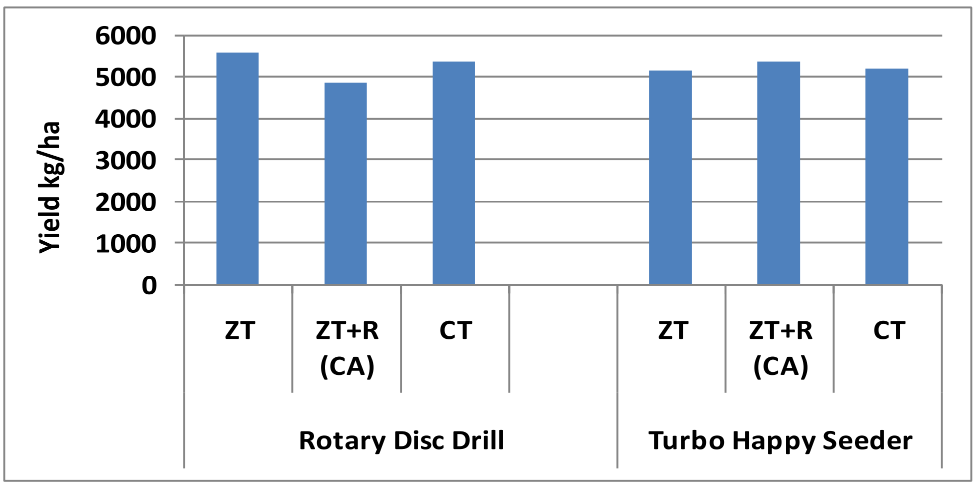


Fig. 3. Comparative performance of two CA machines for wheat seeding in to rice residue

Plate 3. Wheat seeding in rice residue using Turbo Happy Seeder (THS) and Rotary Disc Drill (RDD) at Village Taraori (Karnal)

1.1.2 Rice-Maize/Green gram

Zero till seed drill was successfully used by ***NRRI***, Cuttackfor dry direct seeding of rice (cv. Pooja) in farmerǿs field at Jajpur and Salipur block of Cuttack district, Odisha, India. A minimum tillage approach was followed in which a slight slit was opened in the soil to facilitate for seed soil contact without tillage. Rice seed was used @ 40 kg/ha. Rice crop was harvested leaving 30 % residues. In *Rabi* season maize and green gram were sown in 50% of the area each in CA and farmers practices.Compared to farmers' practice, 10.2% and 7.89 % lesser grain yield was recorded in CA at Jajpur and Salipur, respectively.

Table 2. Yield attributes and yields of rice influenced due to conservation agriculture and farmers practices at Jajpur and Salipur, Odisha, India

Yield attributes	Jajpur, Odisha		Salipur, Cuttack, Odisha	
	CA	**FP**	**CA**	**FP**
Tillers/m^2	256	281	234	255
Number of panicles/hill	11.8	13.2	7.5	9
Panicle length (cm)	23.1	24.3	21.3	21.7
Panicle weight (g)	2.65	2.81	1.9	2.1
Grains/panicle	115	120	89.5	92.7
Spikelet fertility (%)	85.9	87.5	72.1	74.4
1000-grain weight (g)	21.0	21.1	20.1	20.3
Grain yield (t/ha)	4.9	5.4	3.8	4.1
Straw yield (t/ha)	6.4	6.8	5.3	5.7

CA: conservation agriculture practices, FP: Farmers practices

Plate 4. Demonstration of Conservation Agriculture practices in rice-maize cropping system in farmers' field

1.1.3 Rice-fallow

Field demonstrations were conducted by ***ICAR-RCER*** Patna in 13 ha area covering 35 farmers in 5 villages of Naubatpur and Vikram blocks of Patna District on *Utera* crop of lentil and lathyrus and ZT chickpea. The Lathyrus yield under *Utera* ranged from 300 kg/ha to 1725 kg/ha and that of lentil from 650 kg/ha to 1025 kg/ha. The yield of Chickpea under ZT varied from 400 kg/ha to 650 kg/ha.

1.2 Maize based cropping systems

1.2.1 Maize –Wheat

In Rabi 2015-2016, wheat (cv. KRL-210) at two sites in Maize ïWheat cropping system in one acre area on each site adopting two techniques, e.g. wheat sowing with farmers practice and wheat sowing on raised beds. The recommended package and practices were followed. A fertilizer dose of 150:60:40 kg NPK ha^{-1} with Zinc (24 kg $ZnSO_4$ ha^{-1}) was used with surface irrigation. The average of two sites, observed that wherever wheat sowing on raised beds, grain yield was 4.94 t ha^{-}1 (19.8% higher than farmers practice). Raised bed wheat, required lesser amount of irrigation water in comparison to farmersô practices as 1/3 area remains under furrow of the total field area. <u>This experiment is discontinued.</u>

Plate 5. Wheat on furrow raised beds

1.3 Soybean based cropping systems

ICAR-IISS Bhopal demonstrated and popularized the conservation agricultural technologies developed for Vertisols, fifteen farmersô fields were chosen in two villages namely, Mominpur, and Khamkhera in the Bhopal district of Madhya Pradesh. Demonstration was carried out on two predominant cropping systems being practiced in this region viz., soybean-wheat and soybean-chickpea. In each farmerǒs field four modules of tillage systems namely, Farmerǒs Practice, Improved conventional practice, reduced tillage and No tillage were demonstrated on a plot areas of 1000 m^2 each for a tillage module. All the technical expertise and inputs were provided to the farmers and crops were grown under the supervision of the scientist. Crop performance, growth parameters and yield attributes were recorded for all the crops. The overall performance of the crops under CA in farmerǒs field was quite encouraging. Farmers are quite convinced about the potential of the system.

In the *kharif* season (2015) soybean cv. JS-95-60 was sown with standard package as per treatments during the first week of July. The crop performance has been affected severely due to heavy rains during the month of August followed by early with drawl of monsoon which ultimately resulted in poor pod filling and seed development. Crop growth and yield parameter were recorded and presented below (Table3).

Table 3. Growth and yield parameters recorded in soybean under different treatments

Treatment	Plant height at harvest (cm)	No of branches /plant	No of pods /plant	Grain Yield (q /ha)	Straw Yield (q /ha)
No tillage	35.51	7.39	20.52	5.06	8.36
Reduced tillage	33.90	7.14	18.15	4.43	7.64
Improved conventional tillage	33.14	5.89	17.10	4.25	7.09
Farmerǒs practice	30.57	5.29	14.83	3.42	6.02
CV	4.55	13.47	10.29	11.90	8.39
CD	1.11	0.85	1.33	0.37	0.45

Maximum plant height (35.51cm), number of branches/plant (7.39/ plant), number of pods/plant (20.52/ plant), seed yield (5.06 q/ha) and straw yield (8.36 q/ha) were recorded under no tillage and were significantly higher compared to other three treatments (Table4).

During *rabi*season wheat cv. GW-322 was sown in 10 farmers field and chickpea cv. JG-16 was sown in 5 farmers field with the same layout as per technical programme and the crops were grown following standard package of practices. In wheat maximum plant height at harvest

(65.80 cm), maximum number of tillers/m^2 (388.43), grain yield (45.74 q/ha), straw yield (64.01 q/ha) and test weight (38.06g) were recorded under no tillage module which were significantly higher compared to farmerӧs practice (Table4)

Table 4. Growth and yield parameters recorded in wheat under different tillage treatments

Treatment	Plant height at harvest (cm)	No of tillers /m^2	Grain Yield (q /ha)	Straw Yield (q /ha)	Test weight (g)
No tillage	65.80	388.43	45.74	64.01	38.06
Reduced tillage	64.63	371.30	41.54	57.67	37.45
Improved conventional tillage	63.20	374.26	40.62	57.02	37.11
Farmerӧs practice	61.13	358.76	37.08	52.04	35.98
CV	3.05	2.92	8.41	7.84	3.30
CD	1.78	10.01	3.18	4.15	1.22

Plate 6. Demonstration of Conservation Agriculture Practices in Khamkheda Village, Bhopal district

In case of chickpea maximum plant height (41.33 cm), number of pods /plant (62.91), seed yield (23.26q/ha), straw yield (29.59q/ha) and seed index (17.05g) were recorded under no tillage module which was significantly higher as compared to farmers practice (Table5).

Table 5. Growth and yield parameters recorded in chickpea under different tillage treatments

Treatment	Plant height at harvest (cm)	No of pods /plant	Grain Yield (q /ha)	Straw Yield (q /ha)	Seed index (g)
No tillage	41.33	62.91	23.26	29.59	17.05
Reduced tillage	40.66	59.33	21.87	28.01	16.22
Improved conventional tillage	40.66	57.08	19.67	25.17	16.12
Farmer's practice	39.66	50.91	19.20	22.89	15.69
CV	4.59	12.84	6.62	10.69	2.95
CD	NS	4.30	2.22	4.6	0.76

Plate 7.Demonstration of Conservation Agriculture Practices in Momanpur Village, Bhopal

Burning of crop residues after crop harvest is a common practice in areas surrounding Jabalpur causing serious pollution, besides loss of organic matter and soil nutrients. Happy seeder machine was introduced in the region to demonstrate Conservation Agriculture technology (CA) for sowing of wheat for the first time under on-farm research (OFR) in the field of 25 farmers in different districts of Mandla, Katni, Seoni, Narsighpur and Jabalpur of Madhya Pradesh (Table6; Plate7, 8) by ***ICAR-DWR***, Jabalpur. Sowing was done without any tillage operation (ploughing) for land preparation or without removing/ burning of the standing stubbles of previous crop. Demonstrations revealed very good emergence and establishment of crop. Use of ready mix combination of clodinafop + metasulfuron @ 400 g/ha at 25 days of growth controlled weed flora effectively in wheat at compared to farmers practice. Higher grain yield of 4.87, 5.14, 5.05, 4.01 and 4.06 t/ha with B:C ratio of 3.75, 3.44, 3.44, 3.46 & 3.43 were recorded over farmers practice in Mandla, Katni, Seoni, Narsighpur and Jabalpur district of Madhya Pradesh (Table 7). The grain yield of 3.64, 3.49, 2.83, 3.75 and 3.71 t/ha with lower B: C ratio of 2.33, 1.81, 1.78, 2.40 and 2.40 were documented under farmers practice in Mandla, Katni, Seoni, Narsighpur and Jabalpur district of Madhya Pradesh respectively.

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Table 6. Detailsof on-farm research (OFR) trials on conservation agriculture in different districts of Madhya Pradesh during 2015-16

District	Mandla	Katni	Seoni	Narsighpur	Jabalpur
Locality	Bhawal Bijegaon Goojarsani Lalipur Harratikur	Banda Bichiya Chitwara Ghughra Lakhapateri	GhoghriNagan GhoghriNagan NaganDeori NaganDeori Dongargaon	Atariya Simariya Baglai Simarikhera Khamariya	Nibhora Gandhi Gram Belly Neelkhera
No. of trials	8	5	5	5	2
Treatments	T1.Wheat sown with Farmerôs practice (175 kg seed /ha +In-balanced fertilizer along with 2,4-D @ 500g/ha)	T1.Wheat sown with Farmerôs practice (100 kg /ha + metsulfuron 4 g/ha)	T1.Wheat sown with Farmerôs practice	T1.Wheat sown with Farmerôs practice (100 kg /ha + metsulfuron 4 g/ha)	T1. Wheat sown with Farmerôs practice (100 kg seed /ha +POE herbicide (clodinafop + metsulfuron) 400 g/ha
	T2.Wheat sown under CA with RFD & without herbicide	T2.Wheat sown under CA with RFD & without herbicide	T2.Wheat sown under CA with RFD & without herbicide	T2.Wheat sown under CA with RFD & without herbicide	-
	T3.Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron) 400 g/ha	T3.Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron) 400 g/ha	T3.Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron) 400 g/ha	T3.Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron) 400 g/ha	T3.Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron) 400 g/ha

Table 7. Performance of productivity & profitability of wheat with integrated weed management techniques under conservation agriculture at different localities of Jabalpur region (M.P.)

Treatment	Mandla		Katni		Seoni		Narsighpur		Jabalpur	
	Yield (t/ha)	B:C	Yield (t/ha)	B:C	Yield/ (t/ha)	B:C	Yield (t/ha)	B:C	Yield (t/ha)	B:C
T1-Wheat sown with Farmer's practice (100 kg/ha + metsulfuron @4 g/ha)	3.64	2.33	3.49	1.81	2.83	1.78	3.75	2.40	3.71	2.4
T2- Wheat sown under CA with RFD & without herbicide	3.91	3.60	4.34	3.15	2.91	2.15	2.76	2.68	NA	NA
T3- Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron @ 400 g/ha)	4.87	3.75	5.14	3.44	5.05	3.44	4.01	3.46	4.06	3.43

Plate 8. Sowing of wheat under conservation agriculture in Seoni District

Adoption/demonstration of machinery for permanent bed cultivation of soybean –wheat

Package of equipments for bed forming cum seeding/planting, intercultural operation, chemical application and harvesting and bed shaping were identified for of soybean-wheat cropping systems. The equipments were modified to match the track width (1500 mm) of a 35 hp tractor to make the bed size: top width 1200 mm, bottom width 1500 mm and bed height 150 mm. The specifications of package of equipment used for bed cultivation are given in Table 8.

Table 8. Package of equipment for cultivation of soybean-wheat and maize-gram crops on raised bed

Operation	Name of the equipment	Specifications
Raised bed forming cum seeding/ planting	Tractor mounted bed former cum seeder/ planter	Bed size : top width 1200 mm, bottom width 1500 mm, bed height 150 mm, Row spacing adjustment from 100 ï 500 mm , Field capacity 0.3- 04 ha/h
Interculture operation	Tractor mounted sweep cultivator	Sweep size 5 ×150 mm, for soybean and 4 × 150 mm for maize crop, Field capacity 0.15 ha/h
Chemical application	Tractor mounted hydraulic sprayer	Tank capacity: 150 l, nos. of nozzles:14, type of the nozzle: hallow cone, adjustable distance between nozzle: 300 ï 600, Swath: 40 -60 m, field capacity 0.5 ï 0.66 ha/h
Harvesting	Self-propelled vertical conveyor reaper windrower	Reciprocating cutter bar: 1000 mm, length of stroke:75 mm, stroke /min: 740, field capacity: 0.21 ha/h, power: 6 hp diesel engine
Bed shaping cum seeding planting	Tractor mounted bed shaper cum no till seeder planter	Bed shaper for bed size: top width 1200 mm, bottom width 1500 mm, bed height 150 mm and no till drill for seeding and planting of soybean-wheat and maize-gram on beds.

Package of equipment was tested for cultivation of soybean and bed shaper cum seeder planter was tested for sowing of wheat crops on permanent beds during *Rabi* 2015. Permanent bed cultivation of soybean and wheat crops has saved 22 and 18% seeds, 19 and 8% nitrogen, 9 and 8% phosphorous 5% potassium and 36% irrigation water as compared to flatbed cultivation system.

Plate 9. Crop establishment under CA on BBF

Development and refinement of Machinery under CA system in Rainfed region

CRIDA zero till planter with herbicide and fertilizer applicator was designed and developed at CRIDA, Hyderabad. In this planter the furrow openers for sowing was inverted T type. The advantage of this implement was that, the seed has better seed soil contact as compared to traditional disc openers and germination was better when this planter was used for sowing the crop. This planter will be modified and refined based on the requirement at different centres. Apart from the Bed planter, CRIDA also developed CRIDA paired row planter for reshaping of the beds formed and opening of furrows at the time of sowing respectively. The existing CRIDA, 9-row and 6- row planter will be modified as per the requirement of different centres. Seed metering plates will be modified as per the crop. These implements will be given to the centres as per their requirements.

1.4 Sugarcane based cropping systems

Seven demonstrations were conducted with SORF machine at farmersô fields during the year 2015 by ***NIASM***, Baramati. Four treatment combinations including three methods of trash management (open burning of trash and retention of trash in the field as such or after chopping with a trash cutter), two methods of fertilizer application (broadcast as is the farmerôs practice, placement with SORF machine along with off-barring, root pruning and stubble shaving practices). The results obtained from the field experiments revealed that survivability of tillers and plant height increased significantly due to stubble shaving, off-barring, root pruning and band placement of fertilizers with SORF machine as compared to existing farmersô practices of ratoon management. The plant height, tillers and SPAD values were improved due to use of

SORF machine over the farmers practices of ratoon management by 6.3ï 19.5, 3.7ï 15.3 and 5.6ï 28.0 %, respectively at different farmersô fields (Table 9).

Plate 10. Demonstration of SORF machine at farmer's fields

Table 9. Effects of using stubble shaver, off bar, root pruner cum fertilizer drill machine on growth of sugarcane ratoon at farmers' field

Field no.	% increase in growth parameters due to use of SORF machine over farmers practice		
	Plant height	**Tillers**	**SPAD value**
Farmer-1	8.3-14.7	4.5-8.2	8.4-10.2
Farmer-2	13.2-19.5	9.5-12.8	15.4-28.0
Farmer-3	10.2-16.8	7.1-10.4	10.8-19.4
Farmer-4	15.7-19.4	10.0-15.3	10.2-17.2
Farmer-5	12.4-17.6	6.2-10.8	9.5-12.6
Farmer-6	6.3-11.0	3.7-7.9	5.6-11.5
Farmer-7	9.5-16.7	8.5-14.7	12.8-25.5

Wheat seeded in sugarcane ratoon crop with full trash using Rotary Disc Drill

Two farmers (Shri.Mahender Singh, 1.5 Acre and Shri. Shish Pal 1.0 Acre) at Village Bara Gaon fields were selected for seeding of wheat in ratoon crop of Sugarcane by IIWBR, Karnal. The crop was seeded using Rotary Disc Drill. Late sowing of wheat cv PBW 550 was done on 12th and 13th January, 2016 at a seed rate of 150 kg/ha. The sowing was also recorded by DD Kisan Channel. On 4th May 2016 a farmerȇs field day was organized in which more than 50 farmers participated and were impressed with the performance of the wheat crop sown in sugarcane ratoon. The crop was harvested on the same day using mini combine of BeriUdyog Limited. The average wheat yield recorded was 34.3 q/ha (Shri. Mahender Singh, 32.7 q/ha and Shri.Shish Pal, 35.8 q/ha) from the late sown wheat. Most of the farmers of the village were interested to follow this practice if the machine is made available. The growing of wheat or other crops like green gram will be additional crops for the farmers and will enhance the profitability of the farmers as well as the wheat a production. Moreover, this will promote the CA with better environmental health by reducing the pollution with no straw/trash burning.

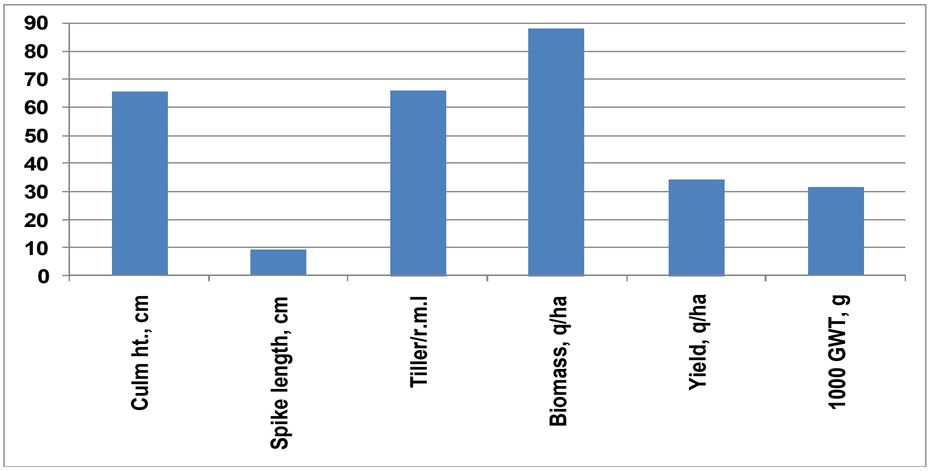


Fig. 4. Performance of late sown wheat cv PBW 550 in sugarcane ratoon

Plate 11. Wheat seeding in sugarcane ratoon using Rotary Disc Drill at Village Bara Gaon

2. DEVELOPING AND VALIDATING LOCATION SPECIFIC CONSERVATION AGRICULTURE TECHNOLOGIES

2.1 TILLAGE AND RESIDUE MANAGEMENT

2.1.1 Rice based cropping systems

2.1.1.1 Rice – maize

A field experiment was carried out at ***NRRI***, Cuttack to study the effect of different nutrient management options on the rice-maize cropping system under different tillage regimes.

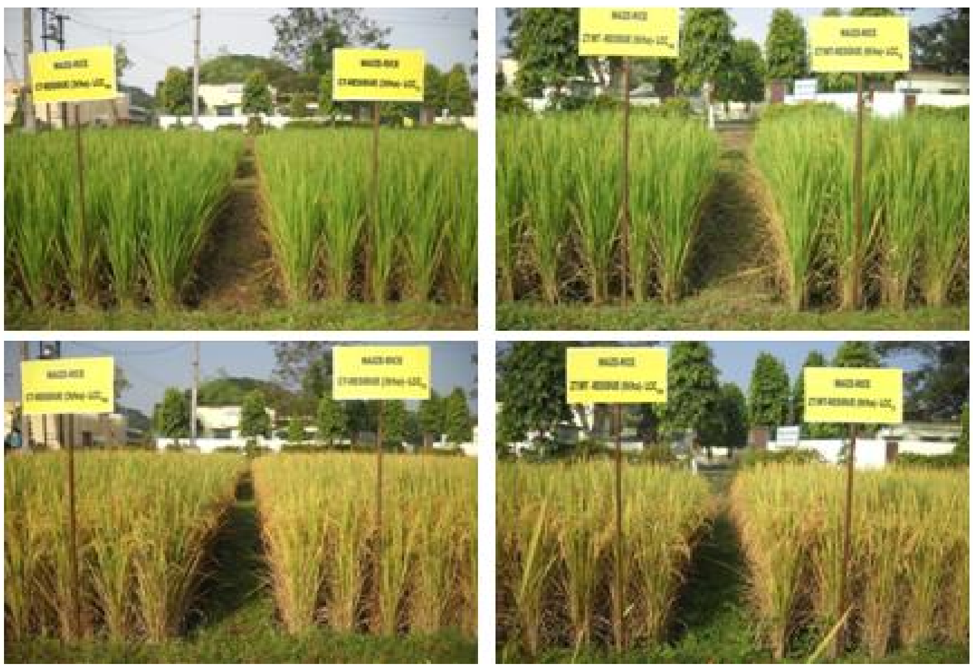


Plate 12. Different growth stages of Rice crop under conventional and minimum tillage and nitrogen levels.

The experiment was laid out in a split - split plot design with two tillage systems i.e. conventional and reduced tillage (zero tillage in maize cv Super 36 and minimum tillage in rice cv. Pooja) in main plots and three residue management system i.e. RDF + No Residue, RDF + Residue Mulching (3 t/ha) and RDF + Residue Mulching (6 t/ha) to maize in subplots and two N levels to rice i.e. LCC based (75% RDN) and LCC based (100% RDN)replicated thrice. The results indicated that although rice performed similar for both tillage systems but Maize yields were poorer (8 % less yield) under zero tillage. Comparable system productivity in terms of rice equivalent yield was in rice ï maize cropping system for the tillage systems was noticed. The maize grain yield was increased with an increase in residue of rice in maize up to 6 t/ha but the residual effect was not seen in rice. Reducing the fertilizer dose of N to rice upto 25% did not reduce rice yield but maize yields were higher in 100 % RDN applied to rice as compared to 75% RDN. The system REY with 100% RDN to rice was 7 % higher than that obtained with 75% RDN applied through LCC.

2.1.1.2 Rice-wheat

Field observations were recorded from a field experiment of ***NRRI***, Cuttack continuing from 2011 to evaluate the effect of tillage, residue and irrigation methods for enhancing crop productivity and sustaining health in semi-reclaimed sodic soils in rice (cv Ariz-6129) - wheat (cv H.D 2967) cropping system.

Plate 13. Zero tillage maize with residue levels

Table 10. Treatment structure

Treatment	Rice	Wheat
T_1	Transplanting of rice	Conventional wheat sowing
T_2	Transplanting of rice after wheat residue incorporation	Wheat sowing after rice residue incorporation
T_3	Direct seeded rice (DSR)	Wheat in reduced tillage
T_4	DSR after wheat residue incorporation	Wheat in reduced tillage after rice residue incorporation
T_5	DSR in zero tillage	Wheat in zero tillage
T_6	DSR in zero tillage with wheat residue retention	Wheat in zero tillage with rice residue retention
T_7	DSR without wheat residue in reduced tillage with surface irrigation	Wheat in Zero tillage with rice residue with surface irrigation
T_8	DSR without wheat residue in reduced tillage with drip irrigation	Wheat in Zero tillage with rice residue with drip irrigation
T_9	DSR without wheat residue in reduced tillage with sprinkler irrigation	Wheat in Zero tillage with rice residue retention and sprinkler irrigation system
T_{10}	DSR with wheat residue incorporation in reduced tillage with sprinkler irrigation	Wheat in Zero tillage with rice residue retention and sprinkler irrigation

Drip irrigation in T_8 treatment has been installed and observations will be started from rice-2016 (June 2016 onwards)

Highest grain yield of rice was recorded in transplanted rice with wheat residue incorporation (7.58 t ha^{-1}) followed by without residue (7.18 t ha^{-1})transplanted rice. Thus wheat residue incorporation enhanced rice grain yield by 5.57 % whereas under DSR it was only 4.67%, probably the residue maintained optimum soil moisture and temperature facilitating seed germination and crop growth as compared to no- residue. Severe weed infestation was found in DSR. Preponderance of *Cyperusrotundus* (motha), *Echinochloa crus-galli*(Barta), *E. colonum* (Sanmak), *Dactylacteniumaegypticum* (Makra) and Kallar grass, etc. severely competed with rice under zero tillage and reduced tillage techniques.

Mini-sprinkler irrigation system for rice

A mini-sprinkler irrigation system with 12960 lph acre^{-1} discharge rates at 2 kgcm^{-2} pressure along with 90 % uniformity coefficient was used in rice-wheat cropping system. A cumulative pan evaporation of 7 and 2 were used for irrigation scheduling of wheat and rice respectively and the results are presented in Table11

Table 11. Effect of surface and mini sprinkler irrigation methods on rice (cv.Arize 6129) during 2015

RCTs	Conventional transplanting	DSR without wheat residue	DSR without wheat residue	DSR with wheat residue incorporation
Mode of irrigation	Surface T_1	Surface T_7	Mini-Sprinkler -T_8	Mini-Sprinkler-T_9
Irrigation criteria	1 DADPW	Soil crack with surface dryness	(CPE) Alternate day	(CPE) Alternate day
Grain yield (t ha^{-1})	7.18	6.97	6.48	6.59
Total crop productivity (t ha^{-1})	13.08	11.75	12.45	11.95
Total irrigation water (ha-cm)	77.50	56.30	32.76	32.76
Total irrigation water (m^3/ha^{-1})	7750	5630	3276	3276
Crop water productivity (kgm^{-3})	1.69	2.09	3.80	3.65
Grain water productivity(kg m^{-3})	0.92	1.24	1.98	2.01
Irrigation water saving (%)	-	27.35	57.73	57.73
Electricity saving (%)	-	27.36	32.49	32.49
NUE(kgkg^{-1} nitrogen)	47.87	46.47	58.81	59.91

Rainfall received = 379.3 mm and Pan evaporation = 519.6 mm during June, 2015 to September 2015, CPE= cumulative pan evaporation criteria used for irrigation through mini sprinkler system, CD (0.05) = 0.35 (grain yield) and NUE= Nitrogen use efficiency.

