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INDIAN COUNCIL OF AGRICULTURAL RESEARCH

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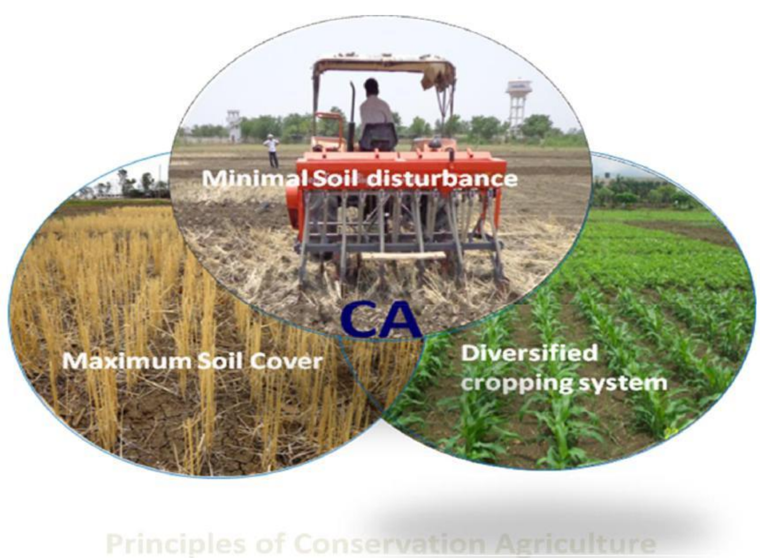
on
Conservation Agriculture

ANNUAL REPORT 2017-18



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1. Background

Agriculture is the most important sector in India; accounting for 17-18 per cent of the country's GDP and employs more than 60 per cent of the labour force. Food grain production of the country has reached a record 284.83 million tonnes during 2017-18, 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 interactions in 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.

1.1 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 rice–wheat system. Other interventions being tested and promoted in the Indo-Gangetic plains include raised-bed planting, laser-aided land-levelling, residue management alternatives, and alternatives to rice–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-levelling, 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.

1.2 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 cellulose–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 m^3 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.

1.3 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.

1.4 Mission

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

1.5 Objectives

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

1.6 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 farmers' 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.

1.7 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 for effective dissemination of CA programme.

2. Research Highlights of Irrigated and RainfedEco-systems (2017–18)

2.1 Irrigated and Rainfed Eco-systems

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.

- Develop and validate location specific CA technologies for sustainable intensification of cropping systems across agro-ecologies.

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

2.1.1 Develop and Validate location specific CA technologies for sustainable intensification of cropping systems across agro-ecologies.

2.1.1.1 Tillage and Residue management

Rice- Greengram (NRRI)

In Rice

A field experiment was carried out to study the effect of different establishment methods on the promising rice varieties under conventional and zero/minimum tillage situations to identify and recommend suitable rice variety for conservation agriculture. The experiment was laid out in a split-factorial plot design with two establishment methods i.e. DSR and TPR, two tillage systems i.e. conventional and zero tillage in main plots 1 and 2, respectively. The sub plot consisted of two residue management systems i.e. no residue incorporation and residue incorporation as sub-plot 1 and, 10 rice varieties as sub-plot 2. The varietiesviz., CR Dhan 201, CR Dhan 202, CR Dhan 203, CR Dhan 204, CR Dhan 300, CR Dhan 303, CR Dhan 304, CR Dhan 305, Swarna and Naveen used in the experiment to study their relative performance. Rice variety Naveen recorded significantly higher yields under ZT+TPR+Residue (6.03 t ha^{-1}) and ZT+TPR+ No Residue (5.95 t ha^{-1}) followed by Swarna, CR Dhan 303 and CR Dhan 304. Significantly higher yield of rice variety Swarna and CR Dhan 304 recorded significantly higher yields under ZT+DSR+Residue (3.76 t ha^{-1}) than rest of the varieties. Rice varieties CR Dhan 303 (4.29 t ha^{-1}) and CR Dhan 304 (4.32 t ha^{-1}) recorded significantly higher yield under ZT+DSR+No Residue than rest of the varieties.

Trial for evaluation of promising rice varieties under conservation tillage (Zero tillage-DSR)

Mechanical transplanting under Zero tillage-TPR

In Green gram

A field experiment was carried out to study the effect of different establishment methods of rice in *kharif* season on the succeeding green gram varieties in *rabi* season under conventional and zero/minimum tillage situations to identify and recommend suitable green gram variety for conservation agriculture.

Among the Green gram varieties, highest grain yield was recorded with IPM-2 – 3 (10. 9 q/ha) followed by IPM-2-14 (10.46 q/ha) and Landrace (8.07 q/ha). Green gram (*Rabi* crop) recorded highest grain yield (10.13q/ha) when grown after ZT- DSR (*Kharif* crop) which was at par with ZT-TPR (10.03q/ha) and significantly higher than green gram yield (8.03 q/ha) grown after conventional DSR.

(a)

(b)

Mechanical seeding of green gram under (a) Zero tillage and (b) Conventional tillage

Rice-Wheat cropping sequence (CSSRI)

In Rice

A) TPR-2017

Highest grain yield of rice (7.42 tha^{-1}) was recorded in conventional transplanted rice with wheat residue incorporation followed by conventional transplanting (7.01 tha^{-1}) without crop residue (Fig.1). Crop residue incorporation in transplanted rice resulted ~5.85% higher additional grain yield without saving any natural resources in TPR.

Fig.1- Experimental view of transplanted rice with wheat residue incorporation

B) DSR-2017 - In DSR with crop residue grain yield was 6.90 tha^{-1}, which was 6.15% higher in comparison to DSR without crop residue, saved 30.95% irrigation water, 37.94% energy and more than 30.95% electricity with a penalty of grain yield ~1.57% in comparison to TPR (Fig 1).

Experimental view of DSR in reduce tillage (Residue incorporation, sowing, germination) and DSR in zero tillage with wheat residue, germination in anchored and rice performance)

In Wheat (CSSRI)

Effects of tillage on grain yield of wheat

The experiment of wheat under basic research trial is continuing and data presented in Table 3&4 and Fig. 2&3 shows that wheat sowing in 50% reduced tillage, conventional with rice residue incorporation produced highest grain yield (5.43 tha^{-1}) compared to conventional (4.73 tha^{-1}). It was 14.80% higher than conventional wheat sowing during 2015-16 crop season. But in 2016-17 crop season, it was 8.02% higher over conventional wheat sowing. In zero tillage wheat sowing method, grain yield increase significantly both in 2015-16 and 2016-17 crop seasons.

Results indicates that wheat grain yield increased in both 50% reduced tillage and wheat in zero tillage wheat management techniques. Grain yield in zero tillage and 50% reduce tillage observed statistically similar without crop residue management. It is clear from the data that growing wheat in zero tillage is better than 50% reduced tillage and conventional wheat sowing after rice crop.

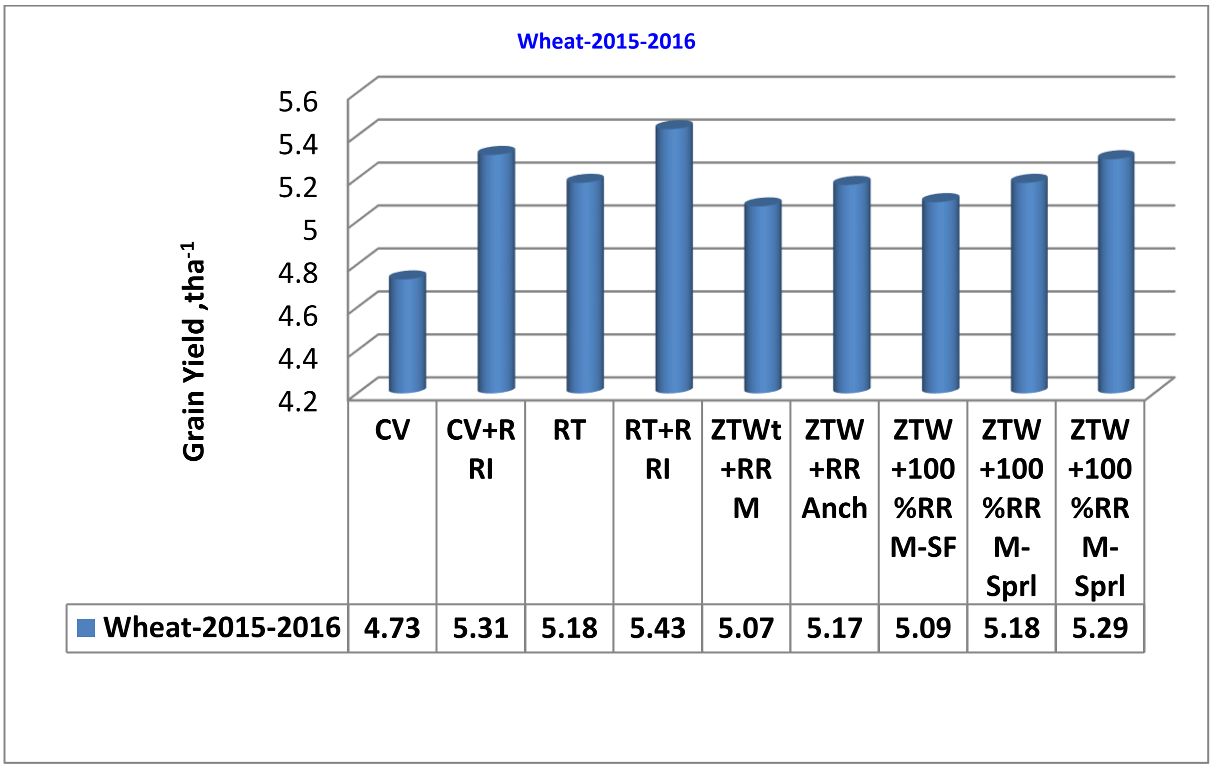


Fig.2 Effects of different resource conservation techniques on wheat grain yield during the period of 2015-16 (CD at 0.05= 0.34)

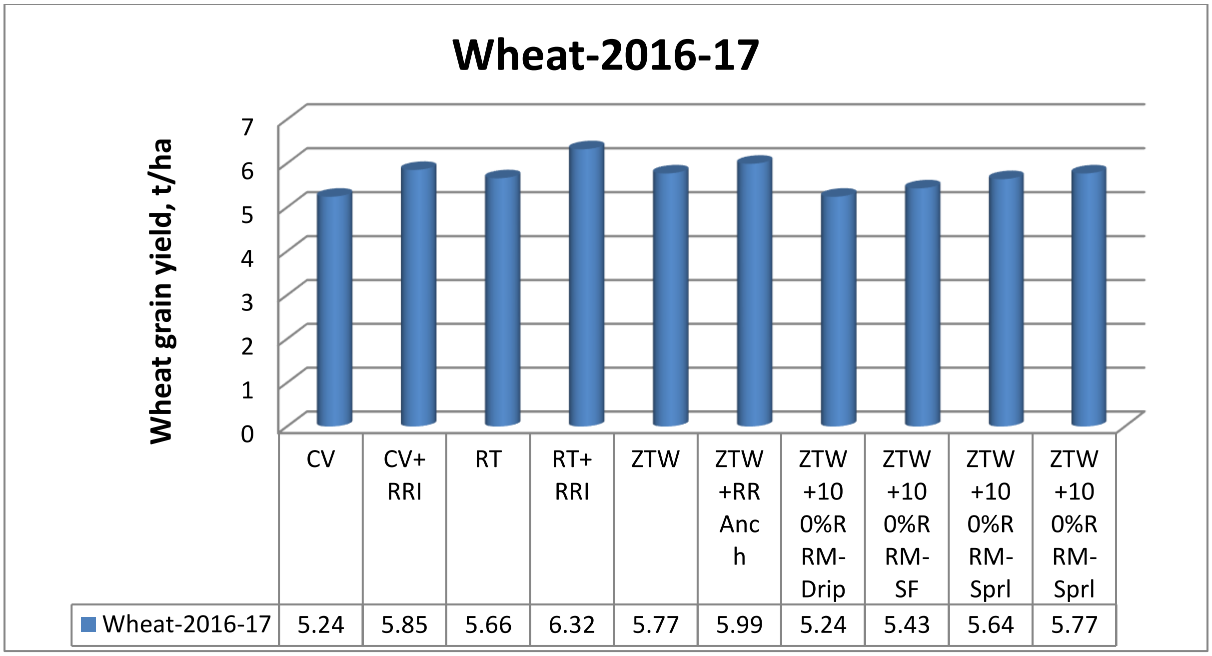


Fig.3. Effects of different resource conservation techniques on wheat grain yield during the period of 2016-17 (CD at 0.05=0.36)

(Note: CV= Conventional tillage; RRI= Rice residue incorporation; RT= Reduced tillage; ZT= zero tillage; RRM=rice residue mulch and SPL= sprinkler irrigation.)

Table-3 Effects of tillage with residue management on wheat grain yield during 2015-16 and 2016-17 in rice-wheat cropping system.

RCTs	**Tillage Management**					
	Without crop residue			**% Grain yield increased over conventional tillage**		
Crop/year	**Wheat 2015-16**	**Wheat 2016-17**	**Wheat 2017-18**	**Wheat 2015-16**	**Wheat 2016-17**	**Wheat 2017-18**
CV-tillage	4.73	5.24	-	-	-	-
50% Reduced tillage	5.18	5.66	-	9.51	8.02	-
Zero tillage	5.07	5.77	-	7.19	10.11	-
CD (0.05)	0.34	0.36	-	-	-	-

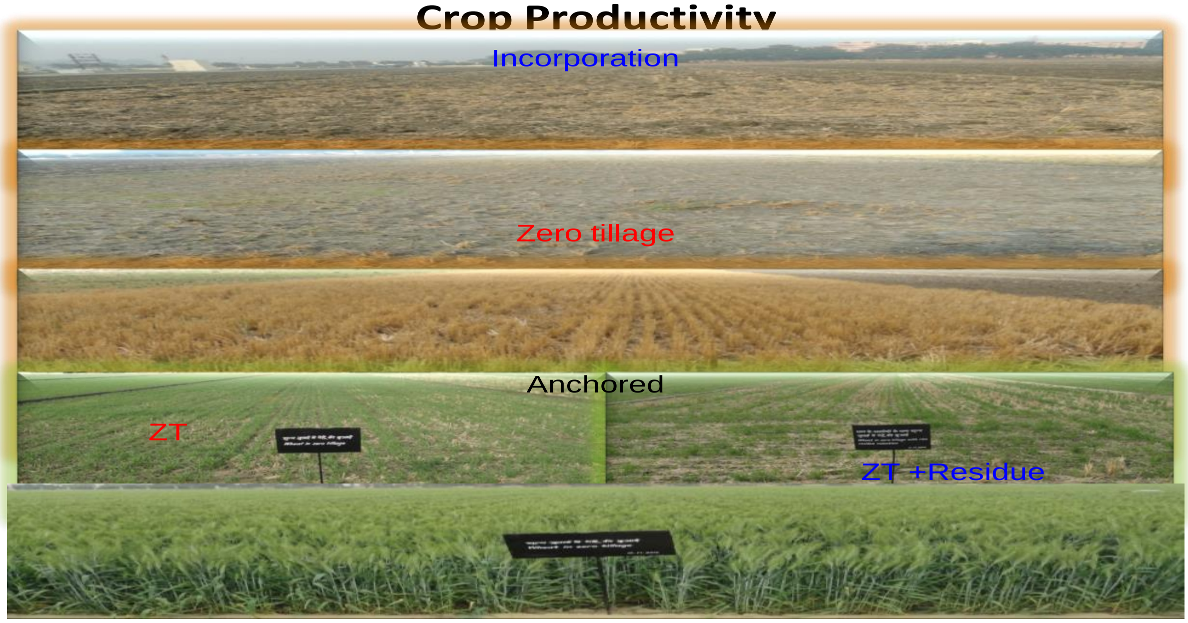
Table-4 Effects of tillage with residue on wheat grain yield during 2015-16 in Rice-Wheat cropping system.

RCTs	**Tillage management with crop residue**					
	With crop residue			**% Grain yield increased over conventional tillage**		
Crops	**Wheat 2015-16**	**Wheat 2016-17**	**Wheat 2017-18**	**Wheat 2015-16**	**Wheat 2016-17**	**Wheat 2017-18**
CV-WR	4.73	5.24	-	-	-	-
CV	5.31	5.85	-	12.26	11.64	-
RT	5.43	6.32	-	14.80	16.60	-
ZT	5.17	5.99	-	9.30	14.31	-
CD at 0.05	0.34	0.36	-	-	-	-
CV-WR=conventional wheat without rice residue. Wheat 2017-18 data will be included in the next RPP-II after presentation in IRC 2018-19.						

Residual effects of crop residue management on wheat yield

Crop residue incorporation/anchored/mulched all influenced wheat grain productivity. The data is given in table 3&4 and fig.2&3 shows that where wheat sown in rice crop residue (1/3 part) incorporation under conventional wheat sowing method, produced ~12.26 % additional grain yield during the year of 2015-16 rabi season and 11.64 % in 2016-17 crop season. Similarly, wheat grain yield increased under 50% reduced tillage with rice residue incorporation wheat sowing method by 14.80 and 16.60% in 2015-16 and 2016-17 crop seasons, respectively in comparison to conventional wheat sowing method. In zero tillage wheat sowing with rice residue anchored method also increased wheat grain yield by 9.30 and 14.31% higher than that of conventional wheat sowing method (table 5&6).The results clearly shows that wheat grain yield increased with rice residue management in-situ under all tillage options. Among the three tillage options found that wheat sowing in zero tillage with rice residue was relatively better. It may be because of optimum soil moisture and favourable temperature regulation under residue managements to facilitated better seed germination and crop growth as compared to no- residue wheat sowing methods. In zero tillage wheat sowing with rice residue anchored produced 5.17 tha^{-1} and 5.99 tha^{-1} which is 9.30 and 14.31% higher than conventional wheat sowing method (table 5&6) and 1.97 and 3.81% greater than zero tillage wheat sowing without crop residue technique in 2015-16 and 2016-17 crop seasons, respectively .

Effect of Tillage and Residue Management on Wheat Crop Productivity



Experimental view of wheat germination under rice residue incorporation/anchored and zero tillage conditions.

Effect of tillage, crop residue and nutrient management practices on sugarcane productivity: (NIASM)

A field experiment was conducted with three main plot treatment combination of tillage and nutrient scheduling and application methods *viz.*, M1: laser land levelling (LLL) + conventional tillage (CT) + 10 % of recommended dose of fertilizers (RDF; 250:120:120; N:P:K; kg ha^{-1}) applied as basal and remaining 90 % doses of fertilizers applied through fertigation, M2: LLL + reduced tillage (RT) by excluding deep tillage + 10 % of RDF as basal and 90 % through fertigation and M3: LLL + RT + 10 % of RDF as basal, 40 % through band placement and remaining 50 % through fertigation. In M3 treatment, 40 % of RDF was band placed with SORF machine rather than broadcasting in standing crop at 60 days after planting of sugarcane. The fertigation was done at 15 days interval started at 15 days after planting as per the treatments. Two treatment of soil surface cover management practices *viz.,* T1: Residue; covering of soil surface with a live mulch of mungbean followed by retention of mungbean residue and trash as mulch and T2: without residue were accommodated in sub-plots. An absolute control with CT without LLL, recommended nutrient and surface irrigation management practices was also maintained to compare the treatment effects. A uniformity trial was also conducted with fodder maize after laser land levelling. The pictorial view of the various treatments applied in the experimental field has been given in Fig. 5.

Laser land leveling (LLL)

Fodder maize

Sugarcane establishment

Mungbean as live mulch

Band placement of fertilizers in sugarcane with SORF machine

Recycling of trash as mulch

Control (without LLL)

Fertigation unit

Fig. 5. Application of treatments in experimental field of sugarcane.

The results revealed that there was no significant difference in cane yields (var. MS 10001) under conventional tillage (M1) and reduced tillage practices (M2) practices. It indicated that reduced tillage could be adopted without compromising with the cane yield. Furthermore, application of 40 % of RDF through band placement and 50 % of RDF through fertigation (M3) improved the cane yield significantly over the application 90 % of RDF through fertigation (Fig. 6 & 7). The yield improvement with M3 over M1, M2 and conventional sugarcane management practices (M4) treatments was 8, 10 and 23 %, respectively. This might be due to that band placement of 40 % of RDF provided the initial boost to the crop growth and remaining 50 % applied through drip fertigation helped in sustaining the crop growth during the grand growth stage through synchronized supply of nutrients. Laser land levelling and drip irrigation practices not only saved the irrigation water (48 %) but also improved the cane yield to the tune of 11 %.

M1: CT + RDF (90% fertigation)

M2: RT + RDF (90% fertigation)

M3: RT + RDF (40% SORF + 50% fertigation)

Fig. 6. Effect of tillage and nutrient management practices on performance of sugarcane.

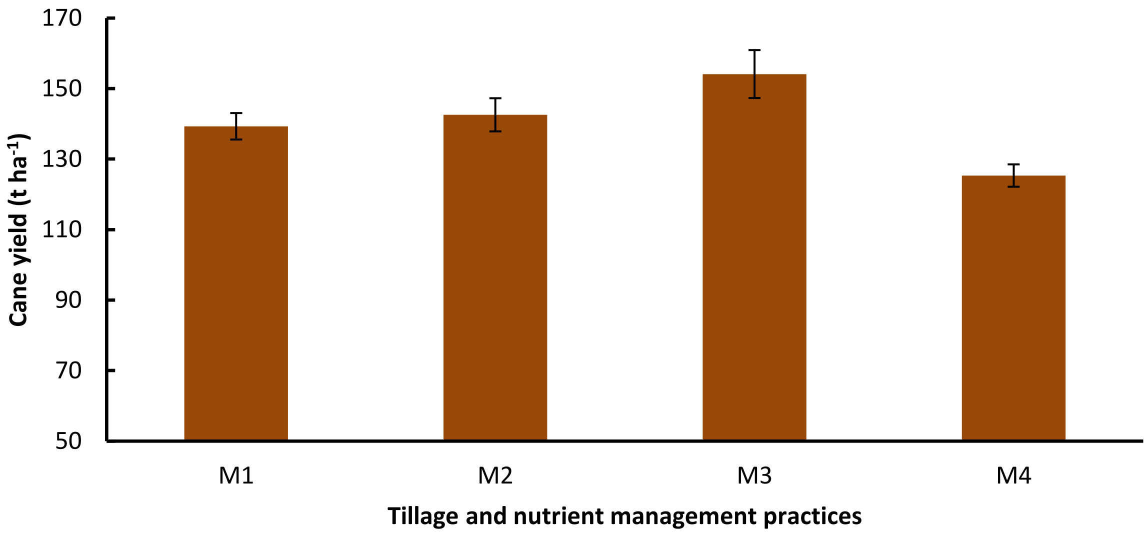


Fig. 7. Effect of tillage, residue and nutrient management practices on cane yield of sugarcane.

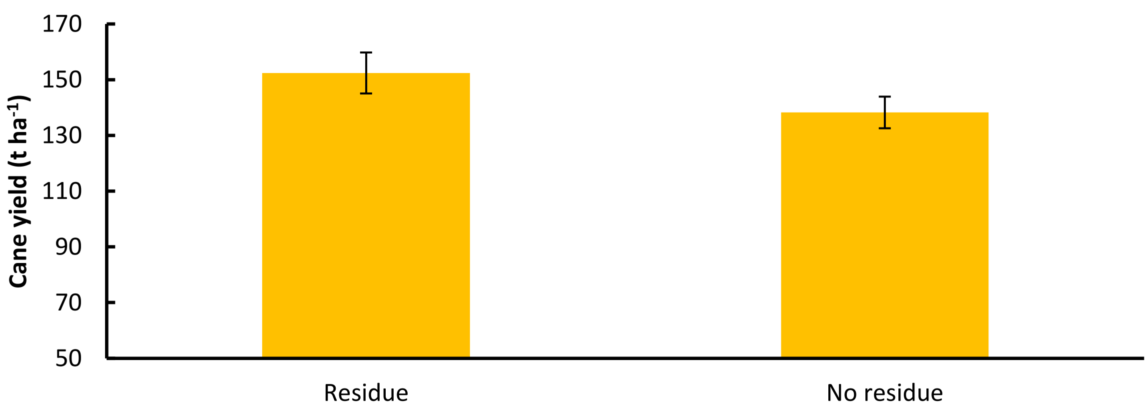


Fig. 8. Effect of crop residues (mungbean + trash) on cane yield of sugarcane.

Furthermore, covering of soil surface with live mulch of mungbean followed by retention of mungbean residue and trash in the field improved the cane yield on an average by 10 % as compared to without residue (Fig. 8 & 9).

RT with residue (mungbean + trash)

RT without residue

CT with residue (mungbean + trash)

CT without residue

Fig. 9. Effect of crop residues (mungbean + trash) on performance of sugarcane.

Moreover, growing of mungbean with sugarcane as live mulch not only served the purpose of soil surface cover but also provided the economic seed yield and crop residues. The maximum seed yield of mungbean was recorded under M3 treatment (RT+RDF applied with SORF (40%) & fertigation (50%)) which was 4 and 8 % higher than M1 and M2 treatments, respectively (Fig. 10). However, stover yield did not influence much due to different tillage and nutrient management practices.

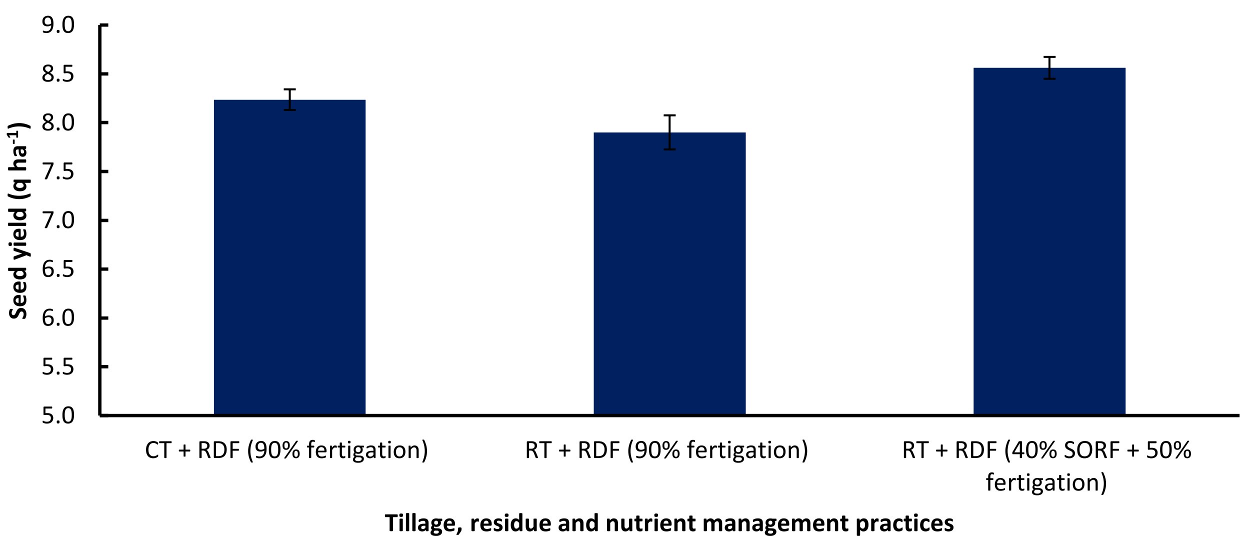


Fig. 10. Effect of tillage, residue and nutrient management practices on seed yield of mungbean.

Strategies to enhance crop residue retention under Rainfed Agriculture (CRIDA)

1. Pigeonpea-Castor system

An experiment was initiated in 2009 in pigeon pea castor cropping system to study the strategies to enhance residues. The test crop in 2017 was pigeonpea. The experiment was laid out in split plot design with tillage practices as main plots and anchored residues (different harvest heights) as subplots. The different tillage practices were: conventional tillage (disc ploughing in off season, cultivator, disc harrow and sowing of crop), Reduced tillage (plouging once with cultivator and disc harrow), Zero tillage (direct sowing in residues). The pigeonpea crop was sown in the castor residue stubbles (previous year crop) retained by harvesting the castor crop at different heights, with CRIDA precision planter. The different residue levels were maintained by harvesting the crop at different heights (0 cm, 10 cm and 30 cm) to increase the residue contribution to the field. In addition to the previous crop residues, the daincha crop was sown in between the widely spaced pigeonpea, this crop was cut at 45 DAS and applied to the field as mulch. This year the germination of pigeon pea in all the tillage treatments was good. The germination and growth of intercrop daincha was good. 1200-1600 kg of daincha was added to the soil. The pigeonpea yields in ZT was 30 and 20% higher as compared to CT and RT after 10 years of experiment. The pigeonpea seed yields increased with increase in residue (harvesting heights). 10 cm and 30 harvest height has recorded 25 and 30 % higher yields as compared to 0 cm height (No residues).

Strategies for enhancing residue retention in Rainfed region

a. Manipulation of harvesting height at 0cm, 10cm, 30cm respectively shown in figure.

b. Growing of green manure crop in between widely spaced Pigeonpea and Castor

2. Sorghum-Black gram system

A long-term experiment was initiated during 2013 with sorghum and black gram as test crops in yearly rotation at Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad. The experiment was laid out in a strip plot design with two tillages: conventional (CT) and minimum (MT) (treatments effective from 1998) and three residue retention treatments (started w.e.f 2013) viz; No residue application (S1), harvesting at 35 cm height (1/3 rd height)(S2), harvesting at 60 cm height (S3) in case of sorghum. For black gram crop, the residue retention treatments were as follows: No residue (S0), 50% of the residue retention (S1) (Clearing of residue from alternate rows), 100% retention (S2). During the current year, sorghum (CSV-27) was the test crop in rotation. Nitrogen @ 60 N kg ha^{-1} and Phosphorus @ 30 kg P_2O_5 were applied uniformly in all the plots. The results of the experiment showed that despite non significant values, sorghum biomass yield was relatively higher (8%) with minimum tillage compared to conventional tillage. However, the biomass yield significantly increased with the increase in the amount of blackgram residue retained. Sorghum grain yield varied from 1108 to 1684 kg ha^{-1} across different treatments. Minimum tillage recorded (1497 kg ha^{-1}) significantly higher grain yield (18%) compared to conventional tillage (1263 kg ha^{-1}) (Table 1). Sorghum grain yield significantly varied with residue retention treatments of previous crop (blackgram). Among the residue retention treatments, 100% residue retention of blackgram crop recorded significantly higher sorghum grain yield of 1565 kg ha^{-1} followed by S1 (50% residue retention) (1386 kg ha^{-1}) compared to no residue retention (control) (1229 kg ha^{-1}). The increase in grain yield with 50% and 100% residue retention was 9 and 27% yield over control. The sorghum grain yield in control and 50% residue were on par.

Table 1. Long term effect of conservation tillage and residue retention of previous crop on biomass and grain yield ($kgha^{-1}$)

Tillage	**S0: No residue retention**		**S1: 50% residue retention**		**S2: 100% residue retention**	
	Biomass Yield ($kgha^{-1}$)	Sorghum Yield ($kgha^{-1}$)	Biomass Yield ($kgha^{-1}$)	Sorghum grain Yield ($kgha^{-1}$)	Biomass Yield ($kgha^{-1}$)	Sorghum grain Yield ($kgha^{-1}$)
Minimum tillage	4111	1351	4525	1455	5234	1684
Conventional tillage	3668	1108	4212	1238	4977	1445
CD (0.05)						
Tillage	NS	200.33	NS	200.33	NS	200.33
Residues*	245.83	116.18	245.83	116.18	245.83	116.18
T X R	NS	NS	NS	NS	NS	NS

3. Finger millet + Pigeonpea

Studies were initiated in fingermillet +pigeonpea in rainfed ecosystem at Bangalore to utilize the off season rainfall and increase the residues. The field bean and horse gram were the cover crops. The performance of both the crops was good.

Table 2: Biomass yield of field bean and horse gram

Treatment	Field bean (kg/ha)	Horse gram (kg/ha)
Conventional tillage	1479	1876
Reduced tillage	1390	1632
Zero tillage	1291	1480


Horse gram


Field bean

The biomass yield of field bean and horsegram were not significantly influenced by the tillage treatments.

Table 3 : Yield, economics and rain water use efficiency as influenced by conservationagriculture practices in finger millet + pigeonpea intercropping (8:2)

Treatments	Yield (kg ha^{-1})				Returns (Rs. ha^{-1})		B: C ratio	RWUE (kg ha-mm^{-1})
	Finger millet grain	Straw	Pigeonpea grain	finger millet equivalent	Gross	Net		
TILLAGE								
M_1	2338	4014	130	2565	65017	34430	2.12	3.74
M_2	2113	3492	117	2316	58498	28755	1.97	3.38
M_3	1644	2380	91	1802	45015	19039	1.73	2.63
S. Em. ±	**42.95**	**210.45**	**6.75**	**51.28**	**-**	**-**	**-**	**-**
CD (p=0.05)	**168.63**	**826.32**	**26.51**	**201.37**	**-**	**-**	**-**	**-**
COVER CROP								
C_1	1776	2827	102	1953	49160	20667	1.71	2.85
C_2	1910	3131	106	2094	52864	23951	1.83	3.05

C_3	2409	3928	130	2635	66507	37607	2.28	3.84
S. Em. ±	**36.69**	**189.43**	**5.21**	**43.32**	**-**	**-**	**-**	**-**
CD (p=0.05)	**113.04**	**583.69**	**16.06**	**133.47**	**-**	**-**	**-**	**-**
INTERACTIONS								
M_1C_1	2094	3473	126	2313	58409	28096	1.93	3.37
M_1C_2	2077	3895	115	2276	58201	27468	1.89	3.32
M_1C_3	2844	4675	150	3106	78441	47728	2.55	4.53
M_2C_1	1971	2748	109	2160	53808	24345	1.83	3.15
M2C_2	1803	3255	100	1976	50328	20445	1.68	2.88
M_2C_3	2566	4472	141	2811	71358	41475	2.39	4.10
M_3C_1	1264	2260	70	1386	35262	9558	1.37	2.02
M_3C_2	1851	2243	103	2030	50064	23941	1.92	2.96
M_3C_3	1817	2637	100	1990	49721	23618	1.90	2.90
S. Em. ±	**63.54**	**328.10**	**9.03**	**75.03**	**-**	**-**	**-**	**-**
CD (p=0.05)	**195.79**	**NS**	**NS**	**231.18**	**-**	**-**	**-**	**-**

Among different tillage practices, conventional tillage recorded significantly higher finger millet equivalent yield (2565 kg ha^{-1}) and straw yield (4014 kg ha^{-1}) as compared to reduced tillage (2316 and 3492 kg ha-1) and zero tillage (1802 and 2380 kg ha^{-1}). Higher gross returns (₹ 65017 ha^{-1}), net returns (₹ 34430 ha^{-1}), benefit cost ratio (2.12) and higher water use efficiency (3.74 kg ha-mm^{-1}) was recorded with convention tillage compared to reduced and zero tillage (Table3). Both cover crops horsegram and field bean recorded significantly higher yield as compared to no cover crop. Among the cover crops horsegram recorded higher finger millet yield, straw yield, net returns, B:C ratio as compared to no cover crops.

Interaction between tillage and cover crops was significant, conventional tillage with horsegram recorded higher equivalent yield (3106 kg ha^{-1}), gross returns (Rs 78441 ha^{-1}), net returns (Rs 47728 ha-1), benefit cost ratio (2.55) and rain water use efficiency**.**

B)Integration of in-situ moisture conservation with CA principles

In general, in rainfed regions, the gap in the crop yields between conservation agriculture and conventional tillage is higher under low rainfall years whereas, this yield gap is narrow in good rainfall years. The low yields in zero tillage in low rainfall also might be due to poor residue yields which results in low soil moisture retention hence, integration of in-situ soil moisture conservation along with three principles of CA is essential to increase the soil moisture content and thereby improve the crop yields in CA systems. Hence, experiments were initiated in maize-horsegram and maize –pigeonpea in Alfisols at Hyderabad and one experiment at Akola in soybean- chickpea system in vertisol to explore the possibility of including insitu moisture conservation as fourth principle in CA systems.

1. Maize – Horsegram

An experiment was initiated with four tillage treatments in maize – horsegram system. Farmers' practice of conventional tillage for both kharif followed by fallow, minimum tillage during *kharif* and the *rabi* crops with zero tillage for both *kharif* and *rabi* crop and zero tillage with ridge and furrow. Both Kharif and the *rabi* crop sown with zero tillage in the standing residues of *kharif* crop. The residue treatments consist of three residue retention treatments, viz., farmers' practice of harvesting close to the ground without any retention of residues, harvesting maize at a height of 30 cm and retaining them, harvesting only cobs and retaining the entire stubbles as such. The experiment was laid out in split plot design. The crop was sown with implement.

Crop growth, biomass production, yield and yield attributing characters were relatively higher in the zero till treatment combined with the ridge and furrow as compared to other treatments. The residue recorded higher biomass, yield attributing characters and yield compared to control. Among the residue retention levels, 100% residue retention recorded higher yield as compared to 50% and control.

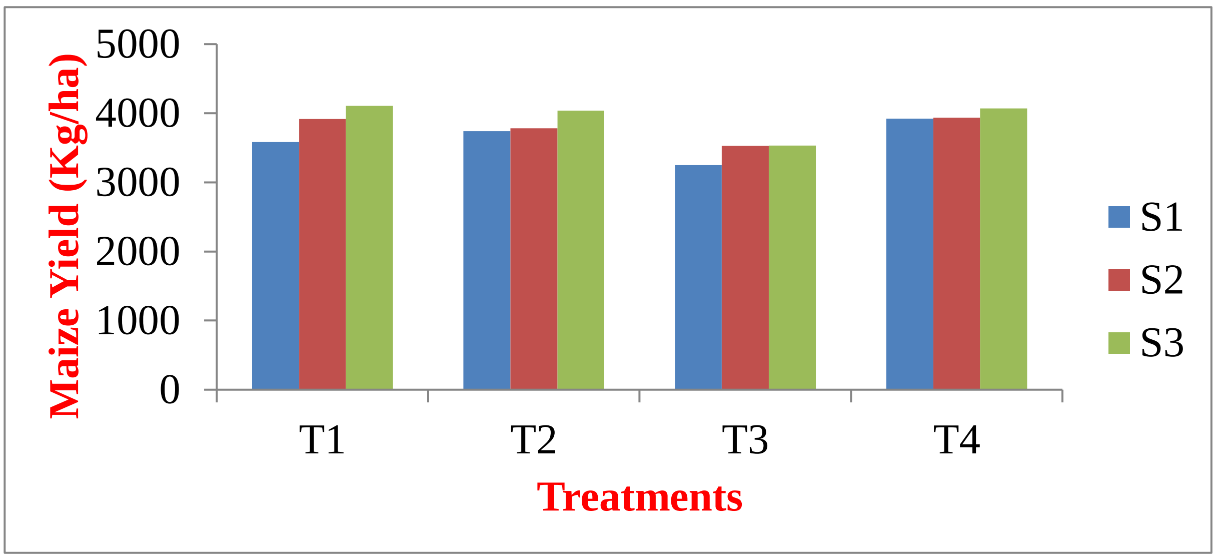


Fig1: Grain yield of maize (q/ha) as influenced by the tillage treatments and the residue retention

T1- Farmers' practice, T2- Minimum tillage, T3-Zero tillage, T4-Zero tillage with soil and water conservation; Sub plots, S1- Framers' practice of harvesting close to the ground (Little residue), S2- Harvesting maize at 30 cm height and remaining residue removed from the field, S3- Harvesting only cobs and retaining the entire residues as such

2. Maize- Pigeonpea system

An experiment was initiated with the integration of insitu moisture conservation with CA practice in maize-pigeonpea system in 2014. This year, pigeonpea was the test crop in rotation. The pigeonpea crop was sown on the permanent bed and furrow which were prepared during 2014 .However, the bed and furrows and conservation furrow were reshaped at the time of sowing in zero tillage, whereas in conventional method, furrows and beds were prepared every year before sowing with the implements.

Integration of insitu moisture conservation practices either through conservation furrow or bed and furrow method in both CA and Conventional tillage has recorded higher yield as compared to no moisture conservation treatments. CT with no residues recorded 10 % lower yields as compared to CT with residues. In both the crops, in both tillage systems viz. ZT and CT, the growth of the crop was better in conservation furrows, and raised bed as compared to flat sowing without conservation furrows. Insitu moisture conservation with furrow has recorded higher yields in both conventional tillage and conservation agriculture treatment.

Fig: 2 Reshaping of a) Bed and furrow in Zero tillage b) Conservation furrow

3. Soybean-Chickpea

Experiments were initiated in 2016 in soybean-chickpea system in black soils at Akola. The crop growth, yield and yield attributes were not significantly influenced by tillage, residue treatments and their interaction.

The growth, yield attributes and yield were significantly influenced by the different treatments. Higher soybean grain yield was recorded in zero tillage and conventional tillage and were found significantly superior over other treatments and are at par with each other. In terms of straw yield of soybean, the treatments T3 and T2 were found significantly superior over other treatments and were at par with each other. The rainwater use efficiency was observed to be higher in the treatments T3 and T1 as compared to other treatments.

Table 4. Growth, yield attributes and productivity of soybean as influenced by differenttreatment combinations

Treatments	Number of filled pods/plant	Grain weight (g plant^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Rain water use efficiency (kg ha^{-1}mm^{-1})
T1	20.3	6.63	733	1040	1.41
T2	18.9	6.54	718	1119	1.38
T3	23.0	7.81	838	1196	1.62
T4	18.0	6.09	688	1003	1.33
T5	17.4	5.73	643	965	1.24
S. E. (m)	0.594	0.392	37.79	31.04	
C.D. 5%	1.85	1.22	117.75	96.71	

Long term effect of tillage, residue and nutrient management in maize-wheat-green gram system (IIWBR)

At ICAR-IIWBR (29˚42'22"N; 85˚40'13"E), a long term experiment was initiated during Kharif 2015, to evaluate the "Long term **effect of tillage, residue and nutrient management in maize-wheat-green gram system**" in a systems' perspective. 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 20.0 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(150 q/ha) after removing the cobs was either removed, or retained or incorporated. The incorporation was done using rotary tiller. The irrigationswere 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).

The perusal of data in Table-1 revealed that the effect of nutrient management was significant, whereas the effect of tillage and residue management and their interactions were non-significant. The plant height was minimum (66.4 cm)in absolute unfertilized control treatment. Among four nutrient management options minimum yield was recorded in unfertilized controlplots having a mean yield of 14.47 q/ha. The poor yield in this treatment was due to lesser yield attributes mainly the effective tillers. The wheat grain yield was maximum (62.48 q/ha) when FYM @ 10t/ha was applied along with Rec. NPK. However, statistically this treatment was at par with Rec. N alone and Rec. NPK application.

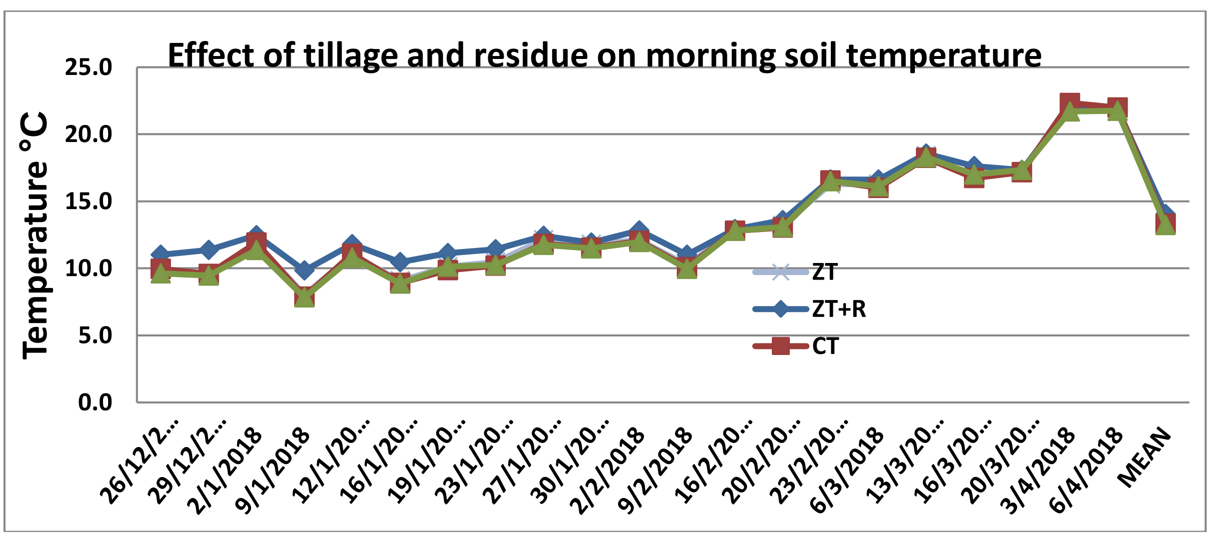
Table 1. Effect of tillage, residue and nutrient management in wheat under Maize-wheat system during 2017-18

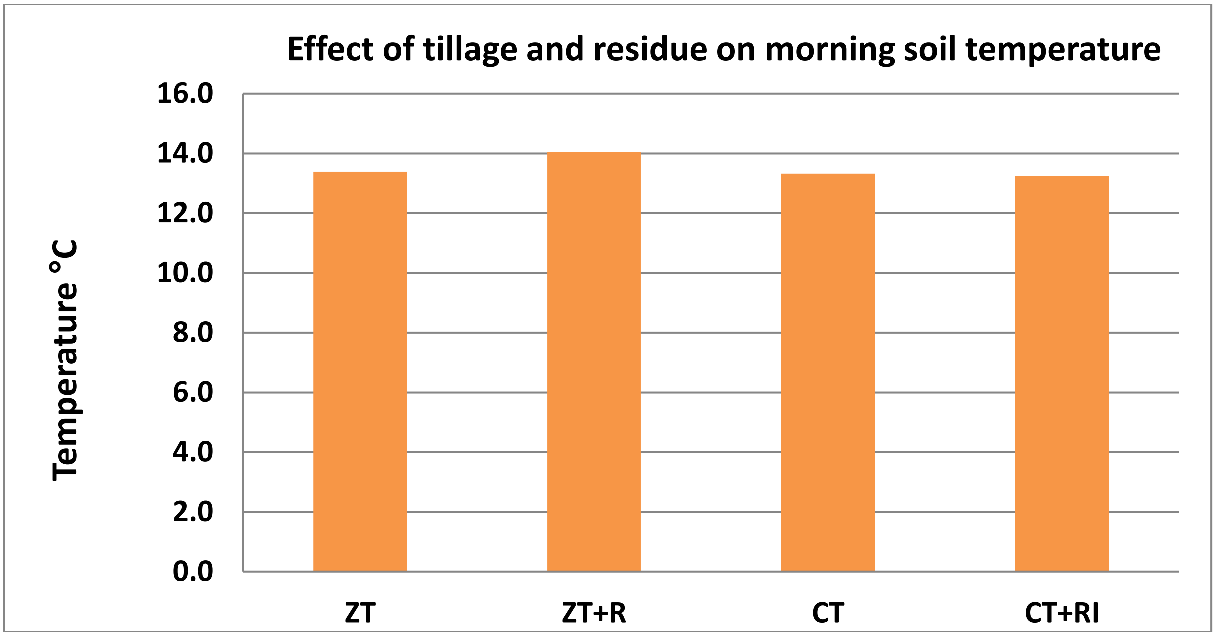
Tillage and residue management	**PlantHeight (Cm)**	**Ear head length, cm**	**Tillers/m^2**	**Yield q/ha**	**1000 grain weight, g**
ZT	98.7	8.5	340.8	50.25	40.70
ZT+R*	99.8	8.5	328.8	49.41	41.22
CT	97.5	8.2	335.4	49.85	40.59
CT+RI*	97.6	8.2	326.7	49.23	41.08
CD at 5%	NS	NS	NS	NS	NS
Nutrient management					
Control	66.4	4.9	221.0	14.47	40.18
N Alone	108.0	9.4	360.4	60.95	40.52
Rec. NPK	109.4	9.6	370.4	60.86	41.05
Rec. NPK+ FYM 10t/ha	109.8	9.6	379.8	62.46	41.84
CD at 5%	3.32	0.50	22.66	2.07	NS

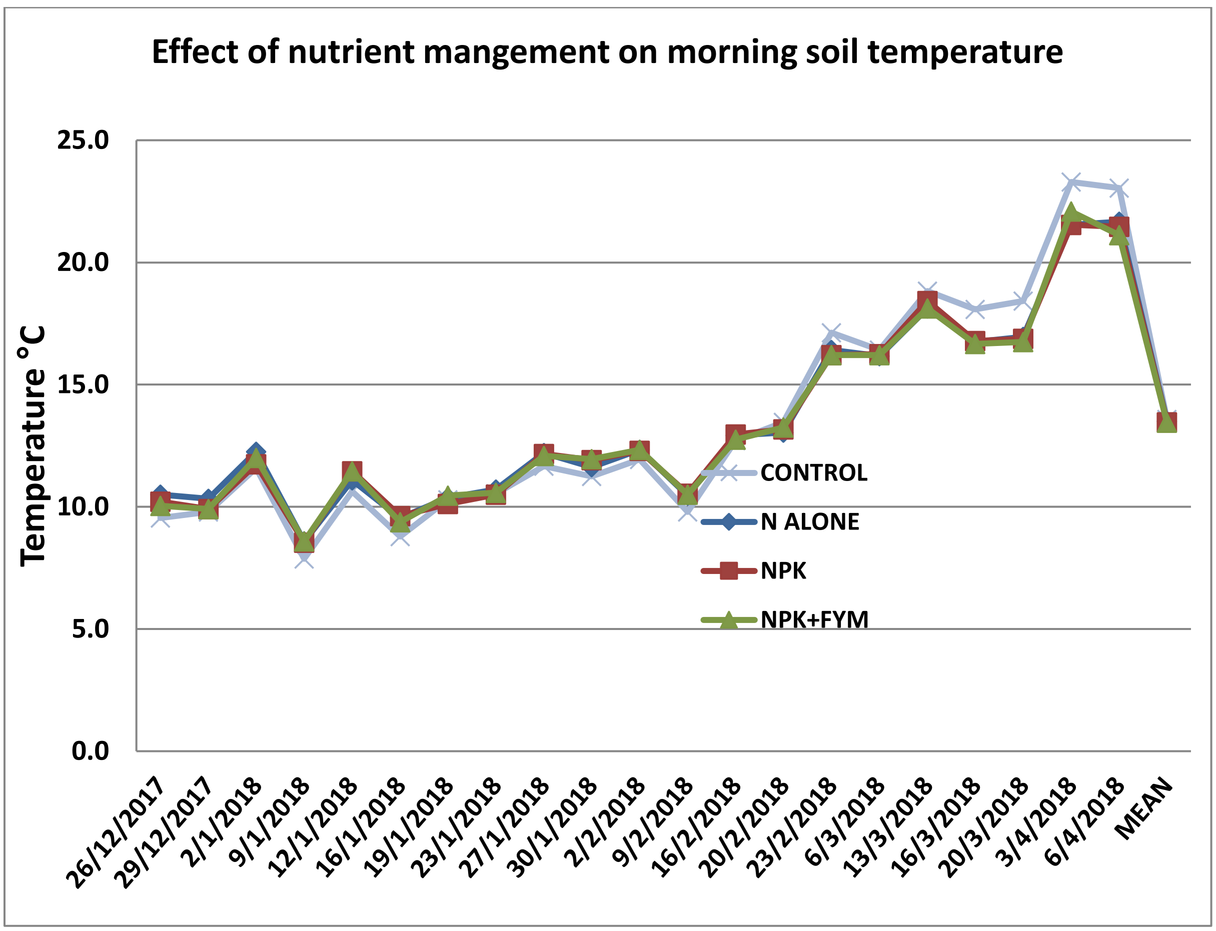
*R=Residue Retention and RI= Residue incorporation

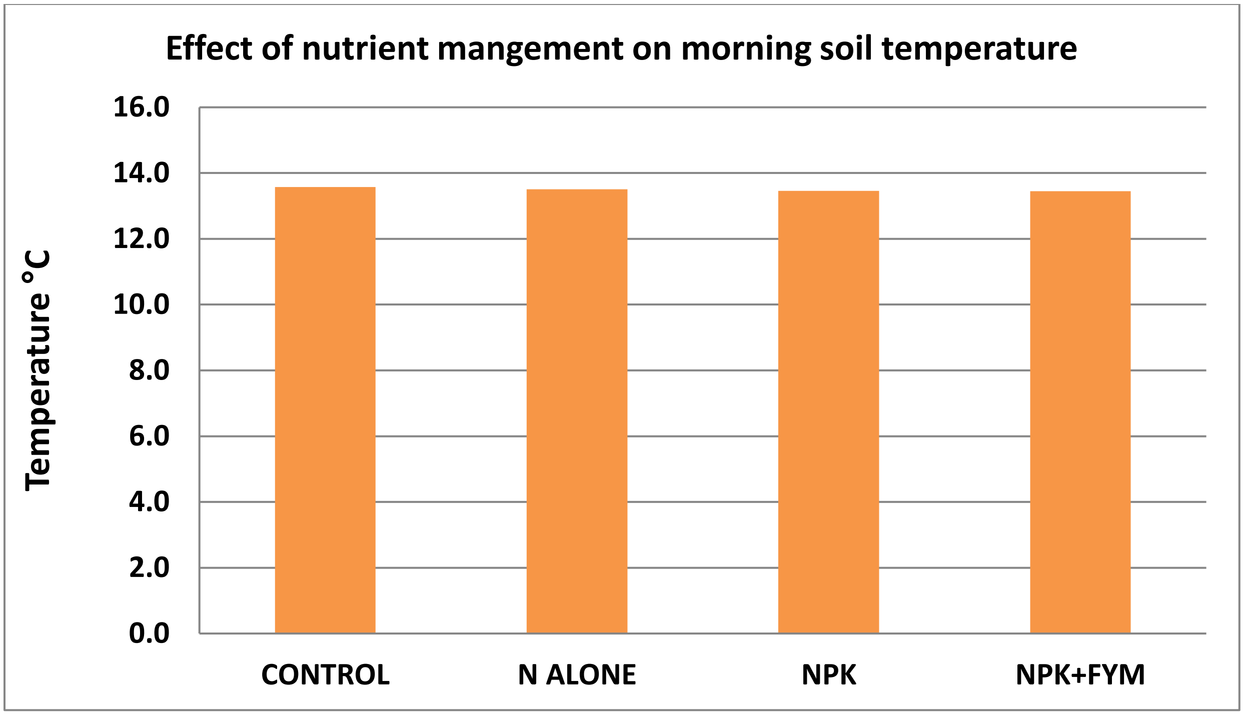
Observations were also taken on soil temperature in the morning and noon on different dates. The morning temperatures were on slightly higher in CA system where as reverse in the noon, where the temperatures were on lower side. The noon temperature in the control plots were higher than different nutrient management treatments.

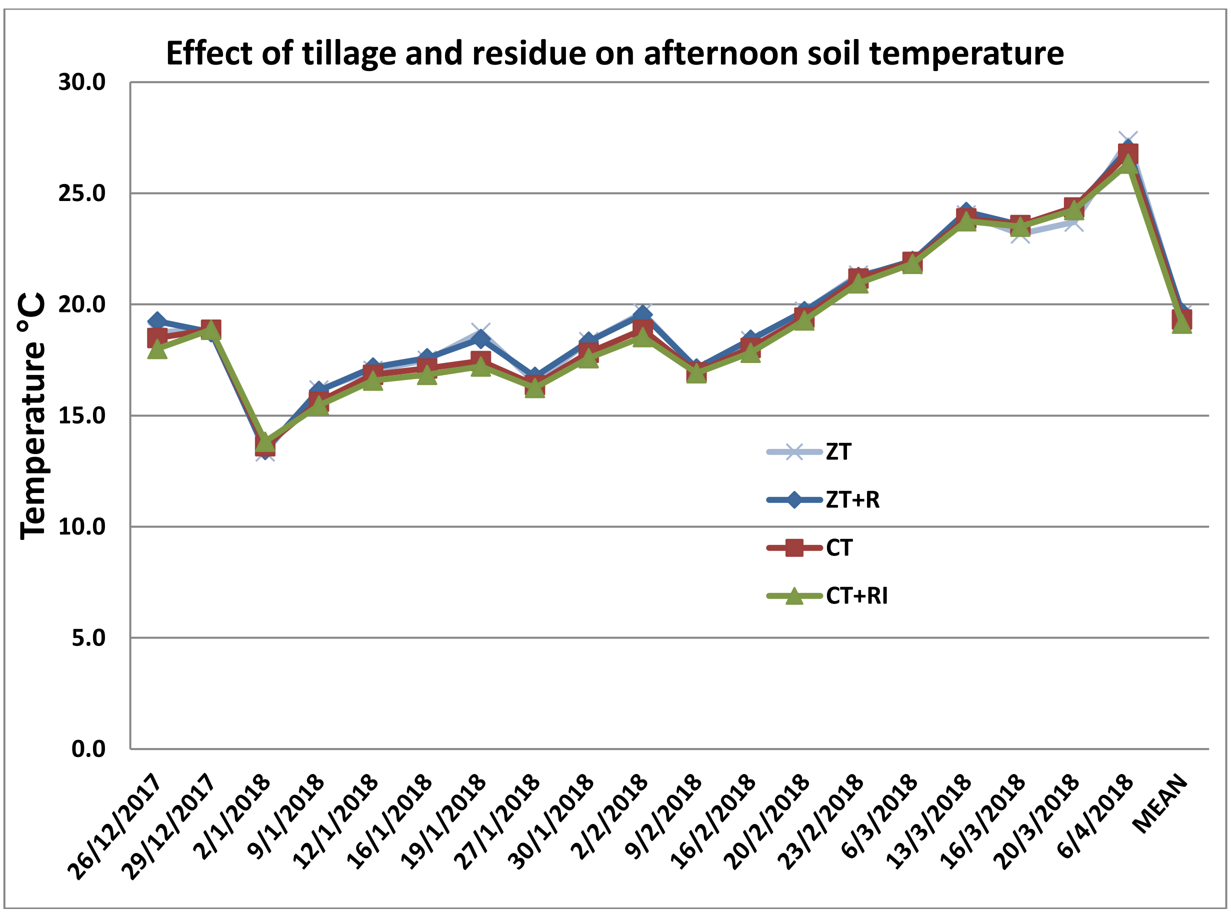
Canopy temperature as measured by LT300 Infrared Thermometer washigher in unfertilized control plots. Whereas the Normalized Difference Vegetation Index (NDVI) values recorded using hand held green seeker, a direct indicator of the crop growth was drastically less in unfertilized control plots, which was reflected in lower crop yields.

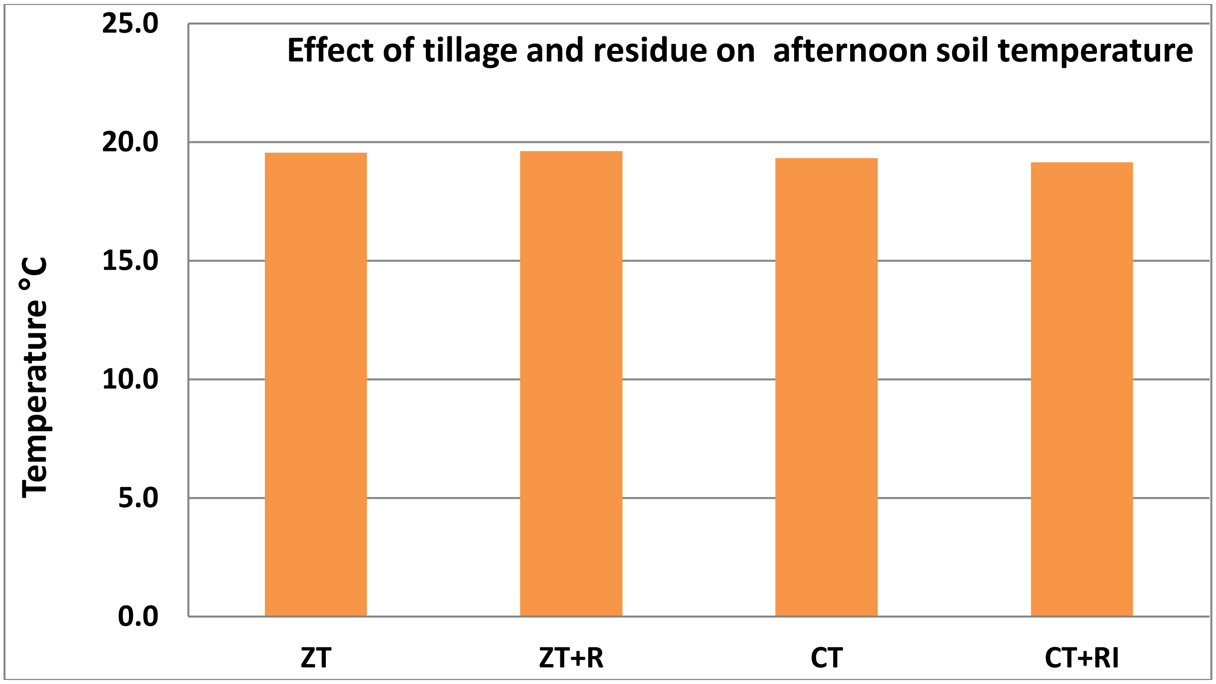


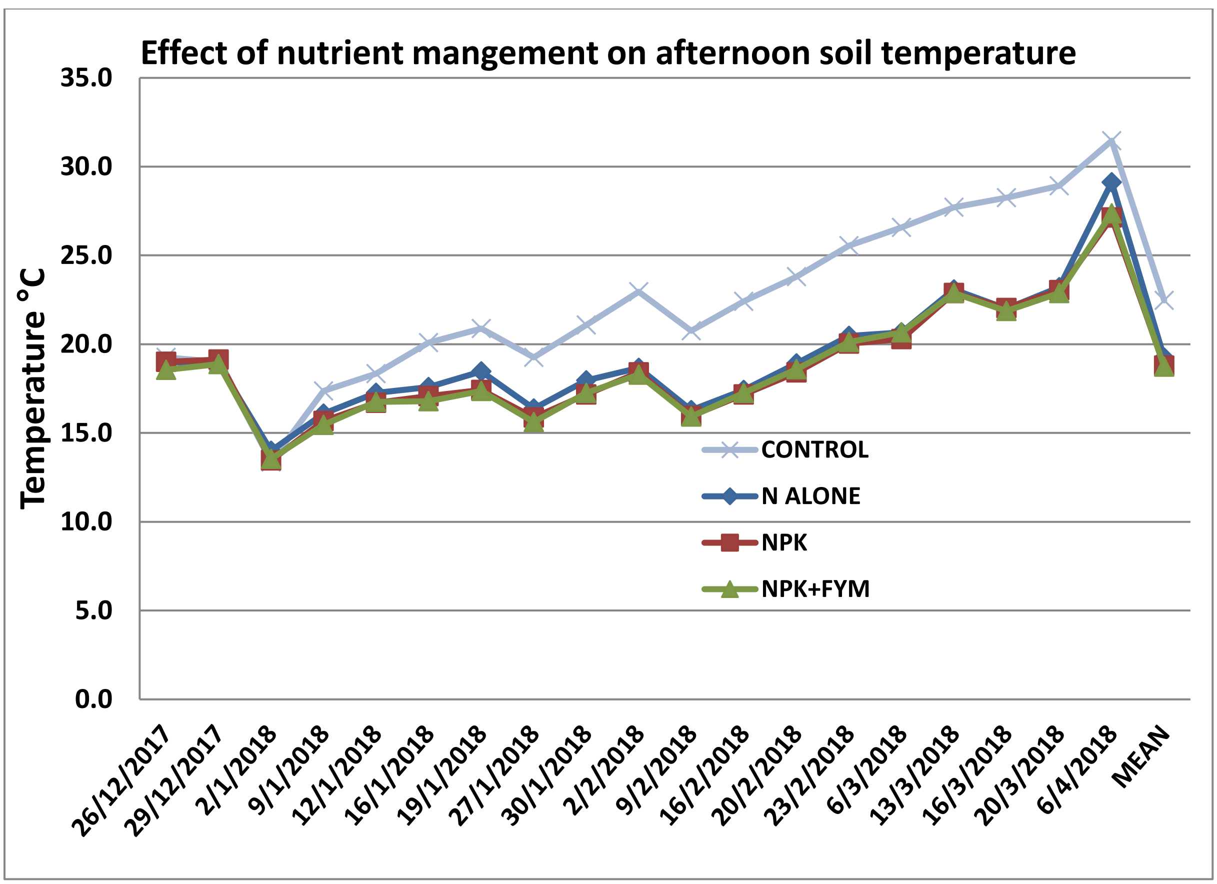

Effect of tillage and residue on morning soil temperature
Temperature °C
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ZT
ZT+R
CT
CT+RI

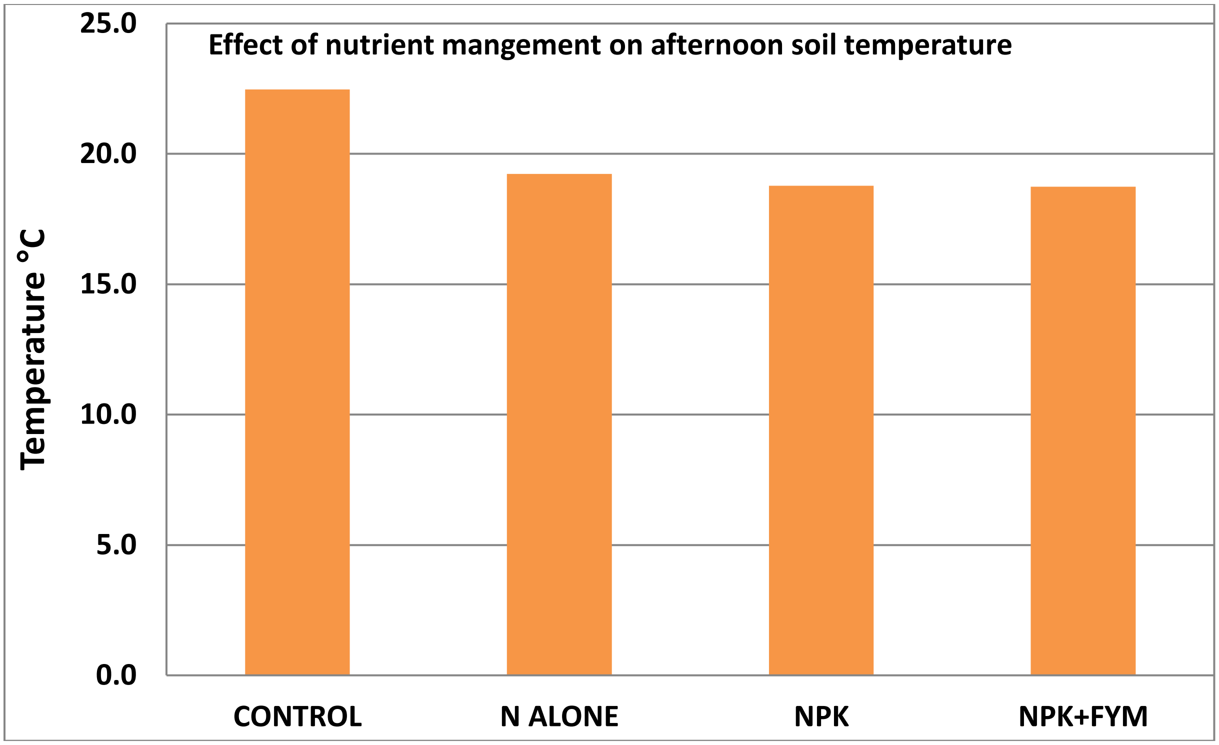

Effect of nutrient mangement on morning soil temperature
Temperature °C
25.0
20.0
15.0
10.0
5.0
0.0
CONTROL
N ALONE
NPK
NPK+FYM
26/12/2017
29/12/2017
2/1/2018
9/1/2018
12/1/2018
16/1/2018
19/1/2018
23/1/2018
27/1/2018
30/1/2018
2/2/2018
9/2/2018
16/2/2018
20/2/2018
23/2/2018
6/3/2018
13/3/2018
16/3/2018
20/3/2018
3/4/2018
6/4/2018
MEAN

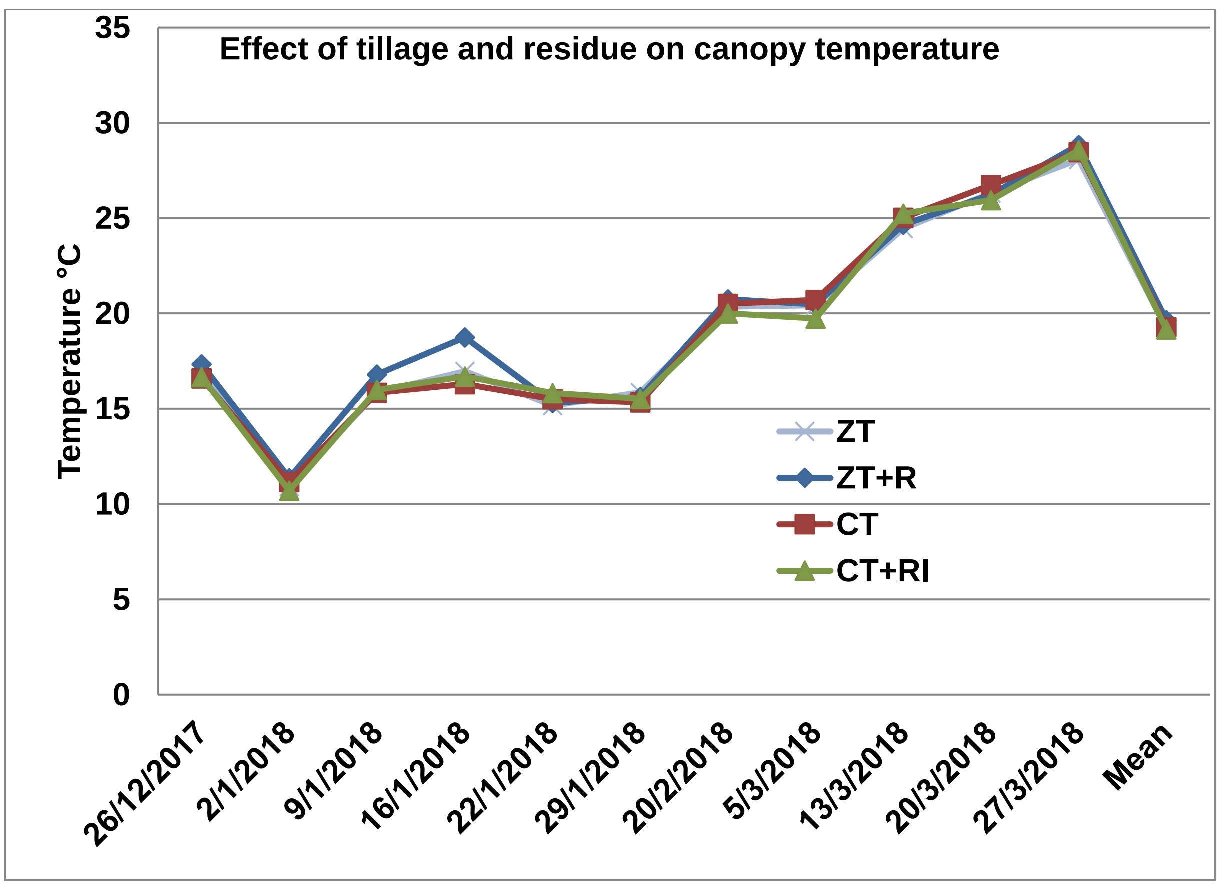

Effect of nutrient mangement on morning soil temperature
Temperature °C
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
CONTROL
N ALONE
NPK
NPK+FYM

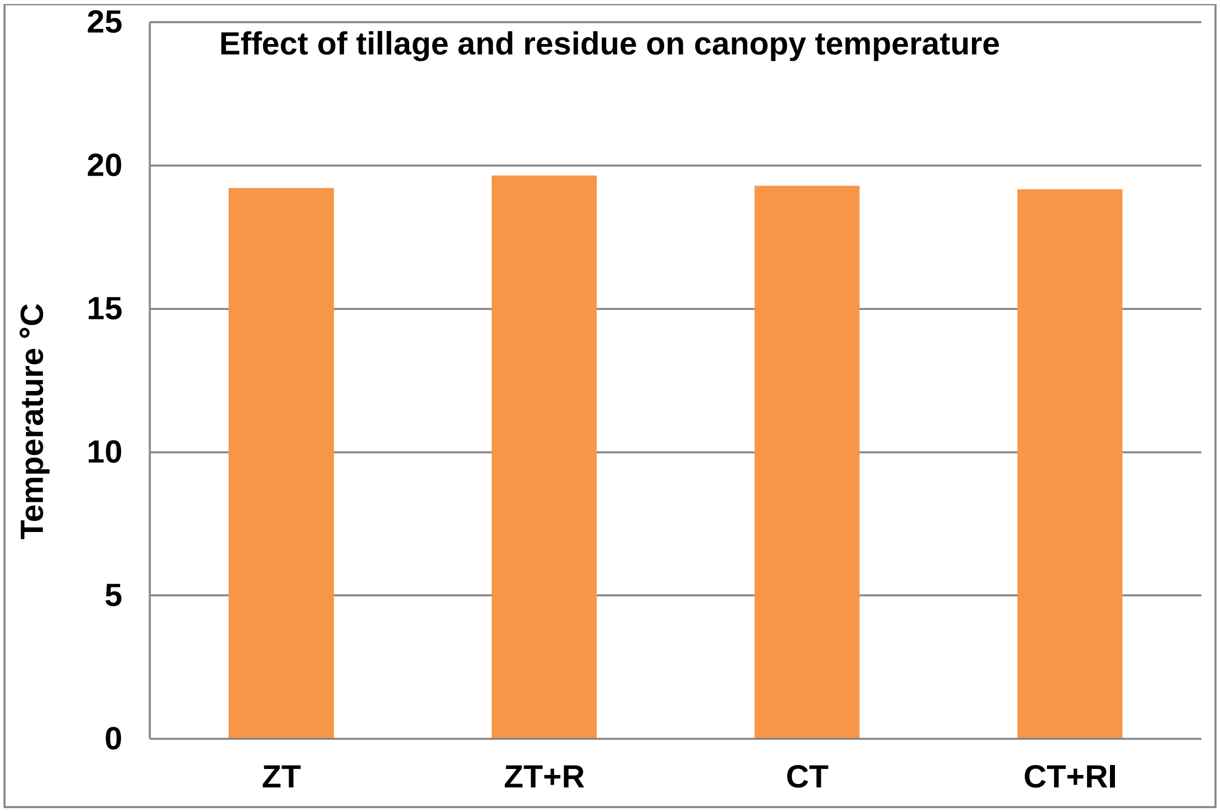

Effect of tillage and residue on afternoon soil temperature
Temperature °C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ZT
ZT+R
CT
CT+RI
26/12/2017
29/12/2017
2/1/2018
9/1/2018
12/1/2018
16/1/2018
19/1/2018
27/1/2018
30/1/2018
2/2/2018
9/2/2018
16/2/2018
20/2/2018
23/2/2018
6/3/2018
13/3/2018
16/3/2018
20/3/2018
6/4/2018
MEAN


Effect of tillage and residue on afternoon soil temperature
25.0
20.0
15.0
10.0
5.0
0.0
Temperature °C
ZT
ZT+R
CT
CT+RI

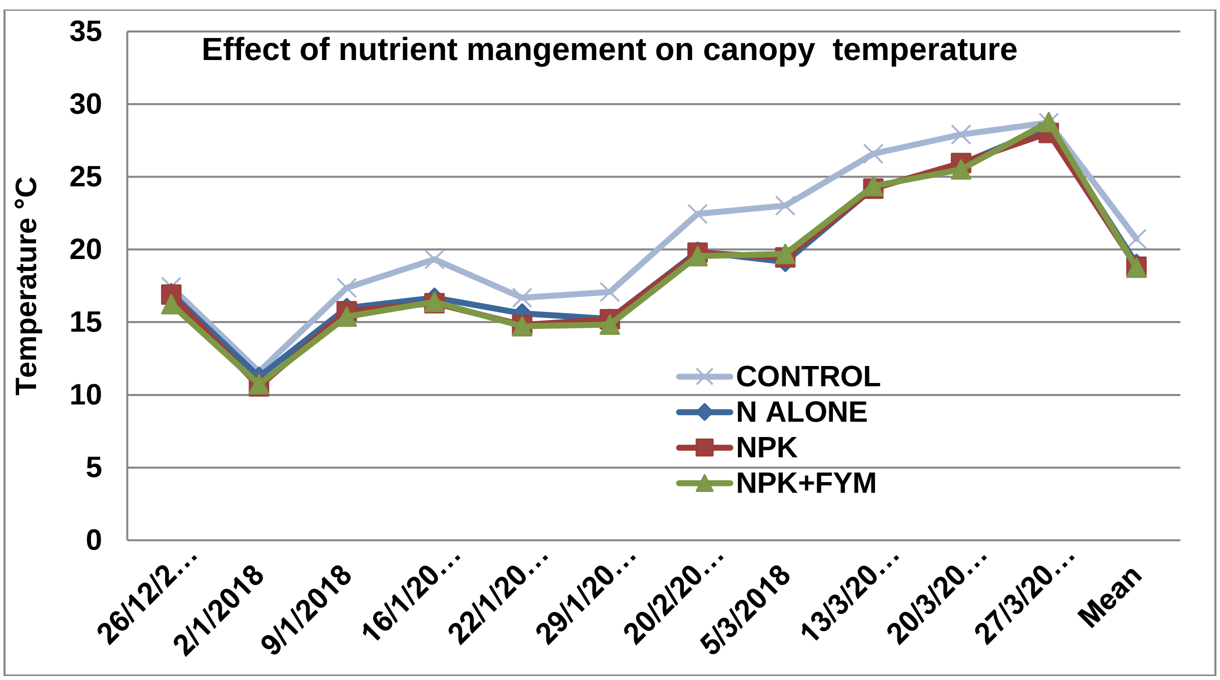

Effect of nutrient mangement on afternoon soil temperature
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Temperature °C
CONTROL
N ALONE
NPK
NPK+FYM
26/12/2017
29/12/2017
2/1/2018
9/1/2018
12/1/2018
16/1/2018
19/1/2018
27/1/2018
30/1/2018
2/2/2018
9/2/2018
16/2/2018
20/2/2018
23/2/2018
6/3/2018
13/3/2018
16/3/2018
20/3/2018
6/4/2018
MEAN


Effect of nutrient mangement on afternoon soil temperature
Temperature °C
25.0
20.0
15.0
10.0
5.0
0.0
CONTROL
N ALONE
NPK
NPK+FYM

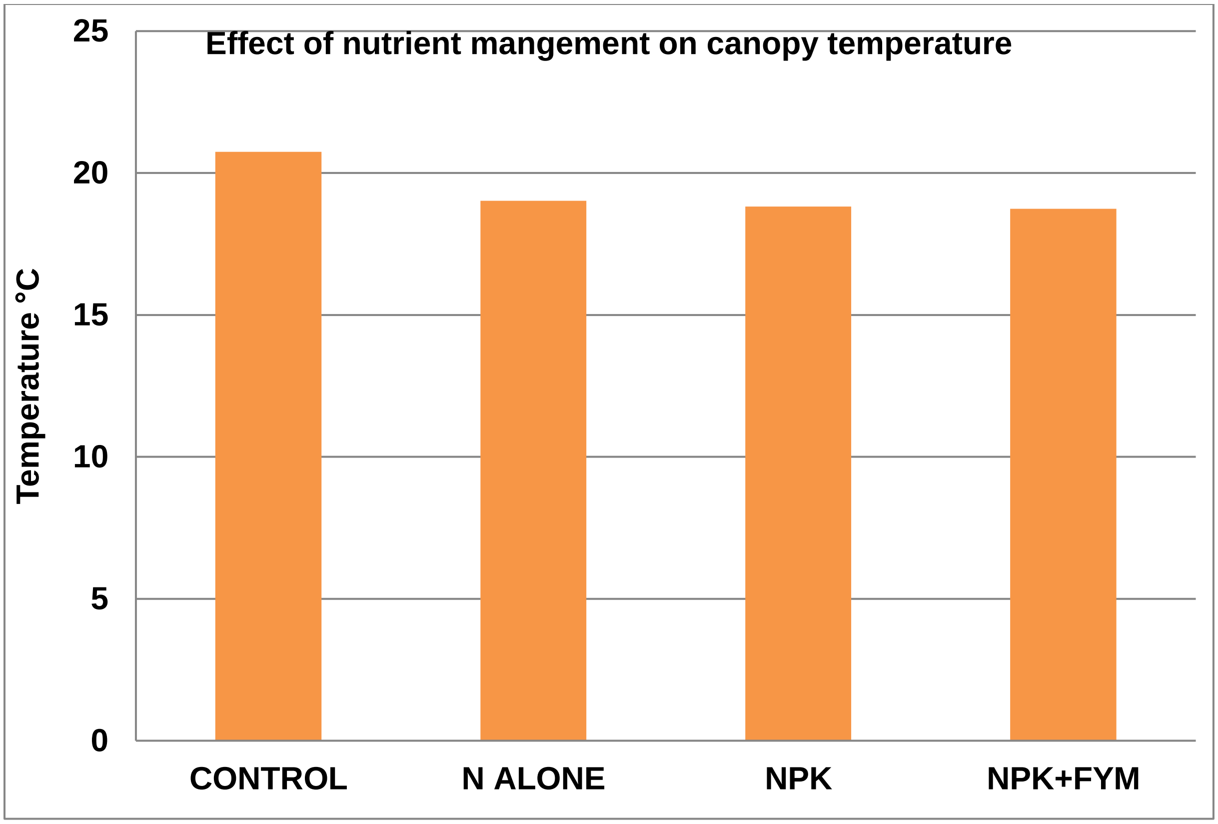

Effect of tillage and residue on canopy temperature
Temperature °C
35
30
25
20
15
10
5
0
ZT
ZT+R
CT
CT+RI
26/12/2017
2/1/2018
9/1/2018
16/1/2018
22/1/2018
29/1/2018
20/2/2018
5/3/2018
13/3/2018
20/3/2018
27/3/2018
Mean

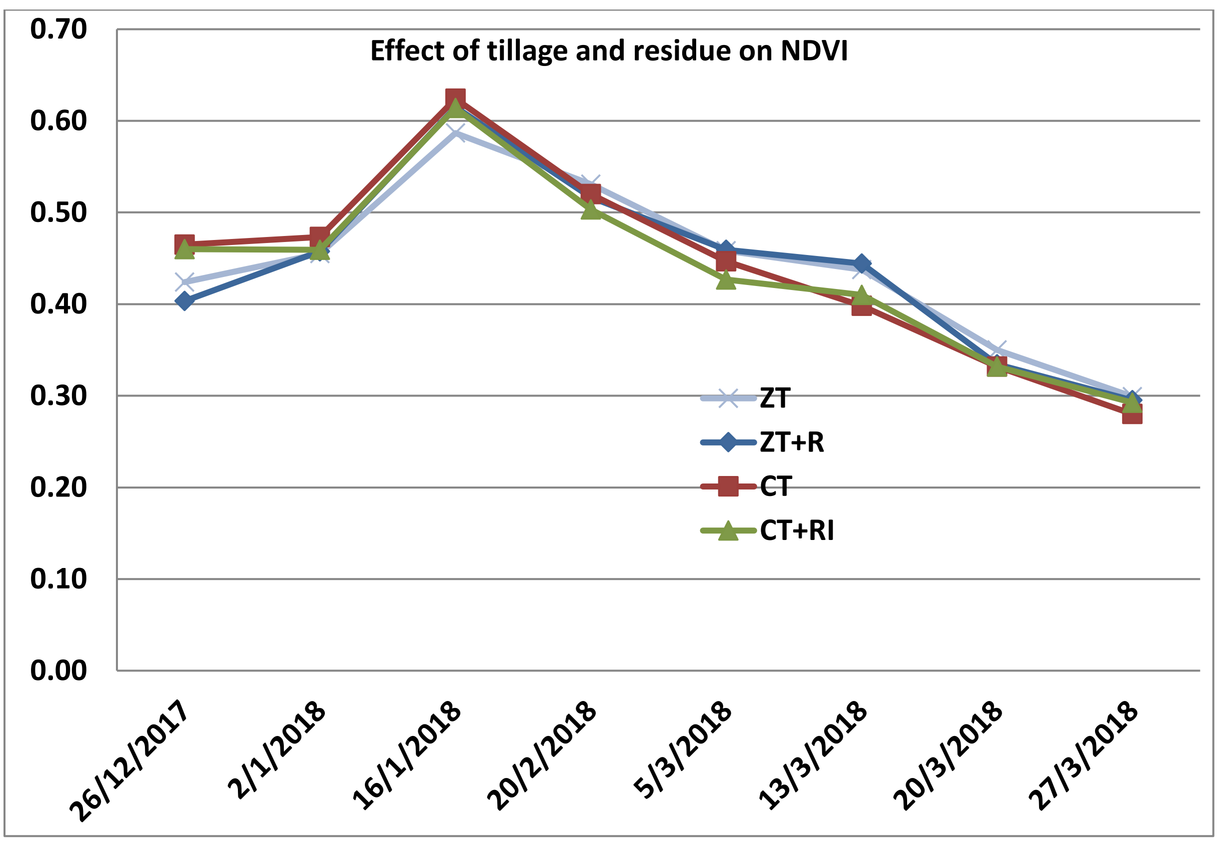


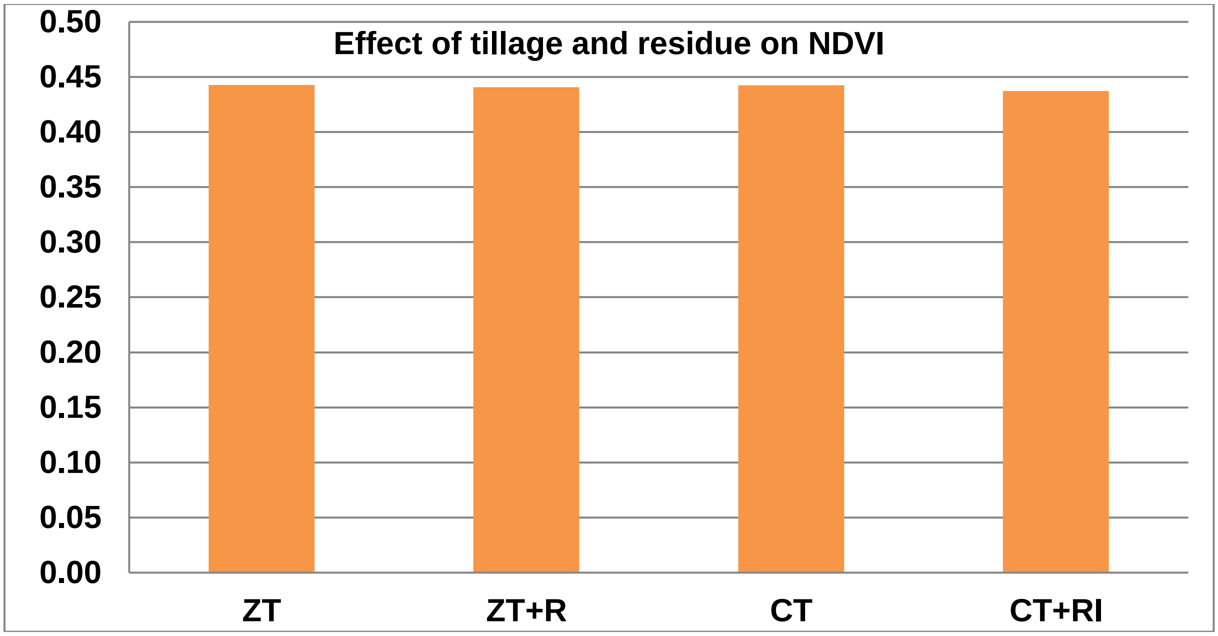
Effect of tillage and residue on canopy temperature
Temperature °C
25
20
15
10
5
0
ZT
ZT+R
CT
CT+RI