A maximum grain yield of 6.59 t ha^{-1} was recorded in DSR under mini sprinkler irrigation, saving 57.73% of irrigation water and 32.49 % electricity consumption. DSR with 50% reduced tillage under surface irrigation method saved 27.36% irrigation as compared to conventional transplanting. Mini sprinkler fertigation in rice saved 27% of recommended nitrogen (40 kg) and increased nitrogen use efficiency up to 59.91 kg kg^{-1} nitrogen as compared to conventional rice.

In Rabi wheat 2015-16, wheat sown in 50% reduced tillage with rice residue incorporation produced highest (7.95 % higher) grain yield (5.43 t ha^{-1}) as compared to conventional tillage (5.03 tha^{-1}). Crop residue incorporation resulted in ~5.57 % additional grain yield in wheat under conventional wheat sowing. 50% tillage with crop residue incorporation yielded 4.83 % higher grain yield in comparison to 50% tillage without crop residue.

Table 12. Effects of tillage with residue management on wheat yield during 2015-16 in rice-wheat system

R.C.Ts	Tillage Management		
	Without crop residue	**% Grain yield increase over conventional tillage**	**Remarks**
Conventional tillage -T_1	5.03	-	Conventional tillage, not increase the wheat grain yield always incorporation.
50% Reduced tillage - T_3	5.18	2.98	Reduced tillage increase the wheat grain yield relatively better.
Zero tillage - T_5	5.07	0.81	Long term zero tillage cultivation practice seems much beneficial.

Table 13. Effects of tillage with residue on wheat grain yields-during 2015-16 in Rice-Wheat system

R.C.Ts	Tillage management with Crop Residue		
	With crop residue	**% Grain yield increase over conventional tillage**	**Remarks**
CV-tillage -T_1	5.03	-	Conventional tillage with rice residue, increase wheat grain yield after two year of rice residue incorporation.
CV- tillage with res.- T_2	5.31	5.57	
Reduced tillage -T_4	5.43	7.95	Reduced tillage with rice residue increase the wheat grain yield relatively better. It is better to be followed.
Zero tillage -T_6	5.17	2.78	Long term zero tillage cultivation practice in wheat, seems much better

In zero tillage wheat sowing with rice residue anchored produced 5.17 t ha^{-1}, which was 2.78% higher than conventional wheat sowing and 1.99 % greater than zero tillage wheat without crop residue.

Wheat under mini sprinkler irrigation

Wheat in Zero tillage (Table 14) with 100% rice straw mulch produced highest wheat grain yield (5.29 t ha^{-1}) under sprinkler irrigation while surface irrigation produced 4.89 tha^{-1} where wheat shown in zero tillage with 100 % rice straw mulch. Sprinkler irrigation system in wheat crop saved 33.82 % more water over the surface irrigation method.

Table 14. Effect of surface and mini sprinkler irrigation method on wheat yield (cv. HD2967), irrigation water requirement, water productivity, saving of water and electricity

RCTs	Conventional wheat sowing	Wheat sowing in ZT with100 % rice mulch / DSR without wheat residue	Wheat sowing in ZT with 100% rice mulch/DSR without wheat residue	Wheat sowing in ZT with 100 % rice mulch/DSR with wheat residue incorporation
Mode of irrigation	Surface T_1	Surface T_7	Mini ï Sprinkler T_8	Mini ï Sprinkler T_9
Irrigation criteria	Growth stage	Growth stage	(7 days CPE)	(7 days CPE)
Grain yields(tha^{-1})	5.03	4.89	5.18	5.29
Total crop productivity (tha^{-1})	12.43	11.82	10.77	10.74
Total irrigation water (ha cm)	28.0	22.0	18.53	18.53
Total irrigation water (m^3 ha^{-1})	2800	2200	1853	1853
Crop water productivity (kg m^{-3})	4.44	5.37	5.81	5.79
Grain water productivity (kg m^{-3})	1.79	2.22	2.24	2.28
Irrigation water saving (%)	-	21.43	33.82	33.82
Electricity saving (%)	-	27.77	8.15	8.15
NUE ($kgkg^{-1}$ nitrogen)	33.53	32.6	69.07	70.53
Physiological observation	Greenness-water stagnated	Greenness-water not stagnated	Greenness-water not stagnated	Greenness-water not stagnated

Rainfall received = 46.2 mm and Pan evaporation=257.1 mm during November 2015 to March 2016, CPE= cumulative pan evaporation of 7 days used for irrigation through mini sprinkler system, CD (0.05) =0.35 and NUE= nitrogen use efficiency.

Plate 14. Mini sprinkler system in Wheat

Mini sprinkler irrigation system in wheat crop with 100% rice residue

Electricity saving in wheat crop was 8.15% in mini sprinkler irrigation in comparison to surface irrigation with conventional wheat sowing. Highest nitrogen use efficiency of 70.53 kg kg^{-1} nitrogen recorded in mini sprinkler fertigation method and saved 50% recommended nitrogen (75 kg N and 162.0 Kg urea per ha) in wheat crop as compared to conventional surface irrigation. Soil samples collected for physio-chemical analysis are in progress in the laboratory.

2.1.1.3 Rice-bottle gourd/mustard

Survey conducted in Chhattisgarh and Jharkhand by ***ICAR-RCER*** Patna revealed that limited access and availability of water restricts the cultivation of second crop to nearly 45% of the cultivated land. This demands the creation of water harvesting structures in farmersô fields. An average yield of 2.8t/ha rice and 23.4t/ha bottle gourd was recorded following CA practices with limited water. Under Jharkhand conditions cultivation of mustard after paddy under CA practices recorded the average yield of 400 kg/ha.

Linseed under *Utera* Lentil under *Utera*

Lathyrus under *Utera*

Mustard in rice-fallow (Jharkhand) Bottle gourd in rice-fallow (Chhattisgarh)

Plate 15. Performance of different crops under Utera in *ICAR-RCER* Patna

2.1.1.4 Other rice-based cropping systems

A study carried out for six consecutive years to replace conventional transplanted rice (TPR), encountering a host of problems and to diversify the rice-wheat cropping system with a suitable direct-seeded rice (DSR)-based rice-wheat and rice-mustard system, involving CA practices. Results showed that a system of ZT DSR with summer mungbean (SMB) residue retention - rice residue (RR) retention in ZT wheat (ZTW) ï wheat residue retention in ZT summer mungbean (SMB) resulted in higher system productivity and net returns (Table15). This treatment gave higher system water productivity than TPR-CTW (conventional tilled wheat). This resulted in a considerable improvement of SOC, and total N in the surface (0-5 cm) soil and showed a considerable reduction in global warming potential (GWP) through reduction in methane emission from rice fields. This ZT DSR with summer mungbean (SMB) residue - rice residue (RR) retention in ZTW ï wheat residue in ZT summer mungbean (SMB) system performed better than conventional TPR-CTW system (Plate 16 & 17). This would provide more adaptation and mitigation to anticipated climate change effects. Similar practice proved useful for rice-mustard system too.

Estimated the economic water productivity, which is important to achieve economic efficiency and sustainability than only water productivity and savings. It was observed that highest economic water productivity accrued from the treatment (MBR+ ZT DSR ï RR + ZTM + MR - SMB) that used all the three residues of rice, mustard and mungbean (Table 16). Though in MR + ZT DSR + BM ï RR + ZTM water productivity is more compared to ZT DSR + BM ï ZTM, but economic water productivity is negative. Again comparing MBR + ZT DSR ï ZTM - SMB and TPR-CTM, though water productivity is almost same but economic water productivity is more in the former. This shows the importance of economic water productivity under conservation agriculture.

Table 15. System productivity (SP) (in rice equiv. yield, REY) and net returns (NR) in rice-wheat cropping system under CA in 2015-16

Treatment	SP (REY) (t/ha)	NR (Rs x 10^3/ ha)
ZT DSR ï ZTW (Double ZT)	9.76	159.8
ZT DSR+BM ï ZTW	8.86	141.8
WR+ZT DSR - RR+ZTW 75%	11.22	168.5
WR+ZT DSR - RR+ZTW 100%	11.27	166.9
WR+ZTDSR+BM - RR+ZTW 75%	9.03	117.28
WR+ZTDSR+BM - RR+ZTW 100%	8.94	121.1
MBR+ZT DSR ï ZTW ï ZTSMB) (Triple ZT system)	10.07	193.6
MBR+ZT DSR - RR+ZTW -WR+ SMB 75%	11.50	225.5
MBR+ZT DSR - RR+ZTW -WR+ SMB 100%	11.32	189.7
TPR-ZTW / ZTM	11.12	172.3
TPR-CTW / CTM	10.62	158.2

Table 16. Water productivity and economic water productivity in Rice under Rice-mustard-mungbean cropping system

Treatment	Yield (t/ha)	Sun-dried straw yield (t/ha)	Total water applied (mm)	Water Productivity (kg/ha-mm)	Economic Water Productivity (Rs./m^3)
ZT DSR - ZTM	3.26c	6.25cd	1420.7	2.29	2.91
ZT DSR + BM - ZTM	2.00d	4.25f	1436.4	1.39	0.32
MR + ZT DSR ï RR + ZTM	3.10c	5.95d	1449.3	2.14	0.90
MR + ZT DSR + BM ï RR + ZTM	2.41d	4.88e	1413.4	1.71	-0.36
MBR + ZT DSR ï ZTM - SMB	3.56c	6.50c	1407.5	2.53	2.94
MBR+ ZT DSR ï RR + ZTM + MR - SMB	4.57b	7.00b	1388.4	3.29	3.43
TPR - ZTM	4.99ab	8.05a	2002.6	2.49	2.53
TPR - CTM	5.19a	7.83a	2053.7	2.53	2.66

Plate 16. DSR under triple ZT conditions (with 75 and 100% N) and transplanted rice

Plate 17. Brownmanuring in direct seeded rice (temporary residue mulch)

2.1.1.5 Rainfed rice-based cropping systems

Zero till seed drill was successfully used for dry direct seeding of rice (cultivar Pooja) in farmerȏs field at Jajpur and Salipur block ofCuttack district, Odisha (Plate 18). A minimum tillage approach was followed in which a slight slit was opened in the soil for seed-soil contact without tillage operation. Rice seed was used @ 40 kg/ha. Proper row to row distance along with optimum plant population was maintained. Rice crop was harvested in such a way that around 30% residues was retained in the field itself. In r*abi* season maize and green gram were sown in 50% of the area each in CA and farmers practices. Results revealed that compared to farmers' practice, 10.2% and 7.89% lesser grain yield was recorded in CA plot at Jajpur and Salipur, respectively (Table 17).

Table 17. Yield attributes and yields of rice influenced due to conservation agriculture and farmers practices at Jajpur and Salipur, Odisha, India

Yield attributes	Jajpur, Odisha		Salipur, Cuttack, Odisha	
	CA	FP	CA	FP
Tillers/m^2	256	281	234	255
Number of panicles/hill	11.8	13.2	7.5	9
Panicle length (cm)	23.1	24.3	21.3	21.7
Panicle weight (g)	2.65	2.81	1.9	2.1
Grains/panicle	115	120	89.5	92.7
Spikelet fertility (%)	85.9	87.5	72.1	74.4
1000-grain weight (g)	21.0	21.1	20.1	20.3
Grain yield (t/ha)	4.9	5.4	3.8	4.1
Straw yield (t/ha)	6.4	6.8	5.3	5.7

CA: conservation agriculture practices, FP: Farmers practices

Plate 18. Demonstration of conservation agriculture practices in rice-maize cropping system in farmers' field

2.1.1.6 Rice- fallow systems

ICAR-RCER Patna evaluated the performance of winter season oilseeds and pulses under rice-fallows viz., lathyrus (cv Ratna), lentil (cv HUL 57), chickpea (cv JG 14), mustard (cv Pusa Bold) and linseed (cv T397) under three crop establishment methods viz., *Utera/para* cropping (sowing of seeds 10 days before rice harvest after seed priming), ZT with rice mulch @5t/ha and ZT without mulch during 2015-16 as rainfed crops. Foliar application of 2% urea at flowering and pod formation were done as a part of the nutrient management strategy in rice-fallows. Crops under *Utera* were sown on 9^{th} November and that in ZT on 24^{th} November. *Utera* system recorded significantly higher plant population (799×10^3 ha) over either ZT with mulch (696×10^3 ha) or without mulch (550×10^3 ha). Significantly higher rice equivalent yield was also recorded with *utera* system (2029 kg/ha) as compared to ZT (1187 kg/ha) and ZT with mulch (1424 kg/ha). The system productivity and system production efficiency was also significantly higher under *utera* system (6409 kg/ha and 17.59 kg/ha/day) as compared to ZT (5581kg/ha and 15.29 kg/ha/day) and ZT with mulch (5833 kg/ha and 1598 kg/ha/day). Among the crops tested, lathyrus produced the maximum seed yield (1165 kg/ha) followed by lentil (706 kg/ha) and linseed (553 kg/ha). However, the highest productivity of lathyrus (1876 kg/ha), lentil (969 kg/ha) and linseed (676 kg/ha) was recorded with *Utera* cropping and mustard (360 kg/ha) with ZT mulch. *Utera* crop depleted maximum soil moisture (121.46 mm) followed by ZT (62.03mm) and ZT mulch (49.8 mm). Among different crops, the moisture depletion ranged from 70.01 mm in linseed to 84.36 mm in lentil.

2.1.2 Maize based cropping systems

2.1.2.1 Maize – Horse gram

Fine tuning of CA practices for Maize - Horse gram system was done by ***ICAR-CRIDA***, Hyderabad. maize was sown in ridge and furrow method where furrows are reshaped every year. This method recorded higher seed and biomass yield as compared to zero tillage without conservation furrow, minimum tillage and farmers practice. (Fig.5)

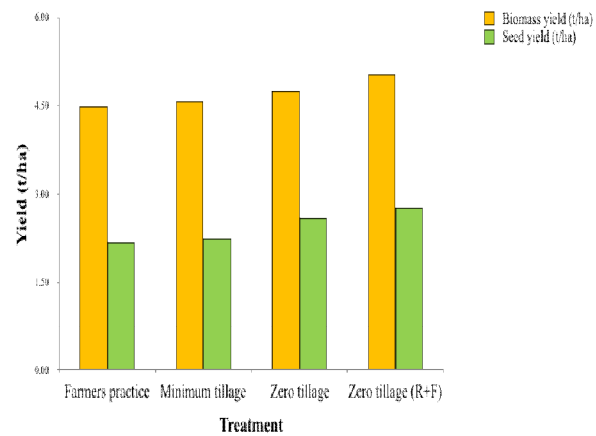


Fig. 5. Maize yield and biomass production under different tillage practices

Experiments were initiated in Maize-Horse gram system at GRF farm with tillage treatments as main plots and nutrient management treatments in subplots. At Gunegal farm rainfall during 2015 was low and there were dry spells, at late vegetative stage and flowering stage. Hence two life-saving irrigations, each of 6 mm were applied. But the average yields of the crop were less. CT recorded significantly higher cob weight, grain and stove yield (73.8 g, 1.27 t/ha and 5.07 t/ha, respectively) over CA (65.2 g, 0.63 t/ha and 1.25 t/ha, respectively). The nutrient application had influence on yields of maize. (Fig.6)

Horse gram was sown after harvest of maize with rainfall of 17.6 mm. Growth and yield of horse gram was very low due to severe moisture stress and this crop did not produce any seed.

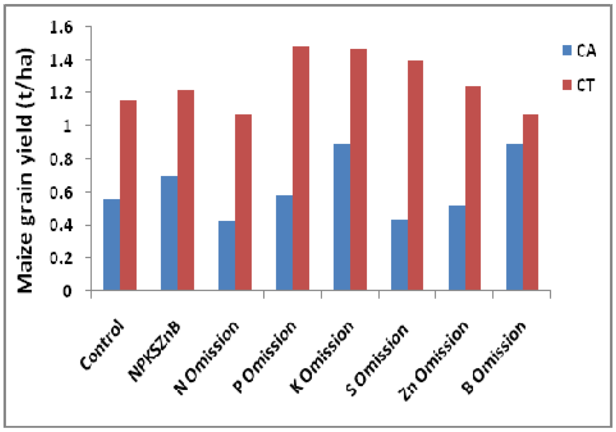


Fig. 6. Influence of different tillage and nutrient treatments on Maize grain yield

2.1.2.2Maize-Pigeonpea

Fine tuning of CA practices for Maize ï Pigeonpea system was done by ***ICAR-CRIDA***, Hyderabad. Tillage cum seeding implement was modified and fabricated to sow the crop with permanent *in-situ* moisture conservation treatments. The pigeonpea crop is sown on the reshaped raised bed and also with the conservation furrow. In ZT and CT the growth of the crop is better in conservation furrows, and raised bed as compared to flat sowing without conservation

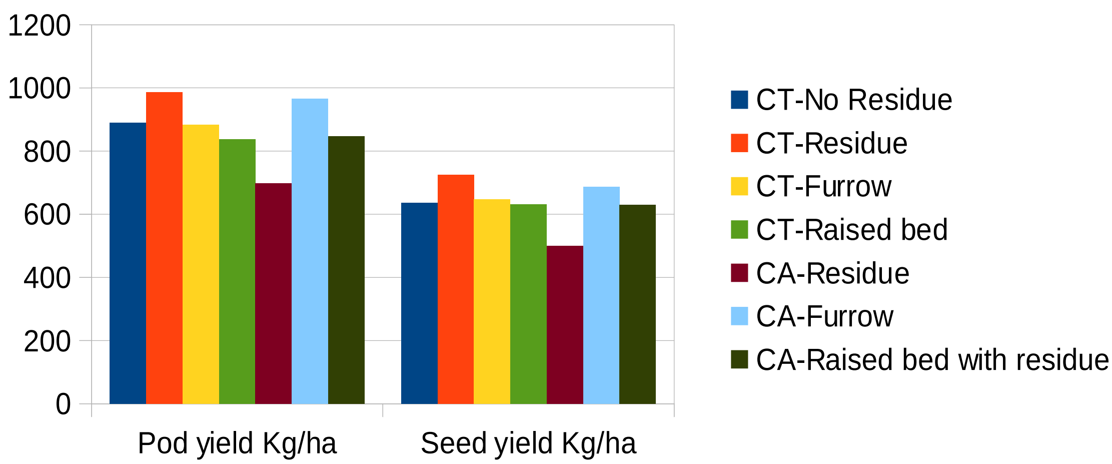


Fig. 7. Influence of different *in-situ* moisture conservation practices on pigeonpea yield

furrows. *In-situ* moisture conservation with furrow has recorded higher yields in both conventional tillage and conservation agriculture treatments (Fig. 7).

In Maize-pigeonpea system this year pigeonpea was test crop. Experiment was conducted in split plot design with tillage treatments as main plot and nitrogen doses in sub plots. Pigeonpea crop (cv. PRG 158) was sown on 22 June, 2015. Delay in germination of pigeonpea by 2 days and about 5% lower seed germination was recorded in No-tillage as compared to the conventional and reduced tillage. There was no effect of the nitrogen levels on seed germination percentage, irrespective of tillage treatments. Tillage practices significantly influenced the seed and stover yield. There were about 17% and 14% higher mean seed yield and 10 and 12% higher mean stover yield in no tillage and reduced tillage, as compared to the conventional tillage respectively. This higher seed yield is due to 8% and 5% higher mean soil moisture in no tillage and reduced tillage, respectively as compared to the conventional tillage during entire crop growing season. About 20%, 23% higher mean seed yield and stover yield was recorded with the application of the N125% treatment over no nitrogen application (Fig.8).

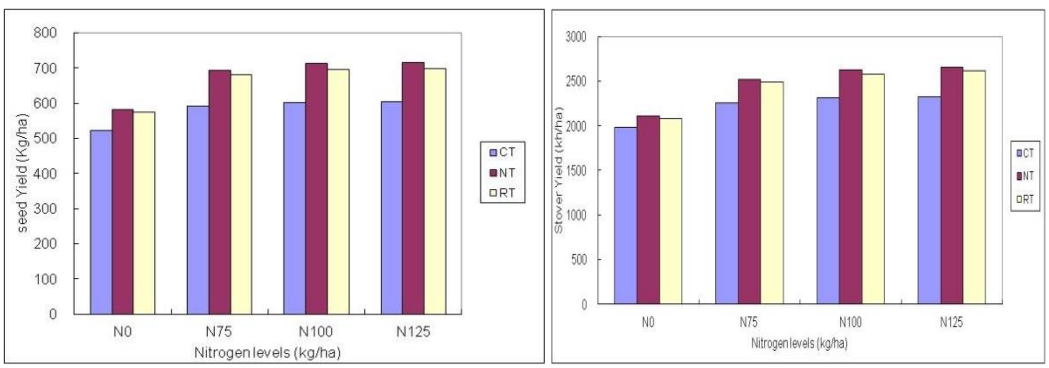


Fig. 8. Effect of different tillage treatments and nitrogen on pigeon pea seed andstover yield

2.1.2.3 Maize-wheat-sesbania (Green manure)

An experiment was conducted at ***ICAR-IIFSR***, Modipuram to increase nitrogen use efficiency under zero tillage conditions. The initial soil sample had a pH of 8.22, EC-0.0.74 ds/m, organic carbon 0.50%, Olsen-P 20.0 kg/ha, available K 153 kg/ha, elemental nitrogen 0.074% and carbon 0.568%. The elemental nitrogen and carbon were analyzed by Euro Vector Elemental Analyzer. Thus, the soil was medium in OC, available P and K content in 0-15 cm soil depth. The experiment was conducted in randomized block design with four replications. The treatments were (T1) 100 % recommended dose of nitrogen through fertilizer, (T2) 75% N through chemical fertilizers + 25 % N through FYM, (T3) 50% N through chemical fertilizers +

50 % N through FYM, (T4) 75% N through chemical fertilizers + green manure of Sesbania and (T5) 50% N through chemical fertilizers + green manure of Sesbania.

In maize, 75% N through fertilizer and the balance through compost recorded significantly higher maize yield (5974 kg/ha) followed by 100% N through fertilizer alone (Fig.9).

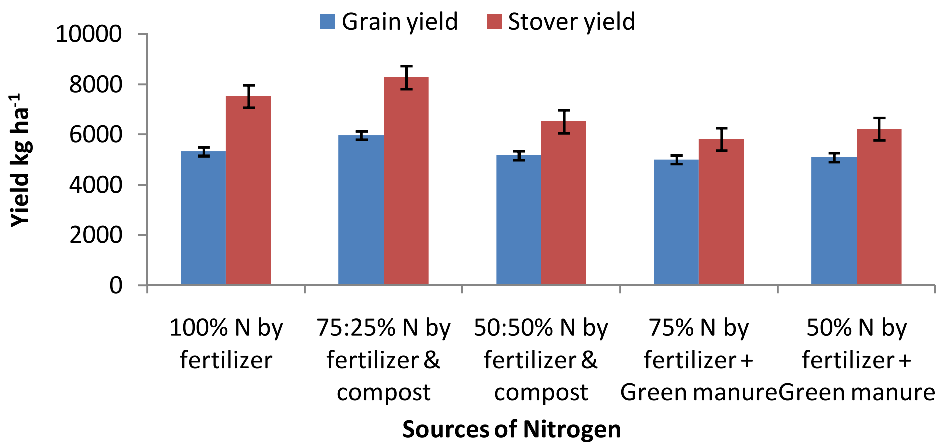


Fig. 9. Grain and Stover yield of maize under zero tillage practices

Substitution of 25% N through compost recorded the highest cost of cultivation (Rs 26950/ha) followed by 75% N by fertilizer + green manure (Rs 25124/ha). The gross returns (Rs 79126/ha), net returns (Rs 52206/ha) and B:C ratio (1.94) were also highest under 75:25% N by fertilizer & compost (Table 18).

Table 18. Effect of nutrient management practices on economic returns of maize

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net returns (Rs/ha)	B:C ratio
100% N by fertilizer	24540	70649	46109	1.88
75:25% N by fertilizer & compost	26950	79156	52206	1.94
50:50 % N by fertilizer & compost	24720	68529	43809	1.77
75% N by fertilizer +Green Manure	25124	66409	41285	1.64
50% N by fertilizer + Green Manure	24560	67469	42909	1.74

Selling rate of maize grain - Rs. 1325/q

2.1.2.4. Maize-wheat-green gram cropping system

A long term experiment was initiated at ***ICAR-IIWBR***, Karnal during Kharif 2015, to evaluate the "Long term effect of tillage, residue and nutrient management in maize-wheat-green gram system". The experiment was conducted in split plot design with three replications. The main plot consisted of four treatments involving the combination of tillage and residue management {ZT (Zero tillage); ZT with residue retention (CA); CT (Conventional tillage) and CT + residue incorporation}and sub plots were having the four nutrient management options (Control; Recommended N alone; Recommended NPK; and Rec. NPK + FYM 10 t/ha). Wheat cv. HD 2967 was sown at a row-row spacing of 22.0 cm at a seed rate of 125 kg/ha using Turbo happy seeder. Total maize residue (245 q/ha on dry weight basis) after removing the cobs was either removed, or retained or incorporated. The incorporation was done using rotary tiller. Irrigation was given as per the recommended practices. For control of weeds clodinafop 60 g/ha fbmetsulfuron 4 g/ha were applied at 35 DAS. The recommended dose of N: P: K consisted of 150:60:40 kg/ha. Full P and K were applied as basal before pre seeding irrigation. Whereas N was applied in two equal splits (half dose each just before first and second irrigation).

A perusal of data in Table 19 revealed that the effect of nutrient management was significant, whereas the effect of tillage and residue management and their interactions were non-significant. Among the nutrient management options, wheat grain yield was maximum (51.73 q/ha) when FYM @ 10 t/ha was applied along with recommended NPK which was at par with recommended N alone and recommended NPK.

Table 19. Effect of tillage, residue and nutrient management in wheat under Maize-wheat system

Tillage and residue management	Culm height (Cm)	Ear head length, cm	Tillers/m^2	Yield q/ha	1000 grain weight, g
ZT	80.5	8.6	380.0	41.45	38.94
ZT+R*	78.7	7.9	391.6	42.50	38.33
CT	81.0	8.5	389.4	41.91	38.60
CT+RI*	80.0	8.3	383.9	42.18	38.63
CD at 5%	NS	NS	NS	NS	NS
Nutrient management					
Control	54.5	6.4	211.9	14.51	38.63
N Alone	86.4	8.9	437.5	50.56	38.51
Rec. NPK	89.7	9.1	441.7	51.24	38.52
Rec. NPK+ FYM 10t/ha	89.6	8.9	453.9	51.73	38.85
CD at 5%	3.48	1.23	24.5	1.27	NS

*R=Residue Retention and RI= Residue incorporation

The morning soil temperatures were on slightly higher in CA system where as the reverse in the noon. Canopy temperature as measured by LT300 Infrared Thermometer was higher in unfertilized plots. Whereas the Normalized Difference Vegetation Index (NDVI) values recorded using hand held green seeker, a direct indicator of the crop growth was drastically less in unfertilized plots, which reflected as poor crop yields.