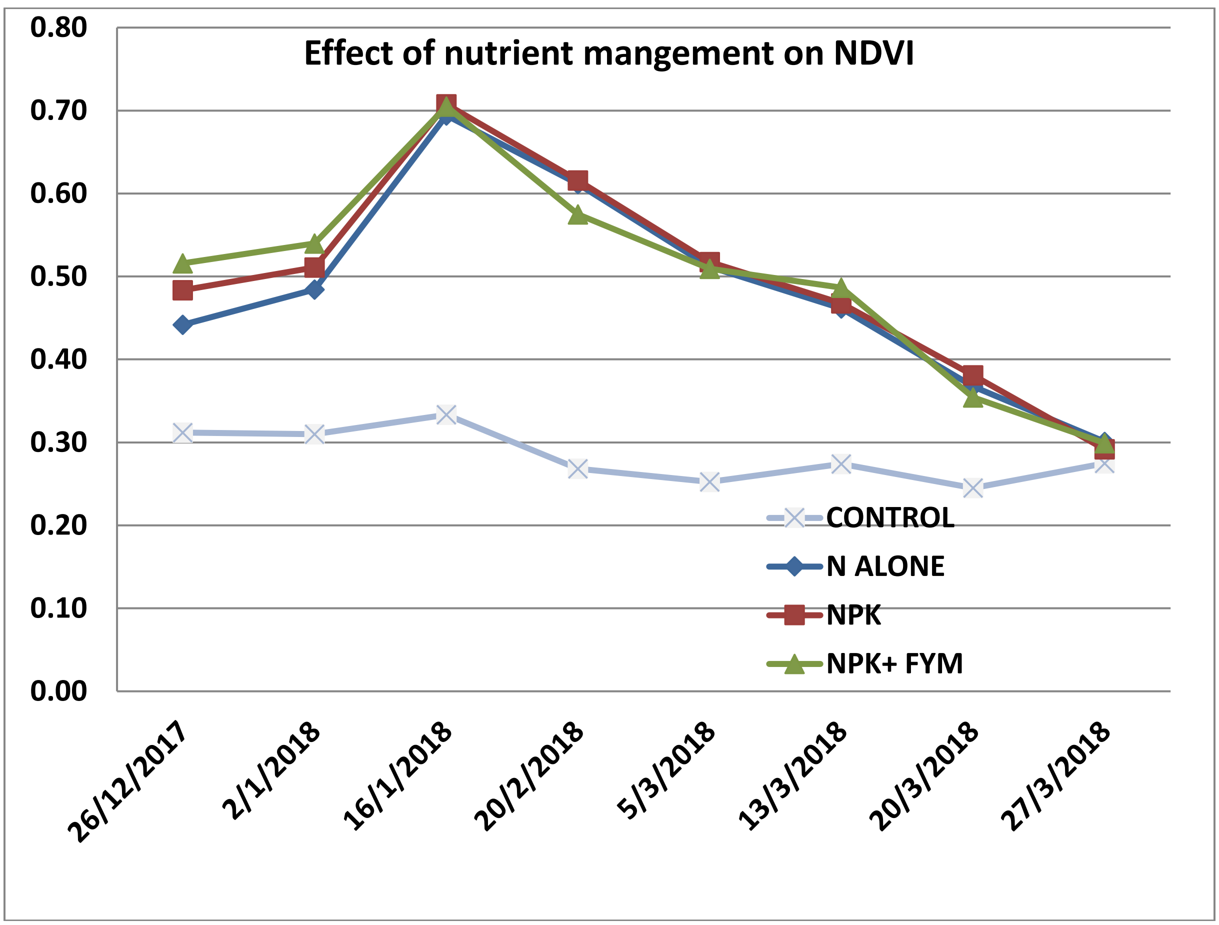


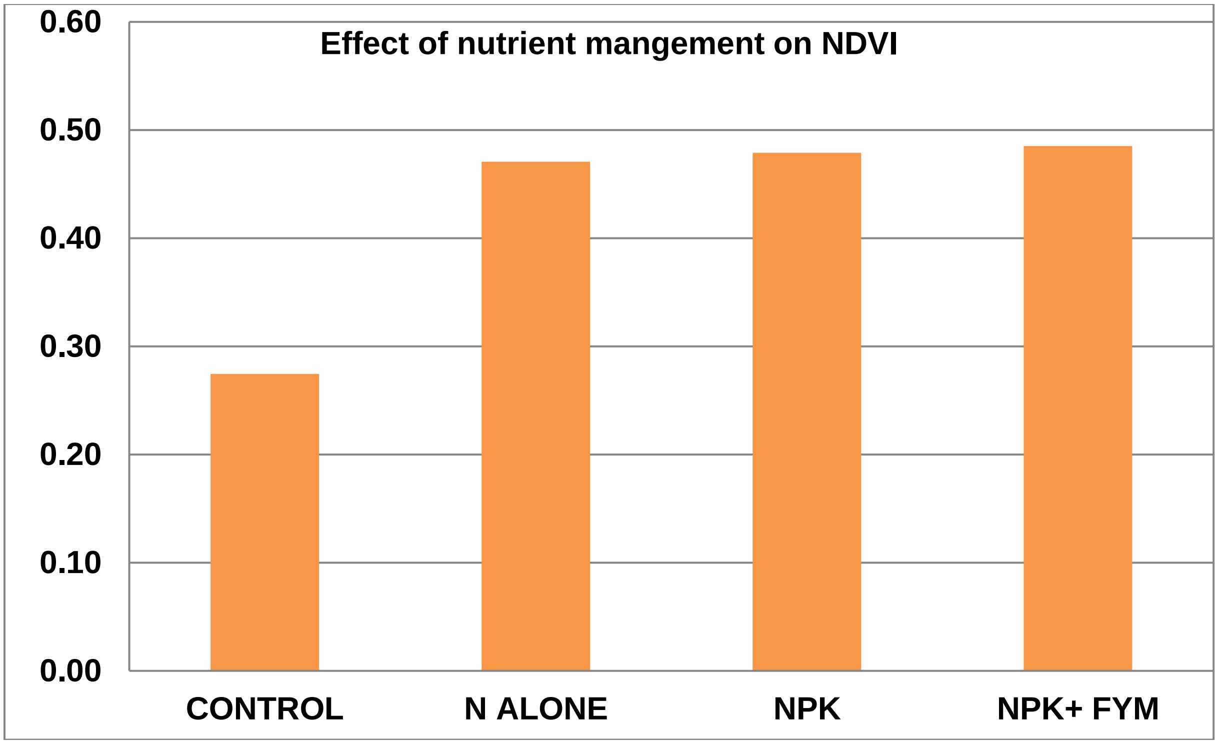
Effect of nutrient mangement on canopy temperature
Temperature °C
35
30
25
20
15
10
5
0
CONTROL
N ALONE
NPK
NPK+FYM
26/12/2…
2/1/2018
9/1/2018
16/1/20…
22/1/20…
29/1/20…
20/2/20…
5/3/2018
13/3/20…
20/3/20…
27/3/20…
Mean


Effect of nutrient mangement on canopy temperature
Temperature °C
25
20
15
10
5
0
CONTROL
N ALONE
NPK
NPK+FYM


Effect of tillage and residue on NDVI
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
26/12/2017
2/1/2018
16/1/2018
20/2/2018
5/3/2018
13/3/2018
20/3/2018
27/3/2018
ZT
ZT+R
CT
CT+RI


Effect of tillage and residue on NDVI
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
ZT
ZT+R
CT
CT+RI


Effect of nutrient mangement on NDVI
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
26/12/2017
2/1/2018
16/1/2018
20/2/2018
5/3/2018
13/3/2018
20/3/2018
27/3/2018
CONTROL
N ALONE
NPK
NPK+ FYM



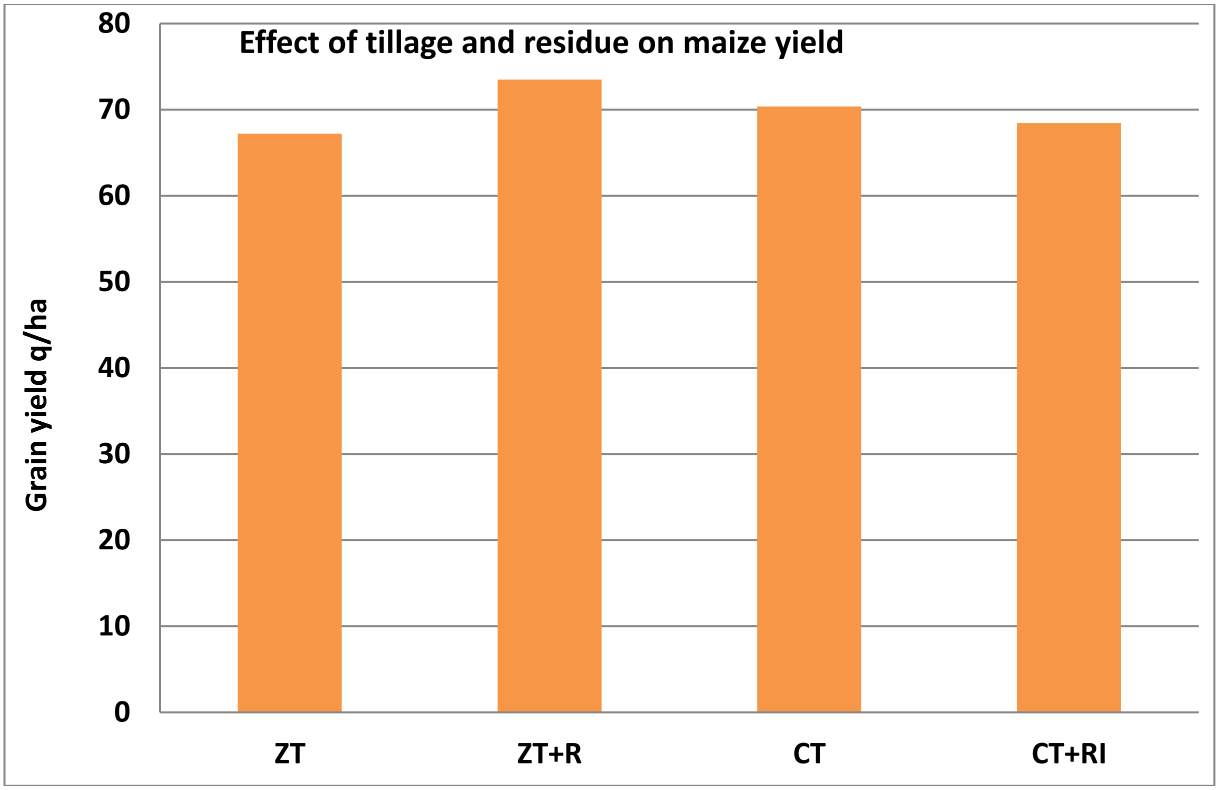
Performance of maize in long term experiment in Maize-wheat-greengram system:

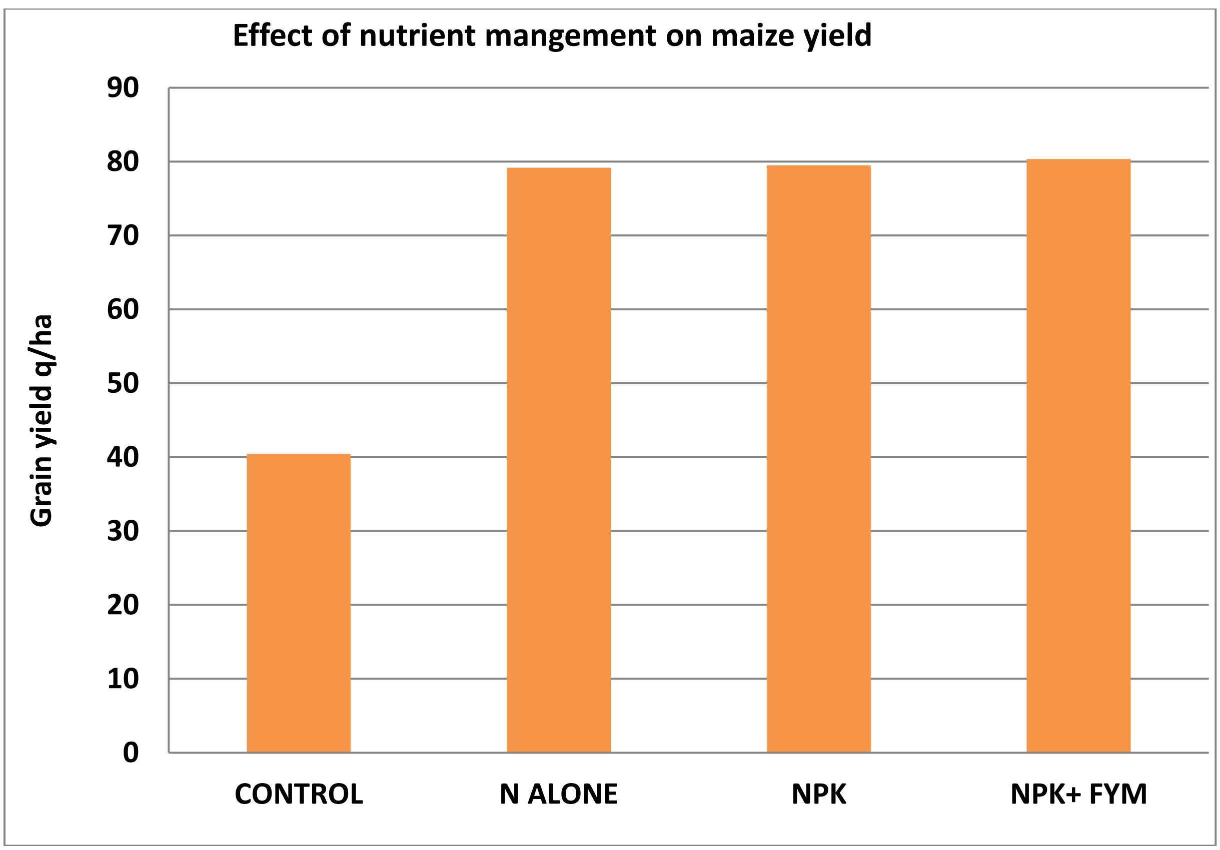
With the same set of treatments as in wheat, maize hybrid DKC 9164 was sown using a seed rate of 25 kg/ha at a row spacing of 60 cm. For weed control tembotrione at 110 g a.i./ha + atrazine 1000 g/ha were applied at 20 DAS. In ZT and CA preplanting glyphosate was also applied at 1.2% spray solution. Among tillage and residue management options, maximum yield was obtained in CA treatment (73.48 q/ha). The main reason for the response in CA was better infiltration and less adverse effect of water logging due to heavy rain as observed in CT system (Photo below). Unfertilized plots recorded significantly lowest yield (40.46 q/ha).

Comparative performance of maize under CA and CT system

CT CA CT CA

Maize yield was about 4-5% higher under CA than CT in long term maize-wheat-greengram system


Effect of tillage and residue on maize yield
Grain yield q/ha
80
70
60
50
40
30
20
10
0
ZT
ZT+R
CT
CT+RI


Effect of nutrient mangement on maize yield
Grain yield q/ha
90
80
70
60
50
40
30
20
10
0
CONTROL
N ALONE
NPK
NPK+ FYM

Fine-tuning of Conservation Agricultural Practices for Vertisols of Central India (IISS)

Under the this theme, 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. However, after 2016, due to some problem in crop establishment using in strip till planter, the treatments were modified and the details are given below

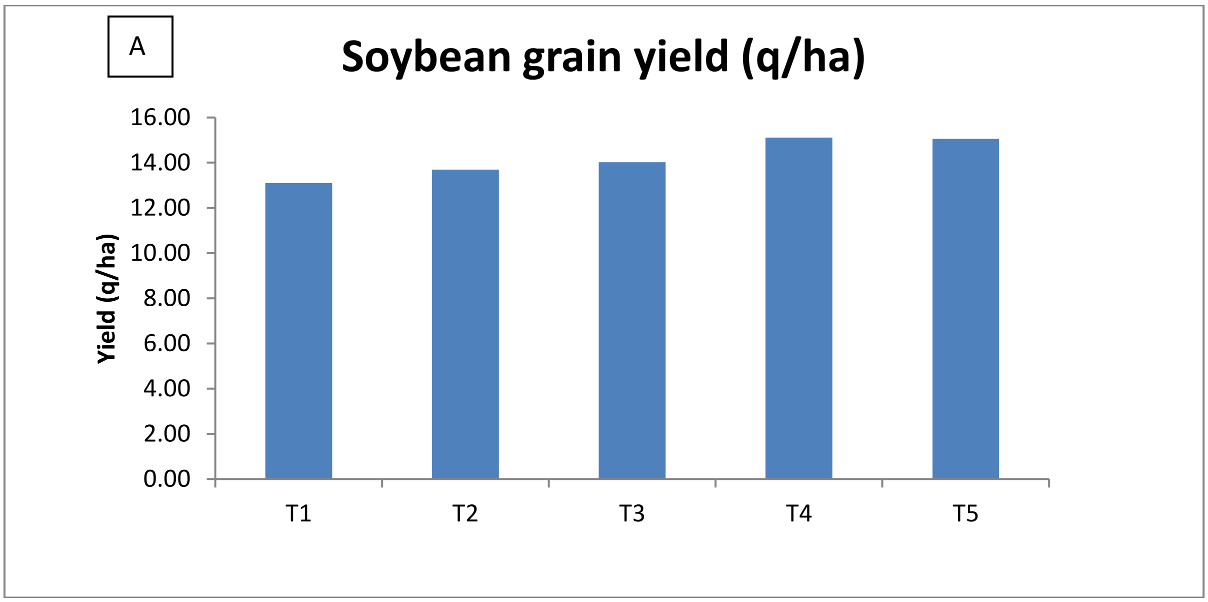
Treatment	Tillage System (From 2015-2016)	From 2017 onwards
T1:	No-tillage	No Tillage (NT) with 30cm height residue
T2:	RT-3 (Strip tillage - sowing with strip till- drill with residues, Hand weeding)	No Tillage (NT) with 60cm height residue;
T3:	RT-2 (Strip tillage – sowing with strip till- drill with residues, WC with herbicides),	Reduced Tillage with 30cm height residue
T4:	Reduced tillage (RT) -1 (sowing with residues + 1 duck foot, weed control (WC) with herbicides),	Reduced Tillage with 60cm height residue
T5:	Conventional tillage (No residues and manual weed control),	Conventional Tillage (CT)/Farmers practices
	Nutrient Doses	
	N1: 75% RDF	
	N2: 100% RDF	
	N3: STCR dose	

Experimental crops were sown using no-till seed drill/happy seeder during rainy and winter seasons by adopting standard package of practices (Fig 1). Soil profile moisture content, soil temperature and crop biometric observation were recorded periodically during crop growth period. 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. Soil samples collected after harvest of rabi crops and analysis of soil samples are in progress.

Fig 1. Crop establishment under Conservation Agriculture during 2017-18.

Soybean yeild was relatively higher under conventional tillage (T5) which is on par with reduced tillage +residue retnetion (T4). Other tillage system T3, T2 and T1 recorded on par soybean yield. However, nutrient doses had significant effect of soybean yield. STCR based fertilizer application recorded significantly higher yield compared to 100% RDF (N2) and N1 (75% RDF) (Fig 2)

Maize yeild was relatively higher under conventional tillage (T5) which is on par with No-tillage +residue retnetion (T2). Other tillage system T1, T3 and T4 recorded on par soybean yield. However, nutrient doses had significant effect of maize yield. STCR based fertilizer application recorded significantly higher maize yield compared to 100%RDF (N2) and N1 (75% RDF) (Fig 3)



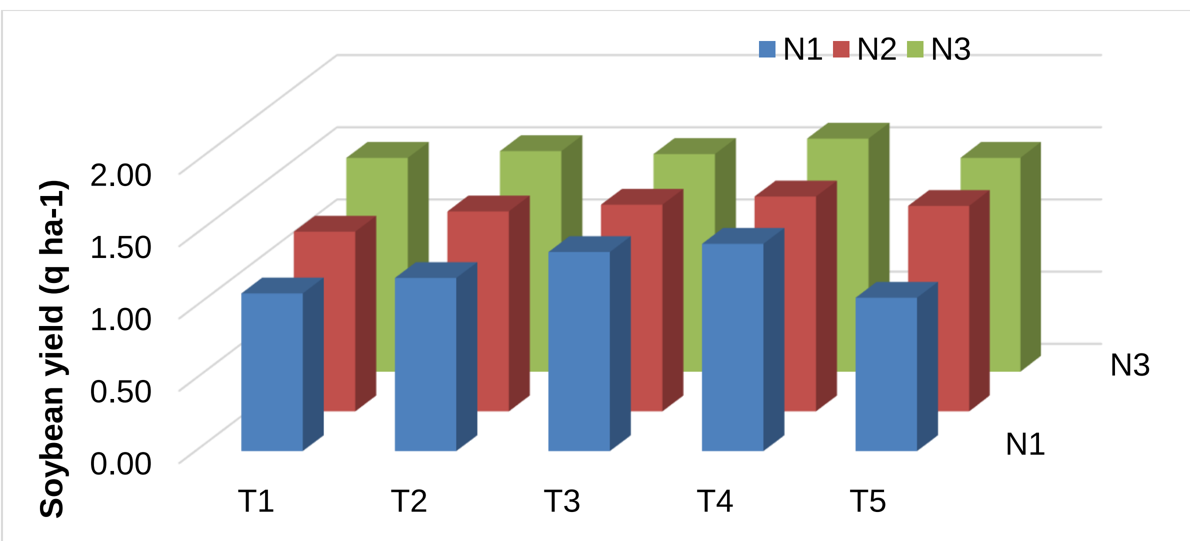
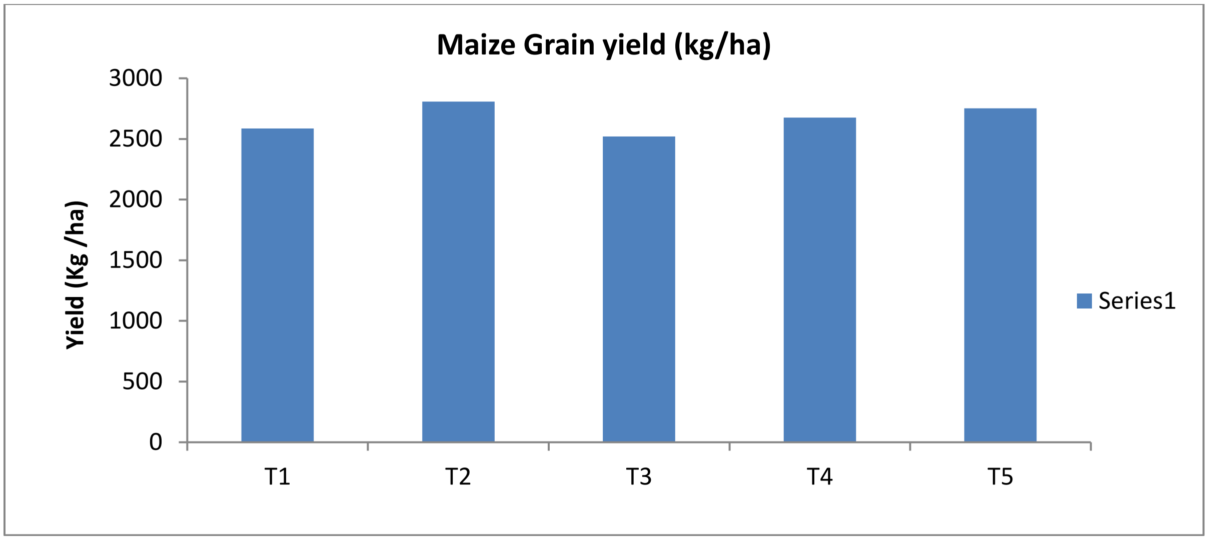


Fig 2. Soybean yield under different tillage system (A) and nutrient levels (B) in Vertisols



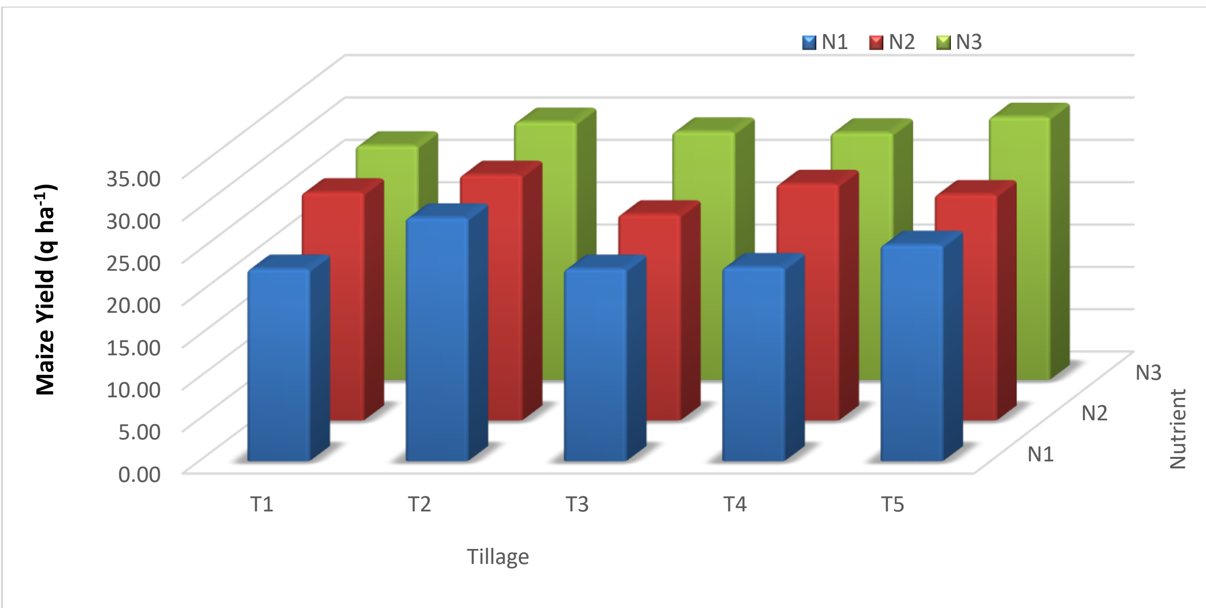


Fig 3. Maize yield under different tillage system (A) and nutrient levels (B) in Vertisols

Tillage system did not have significant efect on wheat yeild. No-tillage with residue retention (T1) recorded on par yield with T4. Tillage system namely T2, T3 and T5 recorded on par yeild. However, nutrient doses had significant effect of wheat yield. STCR based fertilizer application recorded significantly higher yield compared to 100% RDF (N2) and N1 (75% RDF) (Fig 4)

Higher gram yield was recorded under No-tillage with residue retention (T1) whichwas on par with T3. which is on par with No-tillage +residue retnetion (T2). Other tillage system T1, T3 and T4 recorded on par soybean yield. However, nutrient doses had significant effect of gram yield. STCR based fertilizer application recorded significantly higher maize yield compared to 100% RDF (N2) and N1 (75% RDF) (Fig 5).

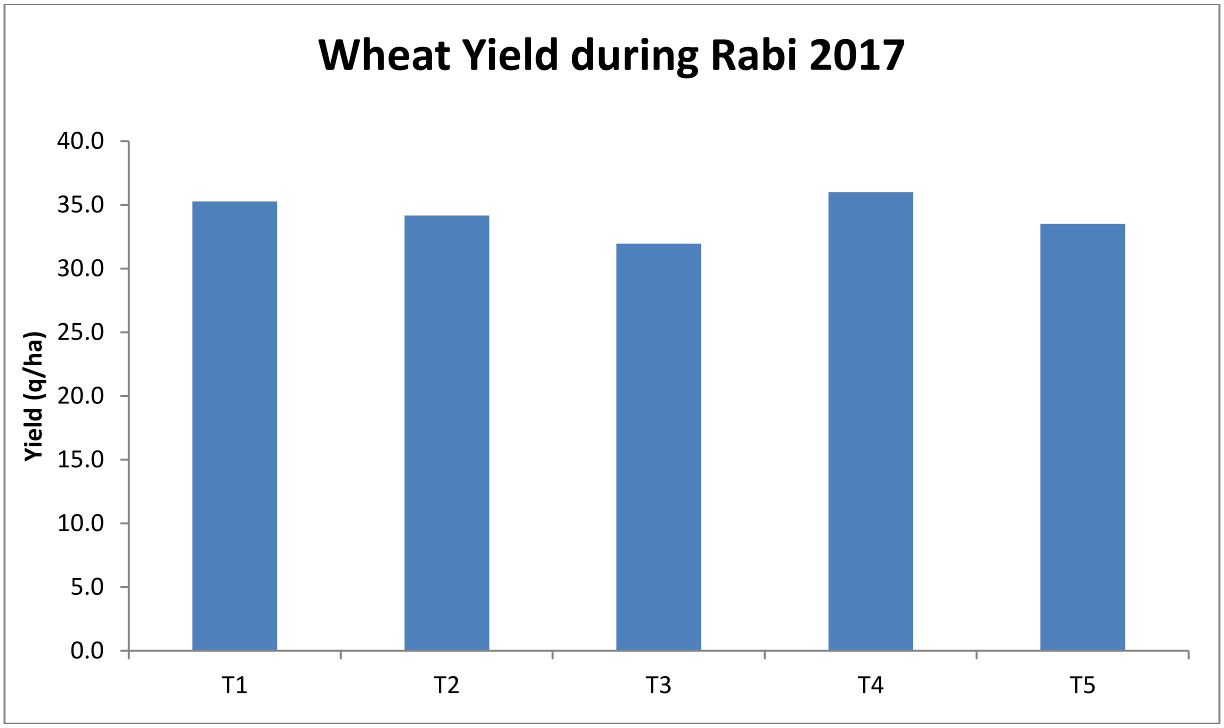


Fig 4. Wheat yield during rabi season (2017) under different tillage system

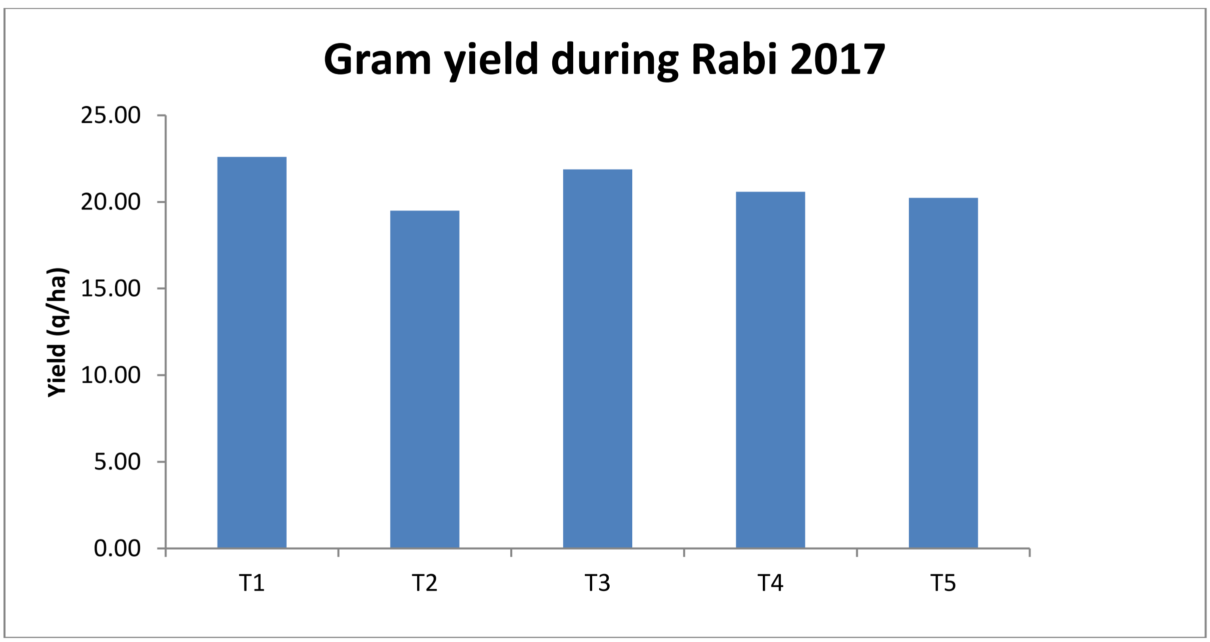
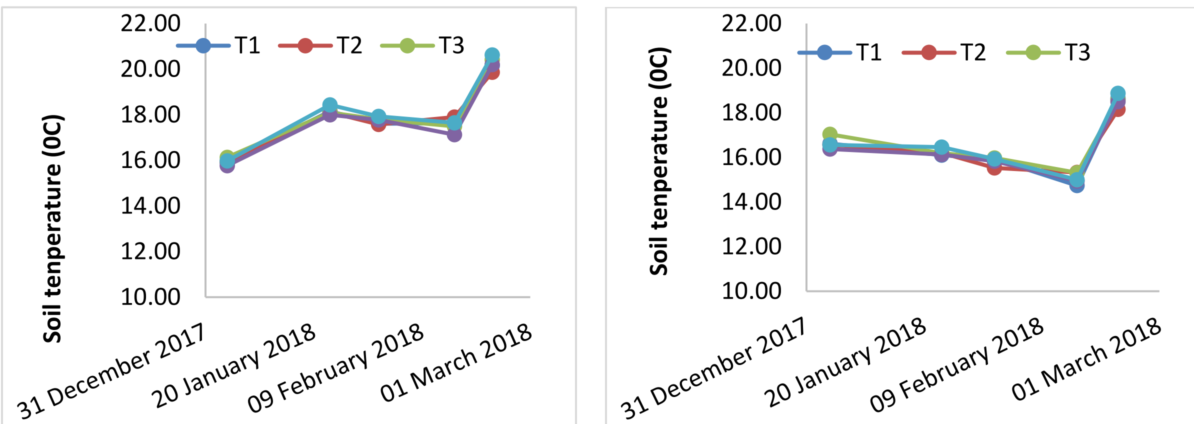


Fig 5. Gram yield during rabi season (2017) under different tillage system

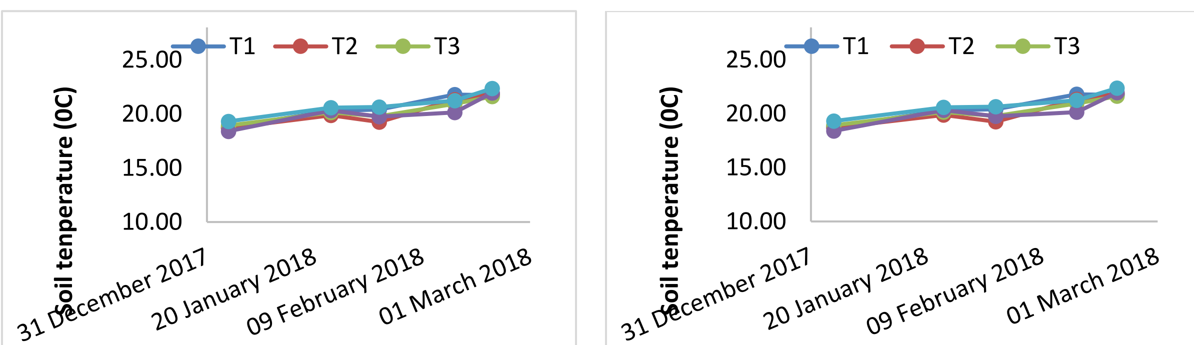
Soil temperature under different tillage system during Rabi season

Soil temperature was recorded during crop growing season (at 7.00 am and 2.00 pm) using a digital thermometer. Tillage treatments and cropping systems had no significant effect on soil temperature recorded during the *rabi* season. In gram, minimum soil temperature (0–5 cm) at 7.00 AM was varied from 14.73-18.87 ^{o}C and maximum at 2.00 PM varied between 20.90-

25.28^{o}C (Fig 6). In wheat crop, the minimum temperature at 7.00AM varied from 14.23-17.90 ^{o}C and maximum at 2.00 PM varied between 21.29-23.60^{o}C (Fig 7). At 7.00 AM, soil temperature tended to be higher under NT and RT compared to CT during the growth period; while at 2.00 PM, the trend was reversed between the two treatments. We observed a moderation in soil temperature i.e. relatively higher soil temperature was under RT/NT in the morning hour (7.00 AM) and lower temperature in the afternoon (2.00 PM), was attributed to the presence of crop residue at the soil surface. Presence of crop residues regulates the soil temperature depending upon its amount and type. Moreover, crop residues usually have reflective and conductive properties that bring changes in the surface net-radiation and soil heat-flux density.



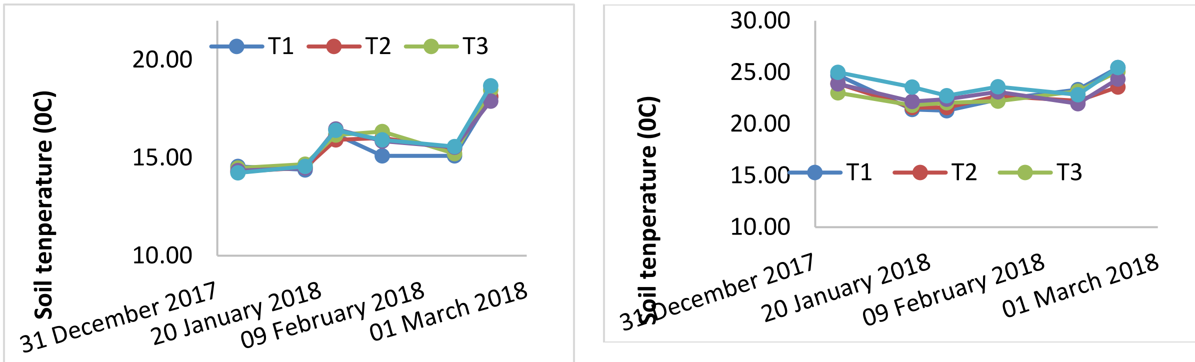
A) Morning temperature at surface and sub-surface



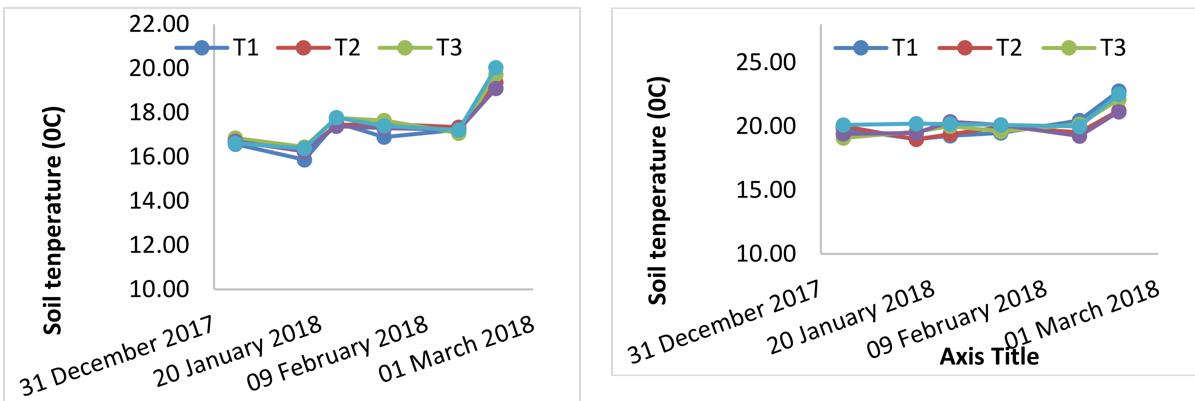
B) Afternoon temperature at surface and sub-surface

Fig 6. Soil temperature recorded during rabi crop at surface (0-5 cm depth) and sub-surface (5-15cm) under Maize-Gram system

[T1: No Tillage (NT) with 30cm height residue; T2: No Tillage (NT) with 60cm height residue; T3: Reduced Tillage with 30cm height residue ; T4: Reduced Tillage with 60cm height residue; T5: Conventional Tillage (CT)/Farmers practices]



A) Morning temperature at surface and sub-surface



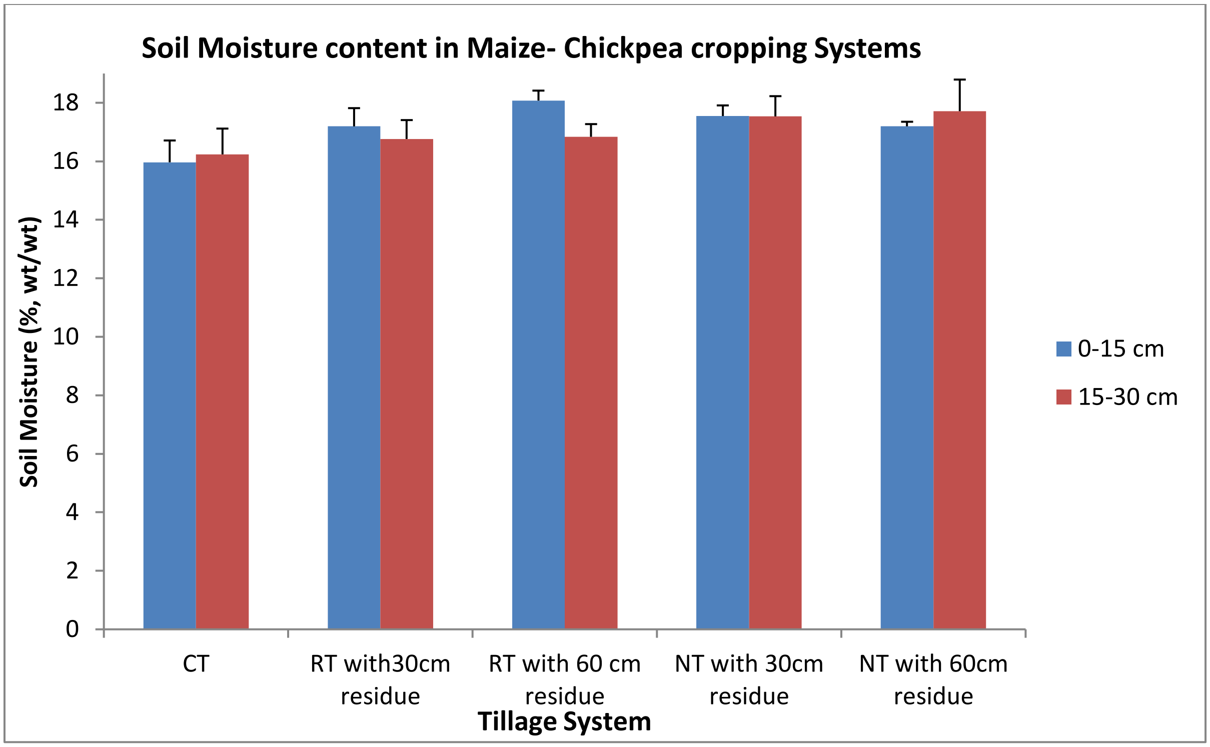
B) Afternoon temperature at surface and sub-surface

Fig. 7. Soil temperature recorded during rabi crop at surface (0-5 cm depth) and sub-surface (5-15cm) under Soybean-Wheat system

[T1: No Tillage (NT) with 30cm height residue; T2: No Tillage (NT) with 60cm height residue; T3: Reduced Tillage with 30cm height residue ; T4: Reduced Tillage with 60cm height residue; T5: Conventional Tillage (CT)/Farmers practices]

Soil moisture status under different tillage system

Soil moisture status recorded under different tillage system. Results indicated that conservation tillage practices (Reduced tillage and no-tillage) with crop residue retention recorded relatively higher soil moisture content (8-18%) compared to conventional tillage practices (Fig 8).