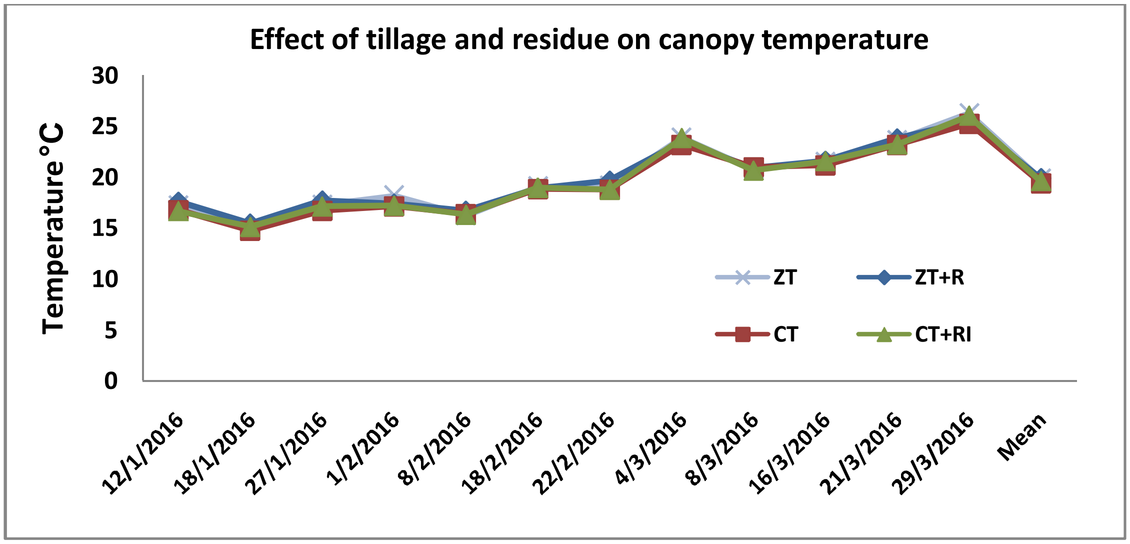


Fig. 10. Effect of tillage and residue on canopy temperature

Residue incorporation **ZT-Wheat**

Plate 19.CA-Wheat (Wheat in total maize residue retained)

2.1.3 Wheat based cropping systems

Diversification of rice-wheat cropping system with non-rice crops*viz*, cotton-wheat, pigeonpea-wheat and maize-wheat with suitable CA practices (namely, zero-till permanent narrow bed (70 cm), broad bed (140 cm) and flat bed with both season crop residues) was carried out ICAR-IARI, New Delhi. Among these cropping systems, cotton-wheat system was consistently superior to pigeonpea-wheat and maize-wheat systems in terms of system productivity. Crop residue retention during both seasons was superior to no residue treatment, irrespective of the land configuration. ZT permanent broad bed (PBB) with residue resulted higher system productivity and net returns in cotton-wheat system than that in conventional till flat bed. After 5 years of CA practice, it was observed that continuous residue retention led to a saving of 25% N of the RDN without any yield penalty.

Table 20. System productivity (SP) (in wheat equivalent yield, WEY) and net returns (NR) in wheat-based cropping system under CA in 2015-16

Treatments	SP (WEY) (t/ha)			NR (Rs x10^3 /ha)		
	C-W	M-W	P-W	C-W	M-W	P-W
CT	6.65	7.58	6.70	85.28	133.79	111.8
ZT NB	7.57	8.53	7.51	109.88	162.17	134.7
ZT NB+R (75% N)	8.04	9.25	-	108.63	163.97	-
ZT NB+R (100% N)	8.07	9.65	8.29	109.28	173.63	142.7
ZT BB	8.42	8.78	8.12	126.54	167.21	149.3
ZT BB+R (75% N)	8.61	9.94	-	121.68	181.80	-
ZT BB+R (100% N)	8.47	10.10	8.58	119.26	185.35	150.0
ZT FB	8.06	9.42	8.58	120.48	181.49	115.9
ZT FB+R (75% N)	8.10	9.33	-	111.94	168.44	-
ZT FB+R (100% N)	7.21	8.37	7.14	90.87	145.17	150.9

Narrow bed planting without residue **Narrow bed planting with residue**

Broad bed planting without residue **Broad bed planting with residue**

Plate 20. Cotton crop in the field under narrow and broad bed with and without residue

Plate 21. Wheat crop after cotton under different beds with and without residues

2.1.4 Soybean based cropping systems

Soybean based cropping systems were evaluated by ***ICAR-IISS***, Bhopal to identify and evaluate potential cropping systems and conservation tillage practices best suited for the Vertisols of central India, to formulate suitable weed management options for major cropping systems and refining and validation of component technologies of conservation agriculture. Under the sub-project two field experiments on soybean-wheat and maize-chickpea cropping systems were initiated during *kharif* 2015 with five tillage treatments namely T1: Conventional tillage (No residues and manual weed control), T2: Reduced tillage (RT) -1 (sowing with residues + 1 duck foot, weed control (WC) with herbicides), T3: RT-2 (Strip tillage - sowing with strip till- drill with residues, WC with herbicides), T4: RT-3 (Strip tillage - sowing with strip till- drill with residues, Hand weeding) and T5: No-tillage with three nutrient doses namely N1:75% of the recommended dose of fertilizer (RDF), N2:100% RDF, N3: Soil test based recommendation following split plot design with three replications.

Experimental crops were raised during rainy and winter seasons. Soil profile moisture content, soil temperature,penetration resistance and crop biometric observation were recorded periodically during the cropping seasons. Regardless of tillage systems, higher nitrogen application namely N100% and N application based on STCR recorded higher grain yield under soybean-wheat and maize-gram systems (Fig.11).

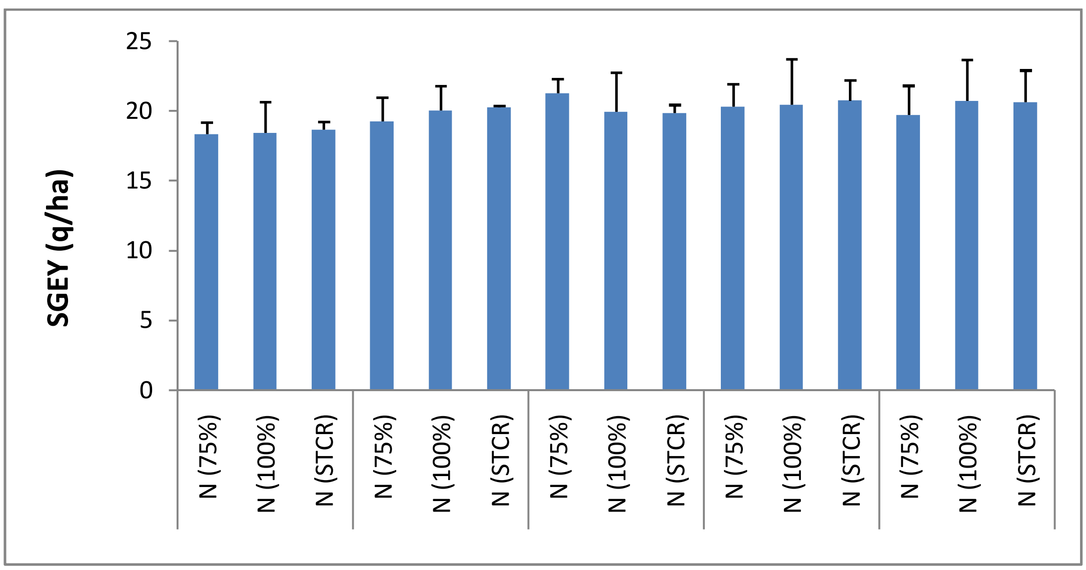


Fig. 11. System productivity, expressed as soybean grain equivalent yield, SGEY (q/ha), of the Soybean-Wheat cropping system

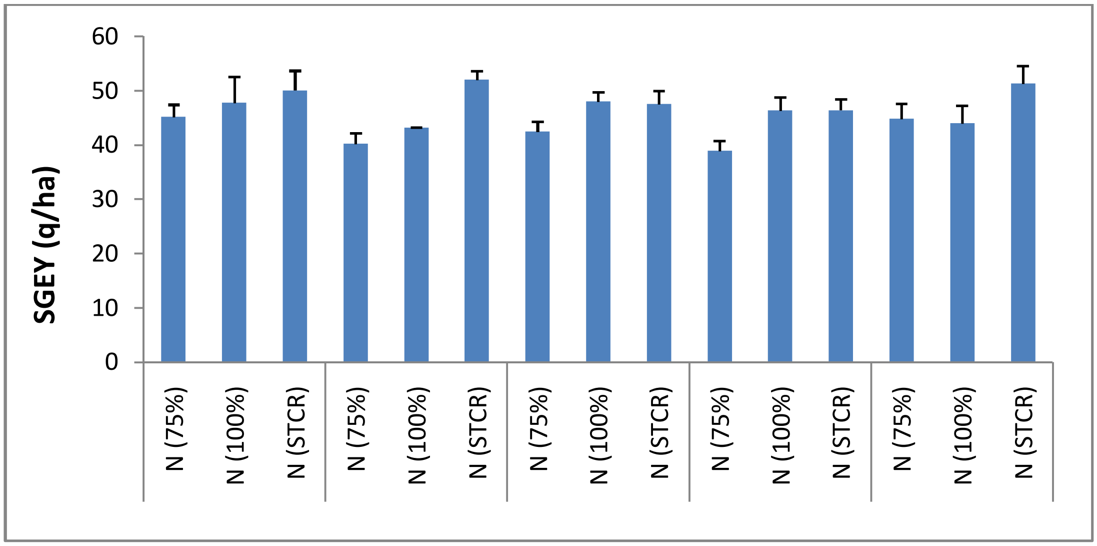


Fig. 12. System productivity, expressed as soybean grain equivalent yield, SGEY (q/ha), of Maize-Gram cropping system

Conservation tillage practices effect on crop yield after 6 crop cycles

Plate 22. Chick pea under reduced tillage at ICAR-IISS, Bhopal

A long-term experiment was initiated during *Kharif* 2010 at the experimental farm of the ***ICAR-IISS*** with two tillage treatments namely conventional tillage (CT) with residue removed and reduced tillage (RT) with residue retained along with six cropping systems namely i) Soybean- Fallow, ii) Maize- Gram, iii) Soybean- Fallow R (R: rotated with maize-gram), iv) Soybean + Pigeon pea (2:1), v) Soybean+ Cotton (2:1) and vi) Soybeanï Wheat. After completion of six crop cycles, crop yields were recorded and converted into soybean grain equivalent yield (SGEY, q ha^{-1}). Yield data indicated that tillage did not have significant effect on soybean grain equivalent after completion of six crop cycles (Fig.13). Irrespective of tillage system, maize-gram recorded significantly higher yield followed by soybean +pigeon pea (2:1) and soybean+ cotton (2:1). The interactive effect of tillage x cropping system on SGEY were non ï significant.. Lower yield recorded under soybean based cropping system was due to lower yield of soybean owing to anomalous weather conditions.

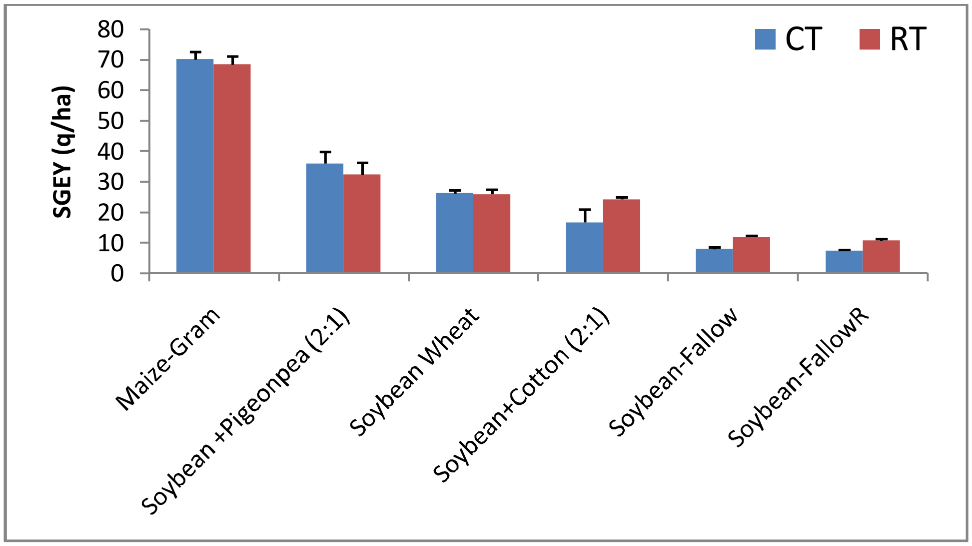


Fig. 13. Effect of conservation agricultural practices on soybean grain equivalent yield ($q\ ha^{-1}$) after six crop cycles

2.1.5 Sorghum based cropping systems

2.1.5.1 Sorghum-black gram

Fine-tuning of sorghum - black gram cropping system was carried out by ***ICAR-CRIDA***, Hyderabad. Experiments were initiated in 2013 with sorghum- black gram system to study the influence of tillage system and residues on sorghum and black gram yield. Sorghum and black gram were annual crop rotation. In 2015 sorghum was taken as a test crop. Sorghum yield was significantly higher in low tillage (7%) compared to conventional tillage (Fig.14). In both tillage systems, 100 and 50% residue retention recorded 28 and 24% higher sorghum grain yield as compared to no residue retention. However, the seed yields in 100 and 50% residue retention were on par with each other.

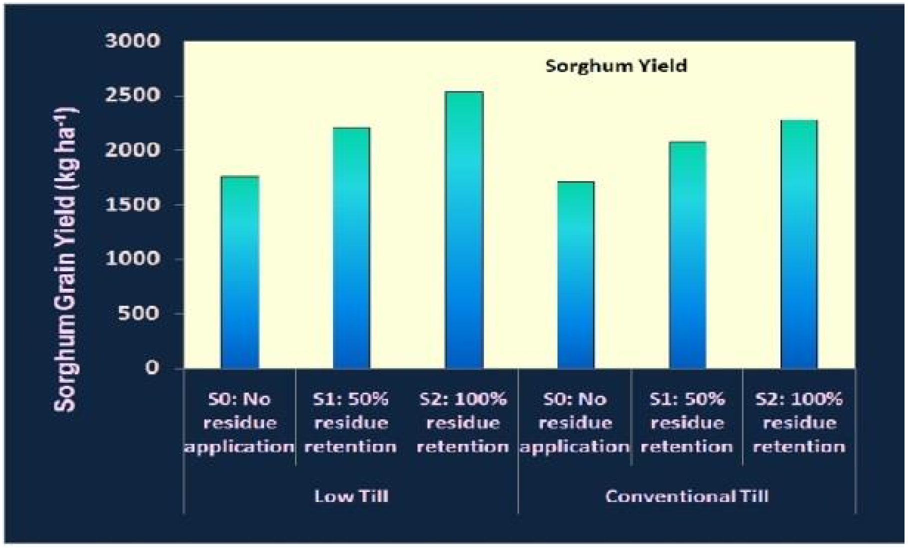


Fig. 14. Influence of different tillage treatments and residues on sorghum grain yield(kg ha^{-1})

2.1.6Pigeonpea based cropping system

2.1.6.1Pigeonpea–Castor

Fine-tuning of Pigeonpea-castor cropping system was carried out by ***ICAR-CRIDA***, Hyderabad. The experiment was initiated in 2009 with pigeon pea-castor rotation system. In this year pigeon pea was sown after castor under different tillage practices namely conventional tillage (Disc ploughing in off season, Cultivator, disc harrow and sowing of crop), reduced tillage (Ploughing once with cultivator and disc harrow), zero tillage (direct sowing in residues) and different residue levels by harvesting at different heights (0 cm, 10 cm and 30 cm) to increase the residue contribution to the field. Results indicated that tillage treatments significantly influenced the crop yields even after 7 years of experimentation. In this year the pigeonpea yields were 20 and 16 % lower in ZT over reduced and conventional tillage, respectively.

The pigeon pea yields increased with increase in residue (harvesting heights). Higher yields were recorded at 10 cm harvest height as compared to 0 and 30 cm harvest height. The per cent yield decrease in zero tillage without residues was higher than zero tillage with residue (Fig.15).

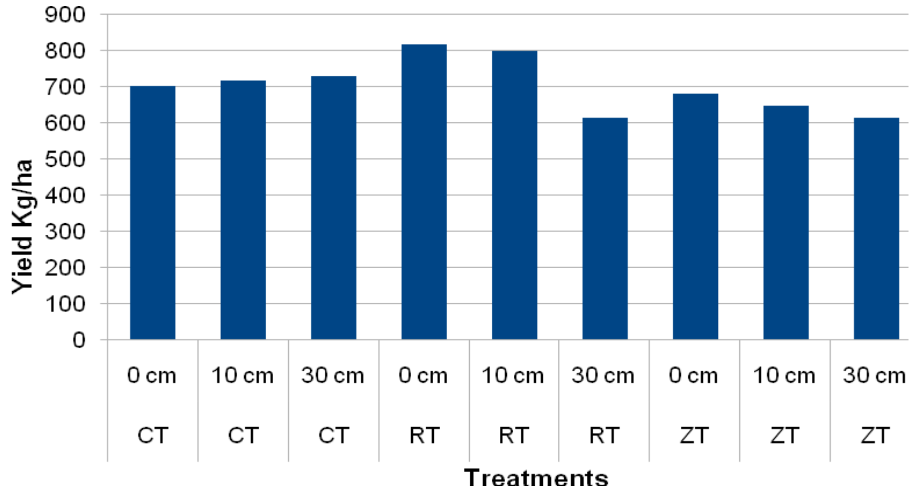


Fig. 15. Influence of different tillage treatments and residues on pigeonpeayield (kg ha^{-1})

2.1.7 Sugarcane based cropping systems

Although retention of trash in ratoon sugarcane can improve the fertilizer use efficiency, this hinders the placement of fertilizers and other intercultural operations and hence farmers burn them. To help the farmers, a stubble shaver, off-bar cum fertilizer applicator developed by the *ICAR-IISR*, Lucknow was further upgraded with the inclusion of larger capacity fertilizer box, power transmission system and root pruning mechanisms which is popularly known as Stubble shaver, off-bar, Root pruner cum Fertilizer Drill (SORF) machine at the ***ICAR-NIASM***, Baramati. The machine was found to improve cane productivity significantly over farmersô practices. Therefore, to determine the individual and combined effects of stubble shaving, off-barring, root pruning and placement of fertilizers in soil on productivity, profitability and resource-use efficiency of sugarcane ratoon crop, a field experiment was conducted at ***ICAR-NIASM*** with eight treatment combinations including four methods of ratoon management (root pruning: RP; off-barring: OB; stubble shaving: SS and control), two fertilizer nitrogen (fert-N) application methods (broadcast as the farmerôs practice: NBC and placement with multipurpose SORF machine: NP), three methods of trash management (clean cultivation: NT; burnt trash: BT and spreading the trash uniformly in the field after chopping with a trash cutter: CT) and two absolute control with no nitrogen and un-chopped trash (UCT+No-N) and without trash (NT+No-N) (Plate 23). 50 and 75 % of recommended dose of fert-N was applied as basal under broadcast and placement of N treatments, respectively.

The results revealed that the plant height varied significantly under different treatments and the differences in height increased gradually with the advancement of crop age (Fig.16). Till 60 days after ratoon initiation (DARI) plant height under stubble shaving treatment (CT+NP+RP+OB+SS) was lower even than the control. However, at 180 DARI and later growth stages, improved gradually under the aforesaid treatment and became significantly higher than rest of the treatments, except CT+NP+RP. Plant heights at maturity were 1.5-1.7, 1.2-1.3 and 1.1 times higher under CT+NP+RP+OB+SS treatment compared to N un-fertilized, N broadcast and N placement treatments, respectively.

Un-chopped trash

Chopped trash

Burnt trash

Clean cultivation

Band placement of fertilizer-N (NP)

Root pruning (RP) + NP

Off-barring (OB) + NP

Stubble shaving + OB+RP+NP

Plate 23. Application of treatments in sugarcane ratoon field

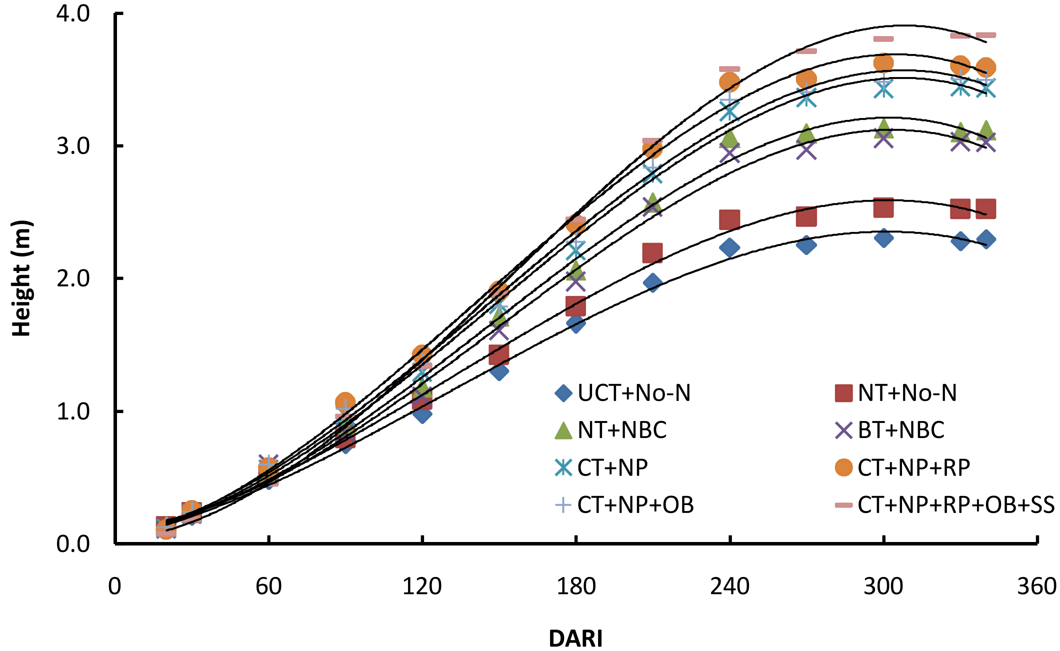


Fig. 16. Effect of ratoon management practices on plant height of sugarcane ratoon crop

In case of tiller number, maximum growth rate was observed till 90 DARI, thereafter the rate decreased and tiller count reached maximum at 120 DARI. However, for treatment CT+NP+RP+OB+SS although tiller growth pattern was similar to others but the initial tiller count was the lowest till 60 DARI (Fig.17). After 120 DARI, tiller mortality rate was lower under CT+NP+RP+OB+SS, as compared to others. The maximum no. of tillers at maturity was recorded under CT+NP+RP+OB+SS closely which was followed by CT+NP+RP and were significantly higher (20-50 %) than the N un-fertilized and other conventional farmerǿs practices. SPAD values were also higher under CT+NP+RP+OB+SS and CT+NP+RP treatments which could be due to improved N uptake (Fig. 18).

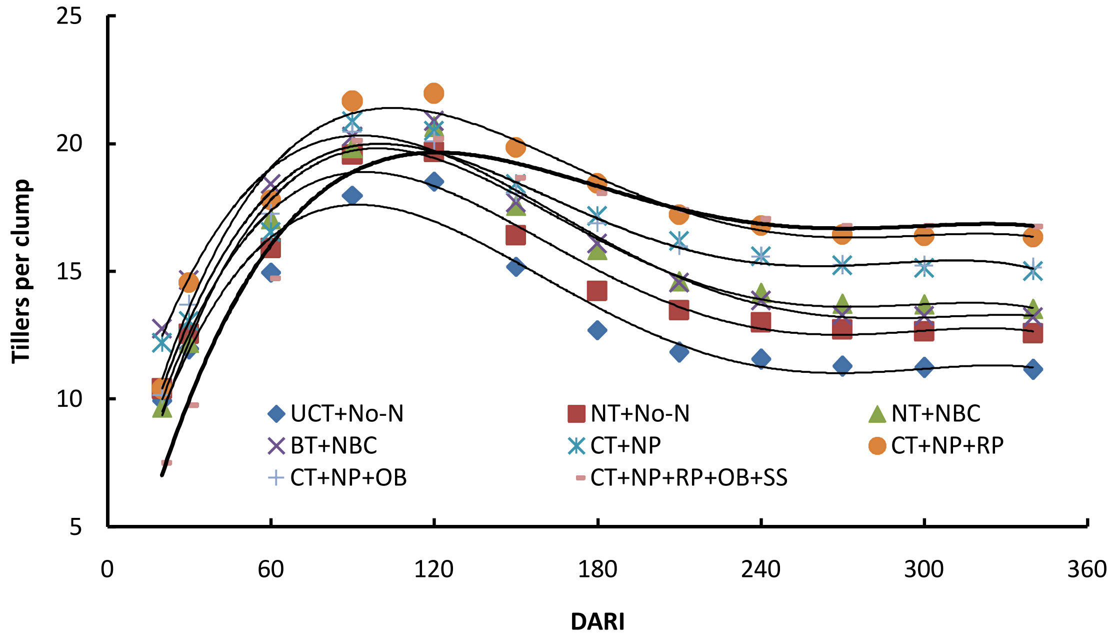


Fig. 17. Effect of ratoon management practices on tillers per clump of sugarcane ratoon crop

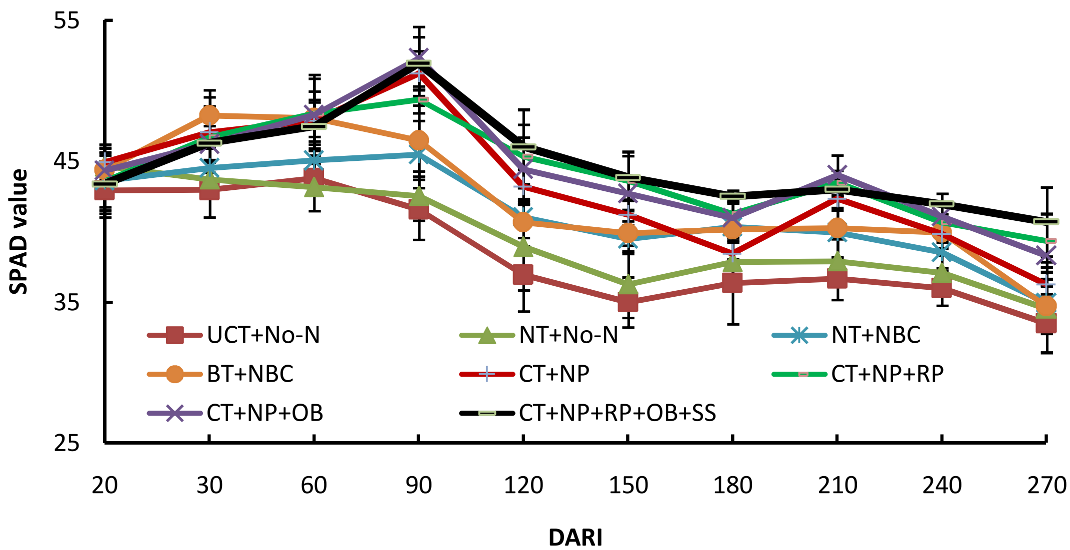


Fig. 18. Effect of ratoon management practices on SPAD values of sugarcane ratoon crop

Maximum millable cane, cane length, cane weight and juice yield were recorded under CT+NP+RP+OB+SS which were significantly (*P* Ò 0.05) higher over others except in case of millable cane which was at par with CT+NP+RP and CT+NP+OB treatments (Table 21). *In-situ* retention of chopped trash and placement of fert-N (CT+NP) in soil increased the no. of millable cane, cane length, cane weight and juice yields by 11-47, 13-38, 14-46 and 12-39 % over control and broadcast application of fert-N treatments, while pruning of older roots (CT+NP+RP) further improved these parameters over CT+NP by 8, 4, 10 and 15 %, respectively. However, there was no significant improvement in these parameters due to off-barring (CT+NP+OB) over the placement of fert-N (CT+NP). However, when stubble shaving, off- barring and root pruning practices were employed together, cane length, cane weight and juice yields improved significantly which were 10, 12 and 9 % higher, respectively than that of individual practices of off-barring and root pruning. The experiment will be repeated to confirm the findings.

Table 21. Effect of trash and nitrogen management on yield attributes of sugarcane ratoon crop

Treatment	Millable cane (1000 ha^{-1})	Cane length (m)	Cane weight (kg)	Juice yield (ml $cane^{-1}$)
UCT+No-N	85.6	1.52	1.11	370.0
NT+No-N	91.4	1.60	1.16	388.8
NT+NBC	112.7	1.85	1.37	445.0
BT+NBC	110.1	1.83	1.41	461.3
CT+NP	125.6	2.09	1.61	515.0
CT+NP+RP	135.4	2.17	1.78	592.5
CT+NP+OB	126.8	2.13	1.67	557.5
CT+NP+RP+OB+SS	140.9	2.39	1.99	646.3
LSD (*P* Ò0.05)	14.7	0.22	0.20	51.6

2.2WEED MANAGEMENT

2.2.1 Rice based cropping systems

2.2.1.1Rice-wheat-*Sesbania* sp. (green manure)

Under CA where puddling is not carried out, weed creates a greater menace and identification of suitable weedicide combinations need to be standardized. An experiment was carried out at ***ICAR- IIFSR***, Modipuram during 2015-16 adopting transplanting without puddling the soil. The initial soil studies made on composite soil sample revealed that pH of soil was 8.22, EC-0.74 ds/m, organic carbon 0.50%, Olsen - P 20.0 kg/ha, available K 153 kg/ha, elemental nitrogen 0.074% and carbon 0.568%. The elemental nitrogen and carbon were analysed by Euro Vector Elemental Analyser. Thus, the soil was medium in OC, available P and K content with depth 0-15 cm.

The plot was irrigated 24 hours before planting of seedlings so as to loosen the soil and make it feasible for transplanting. The experiment was conducted in randomized block design with four replications. The treatments were (T1) Zero till transplanting + glyphosate 41 WSC @ 1.5 kg a.i./ha (pre plant), (T2) Zero till transplanting + glyphosate (pre plant) + pretilachlor 50% EC @ 1.0 kg a.i./ha (pre em.), (T3) Zero till transplanting + glyphosate (pre plant) + Bispyribac Sodium 10% SC @ 25 g a.i. / ha (post em.), (T4) Zero till transplanting + glyphosate 41 WSC @ 1.5 kg a.i./ha (pre plant) + pretilachlor 50% EC @ 1.0 kg a.i./ha (pre em.) + Bispyribac Sodium 10% SC @ 25 g a.i. / ha (post em.) and (T5) Conventional method (transplanting in puddled soil + Bispyribac Sodium 10% SC @ 25 g a.i. / ha (post em.). The results revealed that rice plant height, ear length, number of grains/ear, test weight and grains weight/earwere higher under conventional tillage except highest spikelets/ear under zero tillage in combination with bispyribac sodium (Table 22).

Table 22. Effect of tillage practices and chemical weed control on yield attributes of rice crop.

Treatments	Plant height (cm)	Ear length (cm)	Spikelets/ ear (no.)	Grains /ear (no.)	Test weight (g.)	Grain weight/ear
T1	82.1	24.1	41.2	93.9	23.3	2.3
T2	79.2	23.7	42.4	100.8	23.2	2.3
T3	83.2	25.6	46.2	92.9	22.3	2.2
T4	81.0	25.2	43.4	93.5	23.1	2.1
T5	87.3	26.1	42.8	102.4	26.0	2.5
CD at %	5.1	1.7	1.1	5.1	2.4	0.2

Further lowest total weed count (56 nos. /m^2) was recorded under zero tillage with post emergence application of bispyribac sodium (Table23). The lowest weed dry weight (16g/m^2) was observed under conventional planting.

Table 23. Effect of tillage and chemical weed management on weed count and dry weight (g/ m^2) in rice.

Treatment	Total weed count	Dry wt. (g)
T1	204	52
T2	164	24
T3	56	32
T4	288	20
T5	152	16

Further, *Cyperusrotundus*recorded the highest number (172.8 plants/m^2) followed by *Dactylocteniumaegyptium* and *Eragrostistenella*(Table 24).

Thus combinations of pre plant application of glyphosate and post emergence application of bispyribac sodium recorded significantly higher yields (1838 kg/ha) over glyphosate alone (1025 kg/ha) as well as in combination with pre emergence application of pretilachlor (1119 kg/ha).

Table 24. Effect of tillage and chemical weed control on weed species count and dry weight (g/m^2) in rice

Treatments	Weed Species (nos./m^2)						Weed dry wt. (g/m^2)
	Cyprus rotundus	***Dactyloctenium aegyptium***	***Eragrostisi ndica***	**Eragrost istenella**	***Eclipta alba***	**Other species**	
T1	204.0	52.0	8.0	32.0	4.0	12.0	320.0
T2	164.0	24.0	4.0	8.0	4.0	20.0	204.0
T3	56.0	32.0	4.0	20.0	4.0	12.0	228.0
T4	288.0	20.0	4.0	8.0	4.0	24.0	164.0
T5	152.0	16.0	8.0	20.0	4.0	20.0	160.0
Average	172.8	28.8	5.6	17.6	4.0	17.6	-

However, the highest yield of 2525 kg/ha was recorded under conventional method of transplanting with post emergence application of bispyribac sodium. Similar trend was also observed in straw yield and harvest index. Yield level, in general, was low due to late planting in the month of August.

Table 25. Effect of tillage practices and chemical weed control on yield of rice (*Kharif*, 2015)

Treatment	Grain (kg/ha)	Straw (kg/ ha)	Harvest index (%)
T1	1025	2813	27
T2	1119	2563	30
T3	1838	3375	35
T4	1700	3063	36
T5	2525	4438	36
CD at 5%	274	967	-

The Conventional method (transplanting in puddled soil + Bispyribac Sodium 10% SC @ 25 g a.i. / ha (post em.) recorded the highest cost of cultivation (Rs 25650/ha) followed by Zero till transplanting + glyphosate 41 WSC @ 1.5 kg a.i./ha (pre plant) + pretilachlor 50% EC @ 1.0 kg a.i./ha (pre em.) + Bispyribac Sodium 10% SC @ 25 g a.i. / ha (post em.). Gross returns (Rs 54617ha), net returns (Rs 28967/ha) and B:C ratio (1.13) were also recorded highest under Conventional method (transplanting in puddled soil + Bispyribac Sodium 10% SC @ 25 g a.i. / ha (post em.). This was followed by Zero till transplanting + glyphosate (pre plant) + Bispyribac Sodium 10% SC @ 25 g a.i. / ha (post em.) in respect of gross returns (Rs 40335/ha), net returns (20259/ha) and B:C ratio (1.01)

Table 26. Effect of tillage practices and chemical weed control on the economic returns of rice crop

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net Returns (Rs/ha)	B:C ratio
T1	18676	26217	7541	0.40
T2	19476	26589	7113	0.37
T3	20076	40335	20259	1.01
T4	20876	37072	16196	0.78
T5	25650	54617	28967	1.13

MSP - Rs. 1460/q, Byproduct- Rs.400/q

During *Rabi* season, wheat crop was raised by applying different weed management treatments (Table 23). Weed population and weed dry weight at 45 DAS indicated the highest population of *Cyperusrotundus* (122 no/m^2) followed by *Phalaris minor* (61.6 no/m^2). Among weed management treatments, Zero tillage followed by pre sowing application of glyphosate + post emergence application of sufosulfuron + metsulfuron methyl recorded the lowest total weed count (138 nos./m^2) and total dry weight (9 g/m^2). The crop has not yet been harvested at the time of this report.

Table 27. Weed population as influenced by tillage and herbicides in wheat

Treatment	Weed species						Dry wt. (g/m^2)
	Cyperus rotundus	***Phalaris minor***	***Poa annua***	**Wild spinach**	**Others**	**Total**	
Zt+Gl	153.0	40.0	2.0	14.0	43.0	252.0	19.2
Zt+Gl+Atr	113.0	39.0	11.0	58.0	45.0	266.0	21.0
Zt+Gl+Sulf+met	30.0	91.0	4.0	0.0	13.0	138.0	9.0
Zt+Gl+Atr+Met	221.0	49.0	4.0	0.0	11.2	285.2	15.7
Conventional (2 hand weeding)	93.0	89.0	6.0	12.0	34.0	234.0	17.9
Average	122.0	61.6	5.4	16.8	29.2	-	-

Where: Zt-Zero tillage, Gl-Glyphosate, Atr- Atrazine, Sulf-sufosulfuron, Met- metsulfuron

2.2.1.2 Rice-wheat-green gram

Weed management in Rice-wheat-green gram based cropping system was carried out by ***ICAR-DWR***, Jabalpur. Dominant weed flora in rice were *Echinochloacolona, Dinberaretroflexa, Physalis minima, Ceasuliaaxillaris*and*Cyperusiria.* Among weed control treatments*,* integrated weed management *(*Sesbania co-culture + pendimethalin @ 1000 g/ha fb 2, 4-D at 25-30 DAS fband hand weeding at 45 DAS*)* reduced the weed dry weight in rice as compared with unweeded check. Among tillage and residue management treatments, ZT+RR significantly enhanced number of panicle, panicle length and grain yield over the treatment of conventional tillage with residue burning (Table 28).

Table 28. Yield attributes and grain yield of rice as influenced by tillage and residue management, N-levels and weed management options

Treatment	No. of Panicle m^{-2}	Panicle length (cm)	Grains $panicle^{-1}$	1000 grains weight (g)	Grain yield (t ha^{-1})
Tillage and residue management					
ZT+RR	319.67^{A}	23.31^{A}	130.22	25.34	4.22^{A}
ZT+RB	291.61^{C}	22.81^{A}	123.50	25.04	3.44^{B}
CT+RI	316.67^{A}	22.21^{B}	126.35	25.07	4.21^{A}
CT+RB	304.61^{B}	22.07^{B}	123.72	25.06	3.74^{B}
SEm±	2.91	0.23	2.59	0.31	0.13
CD (P=0.05)	7.12	0.57	NS	NS	0.31
N levels					
100% RDN	300.11^{B}	22.46	124.74	25.01	3.85
125% RDN	316.17^{A}	22.74	127.15	25.25	3.95
SEm±	4.18	0.16	1.13	0.16	0.07
CD (P=0.05)	NS	NS	NS	NS	NS
Weed management					
Unweeded Check	272.25^{C}	21.88^{B}	121.99^{C}	24.53^{B}	3.08^{C}
Chemical approach	315.13^{B}	22.88^{A}	126.19^{B}	25.25^{A}	4.19^{B}
Integrated weed management	337.04^{A}	23.04^{A}	129.66^{A}	25.61^{A}	4.44^{A}
SEm±	4.11	0.19	1.37	0.25	0.09
CD (P=0.05)	8.37	0.39	2.78	0.50	0.19

2.2.1.3 Rice-Maize/Mustard/Pea-Green gram

Weed management in Rice-Maize/Mustard/Pea-Green gram cropping system was carried out by ***ICAR-DWR***,Jabalpur. In maize,*Rumexdentatus, Medicagopolymorpha, Chenopodium*spp.*, Avenafatua, Sonchusoleraceus*were major weeds where as*Dinebraretroflexa, Phalarisminor, Echinochloacolona*were minor weeds. It was observed that higher total weed dry weight was observed under CT+R+S-CT+R-ZT+R resulted in reduced grain and straw yield (Table 29). Among tillage and crop establishment treatments, ZT+R+S-ZT+R-ZT+R resulted in higher grain and straw yield of (t/ha) rice than other treatments (Table29).

Table 29. Weed intensity, dry weight and yield of rice as influenced by different tillage and weed management measures.

Treatment	Total weed population	Total weed dry weight (60 DAS)	Total weed dry weight (at harvest)	100 grain weight	Grain yield (t/ha)	Straw Yield (t/ha)
Tillage and crop establishment						
CT+S-CT-ZT	4.87[b]	5.16[b]	8.76[ab]	2.23[b]	2.10[ab]	3.37[ab]
CT+R+S-CT+R-ZT+R	4.47[b]	4.85[b]	10.61[a]	2.20[b]	1.96[b]	2.87[bc]
ZT+S-ZT-ZT	6.78[a]	6.22[a]	8.85[ab]	2.21[b]	1.82.[b]	2.72[c]
ZT+R+S-ZT+R-ZT+R	6.12[a]	5.35[ab]	7.32[b]	2.31[a]	2.40[a]	3.74[a]
Cropping system						
DSR-Pea-Green gram	6.07[a]	5.31	8.66	2.32[a]	2.42[a]	3.67[a]
DSR- Mustard-Green gram	5.35[b]	5.25	8.55	2.26[a]	2.31[a]	3.27[b]
DSR- Winter maize-Green gram	5.26[b]	5.63	9.44	2.14[b]	1.48[a]	2.62[c]
Weed Management						
W1	9.02[a]	8.76[a]	12.99[a]	2.14[b]	0.39[b]	0.84[b]
W2	3.67[b]	3.59[b]	6.86[b]	2.29[a]	2.96[a]	4.46[a]
W3	3.99[b]	3.83[b]	6.80[b]	2.29[a]	2.87[a]	4.26[a]
Interaction Significant	Main, sub, subsub, Main*subsub, sub*subsub	Main, subsub, Main*subsub	Main, Main*sub, subsub, Main*subsub, sub*subsub	Main, sub, Main*sub, subsub, sub*subsub	All	All

With regard to weed seed bank study, higher grassy weed seeds were observed than the broad leaved weed seed in soil under maize crop. The higher content of weed seed were found at surface (0-2 cm) depth than the lower soil layer. In ZT and ZT+R system had less weed seeds (broad leaved and grassy) compare to CT and CT+R at 2-5 and 5-10 cm depth.

2.2.2 Maize based cropping systems

2.2.2.1 Maize-mustard/wheat-green gram

Weed management in Maize-mustard- green gram cropping system was carried out by ***ICAR-DWR***,Jabalpur. Major weed flora were *Echinochloacolona, Dinebraretroflexa,* *Cyperusiria, Eclipta alba, Phyllanthusniruri*and*Physalis minima*. Among tillage & crop establishment treatments, ZT+GR-ZT+MR+ZT+Msr reduced the weed dry weight and significantly enhanced the yield of maize (5.44 t/ha) over the conventional tillage practice (Table 30). Weed management practices significantly reduced the weed density and dry biomass accumulation at different crop growth stages as compared to un-weeded situation. Among weed management practices Atrazine + pendimethalin @ 500 g + 500 g/ha (PE) fb 1 HW at 25 DAS managed the weed more efficiently and yielded maximum (5.12 ton/ha).

Table 30. Influence of tillage and integrated weed management on weed infestation and yield of maize

Treatment	Weed density (no/m^2)	Weed dry weight (g/m^2)	Grain yield (t/ha)	Stover Yield (t/ha)
CT-CT	58.11 (7.62)	31.88 (5.65)	3.89	7.72
CT-ZT-ZT	51.78 (7.19)	25.40 (5.04)	4.67	7.76
ZT + GR-ZT-ZT+MsR	45.56 (6.74)	24.93 (4.99)	5.11	7.87
ZT-ZT+MR-ZT+MsR	47.22 (6.87)	24.58 (4.96)	5.18	8.00
ZT+GR-ZT+MR+ZT+Msr	41.00 (6.40)	23.11 (4.81)	5.44	8.22
LSD (P=0.05)	0.77	1.28	0.83	0.65
Atrazine + pendimethalin 500 g + 500 g/ha (PE) fbTembotrion 100 g/ha	41.93 (6.47)	22.93 (4.79)	5.07	7.51
Atrazine + pendimethalin 500 g + 500 g/ha (PE) fb 2,4-D500 g/ha (PoE)	59.93 (7.74)	41.60 (6.45)	4.38	7.66
Atrazine + pendimethalin 500 g + 500 g/ha (PE) fb 1 HW at 25 DAS	44.33 (6.65)	13.41067 (3.66)	5.12	8.56
Unweeded (control)	63.78 (7.98)	42.02 (6.48)	3.67	6.80
LSD (P=0.05)	1.11	0.75	0.42	0.63

Weed management in Maize-wheat- green gram cropping system was carried out by ***ICAR-DWR***,Jabalpur. The major weed flora observed in the maize crop comprised of *Echinochloacolona*, *Dinebraretroflexa*, *Cyperusiria*, *Phyllanthusniruri*, *Ecliptaalba*and*Paspalidium sp.* Among the tillage treatments, the lowest weed dry biomass (6.8 g/m^2) was observed in ZT+R (maize) whereas, the weed management treatment, atrazine +

pendimethalin (0.5+0.5 kg/ha) PE *fb* 1 hand weeding 25 DAS recorded the lowest weed dry biomass (2.4 g/m^2). The grain yield of maize was highest (5.98 t/ha) under CT (maize) ï CT (wheat), which was comparable with other tillage treatments except CT (maize) ï ZT (wheat) ï ZT (green gram) (4.83 t/ha) (Table 31). The treatment, atrazine + pendimethalin (0.5+0.5 kg/ha) PE *fb* 1 hand weeding 25 DAS recorded significantly higher grain yield of 6.07 t/ha than unweeded control (4.78 t/ha).

Table 31. Weed biomass and grain yield of crops as influenced by different tillage systems and weed management methods

Treatment	Weed dry biomass (g/m^2)			Grain yield (t/ha)		
	Wheat	Green gram	Maize	Wheat	Green gram	Maize
Tillage						
CT (maize) ï CT (wheat)	2.8 (7.3)	-	7.2 (51.3)	4.42	-	5.98
CT (maize) ï ZT (wheat) ï ZT (green gram)	2.7 (6.8)	6.4 (48.2)	6.9 (47.1)	3.81	0.37	4.83
ZT+R (maize) ï ZT (wheat) ï ZT+R (green gram)	3.5 (11.8)	5.2 (29.3)	6.8 (45.7)	3.98	0.25	5.87
ZT (maize) ï ZT+R (wheat) ï ZT+R (green gram)	2.1(3.9)	4.6 (21.4)	8.1 (65.1)	4.10	0.08	5.46
ZT+R (maize) ï ZT+R (wheat) ï ZT+R (green gram)	2.5 (5.8)	4.8 (26.0)	9.2 (84.1)	4.32	0.15	5.27
SEd	0.34	0.35	0.23	0.17	0.05	0.33
LSD (P=0.05)	0.80	0.85	0.53	0.41	0.13	0.78
Weed management						
Unweeded	4.8 (22.5)	7.7 (61.2)	14.0 (195.5)	3.68	0.14	4.78
Atrazine+pendimethalin(0.5+0.5 kg/ha) PE *fb* 2,4-D (0.5 kg/ha)	2.0 (3.5)	4.4 (19.8)	6.4 (40.5)	4.18	0.22	5.60
Atrazine+pendimethalin(0.5+0.5 kg/ha) PE *fb* 1 hand weeding 25 DAS	1.4 (1.5)	3.6 (12.7)	2.4 (5.3)	4.53	0.28	6.07
SEd	0.26	0.38	0.41	0.12	0.03	0.23
LSD (P=0.05)	0.55	0.80	0.86	0.25	0.06	0.49

CT ï conventional tillage, ZT ï zero tillage, R ï residue weed data subjected to ãx+0.5 transformation, original values are in parentheses

A weed management study conducted at ***ICAR-IISS***, Bhopal revealed that hand weeding has recorded lowest weed density, weed biomass and maximum maize grain yield (62.12 q/ha) which was on par with the chemical weed control treatment of pre emergence application of Pendimethalin @ 750 g ai/ha followed by post emergence Atrazine @ 1000 g ai/ha at 30 DAS (61.24 q/ha) while the yield in these treatments were significantly higher compared to weedy check (22.76 q/ha). Similarly maximum weed index (63.36%) was recorded under weedy check and minimum (1.41%) with pre emergence application of Pendimethalin @ 750 g ai/ha followed by post emergence Atrazine @ 1000 g ai/ha at 30 DAS (Table 32, Plate 24).

Plate 24. Performance of maize in different herbicide treated plots under zero tillage

Table 32. Effect of weed control treatment on yield of maize

Treatment	Biological Yield (q/ha)	Grain Yield (q/ha)	Straw Yield (q/ha)	Weed Index (%)	Weed density/m^2
Absolute control	60.44	22.76	37.683	63.36	230.27
Two hand weeding at 20 & 40 DAS	146.30	62.12	84.186	0.00	70.16
Pre em. Atrazine @ 1500 g ai /ha.	135.82	54.99	80.830	11.47	86.00
Pre em. Pendimethalin @ 1000 g ai/ha	102.22	37.56	64.680	39.54	157.33
PoE Atrazine @ 1250 g ai /ha at 20 DAS.	111.58	43.21	68.363	30.43	124.00
Pre em. Pendimethalin @ 1000 g ai/ha *Fb*PoE Atrazine @ 750 g ai/ha at 30 DAS.	136.68	57.41	79.273	7.58	91.53
Pre em. Pendimethalin @ 750 g ai/ha *Fb*PoE Atrazine @1000 g ai/ha at 30 DAS	141.06	61.24	79.823	1.41	63.33
Critical difference @5%	11.26	7.09	5.09		

After harvest of kharif crops, rabi crops viz. chickpea, wheat and mustard were sown under zero tillage. The crop growth and yield parameters were recorded and the analysis work is in progress.

2.2.3 Soybean based cropping systems

Weed management in soybean based cropping system was carried out by ***ICAR-IISS***, Bhopal. During the *Kharif* season of 2015, maize and soybean crops were sown in the experimental field under zero till condition. Sowing was done with the help of zero seed cum ferti-drill and standard agronomic practices along with weed control treatments were followed. The major weed flora comprised of *Echinocloacrusgalii, Panicumjavanicum and Brechariarecemosa*among grassy weeds whereas *Digiteriaarvensis, Alternentherasessalis, Celosia argentea, and Euphorbia geniculata*were dominant broad leaved weeds present in the experimental field. A uniform application of Glyphosate @ 1 kg ai/ha has been done in all the herbicide treated plots at the time of sowing except absolute control and hand weeding treatment.

Soybean cv. JS-335 was grown following standard package of practices. The crop performance has been affected severely due to heavy rains during the month of August followed by early cessation of monsoon which severely affected pod filling and seed development. Among various weed control treatments Post emergence application of Propaquizafop @ 100 g ai/ha + Chlorimuron ethyl @9 g ai/ha at 20 DAS has recorded lowest weed biomass and maximum seed yield (10.60 q/ha). The yield of soybean was on par with hand weeding (10.33 q/ha) but it was significantly higher compared to weedy check (3.60 q/ha). Similarly maximum weed index (65.13%) was recorded under weedy check and minimum (-2.58%) with application of post emergence Propaquizafop @100 g ai/ha + Chlorimuronethyl @9 g ai/ha at 20 DAS (Plate 25, Table 33).

Plate 25. Performance of soybean in herbicide treated plots under zero tillage

Table 33. Effect of weed control treatments on yield, weed density and weed index under soybean

Treatment	Biological Yield (q /ha)	Grain Yield (q /ha)	Straw Yield (q /ha)	Weed Index (%)	Weed density /m^2
Absolute control	11.40	3.60	7.80	65.13	268.00
Two hand weeding at 20 & 40 DAS	38.57	10.33	28.24	0.00	118.67
Pre em. Pendimethalin @1000 g ai /ha.	37.75	9.63	28.12	6.81	123.33
PoEPropaquizafop @ 100 g ai+ Chlorimuron ethyl @9 g ai/ha at 20 DAS.	31.39	8.06	23.33	22.00	129.63
PoEImazethpyr @100 g ai /ha at 20 DAS.	38.03	10.03	28.00	2.90	98.67
Pre em. Pendimethalin @ 1000 g ai/ha *Fb*PoEImazethpyr @ 100 g ai/ha at 30 DAS.	32.63	6.96	25.66	32.58	141.33
PoEPropaquizafop @100g ai/ha + Chlorimuron ethyl @9 g ai/ha at 20 DAS.	35.93	10.60	25.33	-2.58	116.00
Critical difference @5%	5.98	3.98	3.24		

2.3 SCREENING OF GENOTYPES

2.3.1 Maize based cropping systems

Maize

Screening of genotypes (20 entries) was carried out at ***ICAR-IARI***, New Delhi using HD CSW 18 and HD 2967 as checks. Early seeding of 180 genotypes during 20th Oct, 2015 and normal seeding of 700 advance genotypes (F6-F8) during 5-15th November was carried out. Five thousand plants of F3-F4 were used for single plant selection and 150 plants were used as segregating population (F2). A 150 crosses were made. Observations and characters scored were stand establishment, early vigour, growth habit, days to heading, yellow rust resistance, brown rust resistance, and molecular breeding. Leaf sample was collected from 200 entries for DNA isolation, which was accomplished with CTAB method. Leaf collected for 150 RILs was used for identification of QTLs for CA adaptive traits. The primers used were Vrn gene, Rht gene and Ppd genes. Results indicated that simulation and selection in specific cropping system and production environment (CA *vs* CT) were effective in identifying the varieties suited for each system and the winner genotypes selected were different in each system indicating the specificity for each system.Advanced high yielding lines continuously bred and selected under CA conditions of maize-wheat cropping system were tested under preliminary yield trial. Genotypes out-yielded the check under maize-wheat cropping system of CA by 11.5 to 34% (Table 33). The set of entries were also tested for the disease resistance against yellow and brown rust under artificial epiphytotic conditions of New Delhi, Yamunanagar and Ludhiana. The same set of entries was also tested for yellow rust resistance at Lahaul in the off-season. The check included the latest released varieties of wheat, i.e. HD 2967, PBW 550 and HD 3086.

Table 34. Evaluation of adaptation for early seeding under CA in maize-wheat cropping system

Name of the entry	Pedigree	Yield % of check	Yellow rust at Delhi	Yellow rust at Lahaul	Yellow rust at Ludhiana	Brown rust at Wellington
1083	DL989/WR 196//HW 4022/DW 1221	134.19(HD 3086)	F	MS	F	F
1081	IBWSN	124.24 (HD 3086)	F	20MS	F	F
1329	CL2596/K9451/CL882//HD 2009	129.16(HD2967)	F	MS	F	F
1492	HD 2967/HD 3035	130 (CSW 16)	F	20S	MR	F
1625	HD 2967/PBW 550	111.50(HD CSW 18)	F	MS	MR	F
1663	CL 1705/HD 2687	123.33 (HD CSW 18)	F	MS	F	F
1751	HD 2329/WR 544//PBW 343/NW 3041	140.50(HD 2851)	F	20S	MS	F
1463	DWG107/HDK10 //C 306	135.10 (CSW16)	Disease data not available			

Various generation of breeding materials generated through crossing of CA-adapted genotypes were grown in CA plots continuously maintained under CA of maize-wheat cropping system in Division of Genetics, ***IARI*** since 2007 (Plate.26). Advance breeding material (F7- F8) and early generation bulks (F5-F6) were grown in the plots of 4.5 x 1.40 m^2 in two replications. The single plant progenies (F3-F4) were grown in 2 rows of 1 m length. The F2 were grown in the area accommodating at least 500-700 spaced plants. The break-up of the materials grown is presented in (Table 35).