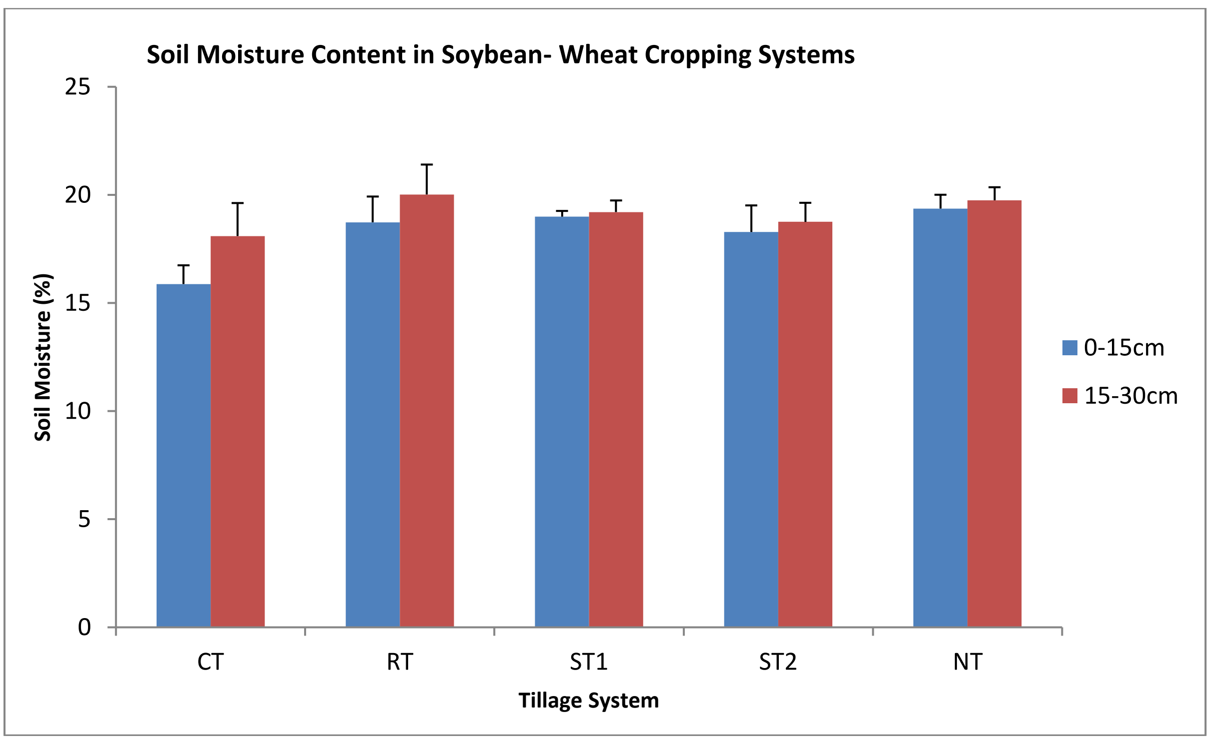
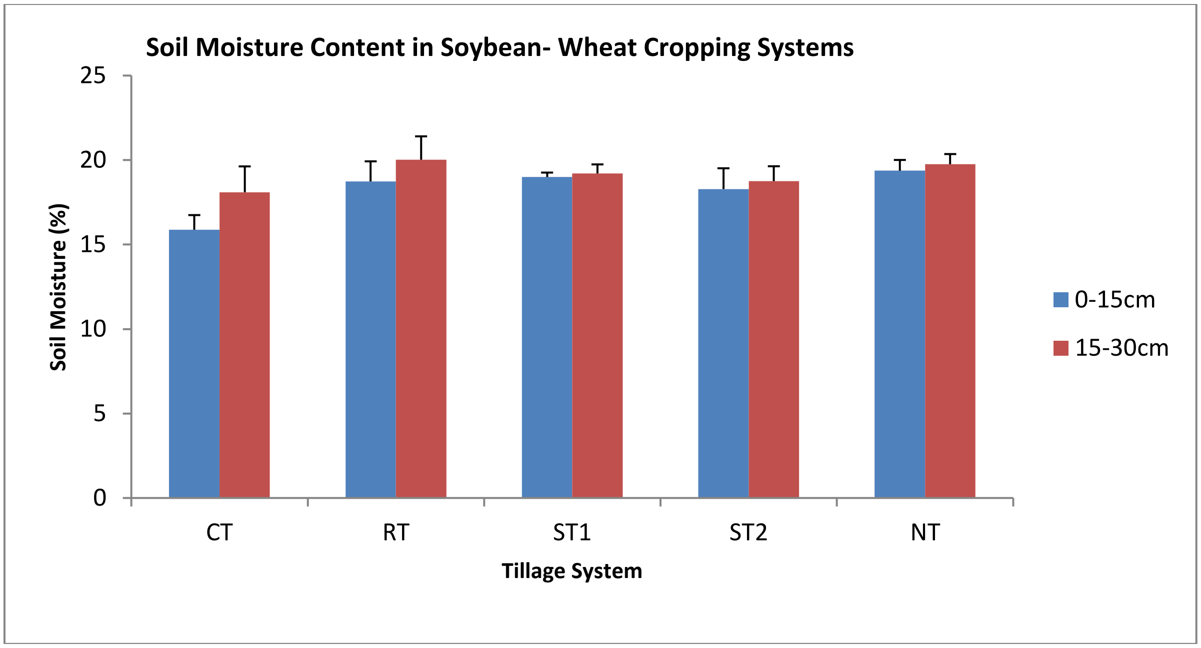


Fig. 8. Soil moisture recorded during Jan 2017 crop at surface (0-15 cm depth) and sub-surface (5-15cm) under maize-Gram and Soybean-Wheat system



Effect of different residue levels on crop performance under conservation agriculture in vertisols. (IISS)

The experiment was initiated with the aim to study the impact of different residue levels on crop establishment, ease of utilizing machinery (happy seeder) under different residue levels, weed management and resource conservation in terms of water and energy saving, in soybean –wheat and maize-chickpea cropping systems. Among different residue level treatments in Soybean maximum seed yield 7.92q/ha were recorded under T4. Similarly maximum grain yield of maize (48.63 q/ha) was recorded under T4. The experiments conducted during rabi season are harvested and data compilation work is under progress.

Soybean				
Treatment	**Plant height at harvest (cm)**	**Pods/plant**	**Grain yield kg/ha**	**Straw yield kg/ha**
T_1 (Control	44.50	20.66	658	1069
T_2 (30% residue)	46.33	22.15	734	1133
T_3 (60% residue)	47.67	24.00	758	1215
T_4 (90% residue)	46.66	25.00	792	1259

Effect of residue level on crop growth due to moisture stress


30% Residue


Control


90% Residue


60% Residue


30% Residue


Control

Treatment	Plant height at harvest	Grain yield q/ha	Straw yield q/ha
T_1 (Control	110.0	40.54	61.75
T_2 (30% residue)	115.0	43.15	63.40
T_3 (60% residue)	123.0	45.38	65.37
T_4 (90% residue)	125.0	48.63	67.77

2.1.1.2 Weed Management

A.Weed management in rice-wheat-greengram sequence under conservation agriculture systems (DWR)

Rice field was comprised with dominant weed species such as *Echinochloa colona*, *Dinebra retroflexa*, *Dactyloctenium aegyptium* and *Eleucine indica* among grasses, *Alternathera paronychiodes*, *Physalis minima*, *Ceasulia axillaris*, *Ludwigia parviflora* and *Eclipta alba* among broadleaf weeds and *Cyperus iria* was only sedge. Crop establishment method influenced the weed flora and weed dry biomass at 60 days after sowing (DAS). Transplanted rice (TPR) recorded lower density of grasses, broadleaved weeds and sedges, but, was comparable to zero till (ZT) and conventional tillage (CT) + previous crop residues (R) + Sesbania (S) as brown manure. Among direct seeded rice (DSR), ZT and CT with R + S recorded significantly lower weed density and dry biomass followed by ZT+ R and CT + R.

Three weed species, *viz. Ludwigia parviflora*, *Phyllanthus urinaria* and *Physalis minima* were emerged only in the CT, whereas, *Caesulia axillaris* and *Dinebra retroflexa* could germinate and established in TPR. Shannon diversity index (H) is commonly used to characterize species diversity in a community. Shannon's index accounts for both abundance and evenness of the species present.

$$\text{Shannon index} \quad (H') = -\sum_{i=1}^{S} (Pi \ln(Pi))$$

where, S = total number of species in a community; *Pi* = proportion of species *i*; *ni* = number of individuals in specie *i*; N = total number of individual in a treatment

Shannon diversity index worked out for different crop establishment methods using the weed density at 60 DAS. In rice, DSR-CT+S and TPR have higher diversity compare to the DSR-ZT+S,but the CT-DSR+S have more diversity compare to the TPR due to the more number of species present and evenly distributed (**Fig. 1**).Among weed management practices, rotational use of herbicides has lowest diversity followed by continuous use of bispyribac and highest with weedy check.

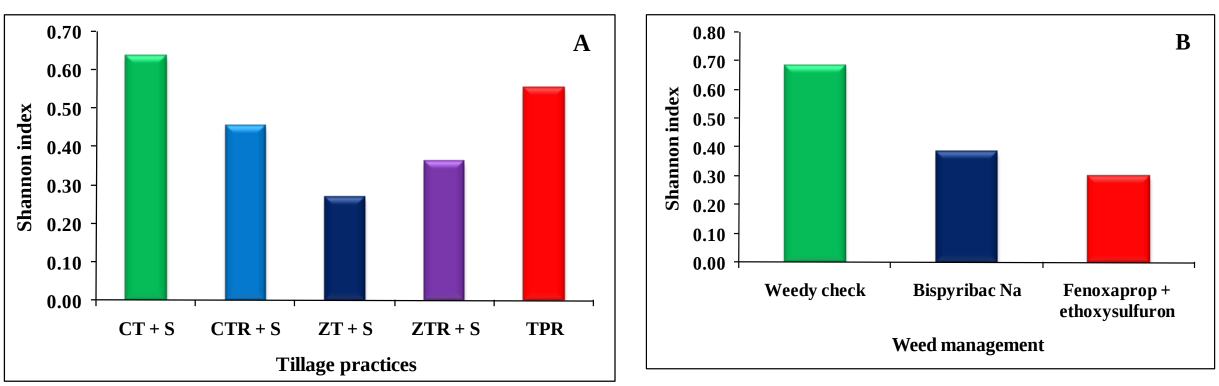


Fig. 1. Effect of weed diversity on crop establishment methods (tillage practices) (A) and weed management (B) in rice

Weed seed bank study were conducted by taking soil sample of 10 cm diameter core at 0-5, 5-10 and 10-15 cm depth in each plot of DSR-CT+S, DSR-CT+R+S, DSR-ZT+S, DSR-ZT+R+S and TPR. In rice, *Echinochloa colona*, *Cyperus iria*, *Dinebra retroflexa* and *Alternanthera paronychioides* are the major weed species germinated in all three depths. Other weeds germinated were *Mollugo pentaphylla*, *Ludwigia parviflora*, *Portulaca oleracea* and *Caesulia axillaris*. It has been found that, there is decreasing trend for *Echinochloa colona* and *Dinebra retroflexa* with the decreasing soil depth in DSR-ZT+S and DSR-ZT+R+S (**Fig. 2**). However, no definite trends observed in DSR-CT, DSR-CT+R and TPR. Seed bank study confirms the dominancy of *Echinochloa colona*, *Cyperus iria* and *Dinebra retroflexa* in rice under rice-wheat-greengram cropping system.

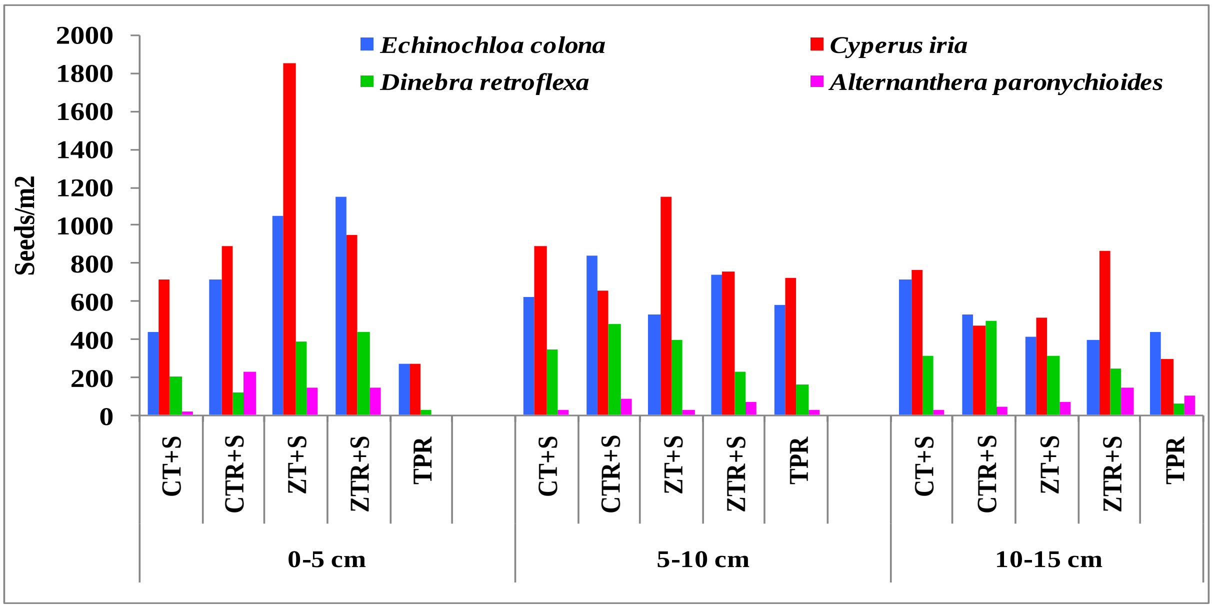


Fig. 2. Effect of weed seeds at various soil depths on crop establishment methods (tillage practices) on weed seed bank dynamic in rice

At 60 DAS, the highest weed density and dry biomass was recorded with DSR-ZT+S (37.4 no./m^2 and 40.8 g/m^2, respectively) followed by DSR-CT+S (37.1 no./m^2 and 40.4 g/m^2, respectively) (**Table 1**). The least weed density and dry biomass was recorded with TPR (11.8 no./m^2 and 15.1 g/m^2, respectively). However, the highest weed control efficiency was recorded in TPR (82.9%) followed by DSR-ZT+R+S (65.6%), whereas the lowest with DSR-ZT+S (42.8%). Among weed management practices, rotational use of herbicides i.e. tank mix of fenoxaprop+ethoxysulfuron (60+18 g/ha) has the lowest weed density and dry biomass (3.4 no./m^2 and 5.07 g/m^2, respectively) followed by continuous use of bispyribac at 25 g/ha (8.33 no./m^2 and 10 g/m^2, respectively). The highest values of weeds were recorded with weedy check (75.87 no./m^2 and 82.53 g/m^2, respectively). Lower weed dry biomass in fenoxaprop + ethoxysulfuron helped to achieve highest weed control efficiency (95.3%) followed by bispyribac (85.6%) over weedy check.

Crop establishment method significantly influence the yield attributes and yield, **Table 1** depicts that the highest grain yield was recorded in TPR (3.59 t/ha) which was significant among other crop establishment methods followed by DSR CT+R+S (2.81 t/ha), whereas, lowest rice grain yield was recorded in DSR-ZT+S (2.53 t/ha). Straw yield followed the trend of rice grain yield and recorded the highest yield in TPR (5.85 t/ha) followed by DSR CT+R+S (4.58 t/ha).

Table 1. Weed and yield parameters in rice as influenced by crop establishment and weed management practices

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	WCE (%)	Grains /panicle	Grain yield (kg/ha)	Straw yield (kg/ha)
Crop establishment						
DSR CT+S	5.00^{a}(37.11)	5.02^{ab}(40.44)	52.2	123.7^{bc}	2691.7^{bc}	4385.1^{bc}
DSR CT+R+S	4.68^{a}(32.56)	4.65^{ab}(35.89)	58.1	123.9^{bc}	2811.1^{b}	4578.3^{b}
DSR ZT+S	4.87^{a}(37.44)	5.27^{a}(40.78)	42.8	121.9^{c}	2527.8^{c}	4114.8^{c}
DSR ZT+R+S	4.40^{a} (27.11)	4.34^{b}(30.44)	65.6	124.4^{b}	2661.1^{bc}	4333.1^{bc}
TPR	3.27^{b}(11.78)	3.32^{c}(15.11)	82.9	137.5^{a}	3594.4^{a}	5850.9^{a}
LSD (p=0.05)	0.72	0.88		2.23	206.54	340.83
Weed management						
Weedy check	8.51^{a}(75.87)	8.42^{a}(82.53)	-	109.0^{b}	1713.3^{b}	2570.0^{b}
Bispyribac sodium (25 g/ha)	2.91^{b}(8.33)	3.24^{b}(10.00)	85.6	133.4^{a}	3408.3^{a}	5453.3^{a}
Fenoxaprop + ethoxysulfuron (60+18 g/ha)	1.90^{c}(3.40)	1.90^{c}(5.07)	95.3	136.4^{a}	3450.0^{a}	5934.0^{a}
LSD (p=0.05)	0.93	0.94		4.68	331.11	542.92

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; **TPRCT:** Transplanted rice followed by CT wheat; **S:** Sesbania as brown manure. Weed data subjected to SQRT transformation; original values are in parentheses; **WCE**: weed control efficiency

Pre-sowing non-selective herbicides (glyphosate) was applied in ZT to kill the unwanted plants present before sowing. Among the weed management practices, rotational use of herbicides fenoxaprop + ethoxysulfuron (60+18 g/ha) recorded the highest grain yield (3.45 t/ha) followed by continuous use of bispyribac 25 g/ha (3.41 t/ha) which was 101 and 98.9%, respectively more over weedy check (1.71 t/ha), however, both weed management practices were statistically comparable (**Table 1**). Straw yield followed the trend of grain yield. It was recorded that retention of previous crop residues and ZT reduced the numbers, length, width and depth of soil cracks, resulting lower soil crack surface area (**Plate 1**).

The energy parameters were evaluated with crop establishment methods and weed management practices, it was found that the highest energy productivity (0.26 kg/MJ) was obtained in TPR along with bispyribac sodium at 25 g/ha. However, the highest energy output

(155660 MJ/ha), net energy (138805.8 MJ/ha) and energy use efficiency (9.2) was obtained in TPR along with fenoxaprop + ethoxysulfuron (60+18 g/ha). However, the least performance of the treatment was observed in ZT – DSR along with weedy check plots (**Table 2 & Fig. 3**).

ZT-DSR+R+S **Transplanted rice**

Table 2. Energy consumption and energy output for rice cultivation under different crop establishment and weed management practices

Treatments	**Energy input (MJ/ha)**	**Yield (kg/ha)**	**Energy output (MJ/ha)**	**Net energy (MJ/ha)**	**Energy use efficiency**	**Energy productivity (kg/MJ)**
CT-DSR:W1	16377.2	1566.7	52405.5	36028.3	3.2	0.10
CT-DSR+S:W2	60663.4	3241.7	112486.4	51822.9	1.9	0.05
CT-DSR+S:W3	60657.6	3266.7	118253.9	57596.2	1.9	0.05
CT-DSR+R:W1	53861.5	1683.3	56307.0	2445.5	1.0	0.03
CT-DSR+R+S:W2	98163.4	3333.3	123683.9	25520.4	1.3	0.03
CT-DSR+R+S:W3	98157.6	3416.7	115666.6	17508.9	1.2	0.03
ZT-DSR:W1	13312.7	1550.0	51847.5	38534.8	3.9	0.12
ZT-DSR+S:W2	57614.7	2983.3	103520.8	45906.1	1.8	0.05
ZT-DSR+S:W3	57608.8	3050.0	110410.0	52801.2	1.9	0.05
ZT-DSR+R:W1	51161.5	1600.0	53520.0	2358.5	1.0	0.03
ZT-DSR+S+R:W2	95463.5	3166.7	109883.9	14420.4	1.2	0.03
ZT-DSR+S+R:W3	95457.7	3216.7	116443.9	20986.2	1.2	0.03
TPR:W1	16802.2	2166.7	72475.5	55673.3	4.3	0.13
TPR:W2	16860.0	4316.7	149788.9	132928.9	8.9	0.26
TPR:W3	16854.2	4300.0	155660.0	138805.8	9.2	0.26

W1: Weedy check; W2: Bispyribac-Na at 25 g/ha; W3: Fenoxaprop + ethoxysulfuron (60+18 g/ha)

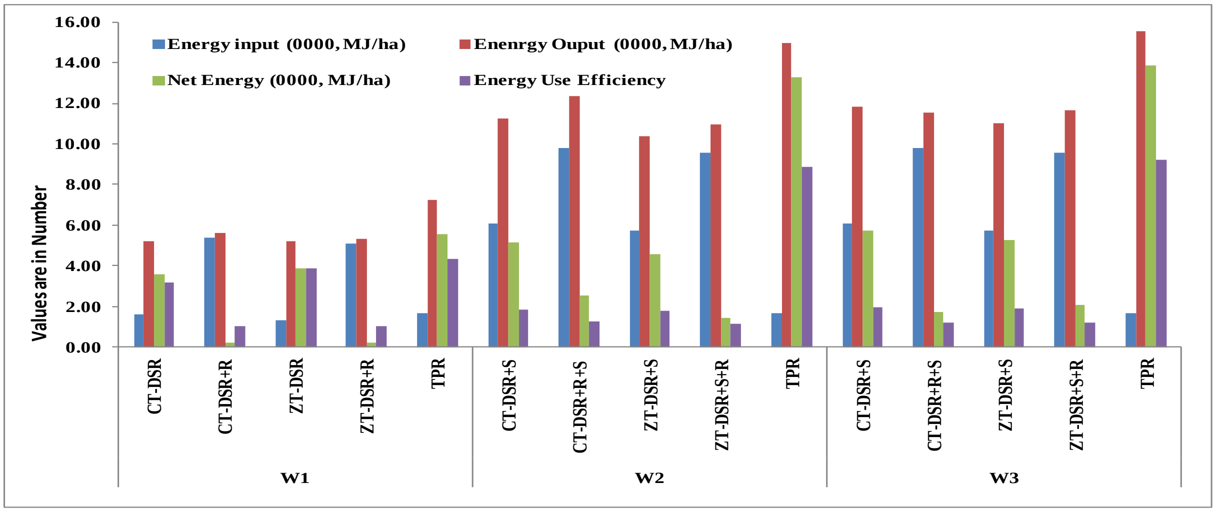


Fig. 3. Energy use pattern of rice under different crop establishment and weed management practices

In wheat

In the study area wheat field comprised with *Medicago polymorpha*, *Chenopodium album*, *Rumex dentatus*, *Sonchus oleraceus*, *Vicia sativa*, *Cichorium intybus*, *Convolvulus arvensis* and *Lathyrus aphacea* were major broadleaved weeds, *Avena fatua*, *Phalaris minor*, *Dinebra retroflexa*, *Digitaria sanguinalis*, *Echinochloa colona* and *Paspaladium* sp. were major grassy weeds and there was no sedge present. *Medicago polymorpha*, *Chenopodium album* and *Avena ludoviciana* was the dominating weed species in wheat. *Physalis minima*, *Sonchus oleraceus*. *Lathyrus sativus*, *Phalaris minor*, *Rumex dentatus*, *Cichorium intybus*, *Convolvulus arvensis* were other weed flora present at 60 DAS. It was noticed that *Digitaria sanguinalis*, *Echinochloa colona* and *Paspaladium* sp. were late emerging weeds in wheat. ZT plots were more with *Avena*, whereas, *Phalaris* was more in CT plots. Weed densities in CT and ZT was comparable and higher than the TPR-CT. Weed density of *Medicago polymorpha* and *Chenopodium album* was higher in CT than ZT and TPR-CT whereas, *Avena ludoviciana* germination was higher in ZT compared to the CT and TPR-CT. *Convolvulus arvensis* was present only in CT plots.

Shannon diversity index in wheat was higher in TPR-CT and ZT compare to the other crop establishment methods (**Fig. 4**). However, CT has the lowest diversity due to *Medicago polymorpha* dominating in the tillage practice. Among weed management rotational use of herbicides and clodinafop+sulfosulfuron has comparable diversity but was lower than weedy check.

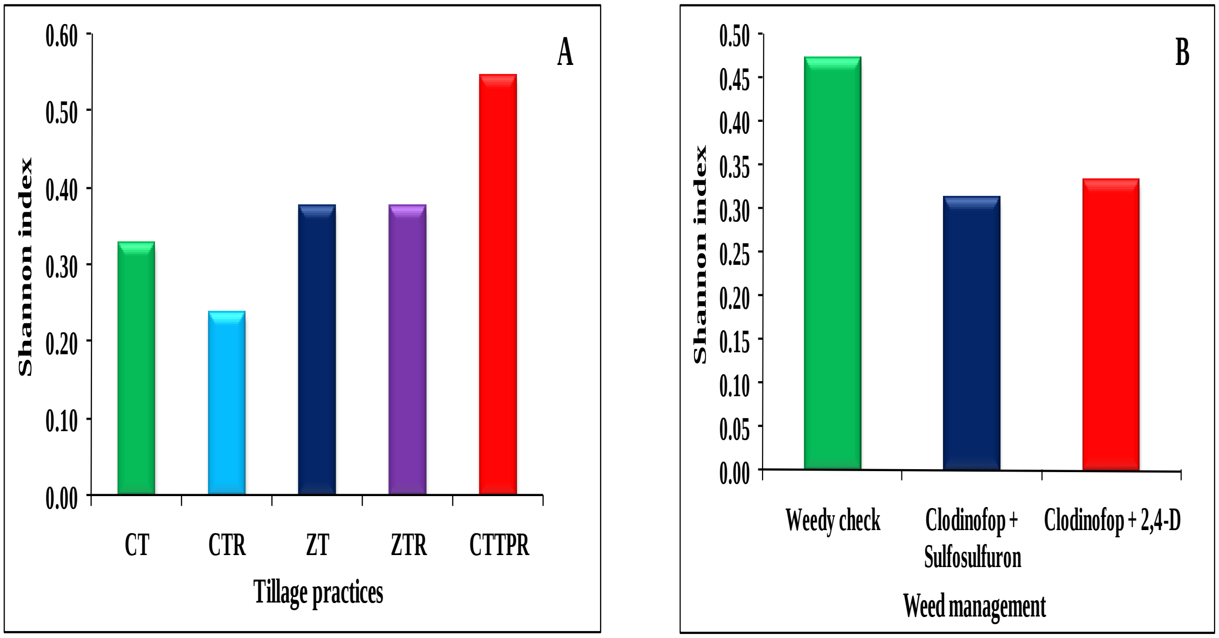


Fig. 4. Effect of weed diversity on crop establishment methods (tillage practices) (A) and weed management (B) in wheat

Seed bank study shows that, in wheat there is a decreasing trend of *Medicago polymorpha* emergence with the depth in all crop establishment method (tillage practices) (**Fig. 5**).

Avena fatua are present mainly in upper layer of ZT and ZTR. However, C*henopodium album* are almost equally distributed in all three layers but in CTR at 0-5 cm depth very few seed germinated and similarly, in TPR-CT at 5-10 cm depth. Seeds of *Avena ludoviciana* were germinated in upper layer (0-5 cm depth) in all the tillage practices except TPR-CT, whereas, in lower layer only few seeds germinated TPR-CT (5-10) and, CT, CTR and ZTR (10-15cm depth).

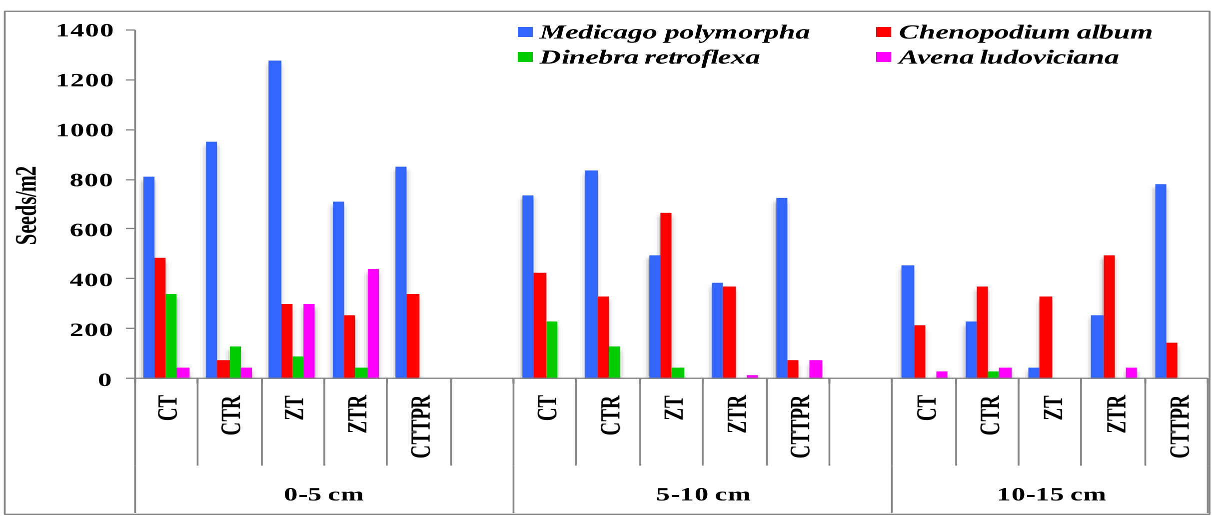


Fig. 5. Effect of tillage practices on weed seed bank dynamic in wheat

Weed seed bank was measured and it was found that ZT plots had more of weeds on top 0-2 cm depth, followed by CT. Inclusion of crop residues significantly reduced the weed seed bank. At 2-5 cm depth, no specific trend was recorded. However, at 5-10 cm depth, CT plots had more seeds than ZT and it was further reduced with the plots where previous crop residues were retained. Regardless of all the depths, ZT plots had 17.2 and 41.6% lower broadleaved and grassy weed seeds, respectively over CT. Residue retention lowered 5.2% of BLW and 43.7% of grassy weeds than residue removal. The highest species diversity was recorded in ZT followed by TPR-CT, whereas, lowest species diversity was recorded in CT. Among weed management practices, tank mix of clodinafop + sulfosulfuron (60+25 g/ha) recorded lowest diversity followed by rotational use of herbicides (clodinafop + 2, 4-D 60+ 500 g/ha), whereas, the highest diversity recorded with weedy check.

It was found that weed density was lower in TPR-CT (33.4 no./m^2) and DSR ZT+R+S-ZTR-ZTR (34.3 no./m^2), whereas, dry biomass was lowest with DSR ZT+R+S-ZTR-ZTR (18.4 g/m^2) followed by TPR-CT but, both were statistically comparable (**Table 3**). Reduction in weed density under DSR ZT+R+S-ZTR-ZTR significantly achieved the higher weed control efficiency (63.7%) followed by TPR-CT (61.8%), whereas, lower weed control efficiency was recorded in DSR CT+S-CT-ZT (45.8%). The highest weed density and dry biomass was recorded with DSR CT+S-CT-ZT (44.7 no./m^2 and 27.5 g/m^2, respectively). It was estimated that weed dry biomass was 14.3% lower in ZT over CT plots, and retention of crop residue further reduced the weed dry biomass by 21.2% over without residues. Among weed management practices tank mix of clodinafop + 2, 4-D has lowest weed density and dry biomass (12.0 no./m^2 and 6.6 g/m^2, respectively) followed by clodinafop + sulfosulfuron, whereas the highest values was measured in weedy check (88.5 no./m^2 and 50.7 g/m^2, respectively). Rotational use of herbicide i.e. tank mix of clodinafop+2, 4 D was controlled the wide range of grassy and broadleaved weeds resulted highest weed control efficiency (87%) followed by clodinafop + sulfosulfuron (80.7%) over weedy check.

Among the crop establishment methods, grains/spike ranged from 39.5 - 42.7/spike, which was statistically comparable. But, grain yield was significantly higher in DSR ZT+R+S-ZTR-ZTR (4.13 t/ha) followed by DSR CT+R+S-CTR-ZTR (3.87 t/ha) which were 21 and 13.4%, respectively better than TPR-CT (3.41 t/ha). Straw yield had followed the trend of grain yield and higher straw yield in DSR ZT+R+S-ZTR-ZTR (5.23 t/ha) followed by DSR CT+R+S-CTR-ZTR and lowest with TPR-CT (**Table 3**). Among the weed management practices grains/spike, grain and straw yield was significantly higher with clodinafop + sulfosulfuron (43.2, 4.94 and 6.27 t/ha respectively) which was close to clodinafop+2, 4 D (42.2, 4.63 and 5.95 t/ha, respectively). However, the lowest yield attributes and yield was recorded with weedy check (39.9, 1.46 and 1.93 t/ha, respectively).

The energy use pattern on long term impact of herbicides in wheat under different crop establishment method was studied during *Rabi*, 2017-18. The highest grain yield (5.4 t/ha) and energy output (168632.8 MJ/ha) was obtained in ZT+R along with clodinofop + sulfosulfuron (60+25 g/ha). However, the energy use efficiency (11.08) and energy productivity (0.35 kg/MJ) was highest in ZT along with clodinofop + sulfosulfuron (60+25 g/ha), whereas net energy (135949.9 MJ/ha) was highest in CT along with clodinofop + sulfosulfuron (60+25 g/ha). The least performance of the treatment was observed in CT+R along with weedy check plots (**Table 4 & Fig. 6**), in which, the net energy return was in negative (-39727.51 MJ/ha).

Table 3. Weed and yield parameters of wheat as influenced by crop establishment and weed management practices

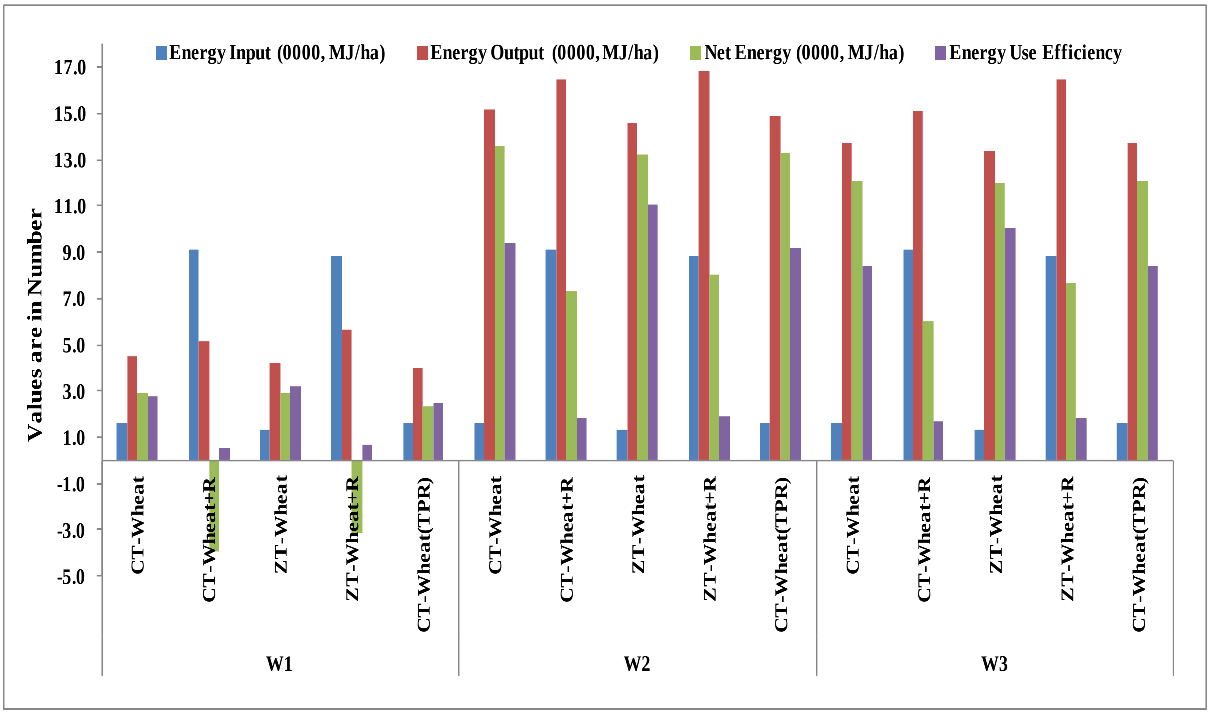
Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	WCE (%)	Grains/spike	Grain yield (kg/ha)	Straw yield (kg/ha)
Crop establishment						
DSR CT+S-CT-ZT	6.05[a](44.7)	4.82[a](27.5)	45.8	39.5[a]	3622.2[c]	4662.9[c]
DSR CT+R+S-CTR-ZTR	5.39[bc](35.2)	4.32[bc](22.3)	56.1	41.0[a]	3866.7[b]	4937.9[b]
DSR ZT+S-ZT-ZT	5.96[ab](43.8)	4.53[ab](24.3)	52.2	41.0[a]	3355.6[d]	4358.4[d]
DSR ZT+R+S-ZTR-ZTR	5.30[c](34.3)	3.93[c](18.4)	63.7	42.7[a]	4133.3[a]	5225.4[a]
TPR-CT	5.16[c](33.6)	3.96[c](19.4)	61.8	41.2[a]	3411.1[d]	4408.3[d]
LSD (p=0.05)	0.64	0.42		(ns)	184.4	236.13
Weed management						
Weedy check	9.41[a](88.5)	7.14[a](50.7)	-	37.9[b]	1460.0[c]	1930.7[c]
Clodinafop+Sulfosulfuron	3.84[b](14.4)	3.18[b](9.8)	80.7	43.2[a]	4943.3[a]	6274.2[a]
Clodinafop+2,4 D	3.47[b](12.0)	2.62[c](6.6)	87.0	42.2[a]	4630.0[b]	5950.8[b]
LSD (p=0.05)	0.49	0.38		2.86	277.23	323.05

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; **TPRCT:** Transplanted rice followed by CT wheat; **S:** Sesbania. Weed data subjected to SQRT transformation; original values are in parentheses

Table4. Energy consumption and energy output for wheat cultivation under different tillage and weed management practices

Treatments	Energy input (MJ/ha)	Yield (kg/ha)	Energy output (MJ/ha)	Net energy (MJ/ha)	Energy use efficiency	Energy productivity (kg/MJ)
CT-Wheat:W1	16147.5	1400.0	45080.0	28932.5	2.8	0.09
CT-Wheat:W2	16210.1	4800.0	152160.0	135949.9	9.4	0.30
CT-Wheat:W3	16341.6	4666.7	137116.3	120774.6	8.4	0.29
CT-Wheat+R:W1	91147.5	1600.0	51420.0	-39727.5	0.6	0.02
CT-Wheat+R:W2	91210.1	5233.3	164587.8	73377.7	1.8	0.06
CT-Wheat+R:W3	91341.6	4766.7	151282.2	59940.5	1.7	0.05
ZT-Wheat:W1	13098.7	1300.0	42022.5	28923.8	3.2	0.10
ZT-Wheat:W2	13161.3	4600.0	145820.0	132658.7	11.1	0.35
ZT-Wheat:W3	13292.8	4166.7	133645.9	120353.1	10.1	0.31
ZT-Wheat+R:W1	88447.5	1766.7	56887.2	-31560.3	0.6	0.02
ZT-Wheat+R:W2	88510.1	5383.3	168632.8	80122.7	1.9	0.06
ZT-Wheat+R:W3	88641.7	5250.0	165112.5	76470.8	1.9	0.06
CT-Wheat (TPR):W1	16147.5	1235.0	39861.9	23714.3	2.5	0.08
CT-Wheat (TPR):W2	16210.1	4700.0	148990.0	132779.9	9.2	0.29
CT-Wheat (TPR):W3	16341.6	4300.0	137116.3	120774.6	8.4	0.26

W1: Weedy check; W2: Clodinofop + sulfosulfuron (60+25 g/ha); W3: Clodinofop + 2, 4-D (60+500 g/ha)



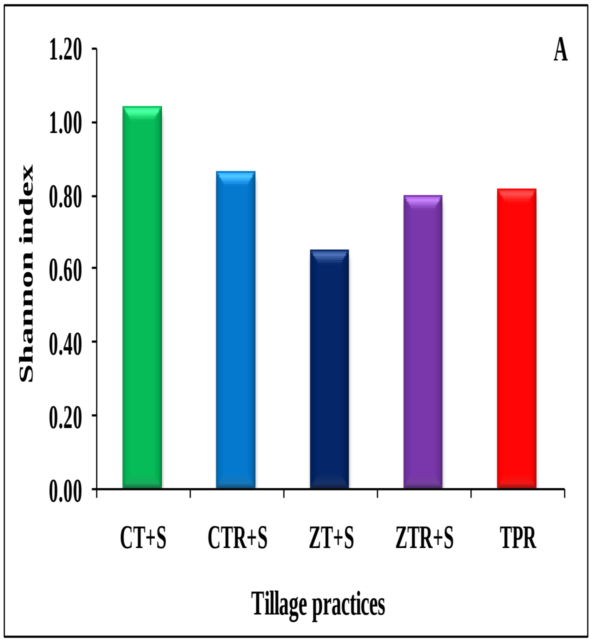
W1: Weedy check; W2: Clodinofop + sulfosulfuron (60+25 g/ha); W3: Clodinofop + 2, 4-D (60+500 g/ha)

Fig.6. Energy use pattern of wheat under different crop establishment and weed management practices

B. Weed management in rice-maize/mustard/pea-greengram based cropping systems under conservation agriculture

Cyperus iria, *Echinochloa colona*, *Phyllanthus urinaria*, *Caesulia axillaris*, *Dinebra retroflexa*, *Alternanthera paronychioides*, *Ludwigia parviflora*, *Physalis minima*, *Eclipta prostrata*, *Digitaria sanguinalis* and *Mollugo pentaphylla* weed flora were observed in rice under rice-maize cropping system. Densities of *Cyperus iria* and *Echinochloa colona* were higher in CT and ZT as compared to the TPR-CT. *Alternanthera paronychioides* seeds were germinated only in ZT, whereas, *Physalis minima*, *Digitaria sanguinalis* and *Eclipta prostrata* were observed in CT practice.