Table 35. Evaluation of adaptation for early seeding under CA in maize-wheat cropping system

Cropping system	No of lines evaluated	Generation	Production condition
Maize-wheat	403	F8	Early seeding under zero tillage condition (CA)
	150	Resistant Advance	Zero till conditions (CA)
	1762	F3-F4	Head to paired row progenies
	170	International Material	Zero till conditions (CA)
	203	F2	Zero till condition spaced planting
	251	F1	Zero till conditions (CA)
	305	Fixed	Germplasm
	202 in 2 REP	F7 ï F8	Genotype x system interaction trial
	159	F5-F7	Flat bed and zero till
	1261	F3-F4	In paired row on flat bed zero till
	207	F2s	Spaced planting
	544 in 2 REP	F7 ï F8	Genotype x system interaction trial
Conventional Fallow ï wheat	350	F6-F7	6 rows of 4 meter length in 2 replication
Maize-wheat	1500	F5-F7	6 rows of 4 meter length

Plate 26. Evaluation of advance breeding material under CA-based maize-wheat system

Wheat

An experiment was conducted at ***ICAR- IIWBR***, Karnal to evaluate the wheat varieties suitable for CA system. Two tillage systems, CT (Conventional tillage) and CA (Conservation tillage) in main plot and eight varieties of wheat (HD 2967, WH 1105, HD 3086, DBW 88, PBW 550, DPW 621-50, 45thIBWSN1147 and HDCSW 18) in subplots replicated thrice were laid out during rabi season of 2015-16 in a split plot design. The residue load in CA treatments was 6.0 t/ha. The sowing was done using Turbo Happy Seeder using a seed rate of 100 kg/ha. The fertilizer and irrigations were given as per the recommended practices. For control of weeds sulfosulfuron + metsulfuron was applied at 25 + 4 g/ha at 35 DAS.The crop was fertilized with 150:60:40 kg NPK/ha. Full P and K were applied as basal dose through 12:32:16 NPK mixture and muriate of potash. NPK mixture was drilled at the time of sowing whereas the remaining N was applied in two equal splits just before first and second irrigation. The crop was irrigated as per the need.

The results revealed that except varieties other treatments and their interactions were not significant.The mean wheat yield under CT and CA system were 57.85 and 56.31 q/ha, respectively. Among varieties, the tallest plants were of HDCSW 18 followed by 45thIBWSN1147 and both these genotypes were significantly taller than rest of the genotypes. The significantly shortest plants were of PBW 550 with an average culm height of 75.2 cm. The longest earheads were of genotype HDCSW 18 (12.6 cm) and showed significant superiority over all the other genotypes. The wheat cultivar HD 3086 had significant higher tiller density over other genotypes. The crop biomass was higher in genotypes HDCSW 18 and 45thIBWSN1147. The boldest grains were of HD CSW 18 with an average 1000 grains weight of 43.6 g and were at par with DBW 88. Among the eight genotypes, the highest yield obtained from HD 2967 which was closely followed by WH 1105 while the lowest yield was of PBW 550. Although PBW 550 had lower biomass and height yet it had better Harvest Index.

Table 36. Performance of wheat varieties under CA and CT in Rice-wheat system

Tillage and residue management	Culm height (Cm)	Ear head length, cm	Tillers/m2	Biological yield q/ha	Yield, q/ha	1000 grain weight, g	HI
CT	92.16	11.2	407.5	147.6	57.89	40.3	0.40
ZT+R (CA)	89.90	11.3	407.2	143.4	56.23	40.6	0.40
CD at 5%	NS	NS	NS	NS	NS	NS	NS
Varieties							
WH 1105	88.37	11.0	380.8	132.7	58.08	39.1	0.44
DBW 88	90.90	11.1	410.0	152.5	57.96	42.5	0.38
DPW 621-50	91.40	11.8	405.8	153.8	57.68	39.6	0.38
HD 2967	91.73	10.7	435.0	151.6	58.54	40.5	0.39
HD 3086	88.37	10.0	462.5	136.3	56.02	38.3	0.41
PBW 550	75.20	10.7	401.7	119.1	55.04	38.5	0.46
45thIBWSN1147	100.47	12.1	389.6	159.9	56.54	41.4	0.35
HDCSW 18	101.80	12.6	373.3	157.8	56.63	43.6	0.36
CD at 5%	3.02	0.47	23.93	5.61	1.80	1.37	0.019

2.4. New initiatives

ICAR-IIFSR, Modipuram is evaluating different cropping patterns for cropping intensification under CA practices with the objective of (1) To increase farmersô income through intensive cropping (2) Maintaining soil health by diversified crop rotations with the following treatments

1. Rice ï Pea (Pod) ï Wheat - Green gram
2. Rice ï Fenugreek (leafy veg.) ï Wheat ï Sesbania
3. Maize (cob) ï Toria ï Wheat - Green gram
4. Maize (grain) ï Pea (Pod) ï Wheat - Green gram
5. Sugar cane + F.B. - Ratoon + Okra ï Wheat (2 years)
6. Sugar cane - Ratoon ï Wheat (2 years)

*For raising the crops minimum tillage is being practiced in all the plots.

Design **:** RBD
Replication **:** 4
Date of start **:** Rabi 2015

Wheat crop was raised during Rabi season 2015-16 and observations related to growth, yield and yield attributes were recorded. Soil samples has been collected for physico-chemical properties *viz.,* Water holding capacity Bulk density, Organic carbon and nutrient N, P & K status.

IIFSR, Modipuram has also initiated agronomic evaluation of elite sugarcane lines (summer planting) for conservation agriculture in April-May 2016 viz.,Co 0238, CoS 03234, UP 05125, CoS 03251, Co 0118,CoLK 011201, CoLK 013201, CoPK 05191 and Co 098014 for their ability to suppress weedsunder conventional and conservation practices

Design **:** RBD
Replication **:** 3
Date of Start **:** Spring season 2016

Studies on root growth, and exploitation of chlorophyll fluorescence meter as a tool for N management in sugarcane

Root samples have been collected by ***ICAR-NIASM,*** Baramati to study the vertical and horizontal distribution of roots under different treatments in sugarcane ratoon crop. The *in-situ* images of living roots were also taken at 15 days intervals from 15 DARI to 180 DARI by using CI-600 in-situ root imager for assessing the effect of root pruning (Plate 27). In addition, observation with chlorophyll fluorescence meter along with SPAD and chlorophyll content in leaves were recorded at 15 days intervals after ratoon initiation to exploit chlorophyll fluorescence meter as a tool for N management in sugarcane (Plate 28).

Plate 27. ***Ex-situ*** **and** ***in-situ*** **root sampling in sugarcane ratoon crop**

Plate 28. Data recording and analysis with chlorophyll fluorescence meter

3. QUANTIFYINGTHE IMPACT OF CONSERVATION AGRICULTURE ON SOIL HEALTH, INPUT USE EFFICIENCY, CARBON SEQUESTRATION AND GREENHOUSE GAS EMISSIONS

3.1 SOIL ORGANIC CARBON

3.1.1 ICAR-Indian Institute of Soil Science, Bhopal

This long-term experiment is continuing at the experimental farm of ICAR-IISS, Bhopal for the last six years with two tillage treatments namely conventional tillage (CT) with residue removed and reduced tillage (RT) with residue retained along with six cropping systems namely i) Soybean- Fallow, ii) Maize- Gram, iii) Soybean- Fallow R (R: rotated with maize-gram), iv) Soybean + Pigeon pea (2:1), v) Soybean+ Cotton (2:1) and vi) Soybeanï Wheat. After completion of six crop cycles, soil organic carbon (SOC) concentration (%) was significantly higher in reduced tillage than that in conventional tillage at the top 0-5 cm soil depth (Fig.19). This was due to minimum soil disturbances coupled with incorporation of residue under reduced tillage system. However at lower soil depths the differences in SOC concentration was not significant. The SOC concentration decreased with increasing soil depth owing to less addition of organic matter through crop residues and plant roots at deeper soil layers. SOC content in 0-5 and 5-15 cm soil depth was higher in maize-gram and soybean-wheat cropping system under RT compared to the same cropping systems under CT. In RT, cropping system where cereal crop is a component like maize-gram and soybean-wheat the SOC content was higher than the non cereal based systems due to addition of less crop residues in the later systems.

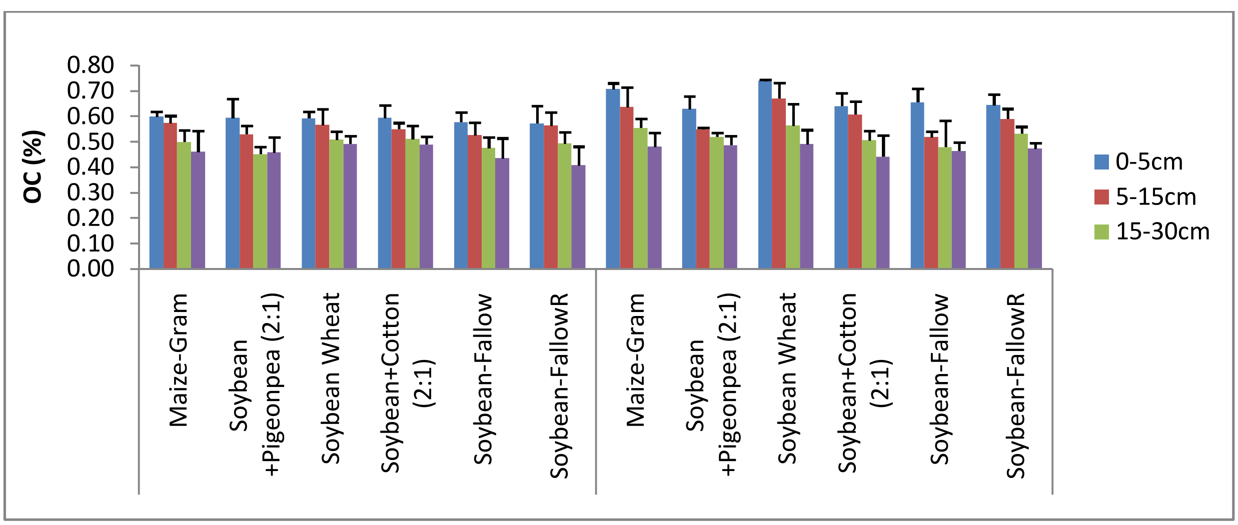


Fig. 19. Soil organic carbon under conservation agricultural practices after five crop cycles

3.1.2 ICAR-Directorate of Weed Research, Jabalpur

For this study, scientists from ICAR-IISS collected soil samples from conservation agriculture experiments under soybean, rice and maize based cropping systems at Jabalpur after the completion of 3 years of experimentation. Soil samples were collected from 0-15 and 15-30 cm of soil depths. The perusal of data from CA experiments of Jabalpur indicated that maximum build up of SOC (0.87%) was recorded from rice based cropping system where zero tillage was practiced along with residue retention. This is significantly higher than the SOC content of conventional tilled plot with residue burnt and retained treatments (Fig.20).Similar observations were recorded in maize based cropping system. The effect of residue retention along with zero tillage was also noticed in 15-30 cm of soil depth. However, there was no significant difference between conventional and zero tillage on soil SOC content in soybean-wheat cropping system.

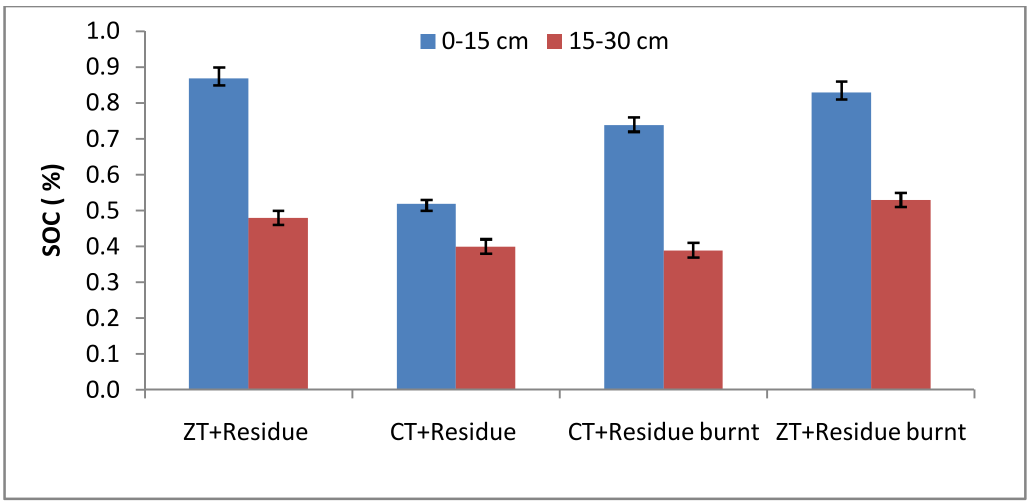


Fig. 20. Soil organic carbon content (%) in rice-wheat-green gram based conservation agriculture experiment

Small changes in the relatively labile fractions of SOC may provide an early indication of soil degradation or improvement in response to management practices. The labile fractions of soil C are often termed as the active C pool whose behaviour is completely different from the highly recalcitrant or passive C pool that is only very slowly altered by microbial activities. We measured $KMnO_4$oxidisable C under different CA experiments of Jabalpur to measure management induced changes in soil quality parameters. It was observed that labile C content (0-15 cm soil depth) was significantly higher under zero tilled plots with residue retention (519 mg kg^{-1}) in rice based cropping system in comparison to conventionally tilled plots with residue retention (429 mg kg^{-1}) (Fig.21). Similar trend was also recorded in maize and soybean based cropping systems. In both these experiments zero tilled plots with residue retention maintained higher level of labile C in comparison to conventional tilled plots with no residue retention. Similar effect was also recorded in 15-30 cm of soil depth.

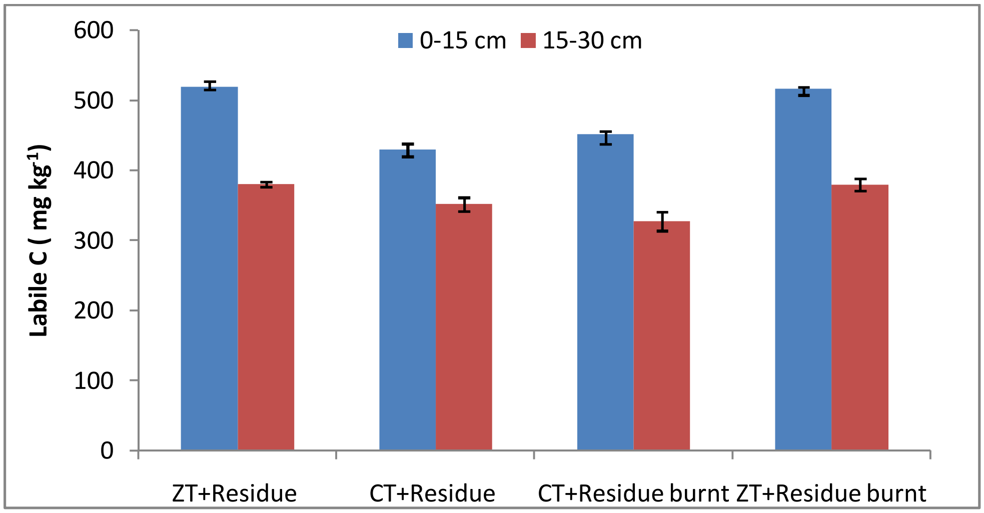


Fig. 21. Labile carbon content (mg kg^{-1}) in rice-wheat-green gram based conservation agriculture experiment

3.1.3 ICAR-Indian Agricultural Research Institute, New Delhi

3.1.3.1 Impact of CA *vis-à-vis* conventional agriculture practices on Soil C and nutrients status (N, P, K and micronutrients)

A field experiment was conducted from 2010 to 2016 at the experimental farm of ICAR-IARI, New Delhi to study the impact of CA *vis-à-vis* conventional agriculture practices on C sequestration in three irrigated wheat-based cropping systems i.e. cotton-wheat, pigeonpea-wheat and maize-wheat systems. It was observed that in all three cropping systems, maximum SOC was found in the very labile (VL) pool followed by labile (L), non-labile (NL) and less labile (LL) pool (Fig.22, 23 & 24). Averaged over tillage systems, total organic carbon at 0-30 cm soil depth was maximum in the cotton-wheat system followed by pigeonpea-wheat and maize-wheat system. Among the tillage treatments, across the cropping systems, the maximum total organic carbon pool was recorded in the zero tilled flat bed sowing with residue retention (ZT + R) treatment. In cotton-wheat system, very labile pool of SOC was maximum under ZT + R system, labile pool was maximum under ZT system, less labile pool was maximum under narrow-bed with residue (NB+R) system and non labile pool was maximum under narrow bed (NB) system.

In maize-wheat system, very labile pool and labile pool of SOC was maximum under ZT + R system, less labile pool was maximum under broad-bed (BB) system and non labile pool was maximum under ZT system. In pigeon pea-wheat system, very labile pool of SOC was maximum under ZT + R system, labile pool was maximum under broad-bed with residue (BB+R) system, less labile pool was maximum under ZT system and non labile pool was maximum under ZT+R system. It was observed that the carbon lability index was maximum for zero tilled flat bed with residue application (ZT+R) and among the cropping systems, it was maximum for pigeonpea-wheat system for 0-30 cm soil depth (Fig.25). The carbon pool index was maximum for zero tilled flat bed with residue application and among the cropping systems, it was maximum for maize-wheat system for 0-30 cm soil depth. However, the carbon management index (Fig.26), which is based on the carbon pool index and carbon lability index, was maximum in the Zero tilled flat-bed with residue (ZT+R) in 0-30 cm soil depth (Table 37). Among the cropping systems, maize-wheat cropping system registered the highest carbon management index in the 0-30 cm soil depth. Application of residues improved the carbon management index in all the conservation tillage treatments.

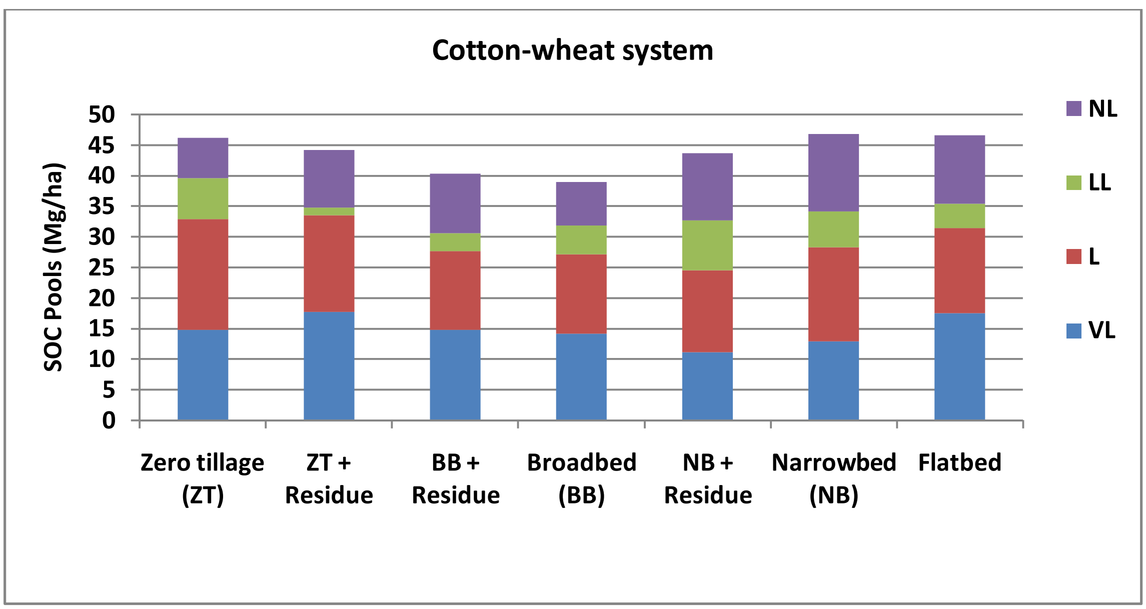


Fig. 22. Soil organic carbon pools at 0-30 cm soil depth after wheat harvest in cotton-wheat system

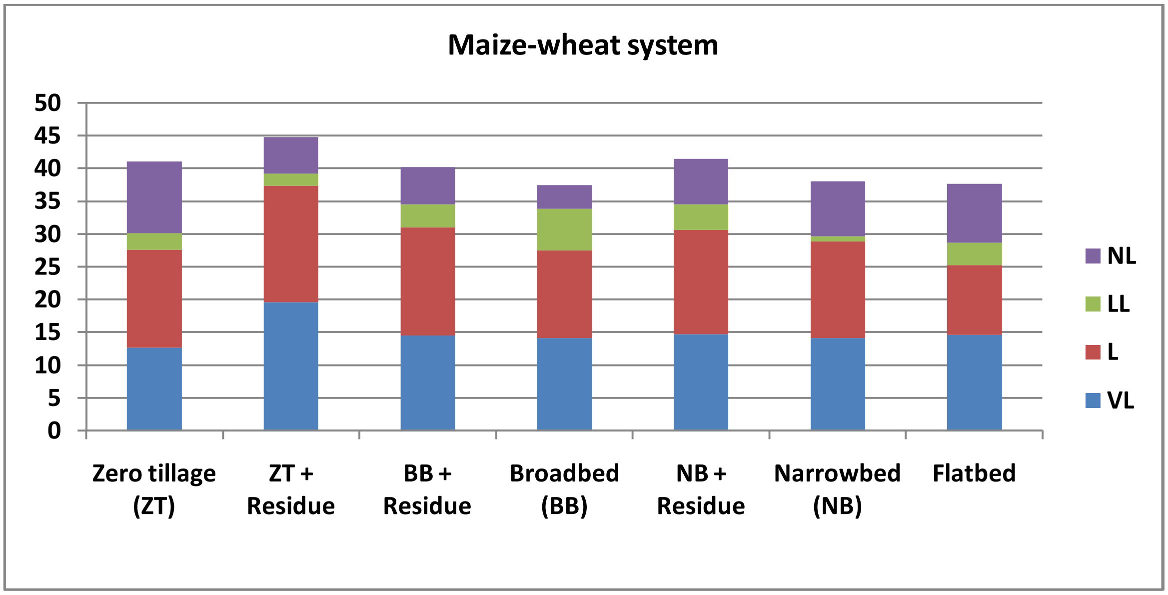


Fig. 23. Soil organic carbon pools at 0-30 cm soil depth after wheat harvest in maize-wheat system

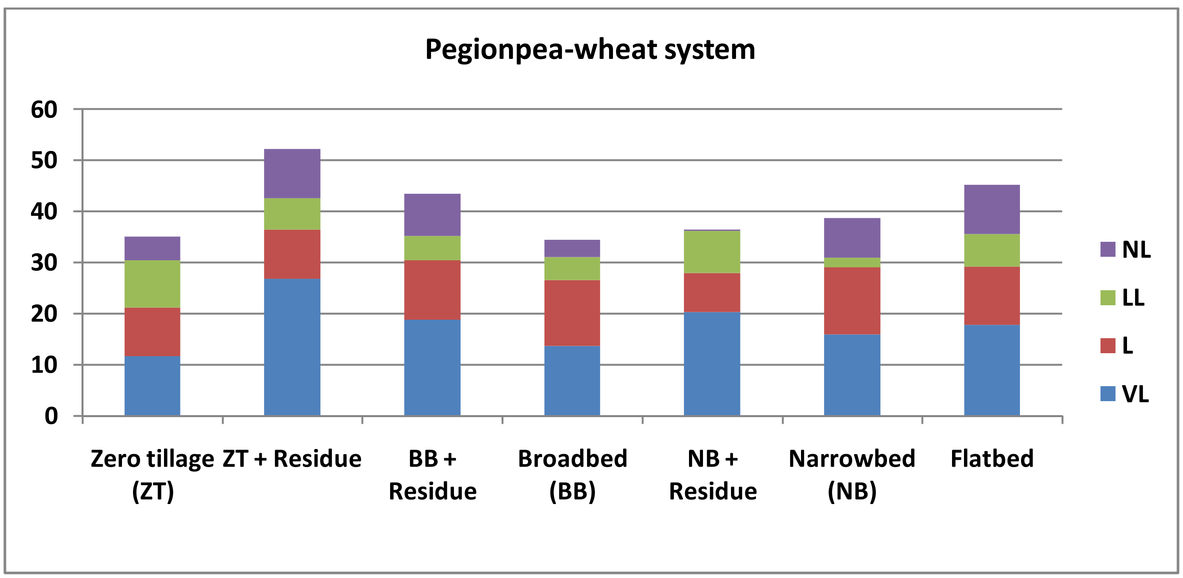


Fig. 24. Soil organic carbon pools at 0-30 cm soil depth after wheat harvest in pigeon pea-wheat system

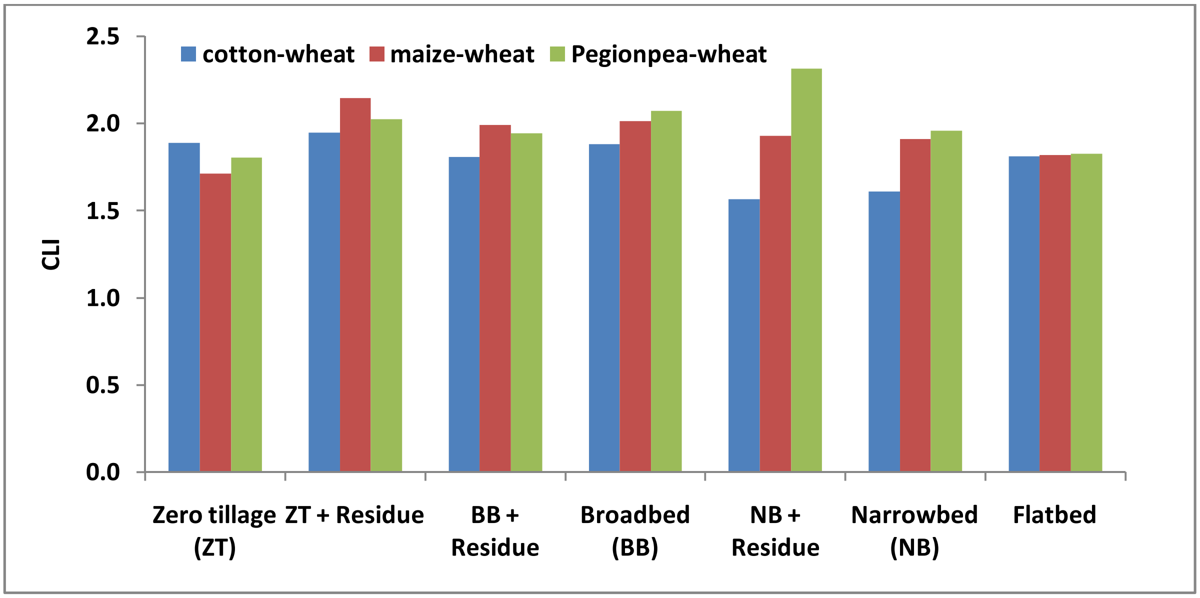


Fig. 25. Carbon lability index (CLI) as influenced by tillage and cropping system

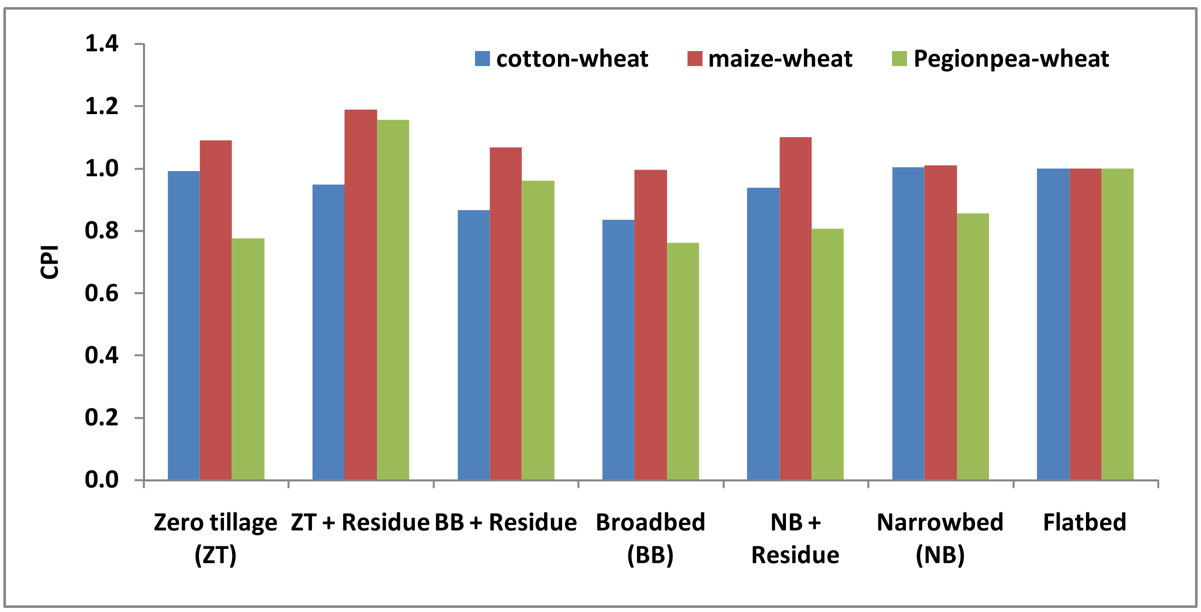


Fig. 26. Carbon pool index (CPI) as influenced by tillage and cropping system

Table 37. Carbon management index in the 0-30-cm soil depth as influenced by tillage and cropping system

Treatment	Cotton-wheat	Maize-wheat	Pigeon pea-wheat	Mean
Zero tillage (ZT)	187.5a	187.0c	140.2d	171.6
ZT + Residue	184.6a	255.4a	234.1a	224.7
BB + Residue	156.7b	212.8b	186.8b	185.4
Broad bed (BB)	157.2b	200.5b	157.8c	171.9
NB + Residue	146.9c	212.4b	186.7b	182.0
Narrow bed (NB)	161.8b	193.1c	167.9c	174.2
CT Flat bed	181.3a	182.0c	182.8b	182.0
Mean	168.0	206.2	179.5	

3.2 SOIL PHYSICAL PROPERTIES

3.2.1 ICAR-Indian Institute of Soil Science, Bhopal

3.2.1.1 Aggregation and mean weight diameter

Soil aggregation expressed as mean weight diameter (MWD) significantly improved only in 0-5 cm under RT than that under CT (Fig.27a). This was ascribed to minimum soil disturbances coupled with residue retentions which helped in soil aggregation. Similar to MWD, the per cent water stable aggregation in 0-5cm depth was also higher in RT than that in CT (Fig.27b).

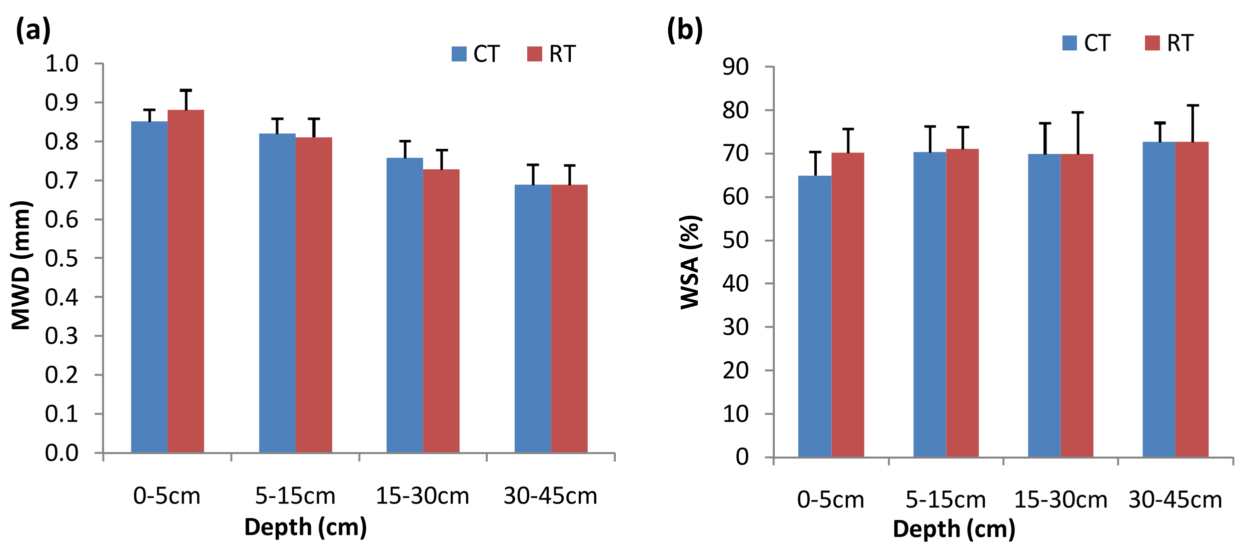


Fig. 27.a & bMean weight diameter (MWD) and b. per cent water stable aggregate (>0.25mm) under different tillage practices pooled over the cropping systems after 5 crop cycles.

3.2.1.2. Soil moisture

The temporal variation of soil moisture content (%) recorded during the *rabi* crop growing season showed that the reduced tillage coupled with residue retention improved soil moisture content by 3-8% wt/ wt in the profile (0-30cm) (Fig.28).

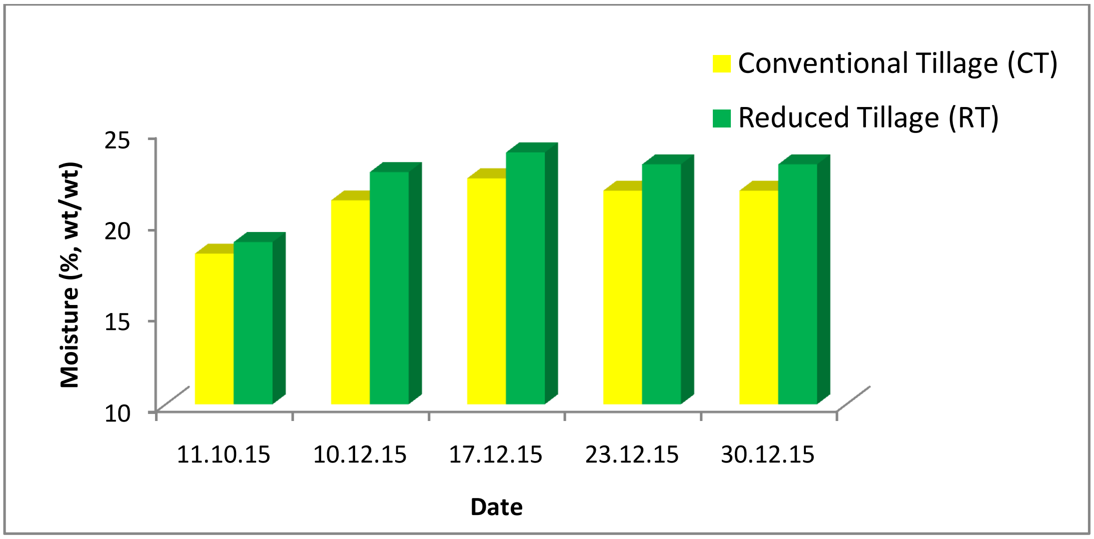
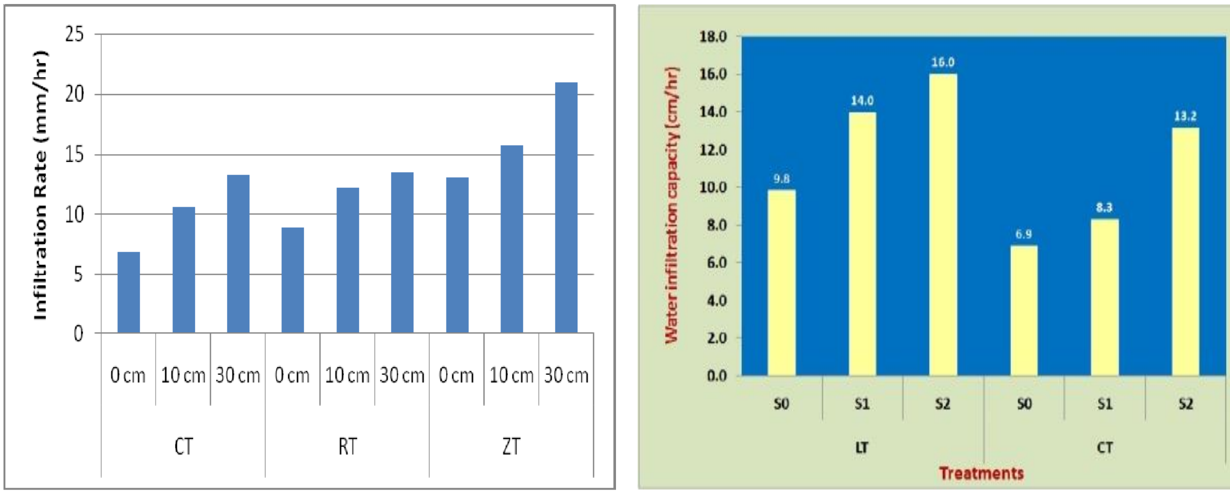


Fig. 28. Soil moisture content (%, wt/wt) under different tillage system during Rabi season 2015

3.2.2 ICAR-Central Research Institute for Dryland Agriculture

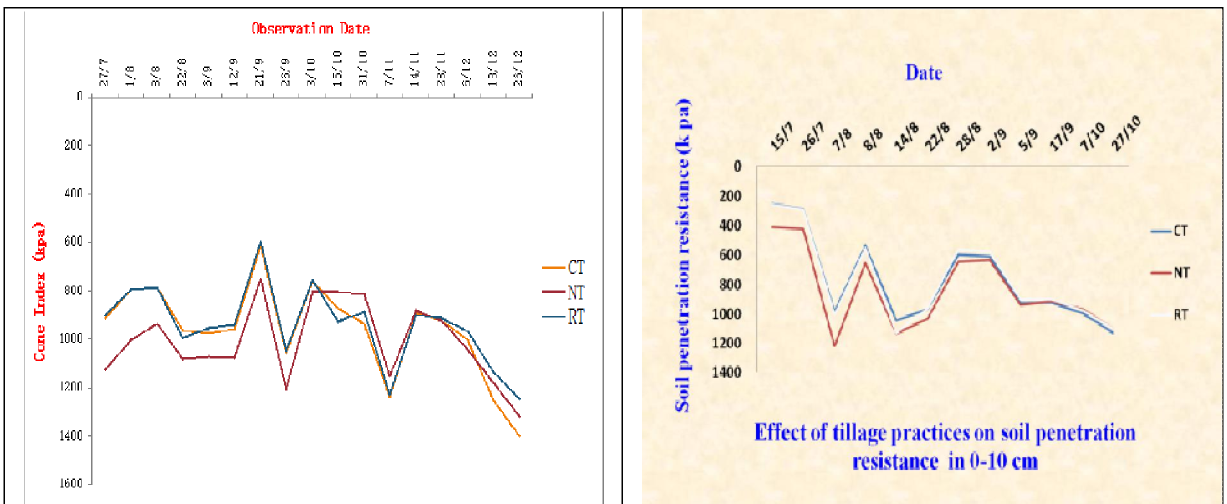
In bothSorghum-Blackgramsystem and Pigeonpea and castor system the **i**nfiltration rate were higher in zero tillage as compared to conventional tillage. Similarly increase in residues also improved the infiltration rate. In sorghum ï blackgram system 60 cm and 30 cm harvest height treatments increased the infiltration capacity by 31 and 77% respectively over no residue retention treatmentwhereas 30 cm harvest height in pigeonpea ï castor system increased infiltration by 39 and 19 % over 0 cm and 10 cm. Similar increase in infiltration rate in CA over CT was observed in Maize- Horsegram system (Fig.29)

In Maize - pigeonpea system, during 2013, the penetration resistance was lower in CT at the time of pigeonpea sowing but at the time of pigeonpea harvesting the penetration resistance was on par in all the tillage treatments. This difference in the penetration resistance in different tillage treatments might be due to variation in soil moisture (Fig. 30)



Pigeonpea- castor system   Sorghum- blackgram system

Fig. 29. Influence of different treatments on Infiltration rate



Pigeonpea	Maize

Fig. 30. Effect of different tillage practices on Penetration resistance and soil moisture

3.2.2.1 Soil, water and nutrient losses

In Pigeonpea- castor system the soil, water and nutrient losses were monitored using guaging experiments. This year the conventional tillage recorded higher soil loss and nutrient losses and this was closely followed by RT. whereas water loss was higher in ZT. ZT recorded 20% and 17% lower soil and nutrient losses (NPK, OC) as compared to CT and RT.

3.2.3 ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra

3.2.3.1 Impact of different ratoon management practices in sugarcane on consumptive use of water

Treatment details are given in the section 2.1.7 (sugarcane based cropping systems) of the report. The seasonal consumptive use (CU) was calculated based on field water balance technique. During the 339 days growing period 13 irrigations were applied with each irrigation equivalent to about 8 cm water. Rainfall during the above period was 365.5 mm which was distributed in 26 numbers of rainy days (daily rainfall > 2.5 mm) (Fig.31). Maximum single day rainfall intensity was 45.5 mm even then no run off was noticed. Total pan evaporation (Pan-E) for the crop season was 2144.2 mm i.e. a daily average rate of 6.2 mm d^{-1} and the daily rates of Pan-E varied between 1.4-13.6 mm d^{-1}. Daily mean temperature ranged between 16.3°C and 32.5°C and the mean stood at 25.9°C. Daily maximum temperature varied between 41°C and 25.5°C while that of minimum between 6.5°C and 25.0°C. Mean daily bright sunshine period (BSS) duration was 6.7 hours and the single day maximum was recorded as 11.3 hr. Daily mean relative humidity was 57 % and on a day to day basis it varied between 24 % and 96 %. Daily average wind speed was 6.9 km h^{-1} and the single day maximum was recorded as 17.2 km h^{-1}.

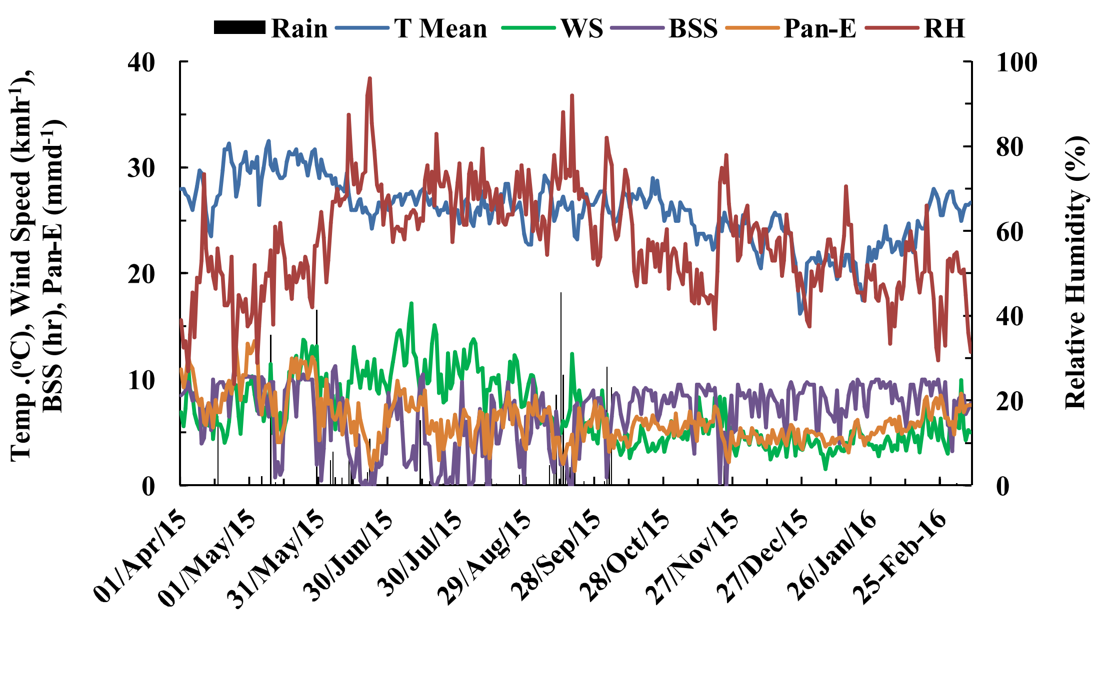


Fig. 31. Daily weather conditions at the experimental site during the sugarcane growing period

For potential evapotranspiration (PET) computation, summer and winter periods pan coefficients were taken as 0.6 and 0.8, respectively. The estimated CU values under *in-situ* trash retained (either chopped or un-chopped) varied between 125.6-138.7 cm whereas in case of without trash (either burnt or removed) treatment CU ranged between148.2-152.0 cm. Thus, adoption of conservation agricultural practices in sugarcane could save water between 6-21 % (Fig.32).

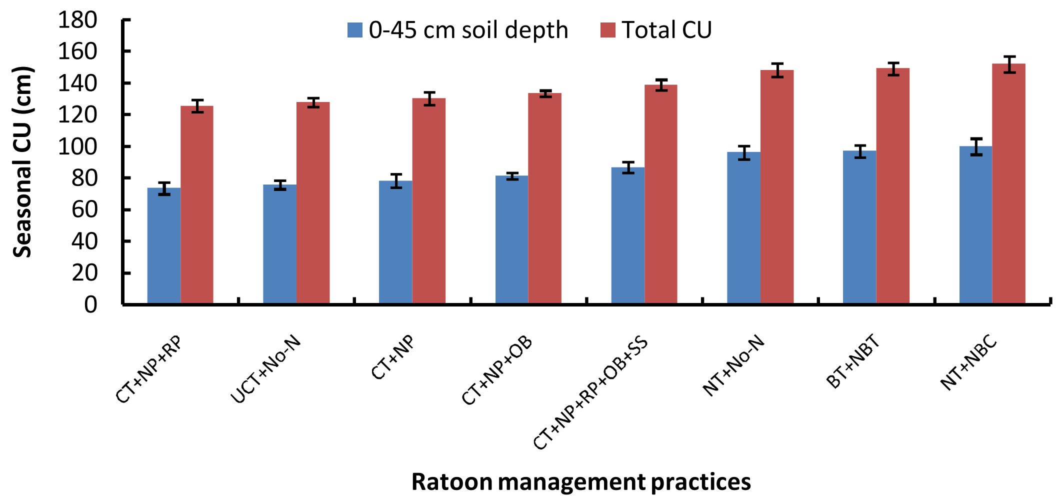


Fig. 32. Effect of ratoon management practices on seasonal consumptive use (CU) of sugarcane ratoon crop

3.2.4 ICAR-Indian Agricultural Research Institute, New Delhi

3.2.4.1 Soil moisture content

Soil moisture content under wheat was determined periodically from different experiments from three depths 0-15, 15-30 and 30-45 cm gravimetrically. It was found that in best treatment i.e. MBR (Mungbean residue) + ZT DSR ï RR + ZTM + MR ï SMB, soil moisture was 37.2, 32.3 and 42.1% under rice-mustard and 62.2, 49.0 and 42.3% in rice-wheat system more in 0-15, 15-30 and 30-45 cm depths compared to transplanted puddled rice field (Fig.33). Similarly, soil moisture was more in residue retained plots compared to non-residue plots and there was 11.3, 5.3 and 3.9% in rice-mustard and 11.3, 4.7 and 1.4% in rice-wheat system more soil moisture in 0-15, 15-30 and 30-45 cm depths in zero tillage transplanted plots compared to transplanted puddle plot (Table 38).

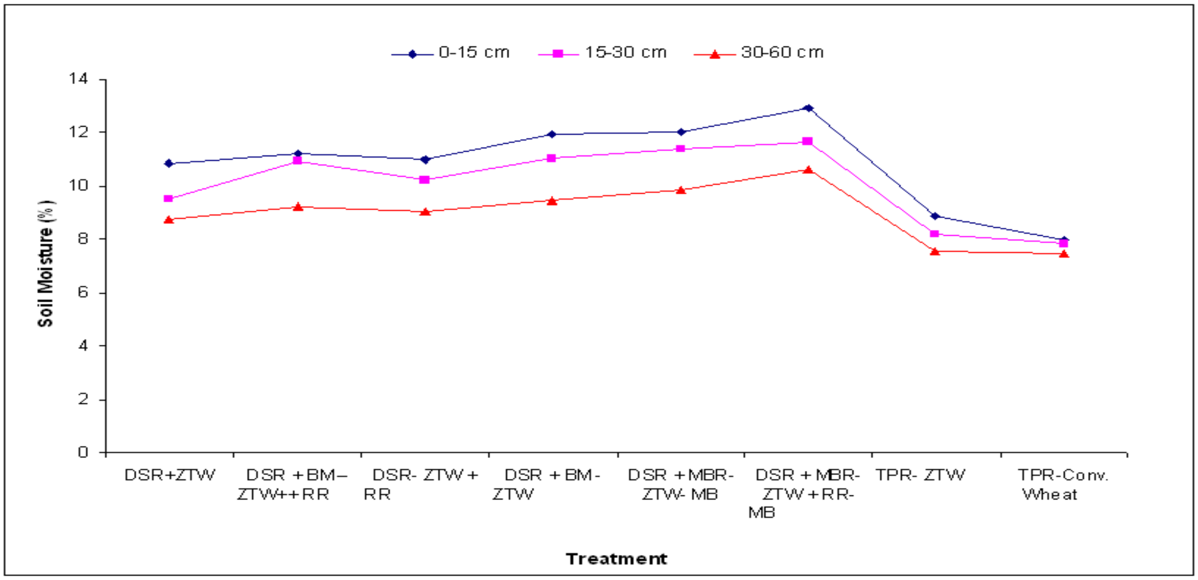


Fig. 33. Soil moisture distribution under conservation agriculture in wheat at different depths in rice-wheat (a) and rice-mustard (b) cropping systems

Table 38. Per cent increase in soil moisture in wheat in different depths under CA

Treatment	% increase in soil moisture					
	Rice-mustard			Rice-wheat		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
ZT DSR – ZTM	22	19.8	17.4	35.8	21.5	17.3
ZT DSR + BM – ZTM	20	19.3	21.9	40.3	40.1	23.4
MR + ZT DSR – RR + ZTM	27.7	22.6	28.8	37.6	30.9	21.3
MR + ZT DSR + BM – RR + ZTM	25.1	23.3	31.9	49.6	40.9	26.9
MBR + ZT DSR – ZTM – SMB	30.5	24.7	32.7	50.7	45.8	31.9
MBR+ ZT DSR – RR + ZTM + MR - SMB	37.2	32.3	42.1	62.2	49.0	42.3
TPR – ZTM	11.3	5.3	3.9	11.3	4.7	1.4
TPR – CTM	-	-	-	-	-	-

3.2.4.2 Bulk density

The bulk density at 15-30 cm soil layer is marginally lower in CA treatments (Fig.34). There was 2-8% reduction in sub-surface (15-30 cm) compaction under the CA practices compared to conventional TPR-CTW treatment.

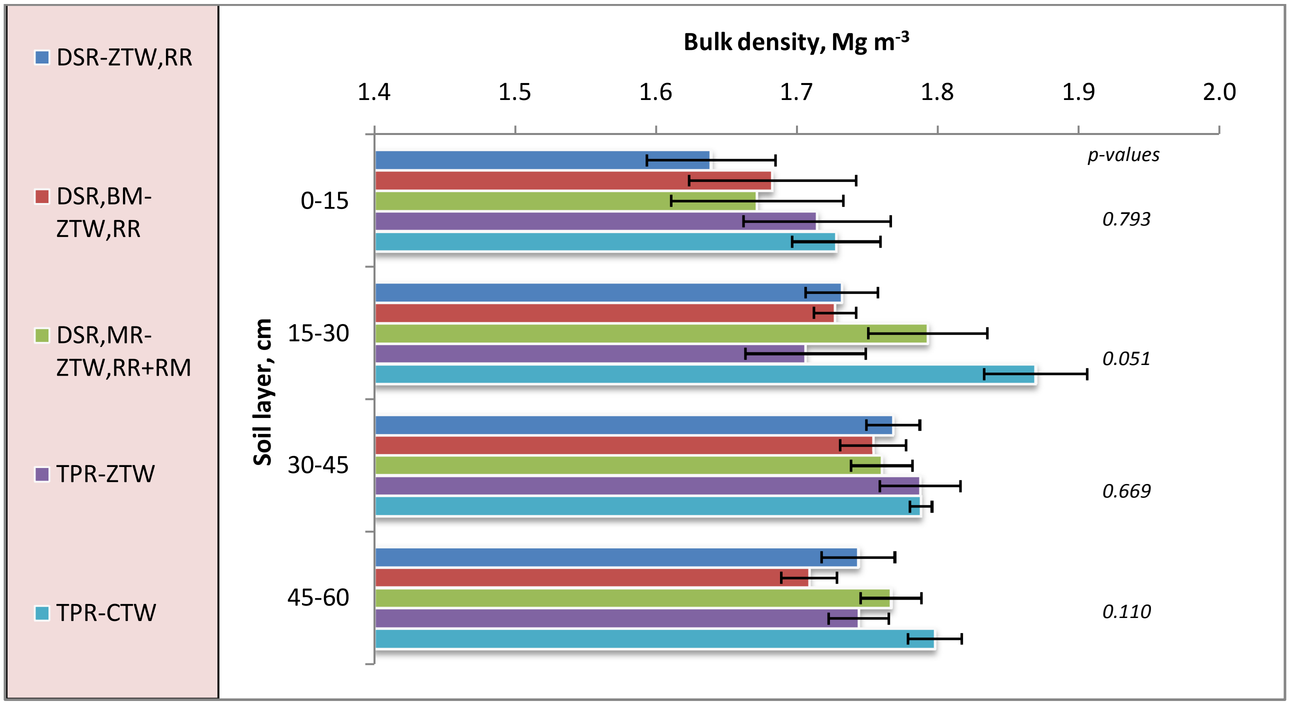


Fig. 34. Bulk density at different soil layers under conservation agriculture practices

3.2.4.3 Soil porosity

Soil pores, which drain water at 100 cm suction, are constituted mostly by macro- and meso-pores. These are estimated at 27-34% of total pores (0-60 cm). These pores are extremely variable across the soil layers among the CA practices, and no clear differences between CA and conventional practice were observed at any of the layers. However, the pores that can retain water (small meso- and micro-pores) corresponding to a suction exceeding 100 cm is higher in CA practices, especially in DSR, BM-ZTW, RR treatment (Fig.35), implying that the CA practices help in modifying soil porosity to generate more smaller pores responsible for holding the plant-available water. These pores are even more abundant in 15-30 and 30-45 cm layers, possibly due to increase in total porosity (due to reduction in soil bulk density) in those layers.