Shannon diversity index in rice was higher in CT+S and which was comparable with CTR+S, ZTR+S and TPR, whereas, lowest diversity was observed in ZT (**Fig. 7**). Among weed management practices, the higher diversity was also observed in weedy check. Between herbicides weed diversity in bispyribac sodium has higher as compared to the rotational use of herbicides (fenoxaprop + ethoxysulfuron).



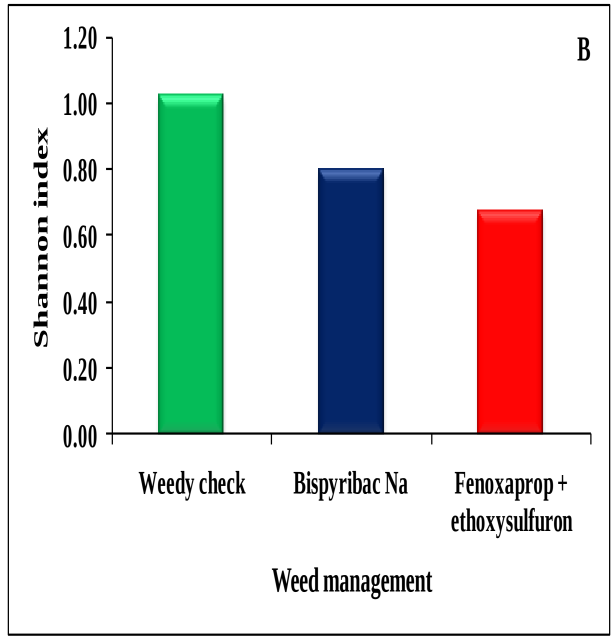


Fig. 7. Effect of weed diversity in rice influenced by (A) tillage practices and (B) weed management

In rice, *Cyperus iria*, *Mollugo pentaphylla*, *Portulaca oleracea* and *Echinoloa colona* are the major weed species germinated. Other weed seeds germinated were *Ludwigia parviflora*, *Corchorus* sp., *Dinebra retroflexa* and *Caesulia axillaris*. It has been observed that, there is decreasing trend for *Cyperus iria* in CTR+S with soil depth and present substantially in all three layers (**Fig. 8**). However, there was no definite trend observed for other weed species. *Echinochloa colona* was germinated in upper soil (0-5 cm depth) layer, whereas, *Portulaca oleracea* were observed in lower soil layer (5-10 and 10-15 cm depth). Seed bank study cofirms the dominancy of the *Cyperus iria* in rice under rice-maize cropping system.

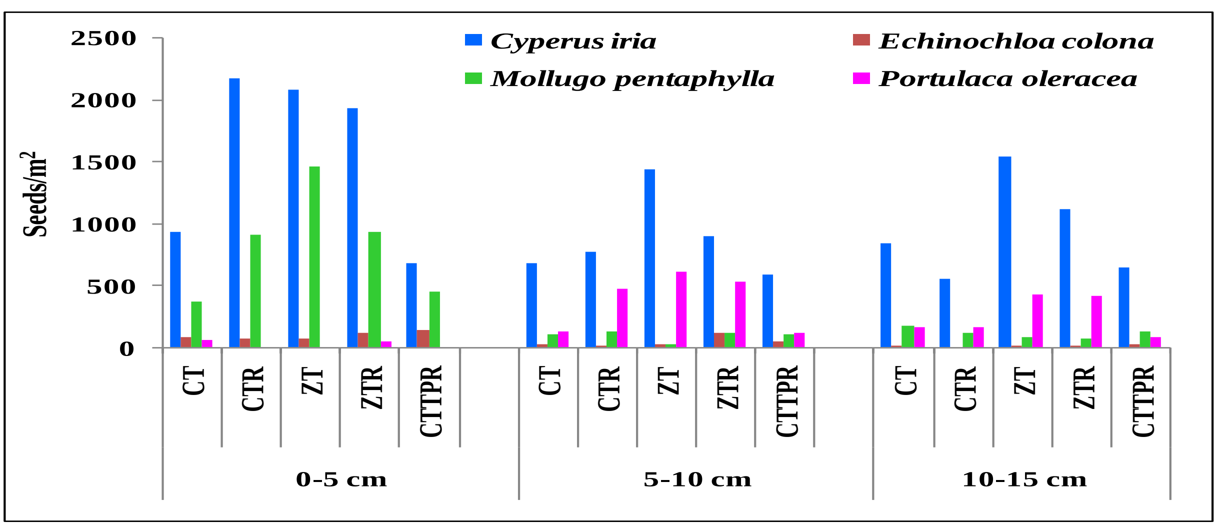


Fig. 8. Effect of weed tillage practices on weed seed bank dynamic in rice

Crop establishment method and weed management practice significantly influenced the weed density and weed dry biomass at 60 (DAS) (**Table 5**). TPR recorded lower weed density and dry biomass (12.7 no./m^2 and 19.67 g/m^2, respectively) which has comprised with lest density of grasses, broadleaved weeds and sedges. ZT-DSR+R+S has lower weed density and dry biomass (25.4 no./m^2 and 33.7 g/m^2, respectively), however, yet their effect was not pertaining to TPR. The higher weed parameters were recorded in ZT-DSR+S (42.31 no./m^2 and 50.26 g/m^2, respectively). Among weed management practices, weedy check has the highest weed density and dry biomass (73.96 no./m^2 and 91.71 g/m^2, respectively). Herbicide rotation with fenoxaprop + ethoxysulfuron has lowest weed parameters (3.47 no./m^2 and 6.92 g/m^2, respectively) followed by continuous use of bispyribac. In TPR weeds were suppressed due to advancement in seedling and thin water layer during early stages of crop suppressed the weeds resulting higher weed control efficiency (78.6%) followed by ZT DSR+R+S (63.2%). In ZT DSR+R+S, retention of crop residues and susbania significantly suppressed the weeds resulted higher weed control efficiency, whereas, ZT DSR+S has lower weed control efficiency (45.2%). Among weed management practices rotational use of herbicide i.e. tank mix of fenoxaprop + ethoxysulfuron has controlled the wide range of grasses, sedge and broadleaved weeds resulted highest weed control efficiency (92.5%) followed by continuous use of bispyribac sodium (83.6%) over weedy check.

Crop establishment methods significantly influenced the yield attributes, and grain and straw yield of rice, Table 5 depicts that the highest grain/panicle was recorded with TPR-CT (137.9 no./panicle), whereas ZT DSR+S, CT DSR+R+S and CT DSR+S were next best treatments. The lowest grains/panicle was recorded with ZT DSR+S (124 no./panicle). Better yield attributes lead to higher grain yield and recorded the highest grain and straw yield in TPR (3.81 and 6.19 t/ha respectively) followed by CT DSR+R+S (3.24 and 5.27 t/ha respectively) and ZT DSR+R+S (3.00 and 4.89 t/ha, respectively). The lowest grain and straw yield was recorded in ZT DSR+S (2.85 and 4.66 t/ha, respectively).

Weed management play crucial role in tackling the weeds during the season, however, it is more rely on type of weed management practice adopted and the kind of weeds present. Weedy check has the lowest yield attributes and yield. The lowest no. of grains/panicle was recorded in weedy check (110.9), which was 25.5% lower than fenoxaprop + ethoxysulfuron (139.2) and 21.5% lower than continuous application of bispyribac (134.7). The grain and straw yield followed the trend of yield attributes and recorded the highest yield 3.87 and 6.66 t/ha, respectively in fenoxaprop + ethoxysulfuron followed by bispyribac (3.77 and 6.02 t/ha, respectively). However, the lowest grain yield was recorded with weedy check (1.88 and 2.82 t/ha, respectively). This clearly illustrated that the adoption of weed management practices significantly increase the rice grain yield. The energy utilization and output study was carried out, the highest grain yield (4.6 t/ha), net energy (148047.8 MJ/ha), energy output (165314.2 MJ/ha), energy use efficiency (9.57) and energy productivity (0.26 kg/MJ) was obtained in TPR along with fenoxaprop + ethoxysulfuron (60+18 g/ha). The least performance of the treatment was observed in ZT – DSR along with weedy check plots (Table 6 & Fig. 9).

Table 5. Weed and yield parameters of rice as influenced by crop establishment and weed management practices

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	WCE (%)	Grains /panicle	Grain yield (kg/ha)	Straw yield (kg/ha)
Crop establishment						
CT DSR+S	5.30^a(35.36)	5.83^a(45.66)	50.2	124.9^{bc}	2955.6^c	4822.2^c
CT DSR+R+S	5.01^a(30.99)	5.42^a(40.13)	56.2	126.8^{bc}	3238.9^b	5271.8^b
ZT DSR+S	5.20^a(42.31)	5.92^a(50.26)	45.2	124.0^c	2854.4^c	4658.9^c
ZT DSR+R+S	4.72^a(25.44)	5.12^{ab}(33.71)	63.2	127.9^b	3001.1^{bc}	4891.7^{bc}
TPR	3.63^b(12.66)	4.07^b(19.67)	78.6	137.9^a	3806.7^a	6187.1^a
LSD (p=0.05)	0.75	1.17		3.15	262.02	421.46
Weed management						
Weedy check	8.89^a(73.96)	9.39^a(91.71)	-	110.9^b	1877.3^b	2816.0^c
Bispyribac	3.17^b(10.63)	3.84^b(15.03)	83.6	134.7^a	3766.7^a	6026.7^b
Fenoxaprop + ethoxysulfuron	2.25^b(3.47)	2.58^c(6.92)	92.5	139.2^a	3870.0^a	6656.4^a
LSD (p=0.05)	0.94	1.04		4.59	311.65	501.07

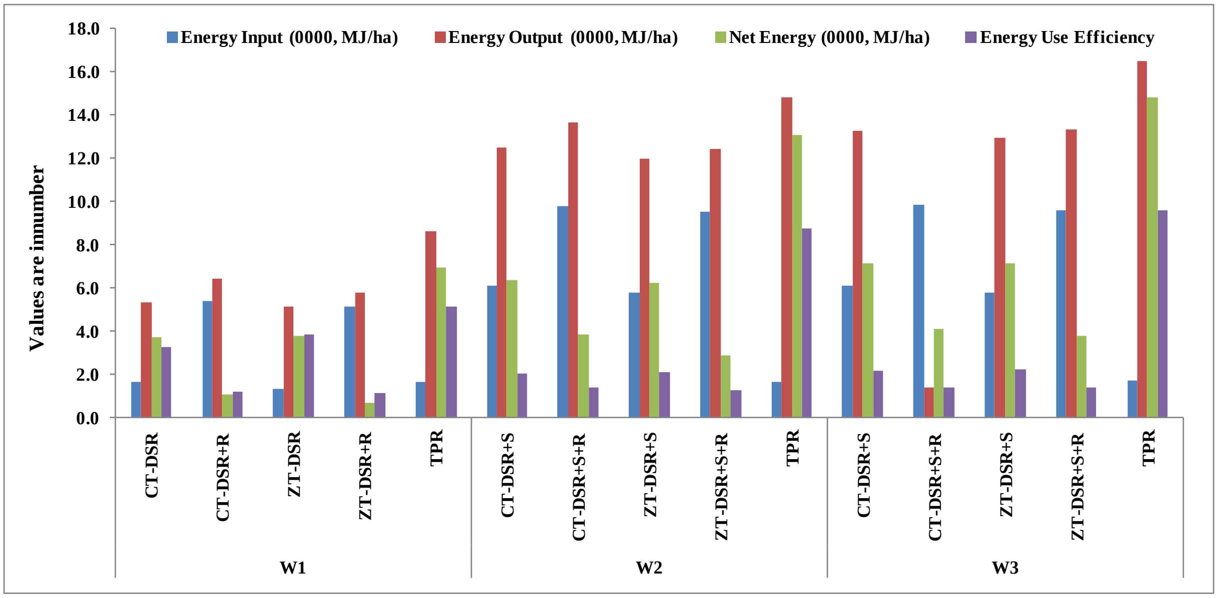
CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; **TPRCT:** Transplanted rice followed by CT wheat; **S:** Sesbania. Weed data subjected to SQRT transformation; original values are in parentheses

Table 6. Energy consumption and energy output for rice under different crop establishment and weed management practices

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; **TPRCT:** Transplanted rice followed by CT wheat; **S:** Sesbania. Weed data subjected to SQRT transformation; original values are in parentheses.

Treatments	Energy input (MJ/ha)	Yield (kg/ha)	Energy output (MJ/ha)	Net energy (MJ/ha)	Energy use efficiency	Energy productivity (kg/MJ)
CT-DSR:W1	16367.7	1600.0	53520.0	37152.3	3.3	0.10
CT-DSR+S:W2	61108.1	3666.7	132734.2	71626.1	2.2	0.06
CT-DSR+S:W3	60969.6	3600.0	124920.0	63950.4	2.0	0.06
CT-DSR+R:W1	53867.7	1933.3	64669.5	10801.8	1.2	0.04
CT-DSR+S+R:W2	98208.7	3576.7	136485.8	38277.1	1.4	0.04
CT-DSR+S+R:W3	98608.1	3693.3	139370.0	40761.9	1.4	0.04
ZT-DSR:W1	13313.5	1533.3	51289.5	37976.0	3.9	0.12
ZT-DSR+S:W3	58053.9	3573.3	129353.8	71299.9	2.2	0.06
ZT-DSR+S:W2	57654.5	3456.7	119947.2	62292.8	2.1	0.06
ZT-DSR+R:W1	51162.8	1733.3	57979.5	6816.7	1.1	0.03
ZT-DSR+S+R:W2	95503.8	3576.7	124111.2	28607.5	1.3	0.04
ZT-DSR+S+R:W3	95903.2	3693.3	133697.8	37794.6	1.4	0.04
TPR:W3	17266.4	4566.7	165314.2	148047.8	9.6	0.26
TPR:W2	16867.0	4266.7	148054.2	131187.2	8.8	0.25
TPR:W1	16809.2	2586.7	86524.5	69715.3	5.1	0.15

W1: Weedy check; W2: Bispyribac-Na at 25 g/ha; W3: Fenoxaprop + ethoxysulfuron (60+18 g/ha)



W1: Weedy check; W2: Bispyribac-Na at 25 g/ha; W3: Fenoxaprop + ethoxysulfuron (60+ 18 g/ha)

Fig. 9. Energy use pattern of rice under different crop establishment and weed management practices

In winter season

In pea

During the study, the study area comprised with *Medicago polymorpha*, *Chenopodium album* and *Rumex dentatus* were major broadleaved weeds, *Avena fatua, Phalaris minor* and *Dinebra retroflexa* were major grassy weeds. **Table 7** illustrated that the weed density and dry biomass was recorded highest in TPR-CT (93 no./m^2 and 159.9 g/m^2, respectively) followed by ZT DSR+S-ZT-ZT (87.4 no./m^2 and 147.9 g/m^2, respectively). However, the lowest weed parameters were obtained in ZT DSR+R+S-ZTR+ZTR (49.2 no./m^2 and 82.9 g/m^2, respectively). However the lowest weed density and dry biomass was observed in CT (9.73/m^2 and 11.44 g/m^2, respectively). It clearly illustrated that ZT DSR+R+S-ZTR+ZTR has 48.2% weed control efficiency over TPR-CT. It was noticed that weed dry biomass reduction in residue retained plots was 35.6% over residue removal plots. Among weed management practices, pendimethalin *fb* hand weeding recorded lower weed parameters (23.1 no./m^2 and 39.8 g/m^2, respectively) followed by pendimethalin alone (40.7 no./m^2 and 69.9 g/m^2, respectively). Whereas, the highest weed density and dry biomass was recorded in weedy check plots (157.3 no./m^2 and 267.4 g/m^2, respectively). Weed control efficiency was recorded highest in ZT DSR+R+S-ZTR-ZTR (69%) followed by CT DSR+R+S-CTR-ZTR (62.4%) and lowest with TPR-CT (40.2%). Pendimethalin *fb* hand weeding significantly reduced the multiple flush of weeds resulted lower weed population and higher weed control efficiency (85.1%) followed by pendimethalin (73.9%) over weedy check.

Crop establishment method influenced the yield attributes and yield of pea (**Table 7**), pods/plant was recorded the highest with ZT DSR+R+S-ZTR-ZTR (21.1 pods/plant), however, rest of the crop establishment method were statistically comparable. Higher yield attributes leads to better seed yield, the highest yield recorded in ZT DSR+R+S-ZTR-ZTR (1.54 t/ha) which was 40.3% higher than ZT DSR+S-ZT-ZT (1.10 t/ha), this has lowest seed yield of pea. CT DSR+R+S-CTR-ZTR (25.6%) and CT DSR+S-CT-ZT (15.9%) are other crop establishment which gave competitive yield to ZT DSR+R+S-ZTR-ZTR. Similarly, haulm yield was followed the trend of seed yield and higher haulm yield with ZT DSR+R+S-ZTR-ZTR (3.83 t/ha) followed by CT DSR+R+S-CTR-ZTR (3.37 t/ha) and the lowest haulm yield recorded with ZT DSR+S-ZT-ZT (2.24 t/ha). Among the weed management practices, application of pendimethalin 1.0 kg/ha *fb* hand weeding increased the pods/plant by 17.3% and seed yield by 174% over weed check. Pendimethalin 1.0 kg/ha also noticed considerable increase in pods/plant (14.5%) and seed yield (136%).

Table7. Weed and yield parameters as influenced by crop establishment and weed management practices in pea

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	WCE (%)	Pods /plant	Grain yield (kg/ha)	Straw yield (kg/ha)
Crop establishment						
CT DSR+S-CT-ZT	8.17^{b}(79.2)	10.61^{b}(137.1)	48.7	19.6^{b}	1274.4^{bc}	3452.1^{b}
CT DSR+R+S-CTR-ZTR	7.04^{c}(59.6)	9.24^{c}(100.5)	62.4	19.9^{b}	1381.1^{b}	3368.4^{b}
ZT DSR+S-ZT-ZT	8.68^{ab}(87.4)	11.10^{ab}(147.9)	44.7	19.2^{b}	1100.0^{d}	2237.7^{d}
ZT DSR+R+S-ZTR-ZTR	6.27^{d}(49.2)	8.29^{c}(82.9)	69.0	21.1^{a}	1543.3^{a}	3833.2^{a}
TPR-CT	9.06^{a}(93.0)	11.86^{a}(159.9)	40.2	19.2^{b}	1213.3^{c}	2997.3^{c}
LSD (p=0.05)	0.61	1.04		1.08	108.48	271.51
Weed management						
Weedy check	12.49^{a}(157.3)	16.25^{a}(267.4)	-	17.9^{b}	640.0^{c}	1810.9^{c}
Pendimethalin	6.33^{b}(40.7)	8.28^{b}(69.9)	73.9	20.5^{a}	1511.3^{b}	3479.4^{b}
Pendimethalin *fb* HW	4.71^{c}(23.1)	6.13^{c}(39.8)	85.1	21.0^{a}	1756.0^{a}	4242.9^{a}
LSD (p=0.05)	0.90	1.27		1.00	144.87	508.75

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; **TPRCT:** Transplanted rice followed by CT in Pea; **S:** Sesbania. Weed data subjected to SQRT transformation; original values are in parentheses

The energy use pattern was studied during *Rabi*, 2017-18 under long term impact of weed control measures in DSR-based cropping system under conservation agriculture in pea. The highest grain yield (2.2 t/ha) was obtained with the ZT+R along with pendimethalin at 1.0 kg/ha PE *fb* one hand weeding at 25 DAS. Similarly, energy output (77708.9 MJ/ha), net energy (67405.4 MJ/ha) and energy use efficiency (7.5) was highest in CT along with pendimethalin at 1.0 kg/ha PE *fb* one hand weeding at 25 DAS. But the energy productivity (0.21 kg/MJ) was highest in ZT along with pendimethalin at 1.0 kg/ha PE *fb* one hand weeding at 25 DAS. The least performance of the treatment was observed in CT+R along with weedy check plots (**Table 8**).

Table8 . Energy consumption and energy output as influenced by crop establishment and weed management practices in pea

Treatments	Energy input (MJ/ha)	Yield (kg/ha)	Energy output (MJ/ha)	Net energy (MJ/ha)	Energy use efficiency	Energy productivity (kg/MJ)
CT-Pea:W1	9673.8	616.7	11326.2	1652.4	1.2	0.06
CT-Pea (TPR):W1	9673.8	633.3	34037.8	24363.9	3.5	0.07
CT-Pea:W2	9989.9	1460.0	26815.4	16825.5	2.7	0.15
CT-Pea (TPR):W2	9989.9	1506.7	60368.9	50379.0	6.0	0.15
CT-Pea:W3	10303.5	1746.7	32080.5	21777.0	3.1	0.17
CT-Pea (TPR):W3	10303.5	1500.0	77708.9	67405.4	7.5	0.15
CT-Pea+R:W1	84673.8	650.0	11938.4	-72735.5	0.1	0.01
CT-Pea+R:W2	84989.9	1583.3	29080.5	-55909.3	0.3	0.02
CT-Pea+R:W3	85303.5	1910.0	35080.4	-50223.1	0.4	0.02
ZT-Pea:W1	6677.5	500.0	9183.4	2505.8	1.4	0.07
ZT-Pea:W2	6993.5	1283.3	23570.5	16577.0	3.4	0.18
ZT-Pea:W3	7307.1	1516.7	27856.2	20549.1	3.8	0.21
ZT-Pea+R:W1	81677.5	800.0	14693.4	-66984.2	0.2	0.01
ZT-Pea+R:W2	81993.5	1723.3	31651.8	-50341.8	0.4	0.02
ZT-Pea+R:W3	82307.1	2106.7	38692.5	-43614.7	0.5	0.03

W1: Weedy check; W2: Pendimethalin at 1.0 kg/ha PE; W3: Pendimethalin at 1.0 kg/ha PE *fb* 1 HW at 25 DAS

In mustard

Crop establishment method and weed control method significantly reduced the weed density and weed dry biomass (**Table 9**). The lowest values of weed parameters was recorded in ZT DSR+R+S-ZTR-ZTR (63.3 no./m^2 and 94.1 g/m^2, respectively) followed by CT DSR+R+S-ZTR-ZTR (72 no./m^2 and 108.6 g/m^2, respectively), whereas, the highest weed parameters was obtained in TPR-CT (110.3 no./m^2 and 175.1 g/m^2, respectively). The reduction in weed density and dry biomass recorded the better weed control. ZT DSR+R+S-ZTR-ZTR has recorded higher weed control efficiency (68.8%) followed by CT DSR+R+S-CTR-ZTR (64%) and lowest with TPR-CT (41.9%). It was observed that retention of crop residues significantly reduced the weed density and dry biomass in ZT and CT. Application of pre-emergence of pendimethalin *fb* hand weeding recorded lower weed density (23.4 no./m^2) and weed dry weight (41.4 g/m^2) followed by pendimethalin alone (43.7 no./m^2 and 74.3 g/m^2, respectively). The highest density and dry biomass was recorded in weedy check plots. Pendimethalin *fb* hand weeding recorded highest weed control efficiency (86.3%) followed by pendmethalin alone (75.3%) over weedy check.

Crop establishment method has significant effect on yield attributes and yield of mustard (**Table 9**). The highest number of siliqua was recorded in ZT DSR+R+S-ZTR-ZTR (190.6/plant) followed by CT DSR+R+S-CTR-ZTR (181.7/plant). The lowest siliqua was recorded in ZT DSR+S-ZT-ZT (179.9/plant). It was recorded that among the crop establishment methods, siliqua/plant was statistically comparable except ZT DSR+R+S-ZTR-ZTR. Seed yield was recorded highest with ZT DSR+R+S-ZTR-ZTR (1.62 t/ha) and lowest with ZT DSR+S-ZT-ZT (1.21 t/ha). It was noticed that seed yield was 33.8% higher over ZT DSR+S-ZT-ZT. Similarly, CT DSR+R+S-CTR-ZTR recorded 21.6% and CT DSR+S-CT-ZT (14.8%) higher over ZT DSR+S-ZT-ZT. The establishment, growth and development of yield attributes was poor when it was sown in ZT-ZT-ZT system, whereas there was further improvement with TPR-CT. However, ZT and CT with placement of previous crop residues significantly suppressed emergence of weeds hence, obtained better yield attributes and higher seed yield. Straw yield also followed the trend of seed yield.

Among the weed management practices, siliqua/plant was highest with pendimethalin *fb* hand weeding (195.2/plant) followed by pendimethalin (185.5/siliqua). The lowest siliqua was recorded with weedy check (167.9/siliqua). Higher yield attributes led to obtain higher seed yield in pendimethalin *fb* hand weeding (1.89 t/ha) which was 1.76 times higher than weedy check (0.67 t/ha). Pendimethalin alone has also recorded significant reduction in initial flush of weeds resulted 1.36 times higher seed yield than weedy check. Pendimethalin *fb* one hand weeding has better weed control, this might be due to suppression of initial flush of weeds through pendimethalin and subsequent flush are being taken care by implying one additional hand weeding. Straw yield followed the trend of seed yield and highest was recorded with pendimethalin *fb* hand weeding (4.45 t/ha) followed by pendimethalin (3.75 t/ha), whereas, the lowest straw yield with weedy check (1.85 t/ha).

Table 9. Weed and yield parameters as influenced by crop establishment and weed management practices in mustard

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	WCE (%)	No. of siliqua /plant	No. of seeds /siliqua	Seed yield (kg/ha)	Straw yield (kg/ha)
Crop establishment							
CT DSR+S-CT-ZT	8.80^b(95.2)	11.08^b(151.8)	49.6	181.1^b	14.1^a	1390.0^{bc}	3326.2^{bc}
CT DSR+R+S-CTR-ZTR	7.54^c(72.0)	9.47^c(108.6)	64.0	181.7^b	13.6^a	1472.2^b	3518.5^b
ZT DSR+S-ZT-ZT	9.44^a(105.8)	11.81^{ab}(165.5)	45.1	179.9^b	13.5^a	1211.1^d	2897.0^d
ZT DSR+R+S-ZTR-ZTR	7.87^d(63.3)	8.66^c(94.1)	68.8	190.6^a	13.8^a	1620.0^a	3872.7^a
TPR-CT	9.72^a(110.3)	12.34^a(175.1)	41.9	181.0^b	13.5^a	1311.1^{cd}	3138.4^{cd}
LSD (p=0.05)	0.38	0.86		7.14	1.09	128.9	307.38
Weed management							
Weedy check	14.14^a(200.9)	17.27^a(301.3)	-	167.9^c	13.6^a	686.7^c	1854.0^c
Pendimethalin	6.54^b(43.7)	8.51^b(74.3)	75.3	185.5^b	13.8^a	1623.3^b	3749.9^b
Pendimethalin fb HW	4.75^c(23.4)	6.25^c(41.4)	86.3	195.2^a	13.7^a	1892.7^a	4447.8^a
LSD (p=0.05)	0.91	1.32		5.16	NS	154.46	366.25

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; **TPRCT:** Transplanted rice followed by CT mustard **S:** Sesbania. Weed data subjected to SQRT transformation; original values are in parentheses

The long term impact of crop establishment and weed control measures in DSR-based cropping system under conservation agriculture in mustard was conducted during *Rabi*, 2017-18. The highest seed yield (2.3 t/ha) and energy output (67375 MJ/ha) was obtained with the ZT+R along with pendimethalin at 1.0 kg/ha PE *fb* one hand weeding at 25 DAS. However, this treatment showed the negative net energy return (-18184.2 MJ/ha) and least other parameters. The highest energy use efficiency (4.4), energy productivity (0.15 kg/MJ) and net energy return (36107.4 MJ/ha) was obtained in ZT along with pendimethalin at 1.0 kg/ha PE *fb* one hand weeding at 25 DAS. The least performance of the treatment was observed in CT+R along with weedy check plots (**Table 10**).

Table10. Energy consumption and energy output for as influenced by crop establishment and weed management practices in mustard

Treatments	Energy input (MJ/ha)	Yield (kg/ha)	Energy output (MJ/ha)	Net energy (MJ/ha)	Energy use efficiency	Energy productivity (kg/MJ)
CT-Mustard:W1	12925.9	700.0	20416.6	7490.7	1.6	0.05
CT-Mustard (TPR):W1	12925.9	666.7	19444.4	6518.6	1.5	0.05
CT-Mustard:W2	13241.9	1650.0	48125.0	34883.1	3.6	0.12
CT-Mustard (TPR):W2	13241.9	1533.3	44722.2	31480.3	3.4	0.12
CT-Mustard:W3	13555.5	1820.0	53083.4	39527.9	3.9	0.13
CT-Mustard (TPR):W3	13555.5	1733.3	50555.6	37000.1	3.7	0.13
CT-Mustard+R:W1	87925.9	700.0	20416.6	-67509.3	0.2	0.01
CT-Mustard+R:W2	88241.9	1716.7	50069.5	-38172.4	0.6	0.02
CT-Mustard+R:W3	88555.5	2000.0	58333.4	-30222.1	0.7	0.02
ZT-Mustard:W1	9929.6	600.0	17500.0	7570.4	1.8	0.06
ZT-Mustard:W2	10245.6	1433.3	41805.5	31559.9	4.1	0.14
ZT-Mustard:W3	10559.2	1600.0	46666.6	36107.4	4.4	0.15
ZT-Mustard+R:W1	84929.6	766.7	22361.3	-62568.3	0.3	0.01
ZT-Mustard+R:W2	85245.6	1783.3	52013.8	-33231.8	0.6	0.02
ZT-Mustard+R:W3	85559.2	2310.0	67375.0	-18184.2	0.8	0.03

W1: Weedy check; W2: Pendimethalin at 1.0 kg/ha PE; W3: Pendimethalin at 1.0 kg/ha PE *fb* 1 HW at 25 DAS; *TPR: transplanted rice in *kharif* plot.

In maize

Medicago polymorpha, Avena ludoviciana and Rumex dentatus was abundant weed species in maize. Other weeds such as *Chenopodium album*, *Physalis minima*, *Sonchus* sp. and *Lathyrus sativus* were also presented in experimental field however, their abundance was less. Weed density was higher in ZT compared to the CT and TPR-CT. *Rumex dentatus* was present only in weedy checks.

Shannon diversity index was higher and comparable in CT, CTR and CTTPR, whereas lowest in the ZT and ZTR (**Fig. 10**). Diversity in weedy check was much higher as compared to the weed management treatments. Pendimethalin + atrazine *fb* on hand weeding effectively controlled the weeds, hence lowest weed diversity was recorded. Although, ZT plots have higher weed densities but have lower weed diversity, this mainly because of dominancy of a single weed species *i.e. Medicago polymorpha*.

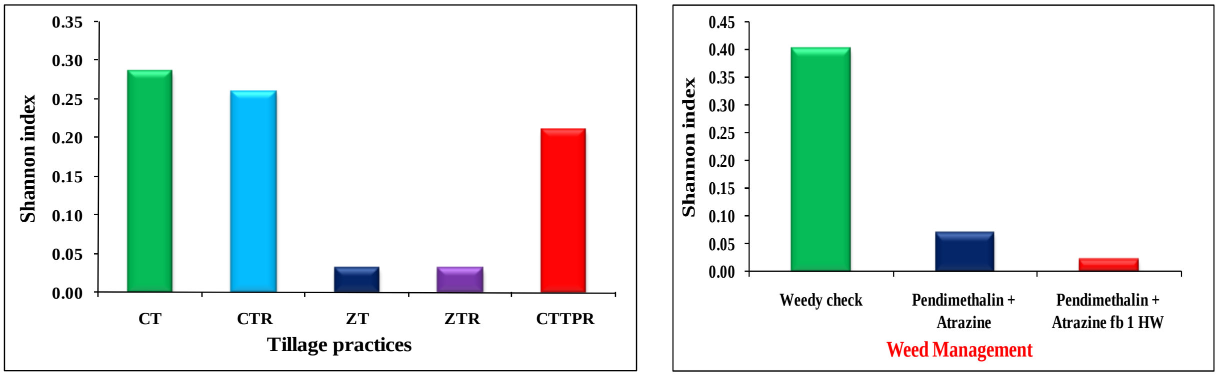


Fig. 10. Effect of weed diversity as influenced by tillage practices (A) and weed management (B) in maize

Seed bank study indicate that, in maize there is a decreasing trend of *Medicago polymorpha* (ZT and ZTR), *Cheopodium album* (ZTR) and *Rumex dentatus* (CTR, ZT and ZTR) emergence with the depth (**Fig. 11**). *Medicago polymorpha* was substantially distributed in all three soil layers. Whereas, *Chenopodium album* germination was higher in CT, ZTR and CTTPR compared to the CTR and ZTR in all three layers. Conversely, CTR and ZT have higher germination of the *Rumex dentatus* in all three layers.

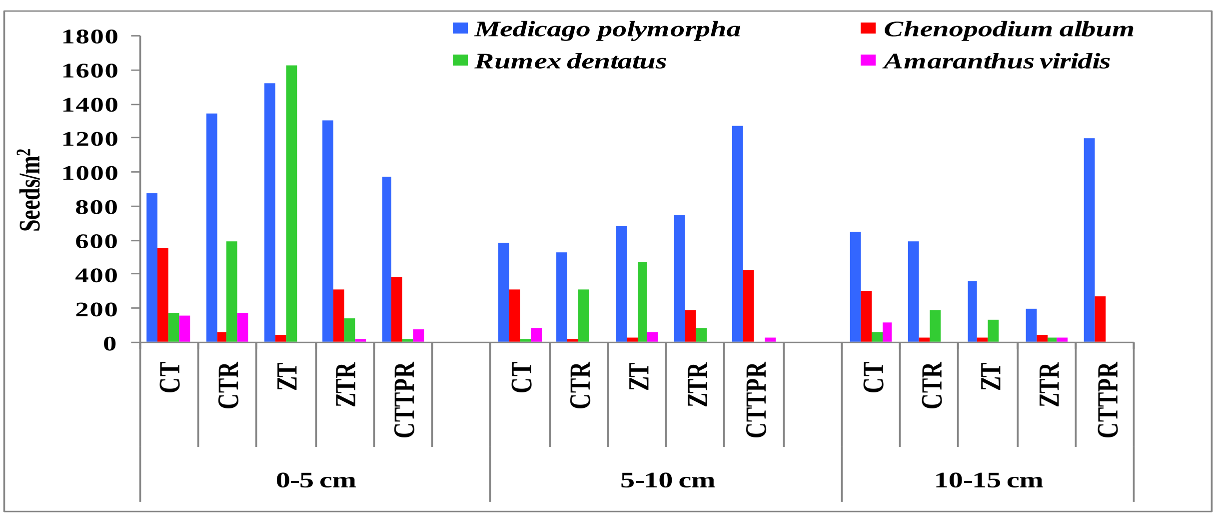


Fig. 11. Effect of weed seeds by tillage practices on weed seed bank dynamic in maize

Crop establishment method and weed management practices significantly influenced the weed parameters at 60 DAS (**Table 11**). It was recorded that the highest weed density and dry biomass was recorded in ZT DSR+R+S-ZTR-ZTR (61.9 no./m^2 and 92.9 g/m^2, respectively) followed by CT DSR+R+S-ZTR-ZTR (73.2 no./m^2 and 110.7 g/m^2, respectively) and highest with TPR-CT (114.3 no./m^2 and 178.5 g/m^2, respectively). Reduction in weed density and dry biomass recorded higher weed control efficiency in ZT DSR+R+S-ZTR-ZTR (69.9%) followed by CT DSR+R+S-ZTR-ZTR (64.1%). Among weed management practices, higher weed density and dry biomass recorded in weedy check (210.5 no./m^2 and 308.4 g/m^2, respectively). The lowest density and dry biomass was recorded in pendimethalin + atrazin *fb* hand weeding (23.1 no./m^2 and 40.8 g/m^2, respectively) followed by pendimethalin + atrazin as pre-emergence *fb* 2,4-D (42.6 no./m^2 and 74.2 g/m^2, respectively). This leads to achieving higher weed control efficiency in pendimethalin + atrazin *fb* hand weeding (86.8%) and pendimethalin + atrazin *fb* 2, 4-D (74.2%) over weedy check.

Crop establishment methods and weed management practices significantly influenced the yield attributes and yield of maize under conservation agriculture (**Table 11**). Cobs/plant was higher in ZT DSR+R+S-ZTR-ZTR (2.4) which was followed by TPR-CT (2.2), whereas, cobs/plant under rest of crop establishment were statistically comparable. Whereas, grains/cob was lowest in TPR-CT (280.2 no/cob) followed by ZT DSR+S-ZT-ZT (287.3 no./cob) and CT DSR+S-CT-ZT (304.6 no./cob). Grain yield was recorded the highest with ZT DSR+R+S-ZTR-ZTR (3.58 t/ha) followed by CT DSR+R+S-CTR-ZTR (3.27 t/ha) and the lowest yield with TPR-CT (2.98 t/ha). The higher yield in ZT DSR+R+S-CTR-ZTR and CT DSR+R+S-CTR-ZTR was due to placement of previous crop residues on soil surface, hampered the emergence and establishment of weeds, resulted lower competition for available resources. Stover yield followed the trend of grain yield and recorded higher stover yield with ZT DSR+R+S-CTR-ZTR followed by CT DSR+R+S-CTR-ZTR.

Maize is a wider spaced crop, during winter, the growth and development was slow in initial stage this prompts weeds to establish and proliferate. However, imposition of weed management practices significantly reduced the weed biomass led to better formation of yield attributes and further grain and stover yield. Application of pre-emergence herbicides pendimethalin + atrazin *fb* hand weeding recorded more number of cobs/plant and grains/cob (2.5 cobs/plant and 377.7 no./cob, respectively) followed by pendimethalin + atrazin *fb* 2,4-D (2.3 cobs/plant and 344.7 grains/cob, respectively) and lowest with weedy check (1.7 cobs/plant). Similarly, grain and stover yield was recorded highest with pendimethalin + atrazin *fb* hand weeding (4.32 and 7.56 t/ha, respectively) followed by pendimethalin + atrazin *fb* 2,4-D (3.35 and 5.69 t/ha, respectively), whereas the lowest yields were obtained weedy check (1.95 and 2.11 t/ha respectively). Pendimethalin + atrazin *fb* hand weeding recorded 122% higher grain yield followed by pendimethalin + atrazin *fb* 2,4-D (71.9%) over weedy check.

Among the cropping system, maize was badly infested with weeds, this may be due to wider row spacing and initial slow growth, whereas, mustard and pea had better suppression of weeds during winter season. However, their effect was not significant. Among the weed management practice, it was noticed that application of pre-emergence herbicides *fb* one hand weeding significantly reduced the weed dry weight followed by pre-emergence herbicide alone. The highest weed density and weed dry biomass was recorded with weedy check.

Table 11. Weed and yield parameters as influenced by crop establishment and weed management practices in maize

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	WCE (%)	No. of cob /plant	Grains/cob	Grain yield (kg/ha)	Stover yield (kg/ha)
Crop establishment							
CT DSR+S-CT-ZT	8.95^{b}(100.3)	11.19^{b}(155.3)	49.6	2.1^{ab}	304.6^{abc}	3122.2^{bc}	5315.0^{bc}
CT DSR+R+S-CTR-ZTR	7.60^{c}(73.2)	9.63^{c}(110.7)	64.1	2.0^{b}	330.7^{ab}	3266.7^{b}	5562.8^{b}
ZT DSR+S-ZT-ZT	9.45^{a}(110.6)	11.79^{ab}(168.2)	45.5	1.9^{b}	287.3^{bc}	3077.8^{bc}	5239.4^{bc}
ZT DSR+R+S-ZTR-ZTR	6.85^{d}(61.9)	8.74^{d}(92.9)	69.9	2.4^{a}	337.3^{a}	3577.8^{a}	6085.6^{a}
TPR-CT	9.80^{a}(114.3)	12.34^{a}(178.5)	42.1	2.2^{ab}	280.2^{c}	2977.8^{c}	5070.6^{c}
LSD (p=0.05)	0.37	0.76		0.43	46.43	272.67	453.54
Weed management							
Weedy check	14.45^{a}(210.5)	17.43^{a}(308.4)	-	1.7^{b}	201.7^{b}	1946.7^{c}	3114.7^{c}
Pendimethalin + atrazin *fb* 2,4-D	6.47^{b}(42.6)	8.55^{b}(74.2)	76.0	2.3^{a}	344.7^{a}	3346.7^{b}	5689.3^{b}
Pendimethalin+ atrazin *fb* HW	4.73^{c}(23.1)	6.24^{c}(40.8)	86.8	2.5^{a}	377.7^{a}	4320.0^{a}	7560.0^{a}
LSD (p=0.05)	0.95	1.31		0.45	41.55	262.23	441.34

CT: Conventional tillage; CTR: Conventional tillage with residue incorporation; ZT: Zero tillage; ZTR: Zero tillage with residue; TPRCT: Transplanted rice followed by CT maize; S: Sesbania. Weed data subjected to SQRT transformation; original values are in parentheses

The long term impact of crop establishment and weed control measures in DSR-based cropping system under conservation agriculture in maize was conducted during Rabi, 2017-18. The highest seed yield (4.7 t/ha) and energy output (91195.5 MJ/ha) was obtained with the ZT+R along with pendimethalin + atrazine (0.5+0.5 kg/ha PE) fb one hand weeding at 25 DAS. However, net energy, energy use efficiency and energy productivity are lower. The highest energy use efficiency (6.2), energy productivity (0.32 kg/MJ) and net energy return (67421.2 MJ/ha) was obtained in ZT along with pendimethalin + atrazine (0.5+0.5 kg/ha PE) fb one hand weeding at 25 DAS. The least performance of the treatment was observed in CT (TPR) along with weedy check plots (Table 12).

Table 12. Energy consumption and energy output as influenced by crop establishment and weed management practices in maize

Treatments	Energy input (MJ/ha)	Yield (kg/ha)	Energy output (MJ/ha)	Net energy (MJ/ha)	Energy use efficiency	Energy productivity (kg/MJ)
CT-Maize:W1	15223.3	1900.0	36606.6	21383.3	2.4	0.12
CT-Maize (TPR):W1	15223.3	1766.7	11632.2	-3591.2	0.8	0.12
CT-Maize:W2	90223.3	3233.3	62295.5	-27927.8	0.7	0.04
CT-Maize (TPR):W2	90223.3	3133.3	27672.5	-62550.9	0.3	0.03
CT-Maize:W3	15223.3	4233.3	81562.2	66338.8	5.4	0.28
CT-Maize (TPR):W3	15223.3	4033.3	27550.0	12326.7	1.8	0.26
CT-Maize+R:W1	90223.3	1933.3	37248.8	-52974.6	0.4	0.02
CT-Maize+R:W2	90786.1	3433.3	66148.8	-24637.3	0.7	0.04
CT-Maize+R:W3	90853.0	4433.3	85415.5	-5437.4	0.9	0.05
ZT-Maize:W1	12227.0	1866.7	35964.5	23737.4	2.9	0.15
ZT-Maize:W2	12789.8	3200.0	61653.4	48863.6	4.8	0.25
ZT-Maize:W3	12856.6	4166.7	80277.8	67421.2	6.2	0.32
ZT-Maize+R:W1	87227.0	2266.7	43671.2	-43555.8	0.5	0.03
ZT-Maize+R:W2	87789.8	3733.3	71928.8	-15861.0	0.8	0.04
ZT-Maize+R:W3	87856.6	4733.3	91195.5	3338.9	1.0	0.05

W1: Weedy check; W2 Pendimethalin + atrazine (0.5+0.5 kg/ha PE) *fb* 2,4-D (0.75 kg/ha) at 25 DAS; W3: Pendimethalin + atrazine (0.5+0.5 kg/ha PE) *fb* 1 HW at 25 DAS; *TPR: transplanted rice in *kharif* plot.

C. **Weed management in soybean-wheat-greengram cropping system under conservation agriculture.**

In greengram

Greengram field comprised with *Echinochloa colona*, *Dinebra retroflexa*, *Paspaladium* sp. *Digitaria singuinalis, Euphorbia* sp. *Alternanthera sessilis, Physalis minima, portulaca oleracea* and *Cyperus rotundus* were the major weed species. Among crop establishment methods, ZT+R-ZT+R-ZT+R recorded the lowest weed dry biomass (7.03 g/m^2). It was recorded that the weed density and dry biomass reduction was recorded when previous crop residues were retained in the soil surface. This helped in forming better yield attributes and resulted the highest seed yield of 0.98 t/ha over others. Among weed management practices, application of pendimethalin *fb* hand weeding recorded the lowest weed dry weight (6.3 g/m^2) which was 46.6% lower weeds than weedy check (11.8 g/m^2). The reduction in weed density and dry biomass leads to harvest more seed yield of greengram (1.12 t/ha) over others.

In soybean

Soybean field comprised with *Echinochloa colona*, *Dinebra retroflexa*, *Commelina banghalensis*, *Causelia axillaris* and *Cyperus rotundus* were major weeds, apart from these following weeds *Alternanthera sessilis, Physalis minima, Digiteria sanguinalis, Paspaladium flavidium* and *Cyperus iria* were also present.

Weed parameters were influenced by crop establishment method and weed management practices (**Table 13**). Total weed density was lowest with ZTSR-ZTWR-ZTGR (35.3 no./m^2) followed by ZT-ZTWR-ZTGR (37.8 no./m^2), whereas, the highest weed density was recorded with CT-CT-CT (68.5 no./m^2). Similarly, weed dry biomass followed the trend of weed density, ZTSR-ZTWR-ZTGR recorded the lowest dry biomass (48.63 g/m^2) followed by ZT-ZTWR-ZTGR (52.72 g/m^2), whereas, the highest dry biomass in CT-CT-CT (109.56 g/m^2). The highest weed control efficiency was recorded with ZTSR-ZTWR-ZTGR (72.8%) followed by ZT-ZTWR-ZTGR (70.5%). Similarly, yield attributes and yield was also influenced by crop establishment method and maximum pod/plant was recorded in ZTSR-ZTWR-ZTGR followed by ZT-ZTMsR-ZTGR. This helped to achieve better yield.

ZT R - ZT – ZTR (W1)

CT- ZT – ZT (W1)

ZTR – ZTR – ZTR (W2)

CT- CT (W2)

ZTR – ZT – ZTR (W3)

CT- ZT – ZT(W4)

Plate 2-Treatment wise crop view in the experimental area

During the season, the growth performance of soybean was exceedingly good (**Plate 2**), but, except number of pods/plant all the yield attributes were very poor i.e. smaller seed size, shriveled seeds, lower test weight and some pods unfilled grain, hence recorded considerably lower yield than previous year yield of soybean. However, the trend of seed yield was recorded the highest yield in ZTSR-ZTWR-ZTGR (773.3 kg/ha) followed by ZT-ZTWR-ZTGR (735.7 kg/ha), whereas, the lowest seed yield was recorded in CT-CT-CT (622.5 kg/ha). The straw yield of soybean was recorded highest with ZTSR-ZTWR-ZTGR (3.40 t/ha) followed by ZT-ZTWR-ZTGR (3.52 t/ha), whereas the lower straw yield harvested with CT-CT-CT (2.97 t/ha) and ZT-ZT-CT (2.98 t/ha).

Among the weed management practices, adoption of any weed management practices significantly reduced the weed density and dry biomass, it was measured that the lowest total weed density recorded with pre-emergence application of metribuzin *fb* one hand weeding (17.7 no./m^2) followed by pre-emergence application of pendimethalin *fb* imazethapyr (38.5 no./m^2). The highest wed density was recorded with weedy check (101.5 no./m^2). Weed dry biomass followed the trend of weed density and recorded the lowest weed dry biomass with metribuzin *fb* hand weeding (23.5 g/m^2) followed by pendimethalin *fb* imazethapyr (43.0 g/m^2). However, it was noticed that imazethapyr+imazamox was little weak on *Dinebra retroflexa*, *Paspaladium* sp. and *Phyllanthus niruri*. The highest weed dry biomass recorded in weedy check (178.8g/m^2). The highest weed control efficiency 87.4% was recorded with metribuzin *fb* hand weeding followed by pendimethalin *fb* imazethapyr (76%) over weedy check. It was also noticed that pre-mix application of imazethapyr+imazamox has considerably lower weed density and dry biomass and recorded 63.5% weed control efficiency over weedy check. Pods/plant was recorded the reverse trend of weed parameters and higher yield attributes obtained in metribuzin *fb* hand weeding (38.7 pods/plant) followed by pendimethalin *fb* imazethpyr (35.2 pods/plant) and lowest with weedy check (17.7 pods/plant). More pods/plant helped in obtaining higher seed and straw yield metribuzin *fb* hand weeding (866.8 and 4507.5 kg/ha, respectively) followed by pendimethalin *fb* imazethpyr (834.1and 4003.5 kg/ha, respectively). Tank mix of imazethapyr+imazamox obtained 801.1 and 3605 kg/ha, respectively, these all are superior to weedy check 262.6 and 1102.7 kg/ha, respectively.

Soil and grain samples were collected after crop harvest extracted and cleaned up by standard methods. The extracts were analysed by LC-MS/MS and GC-MS/MS. Residue of applied herbicides, viz. pendimathalin and imazethapyr were found below detectable limit in soybean.

Table 13. Weed and yield parameters as influenced by crop establishment and weed management in soybean

Treatment	Total weed density (no./m²)	Total weed biomass (g/m²)	WCE (%)	Pods/ plant	Grain yield (kg/ha)	Straw yield (kg/ha)
Crop establishment						
CT-CT-CT	7.75[a](68.50)	9.81[a](109.56)	38.7	27.1	622.5[d]	2971.0[d]
ZT-ZT-CT	7.50[a](64.00)	9.51[a](104.23)	41.7	28.2	623.8[d]	2977.5[d]
ZT-ZTWR-ZTGR	6.65[bc](37.75)	6.75[c](52.72)	70.5	31.9	735.7[b]	3524.2[b]
ZTSR-ZTWR-ZT	6.29[c](51.25)	7.85[b](71.90)	59.8	30.5	702.4[c]	3363.9[c]
ZTSR-ZTWR-ZTGR	5.96[c](35.25)	6.45[c](48.63)	72.8	33.2	773.3[a]	3699.1[a]
ZT-ZT-ZT	6.80[b](50.50)	8.23[b](77.35)	56.8	29.6	689.2[c]	3292.4[c]
LSD (p=0.05)	0.47	0.61			15.49	78.88
Weed management						
Imazethapyr+Imazamox	7.00[b](47.50)	7.99[b](65.22)	63.5	28.7	801.1[b]	3605.0[c]
Pendimethlin *fb* Imazethapyr	5.80[c](38.17)	6.46[c](43.01)	76.0	35.2	834.1[ab]	4003.5[b]
Metribuzin *fb* hand weeding	4.30[d](17.67)	4.71[d](22.53)	87.4	38.7	866.8[a]	4507.5[a]
Weedy check	10.45[a](101.50)	13.23[a](178.84)	-	17.67	262.6[c]	1102.7[d]
LSD (p=0.05)	0.53	1.01			44.54	220.3

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; Weed data subjected to SQRT transformation; original values are in parentheses

In wheat

In wheat, major weed flora *Medicago polymorpha, Chenopodium album, Vicia sativa*, *Euphorbia geniculata*, *Sonchus oleraceus*, *Convolvulus arvensis* and *Physalis minima* were major broadleaved weeds, whereas, *Avena ludoviciana Paspaladium flavidium Digitaria sanguinalis*, *Dinebra retroflexa* and *Phalaris minor* were major grassy weeds present. However, it was noticed that majority of Sonchus, Physalis, Euphorbia and Paspaladium, Digitaria and Dinebra were emerged late in wheat.

The weed density, dry biomass and wed control efficiency was significantly influenced by crop establishment methods and weed management practices in wheat (**Table 14**). It was recorded that among crop establishment methods the lowest weed density and dry biomass was recorded with ZTWR-ZTGR-ZTSR (41.6 no./m^2 and 39.3 g/m^2, respectively) followed by weed density with ZTWR-ZTGR-ZT (42.2 no./m^2) and weed dry biomass with ZTWR-ZT-ZTSR (42.74 g/m^2) and the highest weed density was recorded in CT-CT-CT (50.5 g/m^2).

Whereas, weed dry biomass was more in ZT-ZT-ZT and ZT-CT-ZT (48.1 g/m^2), this was mainly due to more weed biomass accumulation on leftover weeds of previous season, however, the density was less. The highest weed control efficiency was recorded when wheat was sown with ZTWR-ZTGR-ZTSR (71.3%) followed by ZTWR-ZT-ZTSR (68.8%), whereas the lowest weed control efficiency was recorded with ZT-CT-ZT and ZT-ZT-ZT (64.9%). Yield attributes and yield was significantly influenced by crop establishment method and weed management practice (**Table 14**). Grains/spike was highest in ZTWR-ZTGR-ZTSR (41.3) followed by ZTWR-ZT-ZTSR (39.6 no./spike), whereas, the lowest grain/spike was recorded in CT-CT-CT (35.8 no./spike). This helped in achieving higher grain yield and resulted highest grain and straw yield with ZTWR-ZTGR-ZTSR (3.88 and 5.64 t/ha, respectively) followed by ZTWR-ZT-ZTSR (3.71 and 5.41 t/ha, respectively), whereas, the lowest yield obtained in CT-CT-CT (3.32 and 4.78 t/ha, respectively). It clearly illustrated that ZTWR-ZTGR-ZTSR has recorded 16% additional seed yield of wheat over CT-CT-CT.

Among the weed management practices, pre-mix application of clodinafop+metsulfuron at 64 g/ha has recorded the lowest weed density and dry biomass (3.78 $no./m^2$ and 1.78 g/m^2, respectively) followed by mesosulfuron + iodosulfuron at 14.4 g/ha (11.4 $no./m^2$ and 5.28 g/m^2, respectively), whereas the highest weed density and dry biomass was recorded in weedy check (130.5 $no./m^2$ and 136.9 g/m^2, respectively). Application of sulfosulfuron at 25 g/ha also considerably suppressed the weed density and dry biomass (37.2 $no./m^2$ and 35.0 g/m^2, respectively), yet, their effect was less pertaining to clodinofop+metsulfuron and iodosulfuron+mesosulfuron. This clearly illustrate that above herbicides has special ability to kill the wide range of weed flora during the season. Clodinafop+metsulfuron has better ability and controlled almost all the weeds, whereas mesosulfuron + iodosulfuron was little weak on grasses, but was strong on broad leaved weeds. Sulfosulfuron alone at 25 g/ha controlled the initial weed flora but has less persistency and was not so effective for controlling grassy and broad leaved weeds at later stages. This leads to highest weed control efficiency in plots where ready mix of clodinafop+metsulfuron at 64 g/ha was applied (98.7%) followed by mesosulfuron + iodosulfuron at 14.4 g/ha (96.1%) over weedy check. It was also recorded that sulfosulfuron at 25 g/ha was weak on many of the weeds and resulted considerably poor weed control efficiency of 74.4% over weedy check. Weed management practices significantly controlled the weeds which reduced the competition among wheat plants for resources resulted more grains/spike and further helped in higher grain and straw yield in clodinafop+metsulfuron at 64 g/ha (5.01 and 7.20 t/ha, respectively) followed by mesosulfuron + iodosulfuron at 14.4 g/ha (4.75 and 6.58 t/ha, respectively), where sulfosulfuron at 25 g/ha has 3.10 and 4.66 t/ha, respectively. The lowest grain and straw yield was recorded in weedy check (1.36 and 2.15 t/ha, respectively. Application of clodinafop+metsulfuron recorded 2.69 times more wheat yield followed by 2.5 times in mesosulfuron + iodosulfuron.

Soil and grain samples were collected after crop harvest, extracted and cleaned up by standard methods. The extracts were analysed by LC-MS/MS and GC-MS/MS. Residue of applied herbicides, viz. clodinafop and metsulfuron-methyl, iodosulfuron, mesosulfuron and sulfosulfuron was found below detectable limit.

Table 14. Weed and crop parameters as influenced by crop establishment and weed management practices in wheat

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	WCE (%)	Grains /spike	Grain yield (kg/ha)	Straw yield (kg/ha)
Crop establishment						
CT-CT-CT	6.40^a(50.50)	6.84^a(46.22)	66.2	35.8^c	3316.7^d	4782.9^d
ZT-CT-ZT	5.75^c(45.33)	6.97^{ab}(48.10)	64.9	36.8b^c	3432.5^{cd}	4953.5^d
ZTWR-ZTGR-ZT	5.46^d(42.17)	6.68^b(44.06)	67.8	37.8^{bc}	3532.5^c	5170.4^c
ZTWR-ZT-ZTSR	5.51^{cd}(45.25)	6.58^c(42.74)	68.8	39.6^{ab}	3709.2^b	5405.2^b
ZTWR-ZTGR-ZTSR	5.46^d(41.58)	6.31^c(39.28)	71.3	41.3^a	3878.3^a	5644.0^a
ZT-ZT-ZT	6.13^d(49.42)	6.97^{ab}(48.10)	64.9	37.2^{bc}	3465.8^c	4920.5^d
LSD (p=0.05)	0.25	1.01		3.39	143.66	210.04
Weed management						
Sulfosulfuron	6.08^b(37.17)	5.96^b(35.01)	74.4	34.4^b	3102.8^c	4661.3^c
IodoSulfuron+ Mesosulfuron	3.38^c(11.39)	2.40^c(5.28)	96.1	47.5^a	4751.7^b	6581.8^b
Clodinafop+Metsulfuron	1.97^d(3.78)	1.51^c(1.78)	98.7	50.1^a	5010.6^a	7195.6^a
Weedy check	11.44^a(130.50)	11.72^a(136.91)	-	20.3^c	1358.3^d	2145.8^d
LSD (p=0.05)	0.46	2.03		3.04	162.66	279.21

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; **TPRCT:** Transplanted rice followed by CT wheat. Weed data subjected to SQRT transformation; original values are in parentheses

D. Weed management in maize-wheat-greengram cropping system under conservation agriculture.

In greengram, ZT-ZT+R-ZT+R registered the lowest weed dry biomass (21.4 g/m^2), but was comparable to ZT+R-ZT+R-ZT+R (26 g/m^2), whereas the highest weed dry biomass was recorded with ZT+R-ZT-ZT+R (48.2 g/m^2). Reduction of weed dry biomass helped the plants for better establishment and least competition for resources, which finally helped to achieve higher greengram seed yield.

In maize, experimental plots were recorded with grassy weeds viz. *Echinochloa colona*, *Dinebra retroflexa*, *Paspaladium* sp., broad leaved weeds viz. *Phyllanthus niruri*, *Eclipta alba*, *Physalis minima* and *Commelina benghalensis* and *Cyperus iria* was only sedge. In the plots, grassy weeds (54%) were predominant followed by broad-leaved (34%) and lowest with sedges (12%). The lowest weed density (33.1 number/m^2) and dry biomass (18.3 g/m^2) was observed under ZT+GR-ZT+MR-ZT+WR followed by ZT–ZT+MR-ZT+WR (32.8 number/m^2 and 12.0 g/m^2), which were significantly lower than others. This helped in harvesting of more grain yield (5.35 and 4.98 t/ha, respectively).

Among weed management practices, atrazine 500 g/ha *fb* topramezone 25 g/ha considerably suppressed weed density (18.9 number/m^2) and biomass (14.0 g/m^2). The highest weed density (191.8 number/m^2) and weed biomass (77.8 g/m^2) was observed under weedy check. Reduction in weed density and dry biomass leads to higher maize grain yield (5.13 t/ha) over weedy check (4.13 t/ha) (**Plate 3**).

In *kharif*, ZT+R-ZT-ZT+R and ZT+R-ZT+R-ZT+R received more diazotroph population (7.7 log cfu/g soil). Higher nitrite oxidizers (5.5 log cfu/g soil) and P-solubilizers (5.9 log cfu/g soil) were recorded under ZT+R-ZT-ZT+R. Soil and grain samples were collected after crop harvest. Soil samples were extracted and cleaned up by standard methods. The extracts were analysed by LC-MS/MS and GC-MS/MS. Residue of applied herbicides, viz. atrazine, tembotrione and topramezone were found below detectable limit.

ZTR & Tembotrione (100 g/ha)

ZT &Tembotrione (100 g/ha)

Plate 3. Treatment view of experimental field

In wheat, ZT-ZT+R-ZT+R registered the lowest weed dry biomass (3.9 g/m^2), but was comparable to ZT+R-ZT+R-ZT+R (5.8 g/m^2), whereas the highest weed dry biomass was recorded with ZT-ZT-ZT (11.8 g/m^2). Reduction in weed dry biomass helped the crop to produce more grain yield (4.32 and 4.1 t/ha, respectively). During *rabi* season, ZT+R-ZT-ZT+R plots registered maximum amount of diazotrophs, nitrite oxidizers and P-solubilizers (7.4, 4.7 and 6.6 log cfu/g soil, respectively).

E. Long term impact of tillage and chemical weed management in maize/blackgram-mustard- greengram cropping system under conservation agriculture.

In greengram, application of pendimethalin 0.75 kg/ha *fb* one hand weeding controlled weed more efficiently resulted maximum yield (0.99 t/ha). Among tillage and residue management, ZT+GR – ZT+MR – ZT+MsR obtained maximum seed yield (1.26 t/ha) of greengram. It was recorded that ZT+R-ZT+R-ZT+R plots recorded more of bacteria (7.8 log cfu/g soil) diazotroph population (7.2 log cfu/g soil), dehydrogenase activity (38 µg TPF/g soil/24 h). Whereas, higher amount of fungi (5.4 log cfu/g soil) and nitrite oxidizer (6.6 log cfu/g soil), P-solubilizer (4.7 log cfu/g soil) were recorded in ZT+R-ZT-ZT+R.

In blackgram

Blackgram field was infested with major broadleaved weeds such as *Alternanthera peronychoids, Physalis minima, Phyllanthus niruri, Chicorium intybus,* etc and grasses like *Echinochloa colona, Dinebra retroflexa, Digitaria sanguinalis, Paspaladium flavidium* etc.

Crop establishment method and weed management practices significantly influenced the weed dynamics in blackgram (**Table 15**). It was recorded that weed density and weed dry biomass was recorded lowest in ZTMR-ZTMsR-ZTGR (51 no./m^2 and 59.78 g/m^2, respectively) followed by ZT-ZTMsR-ZTGR (53.5 no./m^2 and 57.2 g/m^2, respectively). This helped to achieve better weed control efficiency ZTMR-ZTMsR-ZTGR (80.2%) followed by ZT-ZTMsR-ZTGR (78.9%). Whereas, the highest weed density and weed dry biomass was recorded with CT-CT-CT (81.3 no./m^2 and 174.1 g/m^2, respectively). The lower weed density and weed dry biomass in ZTMR-ZTMsR-ZTGR and ZT-ZTMsR-ZTGR was mainly due to placement of previous crop residues, which restricted the emergence and establishment of majority of broadleaved and grassy weeds. However, CT-CT-CT has maximum weeds, might be due to while land preparation majority of seeds came up to surface and also due to scarification large number of weed seeds germinated resulted maximum weed diversity. Seeds/pod was recorded highest with ZTMR-ZTMsR-ZTGR (6.3) followed by ZT-ZTMsR-ZTGR which was statistically comparable to each other, whereas, the lower seeds/pod was recorded with 4.5 seeds/pod. Better yield attributes in ZTMR-ZTMsR-ZTGR leads to higher seed yield and stover yield (758.7 and 2077.6 kg/ha, respectively) followed by ZTMR-ZTMsR-ZT. The lowest seed yield was recorded with CT-CT-CT (654.1 kg/ha) followed by ZT-ZT-CT (652 kg/ha). The higher yield in ZTMR-ZTMsR-ZTGR was mainly due to lower weed density and dry biomass offered least competition for available resources at site leads to formation of more yield attributes.

Weed management influenced the weed density and dry biomass, the lowest weed density was recorded in application of pre-emergence of pendimethalin *fb* imazethapyr controlled the wide range of weeds at initial stage and further emerged weeds were taken care by imazethapyr resulted 22.8 no./m^2 of weeds, followed by pre-mix of fomesafen + fluazifop (37.8 no./m^2). Dry biomass followed the trend of weed density and recorded lowest with pendimethalin *fb* imazethapyr (21.2 g/m^2) , but, between pre-mix application of herbicides, imazethapyr + imazamox has lower weed dry biomass (51.6 g/m^2) followed by fomesafen + fluazifop (66.3 g/m^2). The maximum weed density and dry biomass was recorded in weedy check (155.3 no./m^2 and 256.2 g/m^2, respectively). Weed control efficiency was followed the trend of weed dry biomass and recorded highest with pendimethalin *fb* imazethapyr (91.7%) followed by imazethapyr + imazamox (79.9%) over weedy check. Lower weed density and dry biomass helped to produce more number of seeds/pod with pendimethalin *fb* imazethapyr (6.4 seeds/pod) followed by fomesafen + fluazifop (5.9 seeds/pod) and lowest with weedy check (4.3 seeds/pod). More yield attributes helped in harvesting of higher seed and haulm yield (835.8 and 2423.8 kg/ha) in pendimethalin *fb* imazethapyr followed by fomesafen + fluazifop (794.6 and 2224.8 kg/ha, respectively). The lowest yield was recorded with weedy check (363.9 and 913.4 kg/ha, respectively).

Table 15: Weed and crop parameters as influenced by crop establishment method and weed management in blackgram

Treatment	Total weed density (no./m^2)	Total weed biomass (g/m^2)	WCE (%)	Seeds/pod	Grain yield (kg/ha)	Haulm yield (kg/ha)
Crop establishment						
CT-CT-CT	8.64^a (81.25)	11.99^a (176.57)	31.1	5.4^{ab}	654.1^d	1788.7^d
ZT-ZT-CT	8.27^a (76.25)	11.22^b (161.06)	37.1	4.8^b	652.0^d	1784.2^d
ZT-ZTMsR-ZTGR	6.74^{cd} (53.50)	6.78^d(54.07)	78.9	6.2^a	722.0^b	1976.9^b
ZTMR-ZTMsrR-ZT	7.19^{bc}(63.50)	7.98^c(80.51)	68.6	5.8^a	687.8^c	1881.3^c
ZTMR-ZTMsR-ZTGR	6.37^d (51.00)	6.53^d(50.73)	80.2	6.3^a	758.7^a	2077.6^a
ZT-ZT-ZT	7.43^b(65.00)	7.83^c(69.94)	72.7	4.5^b	667.3^{cd}	1825.7^{cd}
LSD (p=0.05)	0.46	0.53		0.9^5	24.18	65.69
Weed management						
Imazethapyr + imazamox	6.67^b(44.33)	7.05^b(51.62)	79.9	5.4^b	767.1^b	1994.3^c
Fomesafen + fluazifop	6.37^b(37.83)	7.85^b(66.31)	74.1	5.9^{ab}	794.6^b	2224.8^b
Pendimethalin *fb* imazethapyr	4.62^c (22.83)	4.55^c(21.16)	91.7	6.4^a	835.8^a	2423.8^a
Weedy check	12.08^a (155.33)	15.44^a(256.17)	-	4.3^c	363.9^c	913.4^d
LSD (p=0.05)	0.68	1.78		0.94	32.48	90.52

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; Weed data subjected to SQRT transformation; original values are in parentheses

In mustard

In mustard, crop establishment method and weed management significantly influenced the weed dynamics and yield of mustard (**Table 16**). Weed density and dry biomass lowest in ZTMsR-ZTGR-ZTMR (94.6 no./m^2 and 69.4 g/m^2, respectively) followed by ZTMsR-ZT-ZTMR (97.3 no./m^2 and 85.4 g/m^2, respectively), whereas the highest was recorded with CT-CT-CT (118.5 no./m^2 and 122.7 g/m^2, respectively) and ZT-ZT-ZT (112.7 no./m^2 and 107.3 g/m^2, respectively). This helped in achieving more weed control efficiency in ZTMsR-ZTGR-ZTMR (60.8%) followed by ZTMsR-ZT-ZTMR (51.8%). More no. of seeds/siliqua was with ZTMsR-ZTGR-ZTMR (18.2), higher yield attributes helped in harvesting of more seed and straw yield (1665.8 and 3717.7 kg/ha, respectively) followed by ZTMsR-ZT-ZTMR (1566.7

and 3495.8 kg/ha, respectively) and lowest with CT-CT-CT (1383.3 and 3091.6 kg/ha, respectively).

Application of pendimethalin 0.75 kg/ha *fb* one hand weeding significantly suppressed the initial and subsequent flush of weeds resulted lower weed density and dry biomass (48 no./m^2 and 41.6 g/m^2, respectively) followed by pendimethalin *fb* isoproturon (90.4 no./m^2 and 77 g/m^2, respectively). The highest weed density and dry biomass recorded with weedy check (176.1 no./m^2 and 177.1 g/m^2, respectively). Pendimethalin *fb* hand weeding managed the weeds more efficiently resulting maximum weed control efficiency (76.5%) and more number of seeds/siliqua (19.9) which resulted highest seed yield (2045.6 kg/ha) and straw yield (4745.7 kg/ha) followed by pendimethalin *fb* isoproturon. It was recorded that isoproturon alone was not that effective to control weeds, hence this may be only applied with pre-emergence herbicides or subsequently one hand weeding may be adopted. The lowest seed and straw yield was recorded with weedy check (738.9 and 1514.7 kg/ha, respectively).

Table 16: Weed and crop parameters as influenced by crop establishment and weed management practice in mustard

Treatment	**Weed density (no./m^2)**	**Weed dry weight (g/m^2)**	**WCE (%)**	**No. of seed/ siliqua**	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**
Crop establishment						
CT-CT-CT	10.60^{a}(118.54)	10.77^{a}(122.66)	30.8	14.92^{b}	1383.3^{d}	3091.6^{d}
ZT-CT-ZT	10.37^{a}(112.92)	10.11^{b}(108.75)	38.6	15.53^{ab}	1435.8^{cd}	3200.8^{cd}
ZTMsR-ZTGR-ZT	10.26^{a}(111.08)	9.68^{c}(101.00)	43.0	16.25^{ab}	1508.3^{bc}	3365.3^{bc}
ZTMsR-ZT-ZTMR	9.67^{b}(97.33)	8.99^{d}(85.37)	51.8	17.25^{ab}	1566.7^{ab}	3495.8^{ab}
ZTMsR-ZTGR-ZTMR	9.53^{b}(94.58)	8.09^{e}(69.39)	60.8	18.24^{a}	1665.8^{a}	3717.7^{a}
ZT-ZT-ZT	10.35^{a}(112.67)	10.04^{bc}(107.29)	39.4	15.69^{ab}	1402.5^{cd}	3123.4^{cd}
LSD (p=0.05)	0.44	0.40		2.81	113.56	251.66
Weed management						
Isoproturon	10.80^{b}(116.89)	10.01^{b}(100.65)	43.2	16.06^{b}	1345.0^{c}	2824.5^{c}
pendimethalin *fb* isoproturon	9.50^{c}(90.39)	8.74^{c}(76.96)	56.6	18.46^{a}	1845.6^{b}	4244.8^{b}
Pendimethalin *fb* hand weeding	6.96^{d}(48.00)	6.44^{d}(41.55)	76.5	19.90^{a}	2045.6^{a}	4745.7^{a}
Weedy check	13.26^{a}(176.14)	13.26^{a}(177.14)	-	10.83^{c}	738.9^{d}	1514.7^{d}
LSD (p=0.05)	0.53	0.72		1.99	107.03	239.75

CT: Conventional tillage; **CTR:** Conventional tillage with residue incorporation; **ZT:** Zero tillage; **ZTR:** Zero tillage with residue; Weed data subjected to SQRT transformation; original values are in parentheses

Weed management in conservation agriculture (IARI)

Weed control in CA-based maize using new low-dose herbicides

In conservation agriculture **(**CA) system being continued for 10 years, weed management was envisaged in maize-wheat system with four weed control treatments (Table 1). It was observed that, among weed management treatments, the application of atrazine 0.75 kg/ha pre-emergence and halosulfuron 0.060 kg/ha post-emergence resulted in significantly lower weed population and dry weight, but the atrazine 0.75 kg/ha pre-emergence + tembotrione 0.100 kg/ha post-emergence was on par with it (Table 3). Atrazine + halosulfuron was phytotoxic to maize, and, as a result, gave very low yield of maize. However, atrazine 0.75 kg/ha (pre-emergence) + tembotrione 0.100 kg/ha (post-emergence at 30 DAS) gave better weed control but comparable maize grain yield with the recommended tank-mixture of atrazine + pendimethalin.

Table1. Weed population, dry weight and maize yield across weed control treatments

Treatments	Weed density (No. m^{-2})	Weed dry weight (g m^{-2})	Maize yield (t/ha)
Unweeded control	100.0	221.0	4.75
Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (tank-mix, pre-emergence at 2 DAS)	22.0	20.0	5.62
Atrazine 0.75 kg/ha (pre-emergence) + tembotrione 0.100 kg/ha (post-emergence at 30 DAS)	8.0	14.0	5.23
Atrazine 0.75 kg/ha (pre-emergence) + halosulfuron 0.060 kg/ha (post-emergence at 30 DAS)	6.0	2.0	3.50
LSD (P=0.05)	12	10	0.45

Weed management influences nematodes in CA-based direct-seeded rice

Under long term conservation agriculture (CA)-inclusive direct-seeded rice (DSR) – zero till wheat (ZTW) system, DSR was infested with 82.3% higher weed densities than transplanted rice (TPR) – conventional tilled wheat (CTW). The DSR-ZTW and DSR + brown manuring – ZTW systems encountered significantly higher populations of parasitic nematodes (*Tylenchorhynchus brevilineatus*, *Meloidogyne graminicola*, *Pratylenchus thornei*) than the TPR-CTW, but the retentions of rice residue (RR) and mungbean residue (MR) reduced their populations considerably (Figure 1a). The DSR+ mungbean residue - ZTW+rice residue led to greater reductions in parasitic/total nematodes and gave comparable rice yields with TPR-CTW. There was a significant correlation between weed density and nematode density (Figure

1b), which indicated that controlling weeds could also suppress nematodes and reduce the cost of nematode control.

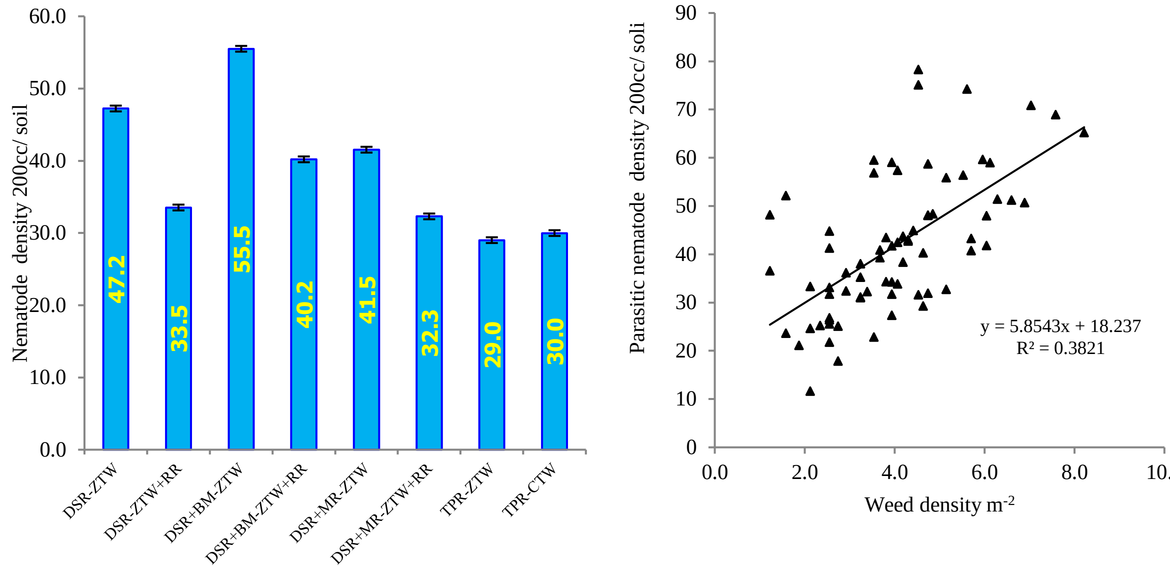


Fig.1: (a) Parasitic nematode population (200 CC soil); and (b) Correlation between the densities of weeds and parasitic nematodes under CA-based rice

2.1.1.3 Water management with different irrigation methods-

(A)In Rice-Wheat (CSSRI)

In Rice

Data given in table 1 for the comparison of different irrigation methods in rice crop cultivation. Micro irrigation methods and surface irrigation methods results discussed below as:

(A) Mini sprinkler irrigation method during kharif season 2017 produced grain yield 6.66 tha^{-1} in DSR with 50% reduce tillage, with wheat residue and saving of 64.2% of irrigation water and 42.7% electricity. Mini sprinkler fertigation method in rice saved 27% nitrogen of recommended (40 kg) and increase nitrogen use efficiency up to 60.6 Kg grain Kg^{-1} nitrogen compared to conventional rice.

(B) Drip irrigation in rice crop during 2017 kharif season saved 70.9% irrigation water, 2.06 irrigation water productivity, 27.4% electricity, with 6.30 tha^{-1} grain yield and 42.0 Kg grain Kg^{-1} N NUE where rice was sown in 50% reduce tillage with zero tillage seed drill machine.

Table-1 Effect of irrigation methods on hybrid rice yield (Arize 6129), irrigation water requirement, water productivity, saving of water and electricity and nitrogen use efficiency during kharif season 2017.

RCTs	TPR	DSR+RT	DSR+RT	DSR+RT	DSR +WR incorporation
Mode of irrigation	Surface T_1	Surface T_8	Drip T_7	Mini –Sprinkler T_9	Mini –Sprinkler T_{10}
Irrigation criteria	1DADPW	Small soil cracks with surface dryness	(previous 3days CPE) Alternate day	(previous 2days CPE) Alternate day	(previous 2 days CPE) Alternate day
Grain yield (t ha^{-1})	7.01	6.53	6.30	6.56	6.66
Total crop productivity (tha^{-1})	12.46	12.17	13.42	14.68	14.69
Total irrigation water (ha-cm)	104.93	72.45	30.52	37.58	37.58
Total irrigation water (m^3/ha^{-1})	10493	7245.4	3052.0	3758.0	3758.0
Crop water productivity (kg m^{-3})	1.19	1.68	4.38	3.91	3.91
Grain water productivity (kg m^{-3})	0.668	0.901	2.06	1.75	1.77
Irrigation water saving (%)	-	30.95	70.91	64.18	64.18
Electricity saving (%)					
NUE (kg grain kg^{-1} nitrogen) 40 kg N saving	46.7	43.53	42.0	59.64	60.55

Rainfall received = 713.6 mm and Pan evaporation = 553.5 mm during June, 2017 to September 2017, CPE= cumulative pan evaporation criteria used for irrigation through mini sprinkler system, CD (0.05) = 0.35 (grain yield) and NUE= Nitrogen use efficiency (saving 86.21 kg urea /ha)

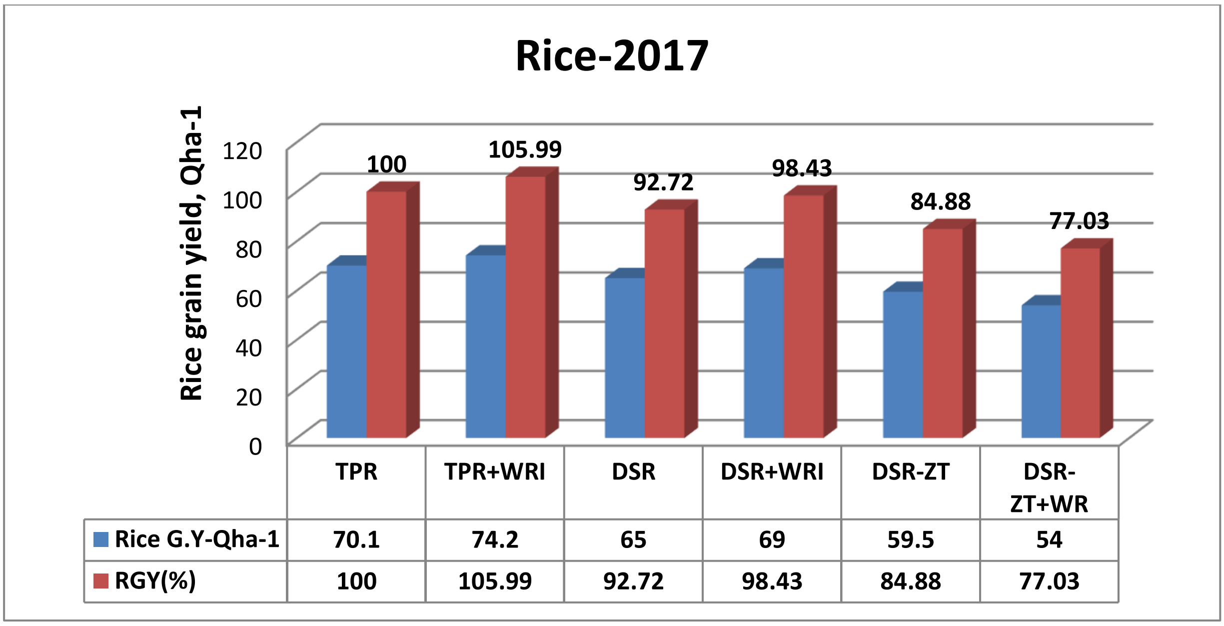


Fig. (1) Effects of different tillage and residue management on rice grain yield during 2017 kharif season.

In Wheat

2. 1-Wheat with mini sprinkler irrigation method:

The results of 2015-16 and 2016-17 presented in table 5 shows that :

- Wheat in Zero tillage with 100% rice straw mulch produced highest wheat grain yield (5.29 and 5.77 tha^{-1}) in 2015-16 and 2016-17 crop seasons, respectively under mini sprinkler irrigation method but in surface irrigation method produced 4.89 and 5.43 tha^{-1} where wheat shown in zero tillage with 100% rice straw mulch in 2015-16 and 2016-17 crop season, respectively.
- Sprinkler irrigation system in wheat crop saved 33.82 and 31.39%, more water over the surface irrigation method during 2015-16 and 2016-17 crop seasons, respectively. This method may be feasible for wheat crop.

Rice residue, wheat sowing using happy seed drill in rice residue under sprinkler irrigation method

2.2-Wheat with drip irrigation method: –

The results of 2015-16 and 2016-17 presented in table 5 shows that :

- Drip irrigation system started in wheat crop Season's 2016-17. It was layout in 1000 m^2 field area. The discharge of dripper was 4litres/hour and 14824 litres/1000 m^2/hr. The criterion of irrigation scheduling was CPE ratio of previous 8 days with 0.8 volume of water of total irrigation water computed.
- The results of the irrigation methods is given in Table 5 indicates that pressurized irrigation methods are water saver in comparison to surface irrigation method in partially reclaimed sodic soil with sandy loam texture.
- The grain yield of wheat under drip irrigation method was 5.24 tha^{-1} and was statistically similar with conventional irrigation method (5.24 tha^{-1}).
- Irrigation water saving was 47.65% in comparison to conventional irrigation method. However this method also saved irrigation water by 16.26% more than mini sprinkler irrigation method with 4.62 Kg m^{-3} water use efficiency.