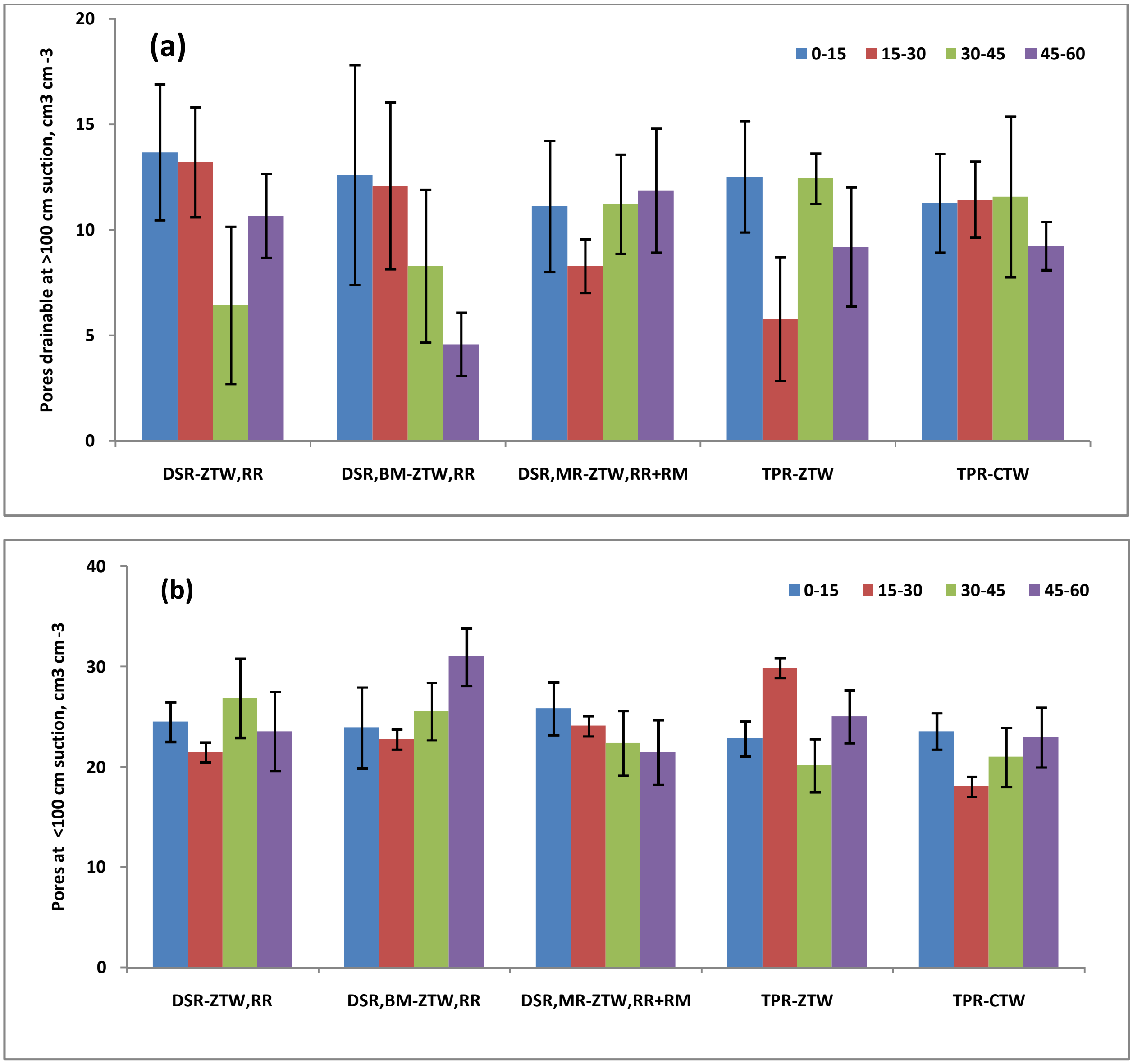


Fig. 35. Soil pores that are drained at 100 cm suction (a), and pores that can retain water at >100 cm suction (b) as affected by conservation agriculture practices

3.2.4.4 Infiltration

The initial rate of infiltration is significantly higher in TPR-ZTW (Table 39), although the final rates are similar among the DSR practices and in comparison to the TPR plots. Addition of mung bean residue and relay cropping had marginally higher final infiltration rate, cumulative infiltration indicating faster water movement down the profile.

Table 39. Infiltration characteristics of soil under conservation agriculture in rice-wheat rotation (Data in March 2016)

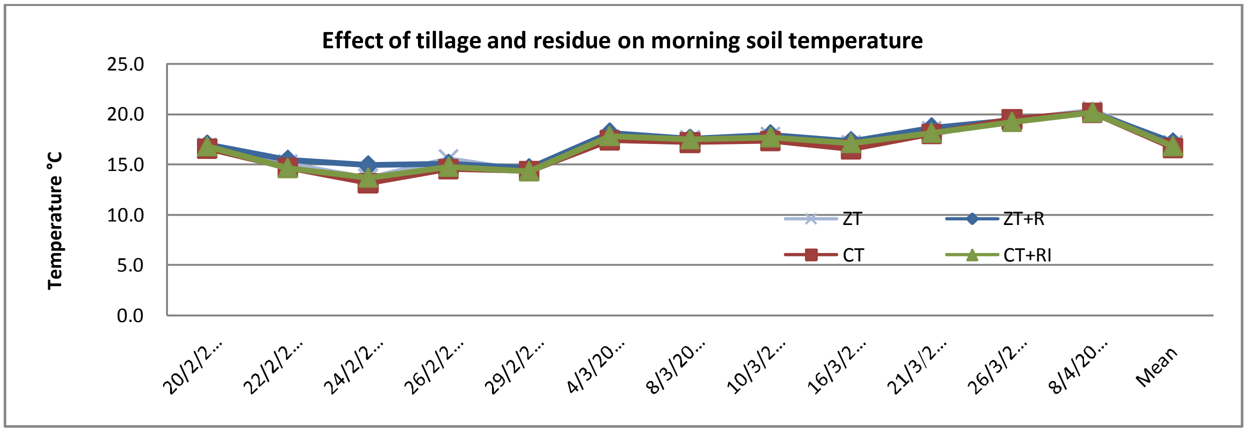
CA practices	Infiltration rate (cm h^{-1})		Cumulative infiltration (cm)	Sorptivity cm $hr^{-1/2}$
	Initial	Final		
ZTDSR-ZTW (T1)	4.5b	0.2a	2.4a	26.0b
RR+DSR-ZTW+WR (T2)	7.1ab	0.4a	4.5a	34.1ab
WR+ZTDSR+BM-ZTW+RR (T3)	4.1b	0.2a	2.2a	30.1ab
WR+ZTDSR+MR-ZTW+RR+Relay Cropping (T6)	8.5ab	0.5a	6.9a	55.8a
TPR-ZTW (T7)	10.2a	0.3a	4.4a	51.0ab

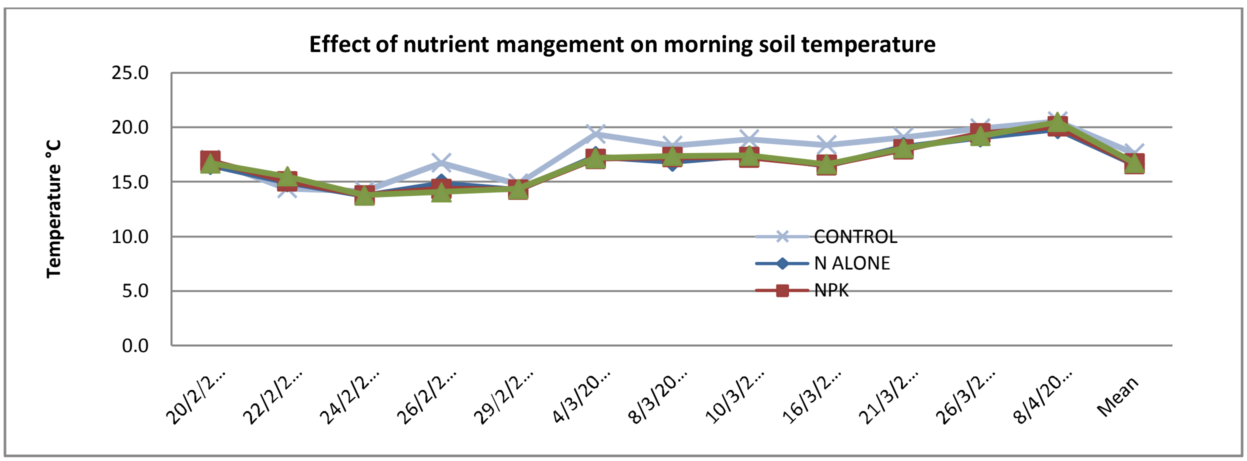
3.2.5 ICAR-Indian Institute of Wheat and Barley Research, Karnal

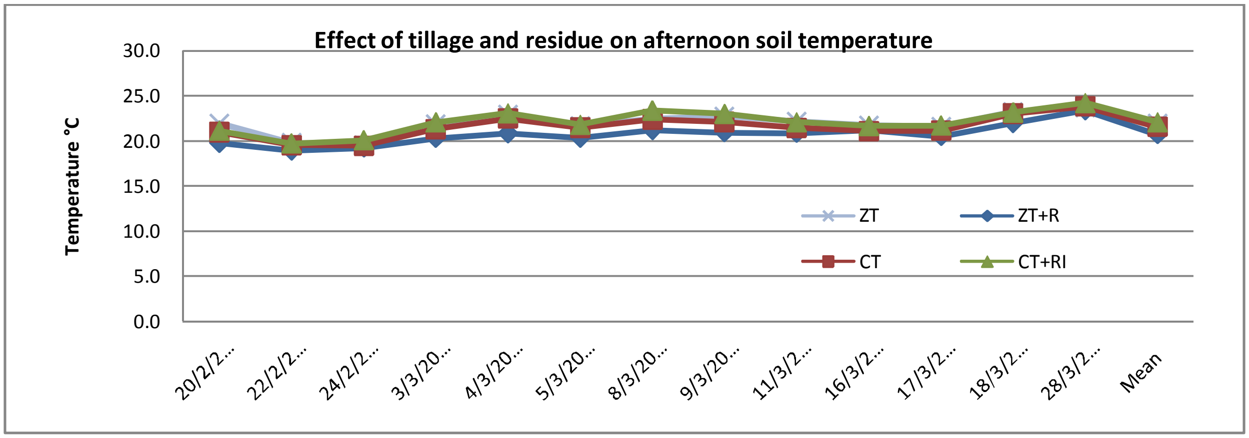
3.2.5.1 Effect of tillage, residue and nutrient management on soil temperature, canopy temperature and NDVI in maize-wheat-green gram system

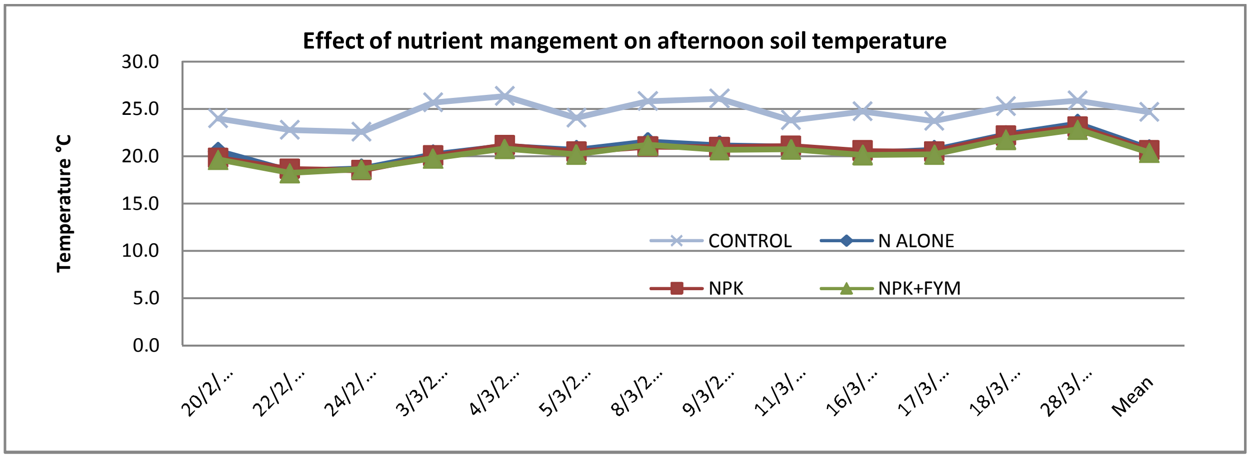
At ICAR-IIWBR, a long term experiment was initiated during Kharif 2015, to evaluate the ñLong term effect of tillage, residue and nutrient management in maize-wheat-green gram systemò in a systemsôperspective. The experiment was conducted in split plot design with three replications. The main plot consisted of four treatments involving the combination of tillage and residue management {ZT (Zero tillage); ZT with residue retention (CA); CT (Conventional tillage) and CT + residue incorporation} and sub plots were having the four nutrient management options (Control; Recommended N alone; Recommended NPK; and Rec. NPK + FYM 10 t/ha). Wheat cultivar HD 2967 was sown at row to row spacing of 22.0 cm using a seed rate of 125 kg/ha considering the 1000 grain weight as 38 g. The sowing was done using Turbo happy Seeder. The full residue load of maize (245 q/ha on dry weight basis) after removing the cobs was either removed, or retained or incorporated. The incorporation was done using rotary tiller. The irrigations were given as per the recommended practices. For control of weeds clodinafop 60 g/ha fbmetsulfuron 4 g/ha were applied at 35 DAS. The recommended dose of N:P:K consisted of 150:60:40 kg/ha. Full P and K were applied as basal before pre seeding irrigation. Whereas N was applied in two equal splits (half dose each just before first and second irrigation).

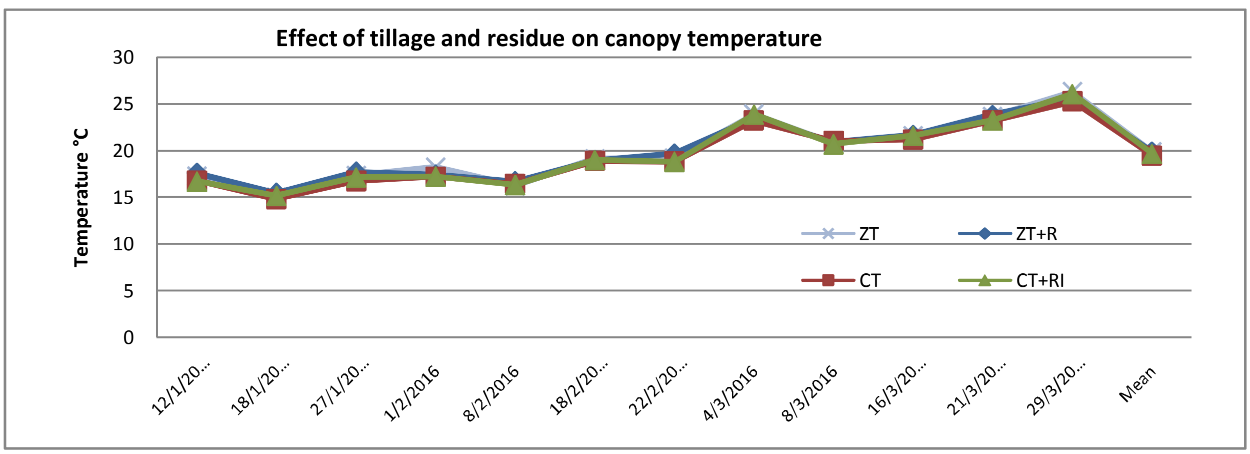
Observations on soil temperature recorded during the morning and noon time during the growing season showed a dampening off effect on the dirural variation of soil surface temperature under conservation agriculture treatment where residues were kept on the surface. The morning temperatures were slightly higher in CA system where as reverse trend were recorded in the noon time temperature, where the temperatures were on the lower side. The noon temperatures in the control plots were higher than different nutrient management treatments. Canopy temperature as measured by LT300 Infrared Thermometer was higher in unfertilized control plots. Whereas the Normalized Difference Vegetation Index (NDVI) values recorded using hand held green seeker, a direct indicator of the crop growth was drastically less in unfertilized control plots, which was reflected in lower crop yields (Fig.36).






Effect of tillage and residue on afternoon soil temperature
Temperature °C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ZT
ZT+R
CT
CT+RI
20/2/2...
22/2/2...
24/2/2...
3/3/20...
4/3/20...
5/3/20...
8/3/20...
9/3/20...
11/3/2...
16/3/2...
17/3/2...
18/3/2...
28/3/2...
Mean


Effect of nutrient mangement on afternoon soil temperature
Temperature °C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
CONTROL
N ALONE
NPK
NPK+FYM
20/2/...
22/2/...
24/2/...
3/3/2...
4/3/2...
5/3/2...
8/3/2...
9/3/2...
11/3/...
16/3/...
17/3/...
18/3/...
28/3/...
Mean


Effect of tillage and residue on canopy temperature
Temperature °C
30
25
20
15
10
5
0
ZT
ZT+R
CT
CT+RI
12/1/20...
18/1/20...
27/1/20...
1/2/2016
8/2/2016
18/2/20...
22/2/20...
4/3/2016
8/3/2016
16/3/20...
21/3/20...
29/3/20...
Mean

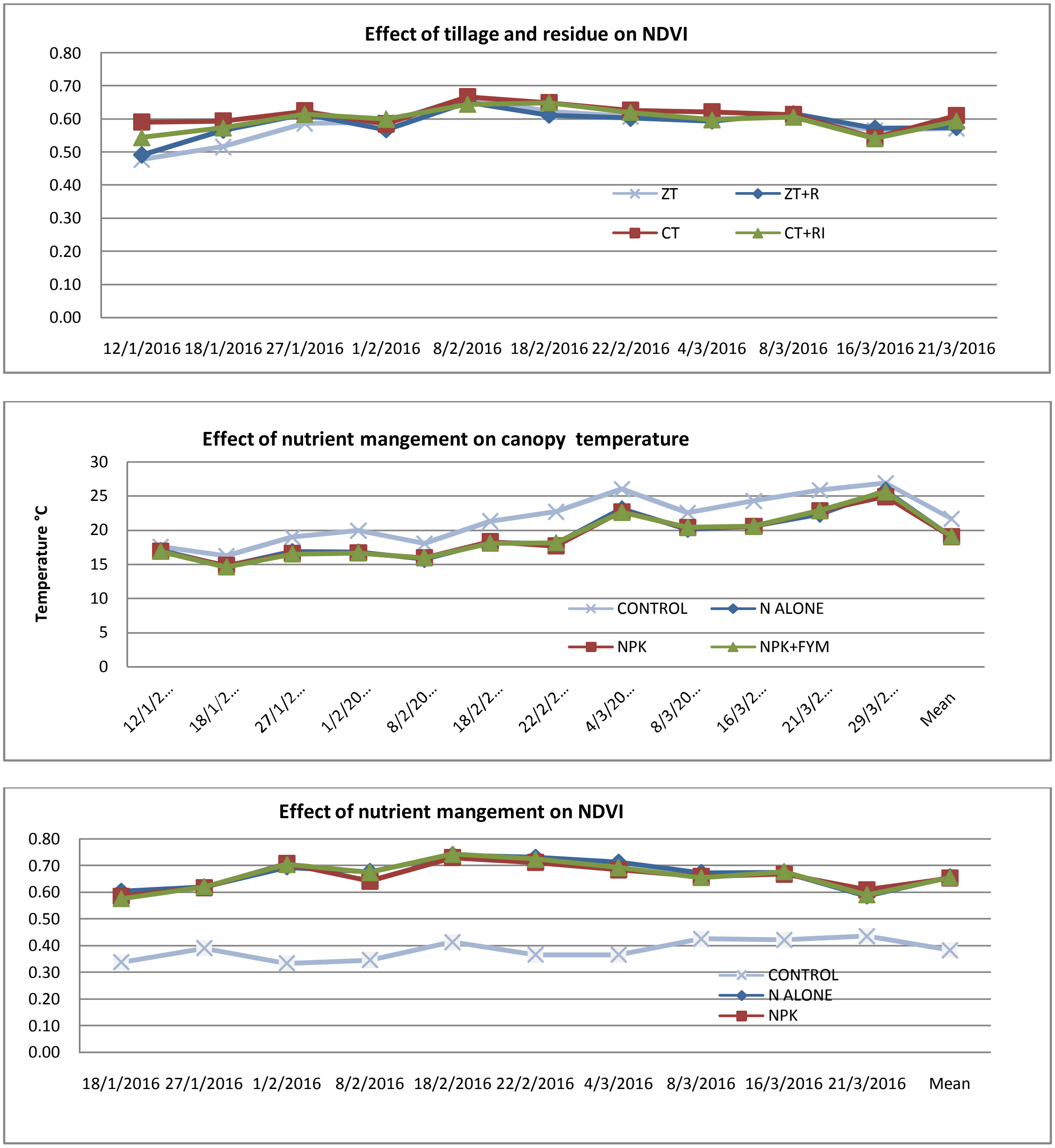


Fig. 36. Effect of tillage and residue management on soil temperature and NDVI

3.3 SOIL CHEMICAL PROPERTIES

3.3.1 ICAR-Directorate of Weed Research

For this study, ICAR-IISS, Scientists collected soil samples from conservation agriculture experiments under soybean, rice and maize based cropping systems at Jabalpur after the completion of 3 years of experimentation. Soil samples were collected from 0-15 and 15-30 cm of soil depths. Changes in available N and P were not found to be significantly different under different treatments in different CA experiments. Available N content of soil ranged from 180-255 kg/ha under different treatments. There was a build-up of P under different treatments in CA experiments of Jabalpur. Available K was relatively higher in zero tilled plots with residue retained in comparison to no residue retained plots in all the experiments. However, the effect was only pronounced to 0-15 cm of soil depth. Available K content was found to be the maximum in zero tilled plots with either residue retained or burnt. It was significantly lower in plots which were conventionally tilled (Fig.37). No significant difference in soil pH and EC were recorded in different experiments under CA at Jabalpur. It was observed that soil pH under different treatments ranged from 6.6 to 7.1 whereas EC ranged from 0.3 to 0.6 dS m^{-1}.

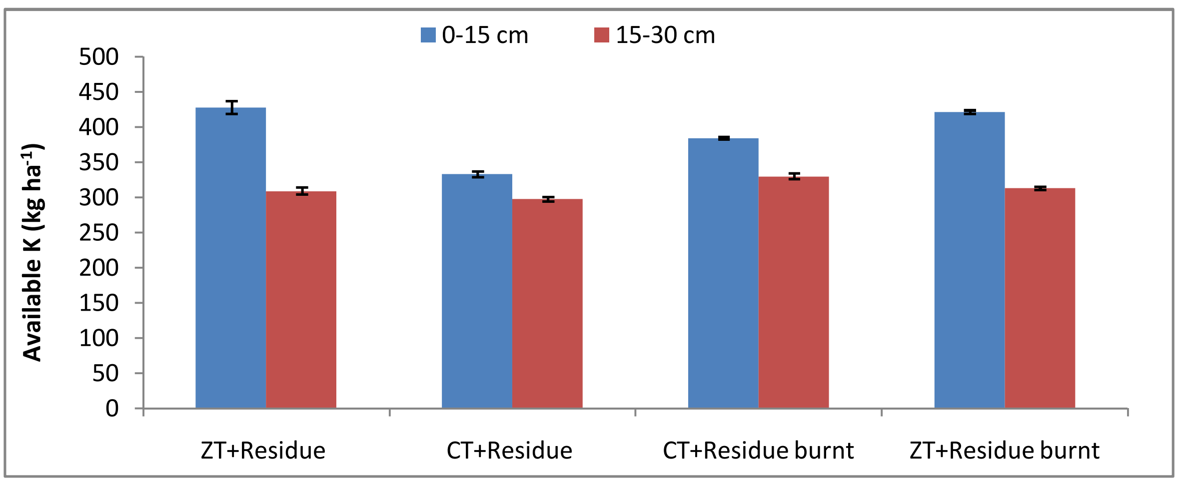


Fig. 37. Available K content (kg ha^{-1}) in rice-wheat-green gram based conservation agriculture experiment

3.3.2 ICAR-Indian Institute of Soil Science, Bhopal

Initial soil samples collected from newly initiated conservation agriculture experiment at ICAR-IISS Bhopal were characterized for pH, EC, organic C, available N, P and K content (Table 40). It was observed that soils of Bhopal are medium in organic C, low in N, medium in available P and high in available K status. The soil pH is 7.8 and EC is 0.4 dS m^{-1}.

Table 40. Initial soil characterization of conservation agriculture field of ICAR-IISS farm

Parameters/Soil depth	0-5 cm	5-15 cm	15-30 cm
pH	7.82 (0.03)	7.88 (0.02)	7.95 (0.01)
EC	0.44 (0.03)	0.39 (0.03)	0.34 (0.03)
OC (%)	0.57 (0.03)	0.46 (0.01)	0.39 (0.05)
Labile C (mg/kg)	418 (6.05)	362 (11.3)	327 (9.11)
Available N (kg/ha)	209.5 (5.47)	173.1 (3.76)	156.8 (1.98)
Available P (kg/ha)	22.4 (0.92)	11.5(1.44)	8.6 (1.66)
Available K (kg/ha)	467.0 (17.4)	333.9 (21.6)	311 (22.7)

3.3.3 ICAR-Indian Agricultural Research Institute, New Delhi

3.3.3.1 Soil N status

After 5 years of CA-based maize-wheat cropping system, it was observed that plots with permanent bed had significantly higher total soil nitrogen (TSN) concentration and stock in all four fractions of aggregates in the 0-15 cm soil layer after 5 years of cropping compared with CT plots. Plots under PBB + R had 12 and 37%, respectively higher TSN concentration and TSN stock associated with macro-aggregates in the 0ï 5 cm soil layer compared with CT (2.016 g kg^{-1} and 247.63 kg N ha^{-1}) plots. Plots under PBB + R treatment had 23 and 9% higher TSN concentration and TSN stock associated with micro-aggregates compared with CT (0.84 g kg^{-1} and 299 kg N ha^{-1}) plots (Table 41). However, in the 5-15 cm layer, plots with permanent broad bed with residue retention (PBB + R) had maximum concentration and stock of TSN associated with bulk soil and the values were 12 and 12% higher, respectively, than conventional tillage (CT) plots (0.79 g kg^{-1} and 1177.5 kg N ha^{-1}). N_2O emissions were significantly higher in residue retained plots compared with residue removal ones, for both crops. In the maize crop, highest emission was observed in the plots under permanent narrow beds with residue retention (PNB + R) (992 g ha^{-1}) and lowest in CT (846 g ha^{-1}), which was~17% less than plots under PNB + R treatment. In the wheat crop, highest emission was observed in the plots under PNB + R treatment (883 g ha^{-1}) and that value was 18% higher than CT and zero tillage (ZT) plots. Thus, in the maizeï wheat cropping system, highest N_2O emission was observed in the plots under PNB

+ R (1875 g ha^{-1}) and least in CT plots. Thus, adoption of ZT in permanent beds with crop residue addition (novel CA practice) is a better management option for improvement of soil N (and thus possibly a reduced dose of fertilizer N can be adopted in the long run), as the management practice has the potential to improve soil aggregation with greater accumulation of TSN within macro-aggregates.