2.3- Wheat with surface irrigation method under crop residue: –

The results of 2015-16 and 2016-17 presented in table 5 shows that :

- Rice residue management in wheat crop with different irrigation methods observedthat 100% rice crop residue management with turbo /happy seed drill machine is feasible, as this machine used for sowing of wheat along with rice crop residue mulching and observed very good germination and crop growth and yields.
- Surface irrigation system revealed that higher grain yield of wheat produced with 100% rice residue mulch with 4.89 and 5.43 tha-1 in 2015-16 and 2016-17 crop seasons, respectively with saving of irrigation water by 21.43 and 19.22% in comparison to without crop residue techniques under surface irrigation method. Rice crop residue maintained favorable soil temperature and moisture to facilitate better germination, growth and yield during the crop growth period.

2.4 Nitrogen use efficiency under different irrigation methods: -

The data presented in table 5 shows that : the nitrogen fertilizer applied with the help of leaf colour chart, always maintained LCC No 4/5.The nitrogen through urea source applied via fertilizer tank at the @ 2.5 Kg along with irrigation water scheduled day. Highest nitrogen use efficiency 70.53 Kg grain Kg^{-1} nitrogen recorded in mini sprinkler fertigation method and saved 50% nitrogen of recommended (75 kg N and 162.0 Kg urea per ha.) compared to conventional surface irrigation method during 2015-16 crop season (table2). During 2016-17, further increased grain yield with lesser amount of nitrogen and highest NUE (88.43 Kg grain Kg^{-1} N) was computed under mini sprinkler irrigation system followed by drip irrigation system with 71.39 Kg grain Kg^{-1} N in 2016-17 crop season. Under surface irrigation method NUE may be increased by 52.11 Kg grain Kg^{-1} N with 100% rice crop residue managed with the help of Turbo/happy seed drill during wheat sowing. Leaf color chart was used for the determination of nitrogen requirement during the crop growth period. NUE increased with increasing grain yield and reducing nitrogen requirement.

Table-2 Effect of surface and mini sprinkler irrigation method on wheat yield, irrigation water requirement, water productivity, saving of water and electricity.

RCTs	Conventional wheat sowing		Wheat sowing in Zero tillage with100% rice mulch/DSR		Wheat sowing in Zero tillage with 100% rice mulch/DSR		Wheat sowing in Zero tillage with 100% rice mulch/DSR with WRI		Wheat sowing in Zero tillage with 100% rice mulch/DSR	
Mode of irrigation	Surface. T_1		Surface.T_8		Mini – Sprinkler.T_9		Mini – Sprinkler.T_{10}		Drip Irrigation-T_7	
Irrigation criteria	Growth stages		Growth stages		(7 days CPE)		(7 days CPE)		(days CPE)	
years	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Grain yield (tha^{-1})	4.73	5.24	4.89	5.43	5.18	5.58	5.29	5.77	-	5.24
Total crop productivity (tha^{-1})	12.43	12.48	11.82	14.16	10.77	14.08	12.74	14.08	-	11.57
Total irrigation water (ha-cm)	28.0	21.65	22.0	17.49	18.53	14.85	18.53	14.85	-	11.33
Total irrigation water ($m^3 ha^{-1}$)	2800	2165	2200	1748.9	1853	1485.3	1853	1485.3	-	1133.3
Crop water productivity (kg m^{-3})	4.44	5.76	5.37	8.09	5.81	9.48	5.79	9.80		10.21
Grain water productivity (kg m^{-3})	1.69	2.42	2.22	3.10	2.24	3.76	2.28	3.88	-	4.62
Irrigation water saving (%)	-	-	21.43	19.22	33.82	31.39	33.82	31.39	-	47.65
Electricity saving (%)	-		27.77	19.23	8.15	4.78	8.15	4.78	-	27.35
NUE (kg grain kg^{-1} nitrogen)	31.53	34.79	32.6	52.11	69.07	88.43	70.53	91.44		71.39

Rainfall received = 46.2 mm and Pan evaporation=257.1 mm during November 2015 to March 2016.Rainfall received= 113.1 mm and pan evaporation = 200.8 mm during November 2016 to March 2017. CPE= cumulative pan evaporation of 7 days used for irrigation through mini sprinkler system, CD (0.05) =0.35 and NUE= nitrogen use efficiency. (Cv.HD 2967).

2.5 Electricity consumption under different irrigation methods in wheat crop: - highest electricity consumption was computed under drip irrigation system (table-5). It was 27.35% in comparison to conventional surface irrigation method. Electricity saving in wheat crop was 8.15% in mini sprinkler irrigation method in comparison to surface irrigation method with conventional wheat sowing during 2015-16 crop season but it was 4.78% in 2016-2017 crop season. The results in table -5 revealed that electricity saved under pressurized irrigation system in comparison to surface irrigation system.

3.1 Feasibility of sprinkler irrigation system in rice–wheat cropping system

The feasibility study of sprinkler irrigation system in rice-wheat cropping sequence was workout with the help of hydraulic parameters in rice-wheat system (Table-3). The results on characterization of hydraulic parameters of installed sprinkler irrigation system shows that operating pressure (kg cm^{-2}) tested at three levels 1.6, 1.8, and 2.0 it was found that uniformity of coefficient (CU %) at start not much affected but water distribution at end much affected and reached at maximum 90.0 in 2012 and 88.07% in 2013. Similarly DU (%), wetted radius (m) also increased with operating pressure and reached maximum 9.69 m at operating pressure 2.0 kg cm^{-2}.

Table. 3 Effects of different operating pressure on hydraulic characterization of installed sprinkler irrigation system

Operating Pressure (kg cm^{-2})	Hydraulic parameters of installed sprinkler system								
	CU(%)		DU(%)		CV(%)		Wetted Radius (m)	Average discharge (lh^{-1})	
	Start	End	Start	End	Start	End	-	Start	End
1.6	84.43	82.53	79.47	74.37	19.78	25.05	6.26	-	-
1.8	85.02	81.20	80.22	75.89	18.58	25.34	8.03	323.0	312.0
2.0	84.96	88.07	82.45	84.05	17.84	15.46	9.69	471.7	396.3

The system coefficient of variation (CV%) also inversely related to operating pressure and recorded minimum CV at 2.0 kg cm^{-2} operating pressure. Thus, hydraulic parameters shows relatively better performance of the system at 2.0 kg cm^{-2} pressure therefore system operated as such in both rice and wheat crops. The results of rice and wheat crops shown in Table 1 & 2 that yields were found statistically at par compared to conventional cultivation. Thus, mini sprinkler irrigation system in rice and wheat crops may be successful with saving of natural resources considerably in higher magnitudes, which may be utilized for more area under cultivation and increasing production from the saved resources where water resource is in scared particularly.

The following observations recorded in rice crop at blooming stage:

1-Insecticides and pesticides should not be used through sprinkler system as at the grain formation stage, grains became brown black, its effects may reduce the grain quality and market price.
2-Sprinkler irrigation at the time of flowering reduced the grain setting.

3-Weedicides application at 50 days after sowing of rice, badly affected plant growth, plants stunted, and gets flowering delay resulted maturity of grain irregular (not gets grain maturity and crop harvesting)

High light of sprinkler irrigation feasibility in rice–wheat cropping system:-"Sprinkler irrigation system in zero tillage wheat with rice residue mulch followed by DSR in reduced tillage either wheat residue incorporation or without crop residue is feasible, promising and sustainable with lower inputs requirement relatively".

3.2 Feasibility of drip irrigation system in rice–wheat cropping system- Results awaited.

3.3 Economic feasibility of rice crop during kharif season 2017 under tillage and crop residue management-

The economic analysis of rice-2017 is presented in table 9 that B:C ratio in TPR and DSR crop establishment techniques, varied from 1.41 to 1.91. It was maximum in DSR where rice sown in reduced tillage and yielded 6.9 tha^{-1} grain yield which was statistically similar to TPR. Minimum B:C ratio was recorded in DSR in ZT where recorded grain yield 5.40 tha^{-1},which was significantly lower in comparison to all practices. Cost of cultivation was lower in DSR in comparison to TPR.

Table. 4 Economic analysis of rice under different CA techniques of tillage and residue management at CSSRI, Karnal on station trial during 2017 kharif season.

Economic analysis of rice -2017					
TPR and DSR crop establishment tehniques					
RCTs	Grain yield, Kg/ha	B-1 Cost of cultivation (Rs)	Gross income (Rs)	Net income (Rs)	B:C ratio
TPR	7.01	44560	1,11459	66899	1.50
TPR+WR	7.42	44560	117978	73418	1.65
DSR	6.5	37646	103350	65704	1.75
DSR+WR	6.9	37646	109710	72064	1.91
DSR-ZT	5.95	35646	94605	58959	1.65
DSR-ZT+WR	5.40	35646	85860	50214	1.41
SEM±	0.13	-	-	-	-
CD at 0.05	0.32	-	-	-	-
MRP was Rs.1590 per quintal for the year 2017. Cost of cultivation includes only operational cost(B-1).					

For the economic analysis of rice-wheat cropping system (rice crop 2017 and wheat crop 2016-2017) data of current year were taken. Operational cost only considered (B-1 cost) for analysis of B:C ratio. In operational cost analysis includes, e.g. Seeds, fertilizer, irrigation, pesticides, insecticides, labours, tillage operations etc. rice market price @ 1590/-per quintal and wheat market price @ Rs.1625/- only considered for the calculation of gross income in the respective techniques.

First option - highest net income (Rs. 73418/-) was observed in T_2 treatment, where rice–wheat was cultivated in conventional with crop residue incorporation, with 1.65 B:C ratio and 0.71kg/m^3 water productivity in rice.

This option is also associated with the use of crop residue for increasing crop productivity and improving soil health. This option of rice–wheat cultivation will care of soil heath, avoiding air pollution and improving crop productivity.

Table. 5 Economic analysis of rice under different irrigation methods at CSSRI, Karnal on station trial during 2017 kharif season

Economic analysis of rice -2017					
Irrigation methods					
RCTs	Grain yield, Kg/ha	B-1 Cost of cultivation (Rs)	Gross income (Rs)	Net income (Rs)	B:C ratio
TPR	7.01	44560	111459	66899	1.50
DSR-drip	6.30	44976	100170	55194	1.23
DSR-Surf.	6.53	37646	103827	66181	1.76
DSR-SPRL	6.56	43725	104304	60579	1.39
DSR+WR-SPRL.	6.66	43725	105894	62169	1.42
SEM±	0.13	-	-	-	-
CD at (0.05)	0.32				

However, **2nd option** was observed among the DSR techniques, that DSR with RT + wheat residue technique (T_4), produced 6.9 t/ha rice with maximum net income Rs. 72064 with 1.91 B:C ratio and 0.0.95 kg/m^3 water productivity in rice. This option of rice–wheat cultivation care of water saving, crop residue incorporation and saved 50% tillage. Two options of rice cultivation in specified situation might be promising for increasing rice productivity in sustainable manner. Among the transplanted rice technologies, rice transplanted with wheat residue incorporation, found productive where irrigation water is not a constraint. However, in limited irrigation water condition, DSR techniques are relatively better option for the sustaining rice productivity. Similarly, it was found that wheat sowing in zero tillage is the relatively nice option for increasing higher wheat productivity in changing environmental condition also. It is clear from results and discussion that crop residue management option is economic and feasible with few labours work in TPR and DSR crop establishment techniques.

Economic feasibility of rice crop during kharif season 2017 under different irrigation methods- Economic analysis of rice under different CA techniques of water management at CSSRI, Karnal on station trial during 2017 kharif season is given in table 10. It reveals that among the DSR with different irrigation method, observed that DSR with surface irrigation method, being less cost of cultivation computed higher B:C ratio (1.76) in comparison to other irrigation methods. Micro irrigation methods varied in B:C ratio 1.23 to 1.42. Highest B:C ratio was observed in DSR with sprinkler irrigation method. Economically feasible with saving of irrigation water and higher nitrogen use efficiency.

Third option -Mini sprinkler irrigation method may be good option for saving of irrigation.

Effect of micro irrigation, planting techniques and residue management practices on sugarcane productivity: (NIASM)

The water requirement of sugarcane is very high (2000-3000 mm) and thus inadequate supply of water resulted in great yield penalty. Subsurface drip irrigation (SSDI) technique offers many advantages over surface drip irrigation (SDI) such as; reduced evaporation, efficient water use, greater water uniformity and thus reduces the water requirement of the crop. However in case of sugarcane, SSDI is taken up in very less area and mostly advocated with paired row planting technique. Though, paired row planting technique saves the irrigation water and also number of drip laterals and their installation costs but also often have resulted lower cane yield production due to inter-row competition between the paired rows. Thus, standardization of planting geometry of paired rows and spacing of drip laterals for SDI and SSDI under paired row planting systems is needed. In addition to this, surface retention of crop residues in conjunction with micro irrigation techniques would be helpful in improving hydro-thermal regimes and soil health further. Keeping these things in mind, a field experiment was conducted with six main plot treatments viz., M1: parallel planting of each plant in single rows spaced at 150 cm with surface drip irrigation (PSR-150 cm + SDI); M2: parallel planting of each plant of paired rows by maintaining spacing of 90 cm between the rows and 210 cm between the pairs with SDI (PPR-90-210 cm + SDI); M3: zigzag planting of each plant of paired rows by maintaining spacing of 75 cm between the rows and 225 cm between the pairs with SDI (ZPR-75-225 cm + SDI); M4: ZPR-60-240 cm + SDI; M5: ZPR-75-225 cm + SSDI; M6: ZPR-60-240 cm + SSDI (Fig. 1). Two treatment of soil surface cover management practices *viz.*, T1: Residue; covering of soil surface with a live mulch of mungbean followed by retention of mungbean residue and trash as mulch and T2: without residue were accommodated in sub-plots. An absolute control surface irrigation management practices was also maintained to compare the treatment effects.


Sub surface drip installation


Parallel paired row + SSDI


Zigzag paired row + SDI


Single row + SDI


Mungbean as live mulch +SSDI


Mungbean as live mulch + SDI

Fig. 1. Application of treatments in experimental field of sugarcane.

The amount of applied irrigation water was equal to 100 and 80 % of the crop evapotranspiration (ETC) under surface and subsurface irrigation methods. The crop was irrigated at 2 days intervals under SDI and SSDI and at 80 mm CPE under surface irrigation method.

The maximum cane yield (139.6 t ha^{-1}) was recorded under the M5 (ZPR-75-225 cm + SSDI) treatment which was significantly higher by 6-13 % as compared to remaining planting and micro irrigation techniques, except M1 (PSR-150 cm + SDI) and M3 (ZPR-75-225 cm + SDI) treatments (Fig. 2).

While covering of soil surface with live mulch of mungbean followed by retention of mungbean residue and trash in the field improved the cane yield on an average by 9 % as compared to without residue retained treatment. This indicated that yield of paired row planted sugarcane could be improved significantly with adoption of zigzag planting, micro irrigation techniques and retaining the crop residues on soil surface.

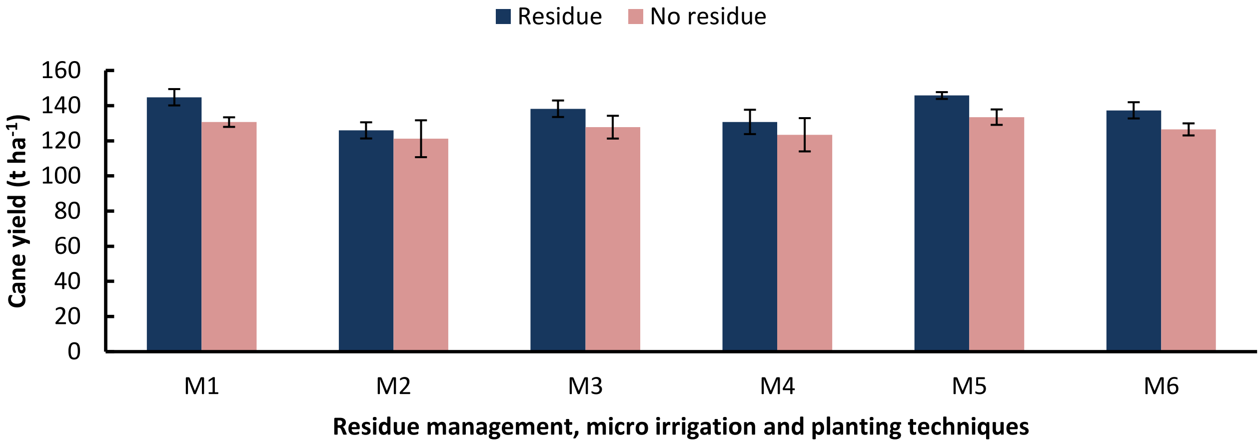


Fig. 2. Effect of crop residue, micro irrigation and planting techniques on cane yield of sugarcane.

In addition to this, a good quantity of seed yield of mungbean (3.5-6.8 q ha^{-1}) also could be obtained while growing of mungbean as intercrop with sugarcane for live mulch and recyclable residue (Fig 3). The maximum seed yield of mungbean was recorded with M1 (PSR-150 cm + SDI) which was 43-95 % higher than rest of the treatments.

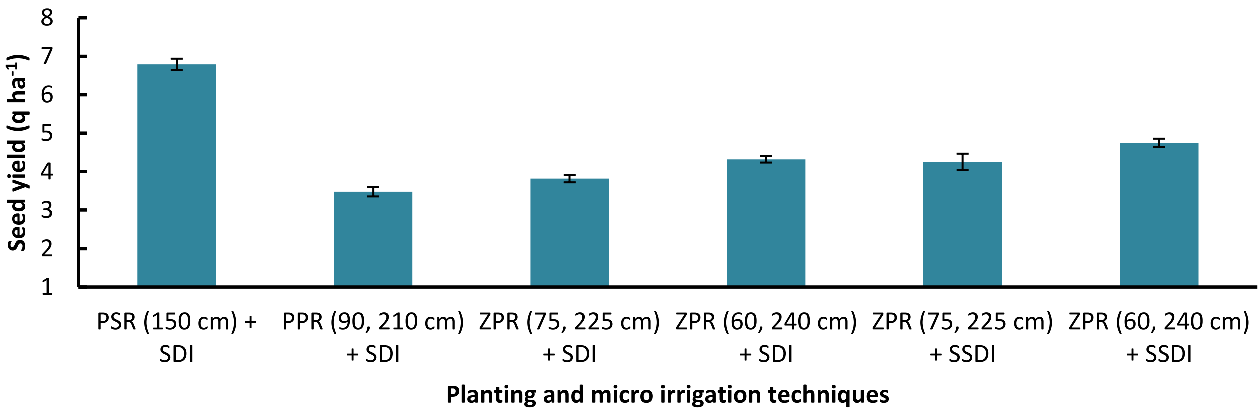


Fig. 3. Effect of planting and micro irrigation techniques on seed yield of mungbean.

Development of Water and Nutrient Management Practices in Conservation Agriculture for Vertisols of Central India (IISS)

This subproject was conducted with three objectives of the project namely

i) Studying root behaviour and nutrient dynamics at different moisture regimes under CA, ii) Quantifying water and nutrient use efficiencies, nutrient, water and energy budgeting under CA and iii) Identifying the best water and nutrient management practices under CA.

During 2017-2018, the field experiment conducted during *kharif* season with four levels of fertilizer treatments [100 % RDF, 75% DRF, STCR (soil test crop response) and 75% RDF with 25% LCC (leaf color chart)) and three levels of tillage treatment (CT-Conventional tillage, RT-Reduced tillage and NT- No tillage] under soybean crop. The soybean was sown in month of June, 2017 and harvested in the month of October, 2017. During this crop growth period, growth parameters and crop yields were recorded.

The during rabi season wheat crop was taken up with four levels of fertilizer treatments (100 % RDF, 75% DRF, STCR and 75% RDF with 25% LCC) and three levels of tillage treatment (CT- Conventional tillage, RT-Reduced tillage and NT- No tillage) were tested in rabi season. The wheat was sown on December 23, 2017 and crop harvested on March 23, 2018. During this crop period, the observation on soil moisture, soil temperature, dry matter production, growth and crop yield recorded. The grain and straw yield of wheat were significantly at par among the treatments of tillage and fertilizer dose. Other parameters like soil moisture, plant height, soil temperature were also not significant difference among the treatments of tillage and fertilizer doses (Table 1, 2, 3, 4 and 5).

Table 1: Effect of tillage and fertilizer dose on grain and straw yield of wheat

	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	CT	RT	NT	Mean	CT	RT	NT	Mean
F1	2712	2832	3220	2921	5433	5207	5149	5263
F2	2963	3002	2931	2966	5065	5181	4650	4965
F3	2984	3044	3088	3039	5017	4868	4919	4935
F4	3070	2969	3243	3094	5917	4924	4421	5087
Mean	2932	2962	3120	--	5385	5045	4785	--
	Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS				Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS			

F1= 100 % RDF, F2= 75% RDF, F3=STCR, F4=75%+25% LCC

Table 2: Effect of tillage and fertilizer dose on Soil moisture content (%)

	Soil moisture content (%) on 1/2/2018				Soil moisture content (%) on 19/2/2018			
	CT	RT	NT	Mean	CT	RT	NT	Mean
F1	17.34	17.17	17.63	17.38	20.17	20.80	21.14	20.70
F2	17.24	17.61	17.55	17.47	20.48	20.22	22.89	21.20
F3	17.19	18.46	16.67	17.44	20.28	21.48	19.63	20.46
F4	17.28	18.25	16.84	17.46	22.66	18.87	21.98	21.17
Mean	17.26	17.87	17.17	--	20.90	20.34	21.41	--
	Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS				Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS			

F1= 100 % RDF, F2= 75% RDF, F3=STCR, F4=75%+25% LCC

Table 3: Effect of tillage and fertilizer dose on plant height of wheat

	Plant height of wheat (cm) on 10/1/2018				Plant height of wheat (cm) on 16/2/2018			
	CT	RT	NT	Mean	CT	RT	NT	Mean
F1	40.3	39.4	37.2	39.0	109.9	106.3	100.7	105.6
F2	39.6	38.7	36.6	38.3	106.9	104.6	104.7	105.4
F3	39.4	41.7	37.5	39.5	105.9	106.7	106.1	106.2
F4	42.7	33.7	37.5	38.0	110.5	96.6	106.3	104.4
Mean	40.5	38.4	37.2		108.3	103.5	104.4	
	Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS				Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS			

F1= 100 % RDF, F2= 75% RDF, F3=STCR, F4=75%+25% LCC

Table 4: Effect of tillage and fertilizer dose on soil temperature on 12/1/2018

	Soil temperature (°C) at 7 AM				Soil temperature (°C) at 2 AM			
	CT	RT	NT	Mean	CT	RT	NT	Mean
F1	14.41	14.85	14.76	14.68	20.21	21.01	21.00	20.74
F2	14.86	14.54	14.83	14.74	20.44	20.60	21.68	20.91
F3	14.82	14.70	14.85	14.79	20.72	21.05	21.21	20.99
F4	14.68	14.77	14.67	14.71	19.85	21.33	21.03	20.74
Mean	14.69	14.71	14.78		20.31	21.00	21.23	
	Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS				Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS			

F1= 100 % RDF, F2= 75% RDF, F3=STCR, F4=75%+25% LCC

Table 5: Effect of tillage and fertilizer dose on soil temperature on 20/2/2018

	Soil temperature (°C) at 7 AM				Soil temperature(°C) at 2 AM			
	CT	RT	NT	Mean	CT	RT	NT	Mean
F1	18.9	18.89	18.49	18.76	24.57	24.13	25.23	24.64
F2	18.7	18.96	18.68	18.78	24.67	24.34	25.26	24.76
F3	18.67	18.70	18.92	18.76	25.04	24.24	24.55	24.61
F4	18.78	18.83	18.88	18.83	24.93	25.14	24.92	25.00
Mean	18.76	18.84	18.74		24.80	24.47	24.99	
	Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS				Tillage : NS, Fertilizer Dose : NS, Tillage x Fertilizer dose : NS			

F1= 100 % RDF, F2= 75% RDF, F3=STCR, F4=75%+25% LCC

2.1.1.4 Nutrient Management (CRIDA)

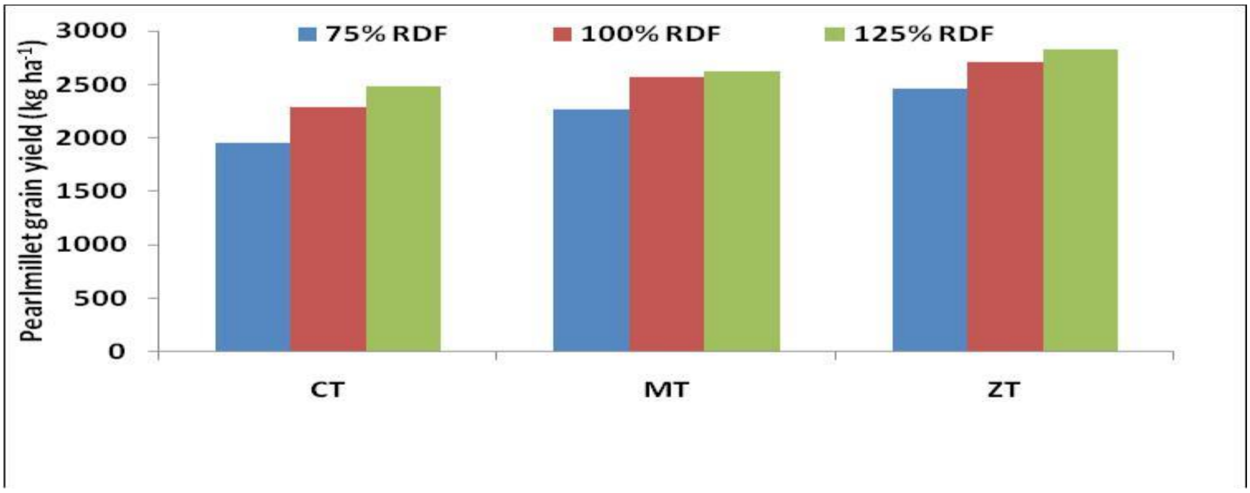
Nutrient Management in Rainfed Conservation agriculture systems

Experiments were initiated in three cropping systems Maize-Pigeonpea, Pearlmillet-Horseg-ram and Cotton-pigeonpea **.**

1. Pearlmillet - Horsegram

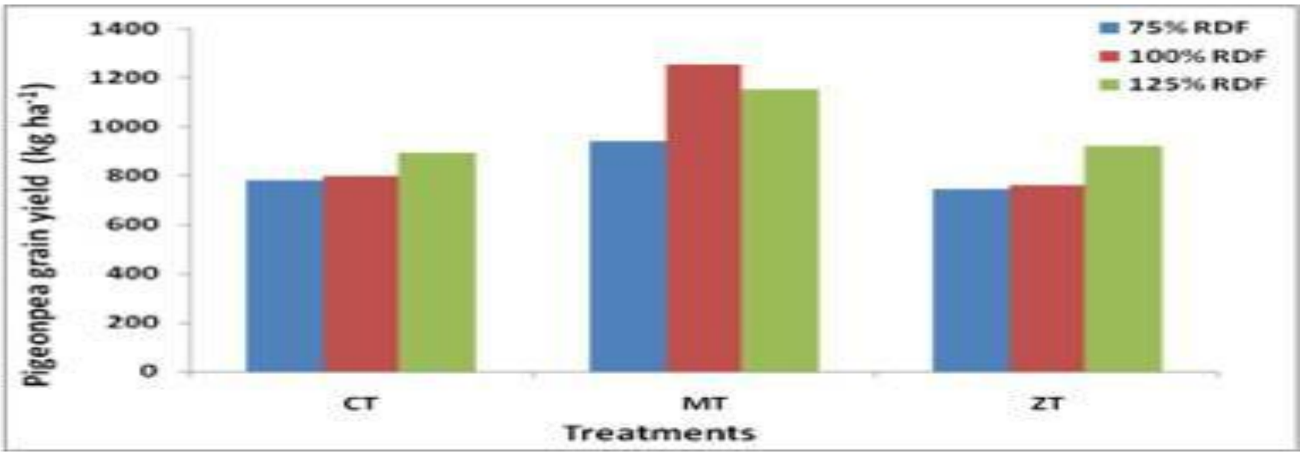
Experiment was laid out in split plot design with three tillage treatments and nitrogen doses as subplots. ZT recorded significantly higher grain yield of pearlmillet (2664 kg ha^{-1}). The yield was statistically on par with MT (2487 kg ha^{-1}) as compared to CT (2243 kg ha^{-1}). Among nitrogen treatments, significantly higher yield was obtained with 125% RDF (990 kg ha^{-1}) as compared to 75% RDF (822 kg ha^{-1}). The interaction of tillage and nutrient management were significant .MT with 100% RDF recorded higher yield. Interaction between tillage and nutrient management was significant. Significantly higher yield was obtained through MT with 100 % RDF (1255 kg ha^{-1}).

Pearlmillet grown in recommended doses of fertilizers and tillage treatments



2. Cotton – Pigeonpea system

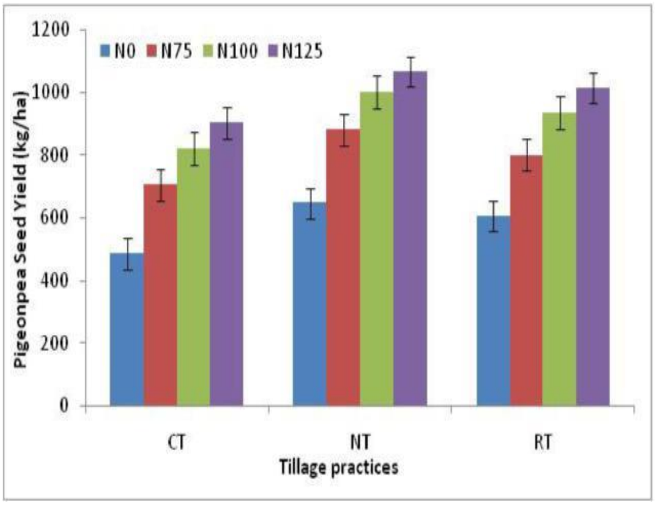
In another experiment, in cotton- pigeonpea system, Pigeonpea yields were significantly influenced by tillage and fertilizer. MT recorded higher grain yield as compared to CT and ZT. Among the nitrogen levels, 125% RDF recorded higher yields. MT with 100% RDF recorded higher grain yield whereas in CT and RT 125% RDF recorded higher grain yield.



Pearlmillet and pigeonpea residue in CA plot in the month of February,2018

3. Maize –Pigeonpea system

An experiment was initiated in 2012-13 to study the effect of nutrient management. Results showed that NT and RT recorded significantly higher seed yield over CT. The increase of 23.4% and 15.1% in yield was observed in NT and RT over CT respectively. Similarly, NT recorded 7.2% higher seed yield over RT. N75, N100 and N125, recorded 37.2, 58.5 and 71.5% higher seed yield respectively over no nitrogen. The mean seed yield at N100 and N125 was found at par. The percent increase in the seed yield in CT at N125 was 85.8% over N0. The corresponding increases in NT and RT at N125 were 64.8% and 67.2% respectively over N0,. Tillage practices also significantly influenced the stover yield (Fig. 1). The per cent increase in stover yield was 18 and 12.4% in NT and RT as compared to the CT. NT recorded 5% higher stover yield over RT. The mean stover yield increase was 30.9, 49.0 and 56.3% in N75, N100 and N125, respectively as compared to the no nitrogen application. There were no statistically significant difference between N100 and N125. The percent increases in CT at N125 over N0 was 61.9%. While, in NT and RT at N125, the yield increase was 52.2% and 55.7%.at N125 over N0.



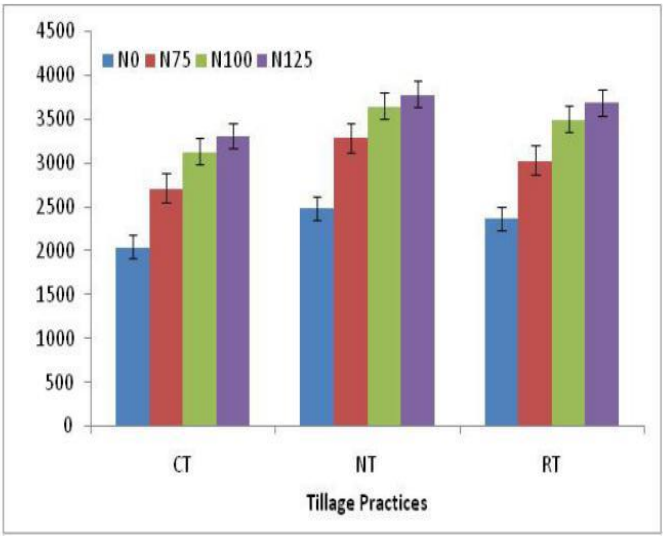


Fig 1 : Effect of tillage and nitrogen on pigeonpea seed and stover (kg ha^{-1})

Formation of the surface crust in CT and RT treatments after the rainfall

CT NT RT

Fig 2: Surface crop residues cover and re growth of pigeonpea in different treatments.

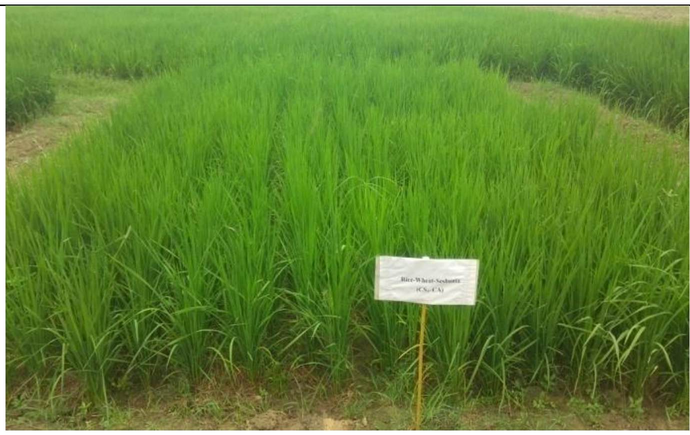
2.1.1.5 Cropping Sequence

Evaluation of different cropping sequences for crop intensification under CA practices. (IIFSR)

As indicated in table number to most of the in attributes character of rice were of higher unconventional practices (transplanted rice) as compared to conservational practice (direct seeded rice) and hence plant height (87.47cm), effective tillers (230/m^2), panicle length (24.3 5cm), grains/ panicle (64) as well as grain and straw yield were recorded higher under conventional practices (transplanted rice) than conservational practices (direct seeded rice).

Cropping Systems		Plant height	Effective tiller/m2	Length / panicle	No. Of grain/ panicle	Grain Yield (t/ha)	Straw Yield (t/ha)
Rice-wheat-green gram	CA	83.73	287	21.57	56	4.14	8.63
Rice-wheat-sesbania		84.93	282	22.80	60	4.60	9.60
Rice-wheat-green gram	CP	88.20	188	24.97	64	4.72	9.87
Rice-wheat-sesbania		86.73	216	23.73	63	5.22	10.88
Average	**CA**	**84.33**	**284.67**	**22.18**	**58.33**	**4.37**	**9.11**
	CP	**87.47**	**201.83**	**24.35**	**63.60**	**4.97**	**10.37**

Rice (rice-wheat-sesbania) under CP conditions.



Rice (rice-wheat-sesbania) under CA conditions.

Wheat residue in rice under CA conditions..

Rice residue in wheat under CA conditions..

Under maize crop as given in table 03, plant height and number of the plant per m^2 were higher under conventional (CP) practice as compared to conservational (CA) practices, however cob weight was more under CA practices. Green cob yield were 18.91% higher under conventional practices than conservational practices (9.88 t/ha).

Table 01: Yield and yield attributes of maize as influenced by CA and CP practices

Plot No.	Average Plant Height	No. Of plants/m^2	Cob yield of 5 plant (kg)	per cob wt. (kg)	Cob yield (kg/plot)	Stower yield kg/plot	Cob yield (t/ha)	Stower yield t/ha
CA	211.49	5	1.62	0.32	23.60	41.67	9.83	17.36
CP	223.58	6	1.45	0.29	28.07	51.17	11.69	21.32

Maize (maize (Cob)-Pea (Veg)-Wheat- Cowpea) under CA conditions.

Maize (maize (Cob)-Pea (Veg)-Wheat- Cowpea) under CP conditions.

Sugarcane yield and yield attributes under sugarcane-ratoon-wheat cropping system, Plant height (332 cm), single cane weight (1.27 kg) were recorded higher under conservational practices, however brix value (21.93%), number of millable canes (273. 67 thousands/ha) and cane yield (98.84 t/ha) were higher under conventional practice as compared to conservational practices.

Table 02: Yield and yield attributes of sugarcane as influenced by CA and CP practices (Sugarcane-ratoon-Wheat)

	Spad	No. of internodes /plant	Plant height (cm)	Single Cane wt. (Kg)	Brix (%)	NMC (Thousand /ha)	Cane Yield (t/ha)	Straw Yield (t/ha)
CA	36.38	17	332.33	1.27	20.33	257.67	92.78	34.44
CP	36.03	16	329.11	1.24	21.93	273.67	98.84	33.47

Fig: Sugarcane (sugarcane-ratoon-wheat) under CP conditions.

Fig: Sugarcane (sugarcane-ratoon-wheat) under CA conditions.

On average basis and across the cropping systems plant height, numbers of tillers/meter square, ear length, and yields (biological, grain and straw) were recorded more under conventional practice; however number of grains were at par under both the conditions. Conventional practice recorded about 12.7 and 68.3 % higher grain and straw yields as compared to conservational practice (zero till wheat).

Table 03: Yield and yield attributes of wheat as influenced by CA and CP practices

Cropping System		Plant Height (cm)	No. Of Tillers /m^2	Ear Length (cm)	No. Of grains/ears	1000 grain wt.(g)	Biological Yield (t/ha)	grain Yield (t/ha)	Straw Yield (t/ha)
Rice- Wheat- Green gram	CP	85.27	579	9.13	43	41.78	11.67	5.17	6.50
	CA	83.93	350	8.53	46	41.86	8.48	4.32	4.16
Rice- Wheat- Sesbania	CP	89.47	493	9.23	48	43.14	10.42	4.27	6.15
	CA	86.73	363	9.57	45	43.63	7.36	3.94	3.42
Maize (Cob)- Pea (Veg)- Wheat- Cowpea	CP	89.47	521	9.97	55	45.59	14.26	6.15	8.11
	CA	86.80	468	9.27	53	45.54	10.27	5.30	4.96
Sugarcane- Ratoon- Wheat	CP	91.07	693	9.83	43	44.87	13.68	5.78	7.91
	CA	89.40	552	9.17	49	43.58	9.93	5.43	4.50
Average	CP	88.82	572	9.54	47	43.85	12.51	5.34	7.17
	CA	86.72	433	9.13	48	43.65	9.01	4.75	4.26

Because of better control of secondary weeds in cowpea, green gram and pea higher yields of all the crops were recorded under conventional practices as compared to conservational practices, which were higher to the tune of 108.6, 53.1and 8.3% (table 04)over the conservational practice.

Table 04: Yield and yield attributes of cowpea, green gram and pea as influenced by CA and CP practices

Crop		Green pod yield (t/ha)	Spad	Residue	
				Fresh wt. (t/ha)	Dry wt. (t/ha)
Cow pea	CP	3.15	55.00	30.45	6.58
	CA	1.51	53.54	28.99	6.38
Green gram	CP	1.24*	51.22	20.54	8.82
	CA	0.81*	52.44	20.42	9.30
Veg. Pea	CA	2.08	-	4.00	1.10
	CP	1.92	-	3.10	0.90

Fig: Green gram (rice-wheat-green gram) under CA conditions.

Fig: Green gram (rice-wheat-green gram) under CP conditions.

Fig: Cow pea (maize (Cob)-Pea (Veg)-Wheat- Cowpea) under CA conditions.

Fig: Cow pea (maize (Cob)-Pea (Veg)-Wheat-Cowpea) under CP conditions.

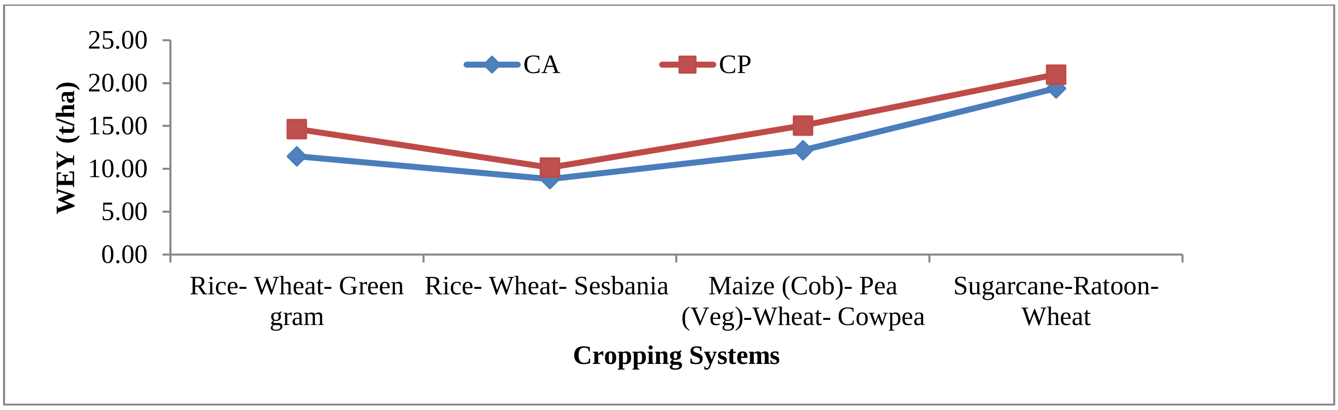
Fig: Sesbania (rice- wheat- sesbania) under CA conditions.

Fig: Sesbania (rice- wheat- sesbania) under CP conditions.

Maximum wheat equivalent yield (20.20 t/ha) was recorded under sugarcane-ratoon-wheat system followed by maize (cob)-pea (pod)- wheat- cowpea (13.62 t/ha) as per shown in table 5. All the cropping systems showed superiority under conventional practices as compared to conservational practices. However higher B:C ratio was scored under sugarcane-ratoon-wheat and rice-wheat-sesbania system when followed conservational practices, which is mainly because of lower cost of cultivation under conservational practices.