Table 41. Effects of conservation agriculture on soil bulk density and total soil N content after five years of maize-wheat cropping system

Conservation agricultural practices*	Soil properties in the 0-5 cm layer			Soil properties in the 5-15 cm layer		
	Bulk density (Mg m^{-3})	Total soil N (g kg^{-1})	Total soil N content (kg N ha^{-1})	Bulk density	Total soil N (g kg^{-1})	Total soil N content (kg N ha^{-1})
CT	1.48b	0.93c	690.4c	1.50b	0.79b	1177.5b
PNB	1.48b	0.98bc	725.2bc	1.51ab	0.80b	1208.0ab
PNB + R	1.46c	1.04b	759.2b	1.50b	0.89a	1335.0a
PBB	1.47bc	1.09ab	801.9ab	1.48bc	0.82b	1213.6ab
PBB + R	1.46c	1.16a	849.7a	1.47c	0.90a	1315.7a
ZT	1.50a	0.96bc	723.0bc	1.53a	0.84ab	1291.3a
ZT + R	1.48b	0.99bc	734.8b	1.51ab	0.86ab	1295.6a

Means followed by similar lowercase letters within a column are not significantly different at P <0.05 according to Tukeyŝ HSD test.

3.3.3.2 Soil P and K status

Among different CA treatments, MBR+ZT DSR- RR+ZTW- WR+ ZT mungbean +100%N and WR+ZTDSR - ZTW+RR+100% N resulted in the highest available K in 5-15 cm soil layer (Table 42).WR+ZTDSR+BM-ZTW+RR+75%N resulted in maximum available K in 0-5 cm soil layer. In 0-5 cm layer available phosphorus was found to be maximum in WR+ZTDSR - ZTW+RR+100% N treatment, which was followed by TPR (Transplanted rice)-ZTW and WR+ZTDSR+BM (Brown manure)- ZTW+RR+ 75% N treatment. In 5-15 cm layer available phosphorus was highest in MBR+ZT DSR- RR+ZTW- WR+ ZT mungbean +100%N.

Table 42. Available phosphorus and potassium under CA-based rice-wheat cropping management system

Treatment	Avail K Kg ha^{-1}		Avail P Kg ha^{-1}	
	0-5cm	**5-15 cm**	**0-5 cm**	**5-15 cm**
ZT DSR - ZTW	321^{a}	342^{a}	43.5^{a}	30.3^{ab}
WR+ZTDSR - ZTW+RR+100% N	362^{a}	472^{a}	60.9^{d}	40.2^{c}
WR+ZTDSR - ZTW+RR+75% N	385^{a}	407^{ab}	48.2^{b}	51.2^{d}
ZT DSR+BM- ZTW	355^{a}	384^{a}	42.2^{a}	27.9^{a}
WR+ZTDSR+BM- ZTW+RR+ 100% N	377^{a}	430^{b}	55.3^{c}	45.6^{c}
WR+ZTDSR+BM- ZTW+RR+ 75% N	413^{b}	392^{a}	58.8^{c}	44.3^{c}
ZT DSR- ZTW-ZTMungbean	396^{a}	322^{a}	55.2^{c}	39.9^{b}
MBR+ZT DSR- RR+ZTW- WR+ ZT Mungbean +100%N	391^{a}	429^{b}	46.3^{b}	53.1^{d}
MBR+ZT DSR- RR+ZTW- WR+ ZT Mungbean +75%N	354^{a}	472^{b}	46.3^{b}	51.5^{d}
	415^{b}	328^{a}	42.5^{a}	38.5^{b}
TPR- ZTW	334^{a}	407^{ab}	57.9^{c}	45.5^{c}

In 0-5 cm depth, available potassium was 39.12% and 38.67% higher in PNB and PNB + R Treatment than CT treatment (Table 43). In 5-15 cm depth available potassium was 36.46% higher in PNB + R treatment than CT treatment. In 0-5 cm depth available phosphorus was 1.72% higher in PNB and PNB + R Treatment than CT treatment. In 5-15 cm depth available phosphorus was 13.72% higher in PNB + R treatment than CT treatment.

Table 43. Available phosphorus and potassium under cotton-wheat management system

Treatment	Avail K mg kg^{-1}		Avail P mg kg^{-1}	
	0-5 cm	**5-15cm**	**0-5cm**	**5-15cm**
CT	172.1a	161.8b	24.5a	18.0d
PNB	282.9c	201.8c	24.9a	15.1c
PNB+R	280.7c	254.6d	24.9a	20.8d
PBB	238.2b	171.4b	24.5a	14.4c
PBB+R	244.3b	164.3b	22.6a	9.3a
ZT	232.5b	153.9b	20.6a	11.1b
ZT+R	272.1b	124.3a	20.7a	10.5a

3.3.3.3 Micronutrient status

Available micronutrients under different CA-based rice-mustard system were determined at maximum vegetative growth stage of mustard. The TPR-CTM resulted in maximum levels of Fe, Mn and Cu in 0-5 cm soil layer, and WR+ZTDSR+BM- RR+ZTM (Zero tillage mustard) resulted in maximum available Zn in soil (Table 44).

In 0-5 cm soil layer, copper concentration was found to be 1.37% higher in ZT treatment than CT treatment (6.46 ppm) (Table 45). In 5-15 cm layer copper concentration was 15.31% higher in ZT+R treatment than CT treatment (6.31 ppm). In 0-5 cm layer zinc concentration found to be 62.11% and 60.73% higher in ZT and ZT+R treatment than CT treatment (2.47 ppm). In 5-15 cm layer zinc concentration was 21.27% higher in ZT treatment than CT treatment (2.22 ppm). In 0-5 cm layer manganese concentration found to be 8.37% higher in ZT treatment than CT treatment (2.08 ppm).In 5-15 cm layer manganese concentration was 10.34% higher in ZT treatment than CT treatment (2.08 ppm). In 0-5 cm layer iron concentration found to be 36.86 and 39.72% higher in ZT and ZT+R treatment than CT treatment (5.72 ppm). In 5-15 cm layer manganese concentration was 44% higher in ZT + R treatment than CT treatment (2.08 ppm).

Table 44. Available soil micro-nutrient status under CA-based rice-mustard system (0-5 cm)

Treatment	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
ZTDSR-ZTM	6.90b	1.51b	3.10ab	1.78bc
ZTDSR+ BM-ZTM	5.55b	1.34b	3.75ab	1.59c
WR+ZTDSR-RR+ZTM	5.02b	0.92b	2.50ab	1.64c
WR+ZTDSR+BM-RR+ZTM	5.50b	0.96b	4.96a	1.54c
ZTDSR-ZTM-ZT SMB	8.07b	1.27b	4.00ab	1.84bc
MBR+ZTDSR-RR+ZTM-WR+SMB	7.96b	3.79a	2.84ab	1.99bc
TPR-ZTM	14.71a	3.81a	2.47b	2.27ab
TPR-CTM	16.44a	4.75a	4.08ab	2.71a

Table 45. Available micronutrients under cotton-wheat management system (0-5 cm)

Treatment	Cu (ppm)	Zn(ppm)	Mn (ppm)	Fe (ppm)
CT	6.46 c	2.47 a	2.08b	5.72a
PNB	5.09 b	3.45b	2.01b	6.02b
PNB+R	4.98 a	3.15b	2.10 b	6.21b
PBB	5.33 b	3.08ab	1.94 a	7.62c
PBB+R	6.10 c	3.45b	2.18b	8.55c
ZT	6.55 c	6.52c	2.27 b	9.06d
ZT+R	6.29 c	6.29c	2.06 b	9.49d

3.4 SOIL BIOLOGICAL PROPERTIES

3.4.1 ICAR-Central research Institute for Dryland Agriculture, Hyderabad

The soil enzyme activity was influenced by tillage treatments and residues in different cropping systems. CT recorded higher dehydrogenase activity whereas CA registered higher Acid phosphatase and aryl phosphatase activity (Fig.38)

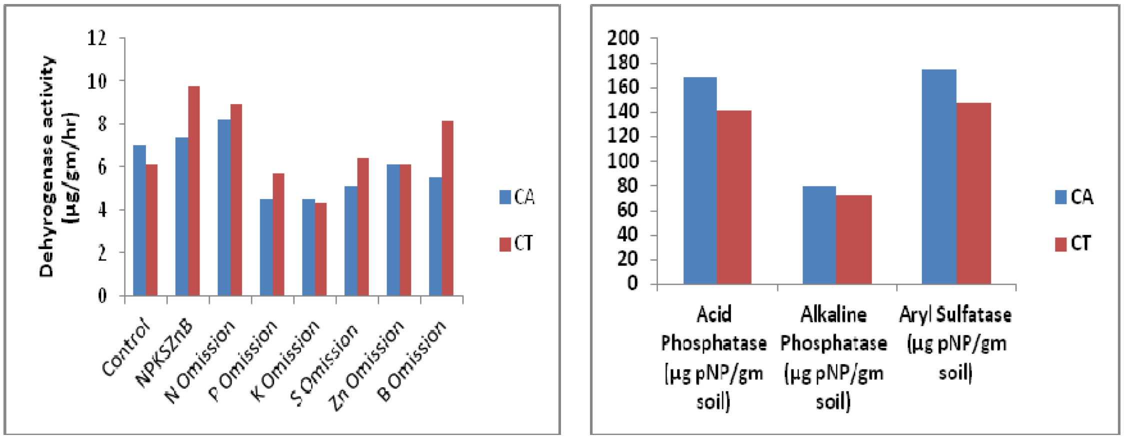


Fig. 38. Effect of Balanced fertilization on Enzyme activity in Maize - Horsegram system under CA

3.4.2 ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra

Different ratoon management practices in sugarcane had significant impact on soil microbial and enzymatic activities. Treatment details are given in the section 2.1.7 (sugarcane based cropping systems) of the report. Just after imposition of the treatments (at 2 Days After Ratoon Initiation, DARI), soil microbial biomass carbon (MBC), FDA hydrolysis and dehydrogenase (DH) activities were the lowest under trash burnt treatment (Fig.39). After 180 DARI, the maximum values of the above parameters were recorded under CT+NP+RP+OB+SS treatment which was closely followed by other N placement treatments, while the least under N un-fertilized without trash treatment. *In-situ* retention of chopped trash in the field as mulch along with placement of fert-N in soil and following of ratoon management practices like root pruning, off-barring and stubble shaving improved the MBC, FDA hydrolysis and DH activities in soil by 12.5-53.0, 5.4-31.1 and 10.6-54.5%, respectively over conventional ratoon management practices and N un-fertilized treatments.

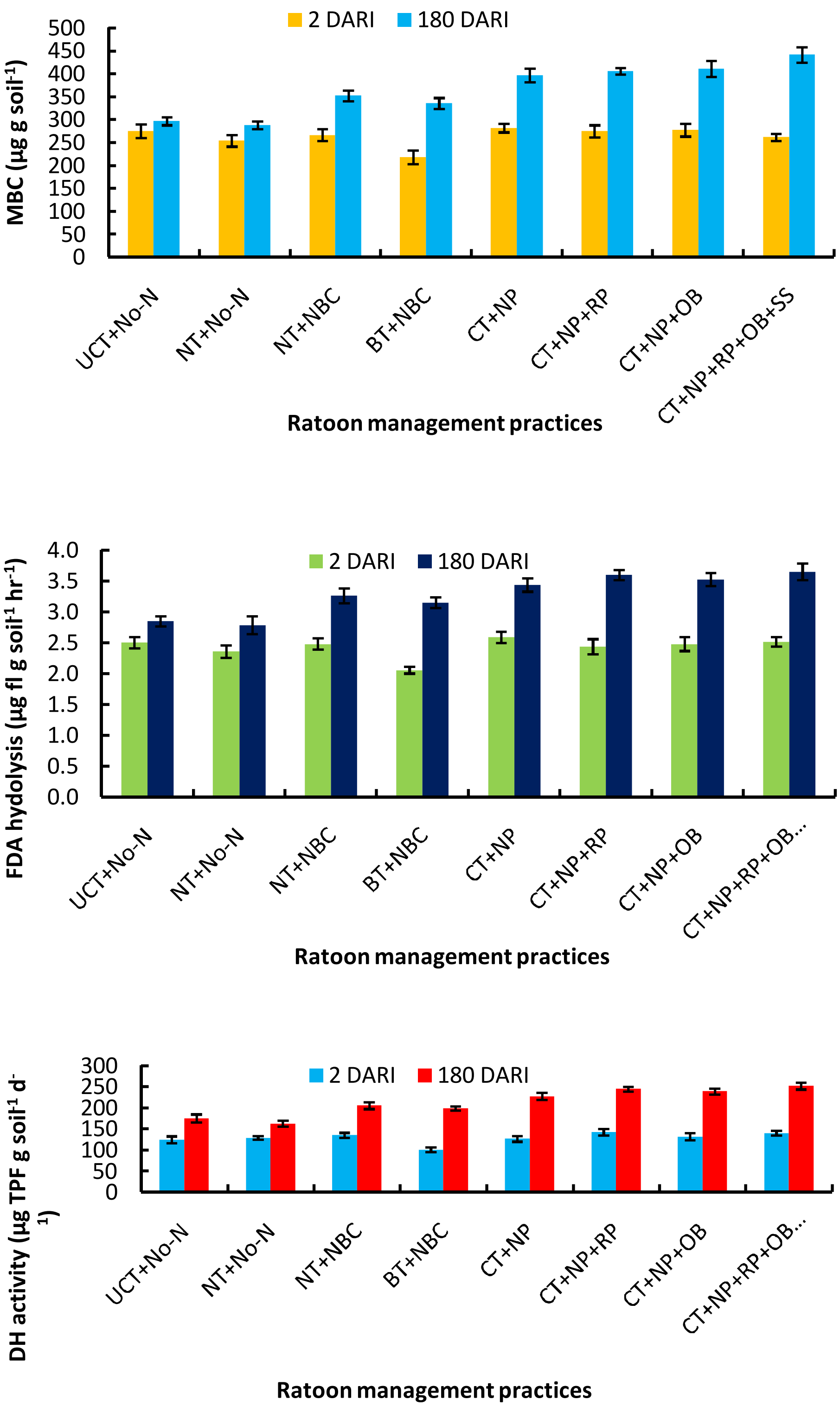


Fig. 39. Effect of ratoon management practices on soil microbial biomass carbon (MBC; top), FDA hydrolysis (middle) and dehydrogenize (DH) activities (bottom) in sugarcane ratoon crop

3.5 GREENHOUSE GAS EMISSIONS

3.5.1 ICAR-Central Research Institute for Dryland Agriculture, Hyderabad

In pigeonpea- castor system CT recorded higher CO_2 and N_2O emissions as compared to reduced and zero tillage. Increase in residues increased CO_2 emissions and N_2O emissions

3.5.2 ICAR-Indian Agricultural Research Institute, New Delhi

Measurement of carbon dioxide and nitrous oxide was carried out for 2015-16 year under resource conserving technologies like, zero tillage, residue retention and different planting methods from soils in cotton-wheat and maize wheat crop rotations for mitigating greenhouse emissions. Zero tillage significantly increased nitrous oxide emissions (8%) in cotton (Fig.40); however the different planting methods of narrow bed and broad bed planting had no significant impact on nitrous oxide emissions. Retention of residue increased N_2O emissions by 17-20% in cotton.

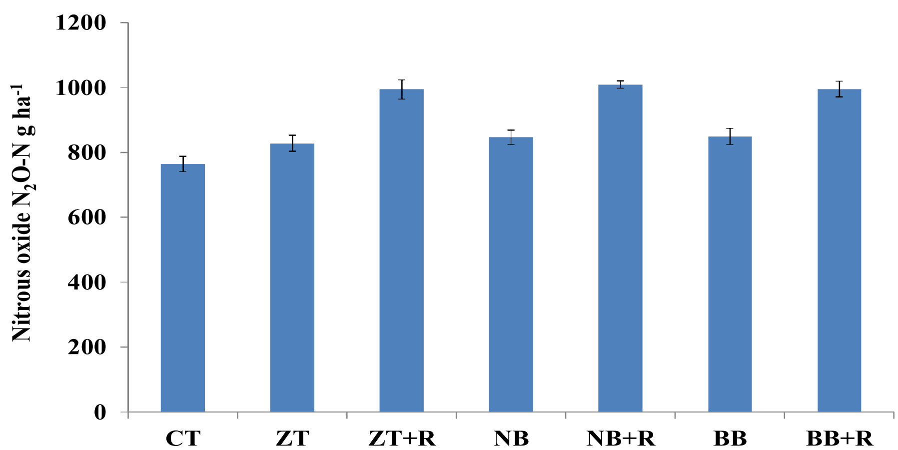


Fig. 40. Impact of tillage and residue treatments on nitrous oxide emission in cotton

4. CAPACITY BUILDING, KNOWLEDGE MANAGEMENT, INSTITUTIONAL ARRANGEMENTS AND ENABLING POLICIES FOR ACCELERATED ADOPTION OF CONSERVATION AGRICULTURE.

Human Resource Development/Capacity Building

4.1Interaction meeting cum training programme for partners of CRP on CA (Held at ICAR- CIAE in collaboration with ICAR- IISS, Bhopal)

Interaction meeting cum training programme for partners of CRP on CA was organized during 29-30 January, 2016. In this programme 27 participants from all eleven partners of CRP on CA participated. Thorough discussion on specific need for CA machinery available in their areas and problems associated in the adoption of equipments at large scale were carried out during the training programme. During discussion need of fine tuning of existing CA machinery and development of new machinery and conducting more training/ demonstration programme was felt to create awareness among farmers for adoption of CA practices. Project PI, gave a brief introduction about the available CA machineries and suggested precautions to be taken for finalization of the specifications of the machines for conservation agriculture practice.

Table 46. List of participants of Interaction meeting cum training programme for partners of CRP on CA

Name of Institute	No. of participants
ICAR-CRIDA, Hyderabad	2
ICAR-IIFSR, Modipuram	1
ICAR-IISS, Bhopal	6
ICAR-IARI, New Delhi	2
ICAR- CSSRI, Karnal	2
ICAR-RCER, Patna	2
ICAR-CIAE, Bhopal	4
ICAR- DWR, Jabalpur	2
ICAR-CRRI, Cuttack	2
ICAR-IIWBR, Karnal	3
ICAR-NIASM, Baramati	1

Group Photograph of participants of Interaction meeting cum training programme for partners of CRP on CA

Participation in Field Day on 05-03-2016 at Village Kham Khera, Bhopal

Plate 29. Demonstration of CA Machinery to the participants of Interaction meeting cum training programme for partners of CRP on CA

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The progress of the project was discussed during the annual meeting of the project held on 30/3/2016 at ICAR- IISS, Bhopal.

4.2. Kisan Divas was organized at Khamkheda on 5/3/2016 to review success and promote conservation agriculture in farmers' field.

A Kisan Divas was organized by ***ICAR- Indian Institute of Soil Science***, Bhopal at Khamkhedha on 5.3.2016 under Consortia Research Platform on Conservation Agriculture (CRP on CA). Dr. A.K. Patra, Director, ICAR-IISS, Bhopal addressed to the farmers gathered from different villages and interacted with farmers and enquired about the problems of the villages in relation to conservation agriculture. Dr. A.K. Biswas, Lead Centre Platform Coordinator (LCPC) of CRP on CA described about goals and objectives of Consortia Research Platform on conservation agriculture (CRP on CA) and the benefits to farmers with respect to resource conservation and better utilization under conservation agriculture and the way forward for conservation agriculture. Similarly Dr. R.S. Chaudhary, Deputy Lead Centre Platform Coordinator (Dy. LCPC) of CRP on CA also highlighted the benefits and profits of the conservation agriculture to the farmers. All the scientists and farmers visited field experiments under Demonstration of Best-Bet Conservation Agriculture Practices on Farmersô Fields in Vertisols of Central India and witnessed the success of field experiments. The field visit was followed by KisanSangosthi for interaction between scientists and farmers to answer the questions related to the conservation agriculture.

Plate 30. Farmer-scientist interaction meet at Khamkheda, Madhya Pradesh

4.3 Kisan Divas was organized at Momanpur on 11/3/2016 to review success and promote conservation agriculture in farmers field.

AnotherKisan Divas was organized by ***ICAR-Indian Institute of Soil Science***, Bhopal at Momanpur, Bhopal on 11.3.2016 under aegis of Consortia Research Platform on Conservation Agriculture (CRP on CA). During the KisanDiwasDr. A.K. Patra, Director, ICAR-IISS, Bhopal addressed the farmers from different villages attending the meeting and briefed the farmers about Institutes programme and also about importance of conservation agriculture. Dr. A.K. Biswas, Lead Centre Platform Coordinator (LCPC) of CRP on CA informed about the Consortia Research Platform on conservation agriculture (CRP on CA) and replied farmerǿs queries. Similarly Dr. R.S. Chaudhary, Deputy LCPC of CRP on CA also highlighted the benefits and profits of the conservation agriculture. All the scientists and farmers visited field experiments under Demonstration of Best-Bet Conservation Agriculture Practices on Farmersô Fields in Vertisols of Central India and appreciated the field experiments. The field visit was followed by KisanSangosthi for interaction between scientists and farmers to answer the questions related to the conservation agriculture.

Plate 31. Farmer-scientist interaction meets at Momanpur, Madhya Pradesh

5. MISCELLANEOUS INFORMATION

(i) Papers published in peer reviewed journal (NAAS rating may be given):

Bhaskar Narjary, Satyendra Kumar, Ranbir Singh, S.K.Singh and D.K.Kamra(2015)Farmer participatory Appraisal of laser leveling to improve water productivity.**Indian farming64 (11), 5-7.**

Jat H.S., Gurbachan Singh, Ranbir Singh, M. Chaudhary, M.L. Jat, M.K.Gathalaand D.K. Sharma(2015) Management influence on maize-wheat system performance, water productivity and soil biology. **Soil Use and Management31(4), 534-543.**

Ranbir Singh, R.S. Tripathi, D.K. Sharma**,** S.K. Chaudhari, P.K. Joshi, P. Dey, S.K.Sharma, D.P. Sharma and Gurbachan Singh (2015) Effect of direct seeded rice on yield,water productivity and saving of farm energy in reclaimed sodic soil. **Indian Journal of Soil Conservation 43(3), 230-235.**

Bhattacharyya, R., Das, T. K.,Sudhishri, S., Dudwal, B., Sharma, A. R., Bhatia, A., and Singh, G.Conservation agriculture effects on soil organic carbon accumulation and crop productivity under a riceï wheat cropping system in the western Indo-Gangetic Plains 2015, **European Journal of Agronomy70: 11–21.**

Mishra, A. K., Aggarwal, P., Bhattacharyya R., Das, T. K., Sharma, A. R. and Singh, R. east limiting water range for two conservation agriculture cropping systems in India 2015**, Soil & Tillage Research 150:43-56.**

Sepat Seema, Sharma, A. R., Kumar D. and Das, T. K. Effect of conservation agriculture practices on productivity and sustainability of pigeonpea (*Cajanuscajan*)- wheat (*Triticumaestivum*) cropping system under Indo-Gangetic Plains of India, 2015 **Indian Journal of Agricultural Sciences 85(2):212-216**

Das, T. K., Bandyopadhyay, K. K., Bhattacharyya Ranjan, Sudhishri, S., Sharma, A. R., Behera, U. K., Saharawat, Y. S., Sahoo, P. K., Pathak, H., Vyas, A. K., Gupta, H.S., Gupta, R.K. and Jat,M.L. Effects of conservation agriculture on crop productivity and water use efficiency under an irrigated pigeonpea-wheat cropping system in the western Indo-Gangetic Plains 2016, ***Journal of Agricultural Science (*Cambridge*)*: 1-16. doi:10.1017/S0021859615001264.**

Hati, K.M., Chaudhary R.S., Mandal K.G., Bandyopadhyay K.K., Singh, R.K., Sinha, Nishant.K., Mohanty, M., Somasundaram, J**.**Saha, R. (2015) Effects of tillage, residue and fertilizer nitrogen on crop yields, and soil physical properties pnderpoybeanï wheat potation in Vertisols of central India. ***Agricultural Research*** 4 (1): 48-56

Kushwaa, V., K.M. Hati, Nishant K. Sinha, R. K. Singh, M. Mohanty**,** J. Somasundaram, R.C. Jain , R.S. Chaudhary, A.K. Biswas, Ashok K. Patra. (2016) Long-term conservation tillage effect on soil

organic carbon and available phosphorous content in Vertisols of central India ***Agricultural Research*** DOI 10.1007/s40003-016-0223-9.

Awanish Kumar, Somasundaram, J,A.K. Biswas, Nishant K. Sinha, V. N. Mishra, R. S. Chaudhary, M.Mohanty, J.K. Thakur and A.K. Patra (2016). Soil organic carbon, dehydrogenase activity and fluorescein diacetate as influenced by contrasting tillage and cropping systems in Vertisols of Central India, ***International Journal of Bio-resource and Stress Management*****(Accepted).**

Awanish Kumar, Somasundaram, J.,A.K.Biswas, Nishant K. Sinha, V.N. Mishra, R.S.Chaudhary, M.Mohanty, K.M.Hati, R.Saha, and A.K.Patra. 2016. Short-Term Effect of Conservation Agriculture Practices on Soil Quality in Vertisols of Central India. ***Journal of Applied Biological Research (*****Accepted).**

(ii) Papers presented at scientific meetings:

Ranbir Singh, D.K. Sharma, S.K. Chaudhari, P.K. Joshi, and R.S. Tripathi, S.K.Sharma,P.Dey, D.P.Sharma, Gurbachan Singh (2015) Effects of direct seeded rice and transplanted rice on yield, water productivity and resource economy of hybrid rice under reclaimed alkali soilò. Presented in XII Agricultural Science Congress-Sustainable Livelihood security for Smallholder Farmers 3rd-6th February 2015 at National Dairy Research Institute, Karnal, (Haryana).

(iii) Manuscripts under preparation:

Ranbir Singh, R.S.Tripathi, S.K.Chaudhari , P.K. Joshi , P.Dey, S.K.Sharma , D.P. Sharma, Gurbachan Singh and D.K.Sharma (2015-16) Changes in soil properties under different techniques of resource conservation in rice ï wheat System.

Saha, S., Minhas, P.S. and Choudhary, R.L. Monitoring Greenhouse Gas Fluxes in Agro-Ecosystems. Manuscript submitted (8-February, 2016) to the Indian Ecological Society for publication as a chapter in a book on the broad theme ñCrop-Environment Interactionò. (*Communicated*)

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रणबीर सिंह, डी0 के0 भार्मा,एस0 के0 चौधरी आर0 एस0 त्रिपाठी एवं सत्येन्द्रकुमार 2015–2016 सपरिंकलर सिंचाइ ंका धान–गेहूँ फसलों के उत्पादन में सफल परीक्षण।

रणबीर सिंह, डी0 के0 भार्मा , एस0 के0 चौधरी एवं आर0 एस0 त्रिपाठी ; 2015 गेहूँ की खेती धान अवशेशों के साथ भुान्य जुताईं करके कम खर्च में अच्छी पैदावार कैसे करें।