Table 05: WEY, net returns and B:C ratio as influenced by CA and CP practices under different cropping systems

Cropping System	CA			CP		
	WEY (t/ha)	Net Returns (Lakhs/ha)	B:C	WEY (t/ha)	Net Returns (Lakhs/ha)	B:C
Rice-wheat-green gram	11.46	1.13	2.3	14.63	1.44	2.3
Rice-wheat-sesbania	8.80	0.82	2.1	10.15	0.80	1.8
Maize (cob)-pea (veg)-wheat- cowpea	12.19	1.26	2.5	15.05	1.57	2.5
Sugarcane-ratoon-wheat	19.39	2.46	3.7	21.01	2.49	3.2



Data given in table 06 indicates that there is little built up of phosphorus, potassium and organic carbon with the adoption of recycling of crops residues like rice and wheat straw; green gram, cowpea and sunhemp residue in various cropping systems. On an average 16.58 t/ha legume crop residue on dry basis is being recycled under conservational practices.

Table 06: Organic Carbon and major nutrients (N, P & K) of soil during 2017-18

Cropping Systems	CP				CA			
	N kg/ha	P kg/ha	K kg/ha	OC (%)	N kg/ha	P kg/ha	K kg/ha	OC (%)
Rice- Wheat- Green gram	175.6	83.5	115.8	0.41	179.8	103.2	103.8	0.48
Rice- Wheat- Sesbania	184.0	65.1	105.3	0.43	204.9	71.6	108.6	0.40
Maize (Cob)- Pea (Veg)- Wheat- Cowpea	200.7	82.2	100.8	0.42	188.2	82.0	132.2	0.47
Sugarcane-Ratoon- Wheat	209.1	80.5	100.4	0.53	192.3	89.1	106.8	0.41
Average	192.4	77.8	105.6	0.42	191.3	86.5	112.9	0.44

Crop/system productivity and economics in rice-based cropping systems (rice-wheat and rice-mustard) (IARI)

1.1 Conservation agriculture based direct-seeded rice-wheat-mungbean system can be a superior alternative to conventional rice-wheat system

Long-term conservation agriculture (CA)-based direct-seeded rice (DSR)-wheat cropping system is being undertaken for eight consecutive years to replace transplanted puddled rice (TPR) - conventional till wheat (CTW) system, which has encountered host of problems related to water, nutrients, labour, fuel/energy, weed, and GHGs emission. A triple zero till (ZT) system (Figure 1) with three crops (rice, wheat, mungbean) residue, which involved ZT DSR with summer mungbean (SMB) residue - ZT wheat (ZTW) with rice residue (RR) – ZT summer mungbean (SMB) with wheat residue (~MBR+ZT DSR - RR+ZTW-WR+SMB) gave 13% higher wheat yield and 40% higher system productivity than TPR-CTW system, although it had 7% lower rice yield (Table 1). This triple ZT system with three crops residues led to a saving of almost 60 kg N/ha in rice and wheat crops in a year. This CA-based system could be a superior alternative to rice-wheat system and an important adaptation and mitigation strategy to climate change.

Fig. 1: DSR under triple ZT conditions (with 75% N and 100% N)

Fig. 2: Brown manuring in direct seeded rice (temporary residue mulch)

Table 1. Rice, wheat and system productivities in rice-wheat cropping system with CA practices

Treatments	Rice productivity (t/ha)	Wheat productivity (t/ha)	System productivity (rice equ.) (t/ha)
ZT DSR – ZTW (Double ZT system)	4.22^{d}	6.11^{e}	10.80^{e}
ZT DSR+BM – ZTW	3.12^{e}	6.16^{de}	9.75^{f}
WR+ZT DSR - RR+ZTW (75%N)	3.16	6.28	9.92
WR+ZT DSR - RR+ZTW (100%N)	3.22^{e}	6.28^{cde}	9.99^{f}
WR+ZTDSR+BM - RR+ZTW (75%N)	3.09	6.34	10.08
WR+ZTDSR+BM - RR+ZTW (100%N)	3.20^{e}	6.45^{abc}	10.14^{f}
ZT DSR – ZTW – ZT SMB (Triple ZT system)	4.45^{c}	6.33^{bcd}	15.17^{b} (3.91)*
MBR+ZT DSR - RR+ZTW -WR+ SMB (75%N)	4.56	6.53	15.57
MBR+ZT DSR - RR+ZTW -WR+ SMB (100%N)	4.64^{c}	6.57^{a}	15.76^{a} (4.05)*
TPR-ZTW	5.23^{a}	6.48^{ab}	12.20^{c}
TPR-CTW	4.99^{b}	5.81^{f}	11.24^{d}

Rice equivalent yield of mungbean grain yield (t/ha) in parentheses

1.2. Conservation agriculture (CA)-based cotton-wheat system can be a promising crop diversification option for conventional rice-wheat system

The predominant rice-wheat cropping system in the Indo-Gangetic plains has encountered a host of problems. A non-rice crop, that is as remunerative as rice, is required to diversify this system. A study carried out for eight consecutive years in three major non-rice cropping systems, *viz*., cotton-wheat, pigeonpea-wheat and maize-wheat with suitable conservation agriculture (CA) practices revealed that cotton-wheat system among these systems was superior in terms of system productivity (Table 2). All ZT permanent broad, narrow and flat beds with residue retentions were superior to conventional till practice on system productivity. Cotton-wheat system under ZT permanent broad and flat bed with residue gave significantly higher system productivity (32.1% & 32.8%) than conventional till system. These two systems performed better under 75% N than 100% N and could save 67.5 kg N/ha in cotton and wheat in a year. Thus, these CA-based cotton-wheat systems could be promising alternatives to rice-wheat system and important adaptation and mitigation strategies to climate change.

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

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

Fig. 3: Cotton crop in the field under narrow and broad bed with and without residue

Table 2. System productivity (wheat equ.) in wheat-based cropping systems with CA practices

Treatments	Cotton-wheat (t/ha)	Maize-wheat (t/ha)	Pigeonpea-wheat (t/ha)
CT	9.56d	9.54e	8.42f
ZTNB	10.34c	10.27d	8.98de
ZTNB+R (75N)	10.51c	10.22d	-
ZTNB+R(100N)	11.37b	10.72b	9.53c
ZTBB	11.19^{b}	10.82b	9.43c
ZTBB+R(75N)	12.63a	11.32a	-
ZTBB+R(100N)	11.69b	11.42a	10.21a
ZTFB	11.34b	11.22a	9.73b
ZTFB+R(75N)	12.76a	11.39a	-
ZTFB+R(100N)	11.27b	10.49c	9.04d

Wheat under ZT + Rice Residue

Wheat under ZT-Narrow Bed+ Maize Residue

Wheat under ZT-Broad Bed + Pigeon pea Residue

Wheat under ZT-Flat Bed+ Pigeon Pea

Mung bean under ZT Flat Bed in Rice-Wheat-Mungbean cropping system

Wheat under ZT in different cropping sytems (C-W, P-W, M-W)

Fig. 4: Wheat crop after cotton under different beds with and without residue

2.1.1.6 Radiation-use efficiency (IARI)

Leaf Area Index

Leaf area index (LAI) of rice under different treatments (Table 1) increased rapidly during vegetative phase (seedling to flowering) reaching at a peak around 90-100 DAS (Days After Sowing) and then decreased thereafter due to senescence. At 100 DAS, maximum and minimum LAI value of rice (4.98 and 3.31, respectively) were observed in T8 (TPR+CTM) and T2 (ZT DSR + BM – ZTM), respectively. Among conservation agriculture plots, T6 (MBR + ZT DSR – RR + ZTM) resulted in maximum LAI of rice. As monsoon was deficit during *kharif* season (2014-15), conventional practices produced more LAI due to application of adequate moisture through irrigation during this year. But in case of mustard, at 90 DAS, maximum LAI value of 4.22 was observed in T6 (MBR+ ZT DSR- RR+

ZTM) followed by T4 (MR+ ZT DSR + BM- RR+ ZTM) and the lowest LAI value of 3.09 was observed in T1 (ZT DSR- ZTM).

Table 1. Temporal variation of leaf area index (LAI) in rice as influenced by different treatments under conservation and conventional agriculture during *kharif* season

Treatments	40 DAS	60 DAS	80 DAS	100 DAS
ZT DSR– ZTM	0.49^D	1.38^E	3.09^D	3.40^C
ZT DSR + BM – ZTM	0.54^D	2.01^AB	3.82^A	3.31^D
MR + ZT DSR – RR + ZTM,	0.66^C	1.58^D	3.17^C	3.42^C
MR + ZT DSR + BM –RR + ZTM	0.72^BC	1.99^ABC	3.99^A	3.45^C
MBR + ZT DSR – ZTM	0.71^BC	1.85^C	3.45^B	3.36^D
MBR + ZT DSR – RR + ZTM	0.70^C	2.10^A	3.99^A	3.49^C
TPR – ZTM	0.77^B	1.61^D	3.02^C	3.79^B
TPR – CTM	0.89^A	1.89^BC	3.21^C	4.11^A
LSD at 5%	0.063	0.164	0.1968	0.164

Biomass Accumulation

In rice crop, at 40 DAS, the highest and lowest biomass accumulation (2.0 t ha^{-1} and1.27 t ha^{-1}, respectively) were observed in T8 (TPR – CTM) and T4 (MR + ZT DSR + BM –RR + ZTM) **(Table 2)**. In mustard, at 80 DAS, T6 (MBR+ ZT DSR- RR+ ZTM) resulted in significantly higher biomass accumulation (4.25 t ha^{-1}) than other treatments. The T1 (ZT DSR- ZTM) resulted in the lowest biomass accumulation (3.24 t ha^{-1}). At 130 DAS, similar pattern was also observed, T6 (MBR+ ZT DSR- RR+ ZTM) being resulted in the highest biomass accumulation (7.80 tha^{-1}).

Table 2: Temporal variation of biomass in rice as influenced by different treatments under conservation and conventional agriculture during *kharif* season

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS
ZT DSR– ZTM	0.35	1.70	3.50	6.10	8.90	10.55
ZT DSR + BM – ZTM	0.30	1.45	3.00	5.33	8.25	10.03
MR + ZT DSR – RR + ZTM,	0.30	1.55	3.20	5.85	8.76	10.37
MR + ZT DSR + BM –RR + ZTM	0.40	1.27	3.37	6.20	8.80	10.50
MBR + ZT DSR – ZTM	0.30	1.34	3.10	5.46	8.57	10.21
MBR + ZT DSR – RR + ZTM	0.39	1.68	3.50	6.25	9.10	10.92
TPR – ZTM	0.40	1.70	4.10	6.90	9.70	12.28
TPR – CTM	0.50	2.00	4.50	7.70	11.75	13.77
LSD at 5%	0.21	0.24	0.21	0.35	0.16	0.19

Radiation Interception

The FIPAR (Far Infrared Photosynthetic Active Radiation) for rice in different treatments under conservation and conventional agriculture followed the similar trend as that of LAI. In all the cases, it increased rapidly during initial period (till 100 DAS) and then became plateau (at 100 DAS) and decreased thereafter with progress of season (till physiological maturity). **(Table 3)**. At 100 DAS, T8 (TPR – CTM) resulted in the peak fIPAR value (0.95) and T2 (ZT DSR + BM – ZTM) resulted in the lowest peak fIPAR value (0.88). T8 showed the highest and T2 showed the lowest fIPAR throughout the growing season.

Table 3: Temporal variation of fIPAR in rice as influenced by different treatments under conservation and conventional agriculture during *kharif* season

Treatments	**40 DAS**	**60 DAS**	**80 DAS**	**100 DAS**	**120 DAS**
ZT DSR– ZTM	0.24^{AB}	0.51^{AB}	0.79^{AB}	0.95^{A}	0.74^{B}
ZT DSR + BM – ZTM	0.17^{B}	0.37^{B}	0.65^{B}	0.88^{AB}	0.71^{E}
MR + ZT DSR – RR + ZTM,	0.21^{AB}	0.45^{AB}	0.75^{AB}	0.90^{AB}	0.73^{C}
MR + ZT DSR + BM –RR + ZTM	0.23^{AB}	0.48^{AB}	0.76^{AB}	0.92^{AB}	0.73^{C}
MBR + ZT DSR – ZTM	0.17^{B}	0.37^{B}	0.67^{B}	0.89^{AB}	0.72^{D}
MBR + ZT DSR – RR + ZTM	0.31^{A}	0.60^{A}	0.78^{AB}	0.86^{B}	0.72^{D}
TPR – ZTM	0.27^{AB}	0.56^{AB}	0.82^{A}	0.91^{AB}	0.74^{B}
TPR – CTM	0.32^{A}	0.63^{A}	0.83^{A}	0.95^{A}	0.75^{A}
LSD at 5%	0.12	0.19	0.15	0.07	0.01

TIPAR, Final biomass and Radiation Use Efficiency

In rice, (Table 4) T8 (TPR – CTM) (554 MJ m^{-2}) and resulted in significantly higher TIPAR (Total incident Photosynthetic Active Radiation) than other treatments for the whole crop growing period. Among conservation treatments, T6 (MBR + ZT DSR – RR + ZTM) resulted in significantly higher TIPAR (518 MJ m^{-2}).

Fig. 1: Mustard crop after cotton under different beds with and without residue

The T2 (ZT DSR + BM – ZTM) (430 MJ m^{-2}) resulted in the lowest TIPAR. In rice, T8 was recorded with the highest final above ground biomass (1377 g m^{-2}) and T2 with the lowest above ground biomass (1003 g m^{-2}). Among the conservation agriculture treatments, T6 resulted in higher above ground biomass (1092 g m^{-2}) than other treatments. Radiation use efficiency (RUE) was reported to be the highest in T8 (2.5 g MJ^{-1}) and the lowest RUE in T6 and T1 (ZT DSR– ZTM) (2.1 g MJ^{-1}).

Table 4: Variation of TIPAR, final above ground biomass and radiation use efficiency (RUE) in rice as influenced by different treatments under conservation and conventional agriculture during *kharif* season

Treatment	Biomass (g/m^2)	TIPAR(MJ/m^2)	RUE (g/ MJ)
ZT DSR– ZTM	1055	511^{AB}	2.1^{B}
ZT DSR + BM – ZTM	1003	430^{C}	2.4^{AB}
MR + ZT DSR – RR + ZTM,	1037	476^{ABC}	2.2^{AB}
MR + ZT DSR + BM –RR + ZTM	1050	491^{ABC}	2.1^{AB}
MBR + ZT DSR – ZTM	1021	435^{BC}	2.4^{AB}
MBR + ZT DSR – RR + ZTM	1092	518^{A}	2.1^{B}
TPR – ZTM	1223	523^{A}	2.4^{AB}
TPR – CTM	1377	554^{A}	2.5^{A}
LSD at 5%	136	81	0.4

2.5 Relationship of Biomass with TIPAR

There was a good correlation (R^2 = 0.65) between TIPAR and above-ground biomass yield (Figure 6) It indicates that TIPAR can account for 65% variability in above ground biomass accumulation in rice. Similarly in mustard, the TIPAR showed positive correlation (R^2=0.88) with above-ground biomass and thus accounting for 88% variability in biomass accumulation in mustard crop(Figure 7).

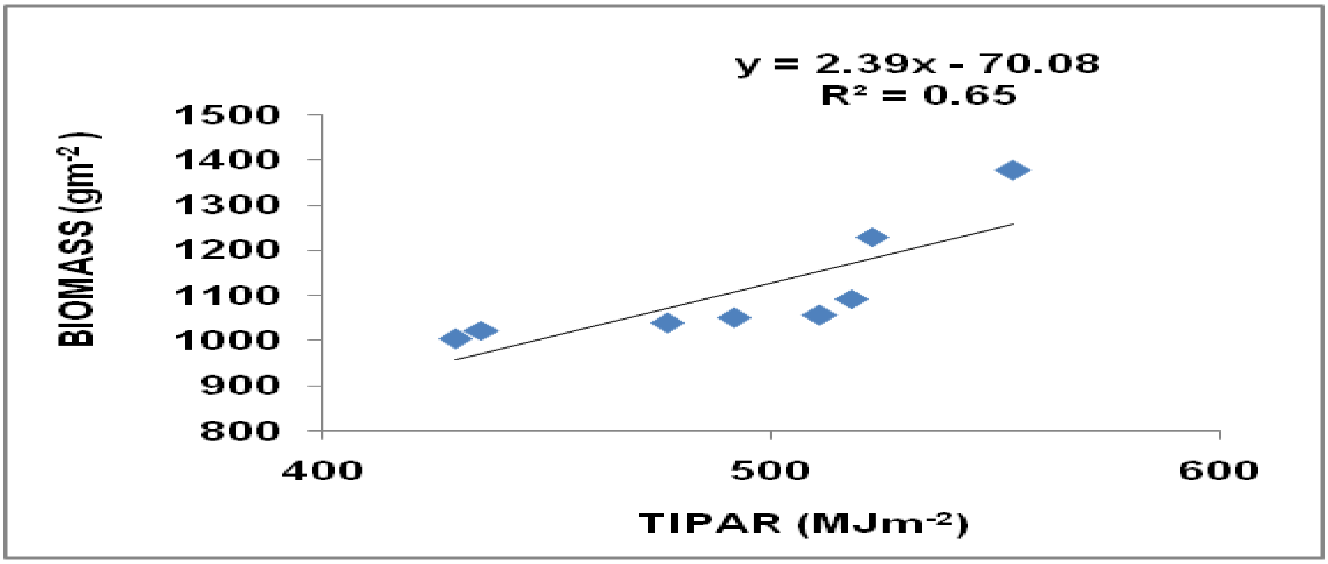


Fig.2: Relationship between TIPAR and biomass of different treatments in rice

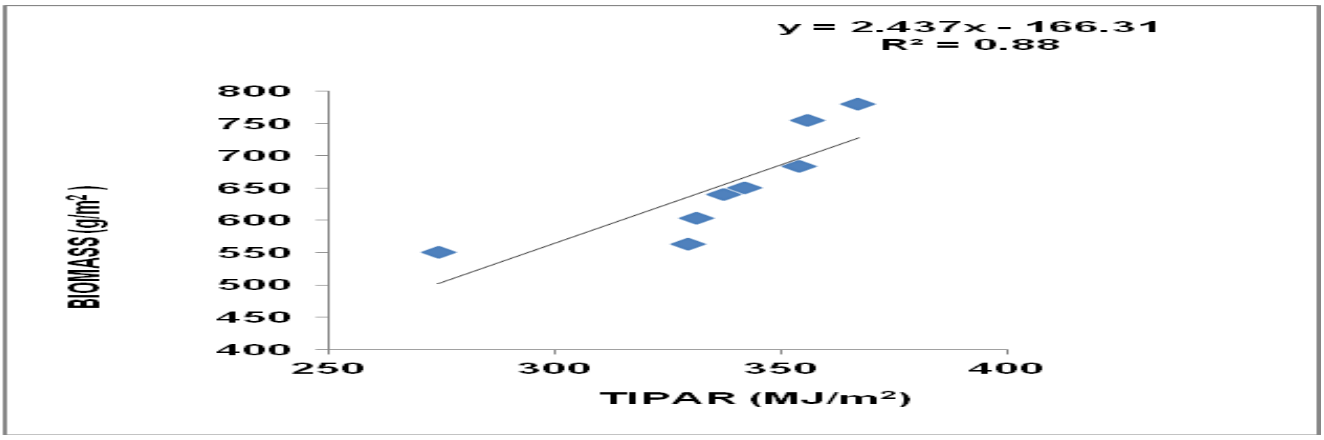


Fig. 3: Relationship between TIPAR and biomass of different treatments in mustard under conservation and conventional agriculture during *rabi* season

2.1.1.7 Genotype based Agronomic evaluation of sugarcane varieties under CA and CP practices (IIFSR)

Nine varieties of sugarcane viz. Co 0238, CoS 03234, UP 05125, CoS 03251, Co 0118, CoLK 011201, CoLK 013201, CoPK 05191, Co 098014were evaluated under CA practices. Yield and yield attributes of cane varieties (table 1 & 2) are here as under:

Agronomic evaluation of elite lines is extremely important for expression of the traits suitable for practices of conservation agriculture. An experiment on evaluation of sugarcane varieties has been initiated on summer planting of sugarcane in which planting of sugarcane is done after the harvest of wheat crop. Varieties respond differently and higher number of millable canes (145220 per hectare) in variety CoPk 05191, cane height (304.11 cm) in variety CoS. single cane weight (2.28 kg/cane) in varieties Co 0238, were recorded under conventional practice. Likewise yield attributing characters of sugarcane varieties also varied under conservational practice.

Table 01: Yield and yield attributes of sugarcane varieties under CP condition

Varieties	Height (cm)	girth (cm)	Single Cane Wt. (kg)	NMC ('000'/ha)	Leaf Area index	SPAD	Brix (%)	Yield (t/ha)	Green Top (t/ha)
CoSe 03234	281.78	9.7	1.78	101.85	10.04	44.19	22.53	125.01	24.46
CoLk 013201	253.11	8.9	1.28	110.50	10.97	47.31	20.07	83.19	17.54
Co 098014	304.11	8.0	1.53	120.99	8.38	45.10	21.87	138.13	16.83
CoPk 05191	247.11	7.5	1.48	145.22	10.02	50.10	20.87	141.99	27.61
UP 05125	229.33	7.6	1.25	79.64	7.23	39.26	22.17	74.08	11.23
Co 0238	264.44	8.2	2.28	90.59	10.22	46.73	21.65	128.09	19.10
CoLk 011201	210.11	7.4	0.96	84.42	8.21	39.80	20.70	54.02	14.48
Co 0118	245.55	8.0	1.48	79.17	9.10	45.02	22.33	96.46	21.73
CoS 03251	233.33	8.3	1.18	104.79	8.05	45.97	19.93	86.43	23.44

Table 2: Yield and yield attributes of sugarcane varieties under CA condition

Varieties	Height (cm)	girth (cm)	Single Cane Wt. (kg)	NMC ('000'/ha)	Leaf Area index	SPAD	Brix (%)	Yield (t/ha)	Green Top (t/ha)
CoS-03234	221.11	7.12	2.47	116	7.4	28.78	20.20	86.08	18.46
CoLk-013201	250.89	7.47	3.71	126	7.5	31.73	20.73	104.39	23.82
CoS-098014	242.44	7.47	2.85	114	9.1	27.82	21.33	94.14	18.02
CoPk-05191	170.83	5.87	2.28	103	5.7	24.44	15.70	85.07	22.92
UP-05125	223.33	7.84	3.03	114	12.0	31.26	19.53	80.77	38.73
Co-238	249.33	8.17	3.34	153	10.9	32.29	20.40	100.99	19.16
CoLk-011201	250.56	7.63	3.16	118	9.4	32.04	19.33	85.23	31.17
Co-0118	252.67	8.04	3.68	116	7.4	37.58	19.73	84.41	23.92
CoS-03251	254.44	7.80	3.33	148	7.3	34.32	18.47	122.69	35.79

Table 3: Yield of sugarcane varieties under CP and CA conditions (average of two years)

Varieties	CA			CP		
	Cane yield (t/ha)			**Cane yield (t/ha)**		
	Plant crop	Ratoon	Average	Plant crop	Ratoon	Average
CoS-03234	56.5	86.1	71.3	115.1	125.0	120.1
CoLk-013201	75.2	104.4	89.8	126.2	83.2	104.7
CoS-098014	58.2	94.1	76.2	129.6	138.1	133.9
CoPk-05191	100.2	85.1	92.6	146.8	142.0	144.4
UP-05125	65.4	80.8	73.1	79.0	74.1	76.6
Co-238	94.3	101.0	97.6	104.9	128.1	116.5
CoLk-011201	60.2	85.2	72.7	88.0	54.0	71.0
Co-0118	75.6	84.4	80.0	108.0	96.5	102.3
CoS-03251	68.2	122.7	95.4	71.0	86.4	78.7
Mean	**72.6**	**93.8**	**83.2**	**107.6**	**103.0**	**105.3**

As indicated in the table 11, variety CoPk 05191 recorded maximum average yield of 144.4 t/ha followed by CoS 098014 (133.9 t/ha) under conventional practice. However Co 0238 and CoS 03251 recorded the respective higher yields of 97.6 and 95.4 t/ha under conservational practices.

Varieties in Rice Fallow (RCER)

1. Evaluation of lentil and linseed verities in rice fallows:

Eleven linseed varieties were evaluated during the *rabi* season of 2017-18 after harvesting of rice in rice fallows plot under the zero tillage system. Results revealed that significantly higher lentil yield was recorded with cv. Pusa Masoor 5 (1560 kg/ha) followed by Vaibhav (1517 kg/ha) and DPL 15 (1507 kg/ha). In similar set of the experiment, 11 linseed varieties were evaluated to find out the suitable cultivars of linseed (Table1). Results revealed that significantly maximum linseed seed yield was recorded with cv. Uma (1209 kg/ha).

Table 1. Performance of lentil and linseed cultivars under rice fallows system

Lentil variety	Seed yield (kg/ha)	Linseed variety	Seed yield (kg/ha)
HUL 57	1350	RLC 133	1064
DPL 62	1257	RLC 138	1138
Arun	1478	RLC 143	1175
DPL 15	1507	Uma	1209
Vaibhav	1517	Indu	1013
IPL 01	1417	BAU 06-03	1096
Ranjan	1233	BAU 2012-1	976
IPL 406	1324	BAUP 101	1128
K-75	1378	SLS 79	1085
IPL 316	1266	JLS 95	1066
Pusa Masoor 5	1560	Shekhar	1040
LSD (P=0.05)	119	LSD (P=0.05)	93

Fig.1. Field view of lentil and linseed genotypes under zero tillage system in rice fallows

Effect of trash, fertilizer-nitrogen and SORF techniques on growth, yield attributes and cane yield of sugarcane: (NIASM)

To address the issues of trash burning (~10-20 t ha^{-1}), poor sprouting of stubbles, lower nutrient-use efficiency and cane productivity, a field experiment was conducted with ratoon sugarcane (var. CoM 0265) at ICAR-NIASM, Baramati. There were eight treatment combinations of 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 farmer's practice: NBC and placement with multipurpose SORF machine: NP), three methods of trash management (clean cultivation/ no-trash: NT; burnt trash: BT and spreading the trash uniformly in the field after chopping with a trash cutter: CT) and two absolute controls (un-chopped trash without fert-N (UCT+No-N) and no-trash-no fert-N (NT+No-N)). The 50 and 75 % of recommended dose of fert-N was applied as basal under broadcast and placement of fert-N treatments, respectively. A multi-purpose SORF machine has been developed and used for stubble shaving, off-barring, root pruning and placement of basal dose of fertilizers as per the treatments (Fig. 1).

Un-chopped trash | Chopped trash | Burnt trash | Clean cultivation

Band placement of fert-N (NP) | Root pruning (RP) + NP | Off-barring (OB) + NP | Stubble shaving + OB+RP+NP

Fig. 1. Application of treatments in experimental field of sugarcane ratoon.

The results revealed that surface retention of chopped trash and adoption of SORF techniques improved the growth and yield parameters of sugarcane significantly ($P \leq 0.05$) over conventional farmers' practices of trash burning and broadcast application of fertilizers. Plant height recorded at maturity was the maximum with CT+SORF treatment which was 49-60, 22-31 and 5-10 % higher as compared to N un-fertilized, N broadcast and N placement treatments, respectively (Fig. 2). Surface retention of chopped trash and following either individual or in combination of ratoon management practices *i.e.* off-barring, root pruning and band placement of fert-N improved the plant height significantly over trash burnt/removed and broadcasting of fert-N treatments by 11-24 %.

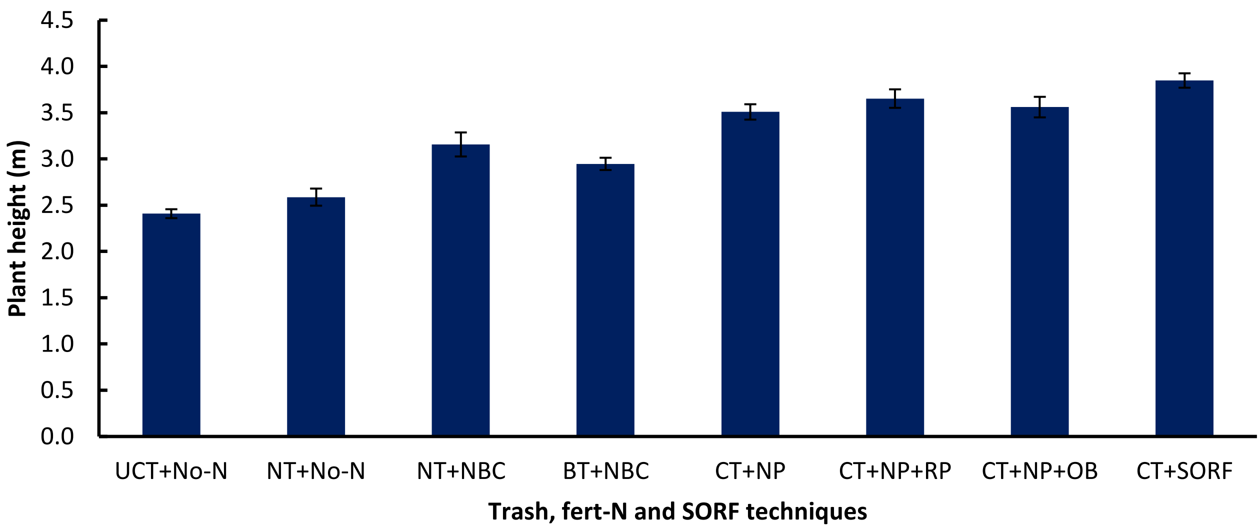


Fig. 2. Effect trash, fert.-N and SORF techniques on plant height of sugarcane.

Similarly, the maximum numbers of tillers at maturity was also recorded with CT+SORF treatment which was closely followed by CT+NP+RP treatment and both were significantly higher by 21-58 % over the conventional trash burnt and broadcasting of fert-N and N un-fertilized treatments (Fig. 3). However, surface retention of chopped trash and band placement of fert-N alone did not improve the tillers number significantly over the conventional trash burnt and broadcasting of fert-N treatments, indicated that stubble shaving and root pruning are the important practices for sustaining higher numbers of tillers of ratoon sugarcane.

The yield attributes of sugarcane were influenced significantly due to different trash, fert.-N and ratoon management practices. The maximum values of millable cane, cane length, cane weight and juice yield were recorded with CT+SORF treatment which was significantly ($P \leq 0.05$) higher than the other treatments except in case of millable cane where it was at par with CT+NP+RP treatment (Table 1). Surface retention of chopped trash and placement of fert-N in soil (CT+NP) improved the millable cane numbers, cane length, cane weight and juice yields by 12-51, 13-36, 18-43 and 15-40 % over the conventional trash burnt and broadcasting of fert-N and N un-fertilized treatments. While pruning of older roots (CT+NP+RP) further improved these parameters over CT+NP by 6, 3, 9 and 14 %, respectively. However, these parameters did not improve significantly due to off-barring (CT+NP+OB) over the placement of fert-N (CT+NP). But, cane length, cane weight and juice yields further improved significantly due to stubble shaving (CT+SORF) by 10, 14 and 9 %, respectively over CT+NP+RP treatment, indicated the benefits of using SORF techniques together rather than their individual use.

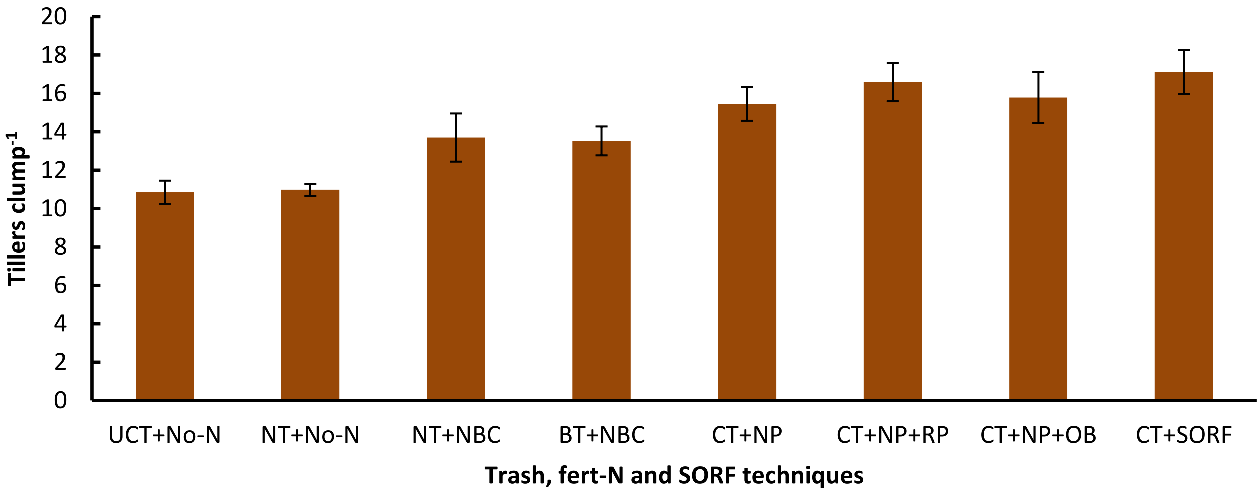


Fig. 3. Effect trash, fert.-N and SORF techniques on number of tillers of sugarcane.

Table 1. Effect of trash, fert.-N and SORF techniques on yield attributes of sugarcane.

Treatment	Millable cane (1000 ha^{-1})	Cane length (m)	Cane weight (kg)	Juice yield (ml $cane^{-1}$)
UCT+No-N	83.9	1.56	1.15	377.5
NT+No-N	89.2	1.65	1.17	396.3
NT+NBC	113.1	1.88	1.40	457.5
BT+NBC	111.5	1.86	1.38	453.8
CT+NP	126.3	2.13	1.65	527.5
CT+NP+RP	134.3	2.19	1.80	602.5
CT+NP+OB	128.4	2.15	1.73	570.0
CT+SORF	142.2	2.42	2.05	658.8
LSD ($P \leq 0.05$)	12.7	0.21	0.17	53.3

Surface retention of chopped trash and placement of fert-N in soil (CT+NP) improved the cane yield significantly by 14-18 and 57-67 % over conventional trash burnt/removed with N fertilized through broadcasting (NT/BT+NBC) and N un-fertilized with un-chopped trash (UCT+No-N) or without trash (NT+No-N) treatments, respectively. While pruning of older roots along with CT+NP (CT+NP+RP) improved the cane yield significantly by 26% over conventional trash burnt and broadcast application of fert-N. There was no significant improvement in the cane yield due to individual practices of root pruning and off-barring over the CT+NP. But, employing of stubble shaving, off-barring and root pruning practices together improved the cane yield significantly ($P \leq 0.05$) by 17, 9 and 14 % over individual practices of band placement of ferti-N, root pruning and off-barring, respectively. It indicate that shaving of stubbles, pruning of old roots of sugarcane and band placement of fert-N along with surface retention of chopped trash helps in maintaining of better plant health as reflected in the other growth and yield parameters and thus have contributed in the cane yield production. Thus, surface retention of chopped trash and adoption of SORF techniques with application of 75% recommended dose of fert-N as basal improved the cane yield by 38 % over conventional trash burnt and broadcast application of fert-N (Fig. 4).

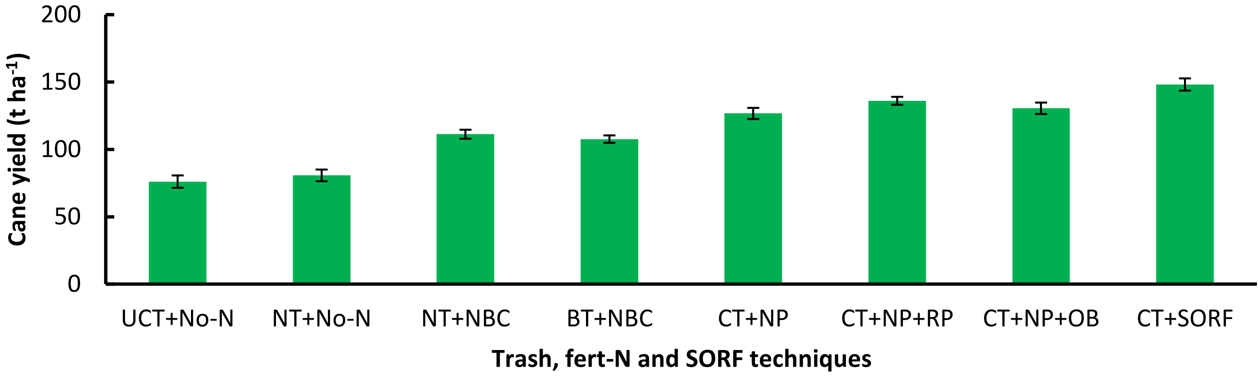


Fig. 4. Effect trash, fert.-N and SORF techniques on cane yield of sugarcane.

Screening of wheat varieties under CT and CA systems (IIWBR)

Another experiment was conducted on evaluation of varieties suitable for CA system. Here two tillage crop establishment methods {CT (Conventional tillage), CA (Conservation tillage)} in main plot and eight latest popular varieties of the area (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 2016-17. The experiment was conducted in split plot design with a subplot size of 20 m^2. 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 considering the 1000 grain weight as 38 g. 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 kg N, 60 kg P_2O_5 and 40 kg K_2O/ 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.Based on the results of 2016-17, 12 better yielding cultivars (Table 1) were again evaluated under CA and CT system under early sown conditions (Last week of October) during *Rabi* 2017-18. The sowing was done using Turbo Happy seeder using a seed rate of 125 kg/ha considering 1000 grains weight as 38 g. The perusal of data in Table-2 revealed that the tillage and residue management as well as their interaction with varieties were not significant. However, the varietal differences were found significantfor yield and 1000 grains weight. The mean wheat yield of CT and CA system was 63.6 and 63.3 q/ha, respectively. However, the genotypic differences were significant. The five better yielding genotypes were HI 8498, HD 2733, HDCSW 18, HD 2967 and GW 322 with a mean yield of 69.1, 68.9, 67.6, 67.3 and 65.0 q/ha, respectively. Statistically, HD 2967, HDCSW 18 and HD 2733 yielded at par with top yielder HI 8498. The top yielder HI 8498 had the boldest grains with mean 1000 grain weight of 63.9 g and was followed by MPO 1215 (58.9 g) and GW 366 (56.6 g). In comparison to previous year study all the varieties had heavier 1000 grain weight during 2017-18. The early sowing (26th Oct. 2017) as well as favourable weather in the season were responsible for bolder grains. The cultivars recommended for central zone (HI 8498, GW 322) and eastern zone (HD 2733) also performed well in north western conditions. However, based on the multiplications evaluation, HD 2967 performed well under the both CT and CA systems and seems a stable genotype. Jat*et al.*, 2017 also reported genotype HD 2967 as the best performer and highly stable across locations of three states under ZT. Presently this genotype is occupying maximum wheat area in India and it can be effectively grown under CA conditions of the northern plains.The results of the multi-locations evaluation suggest that the wheat cultivars developed and recommended for CT conditions can also be extended to CA in a rice-wheat rotation.

Table 1 Performance of wheat varieties under early sown (26th Oct. 2017) CT and CA conditions at village Rambha during 2017-18

Wheat Varieties	Yield, q/ha			1000 Grain weight, g		
	CT	CA	Mean	CT	CA	Mean
HI 8498	68.3	69.8	69.1	64.26	63.50	63.9
PBW 723	63.4	64.3	63.9	51.12	50.97	51.0
UAS 428	59.1	57.2	58.2	54.07	56.43	55.3
MPO 1215	55.9	58.0	57.0	59.29	58.43	58.9
UAS 415	61.0	59.3	60.2	53.44	52.14	52.8
HDCSW 18	68.9	66.3	67.6	48.09	48.18	48.1
GW 366	57.7	58.1	57.9	56.93	56.23	56.6
HD 2733	69.9	68.0	68.9	47.56	47.77	47.7
MACS 6222	63.0	64.1	63.5	46.67	46.77	46.7
GW 322	64.4	65.6	65.0	45.43	44.11	44.8
WH 542	63.2	62.1	62.6	31.80	34.57	33.2
HD2967	68.1	66.5	67.3	44.64	46.10	45.4
	63.6	63.3		50.3	50.4	
	Tillage= NS Variety = 2.99 Two Tillage at same/different level of variety = NS Two varieties at same/different level of Tillage = NS			Tillage= NS Variety = 1.98 Two Tillage at same/different level of variety = NS Two varieties at same/different level of Tillage = NS		

Performance of new flails of Turbo Happy Seeder for seeding in paddy residue:

With new design of serrated flails provided by BISA-CIMMYT (**Dr ML Jat and HS Sidhu**) the performance of the Turbo Happy Seeder has improved and wheat was successfully seeded at 20 cm instead of 22.5

Old version of Flails

New serrated Flails

2.1.1.8 Based on Machinary (CIAE)

Adaptation and performance assessment of agricultural machinery for permanent bed cultivation of soybean - wheat, and maize -gram cropping systems.

Objectives

i) Adaptation of tractor operated machineries for permanent bed cultivation of soybean-wheat and maize-pigeon pea cropping systems.
ii) Performance assessment of adopted machineries/technologies for resource saving along with energy and carbon foot print.

Progress

Tractor operated package of equipment were identified for soybean-wheat cropping systems for permanent bed forming cum seeding/planting, intercultural operation, chemical application, harvesting and bed shaping. The equipment were modified/developed 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 detail specifications of modified package of equipment are given below.

Operation/ equipment		**Specifications**
Bed forming cum seeding/planting (Bed seeder/planter)		Bed size : top width 1200 mm, bottom width 1500 mm, bed height 120 mm, Row spacing adjustment from 100 – 500 mm , Field capacity 0.3- 04 ha/h.
Intercultural operation (Sweep cultivator)		Sweep size 5 ×150 mm, for soybean and 4 × 150 mm for maize crop, Field capacity 0.15 ha/h.
Chemical application (Hydraulic sprayer)		Tank capacity: 150 l, nos. of nozzles:14, type of the nozzle: hallow cone, adjustable distance between nozzle: 300 –600, Swath: 40 -60 m, field capacity 0.5 –0.66 ha/h.
Harvesting (Front-mounted VCR)		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 shaper cum seeder)		Bed shaper for bed size: top width 1200 mm, bottom width 1500 mm, bed height 110 mm and no till drill for seeding and planting of soybean-wheat and maize-gram on beds.

The package of machines was evaluated for cultivation of soybean and wheat on permanent bed and performance parameters were compared with conventional method i.e. flat bed cultivation. On permanent bed cultivation developed machinery has saved 22 and 18% seeds, 19 and 8 % nitrogen, 9 and 8 % phosphorous and 5% potassium for soybean and wheat crops as compared to flatbed cultivation system. Similarly it saved 75 and 13% for seeds, 6.3 and 21.8% for nitrogen, 5.9 and 6.5 % for phosphorous and 9.0 % for potassium as for maize and gram crops compared to conventional flatbed cultivation system. The saving of irrigation water was 36% in permanent bed as compare to conventional system.

Energy and carbon footprint

The operational energy for soybean-wheat and maize-gram cropping systems were 11498 & 8614 MJ/ha in bed and 12295 & 8972 MJ/ha in flat bed cultivation systems, respectively. The saving in operational energy for soybean-wheat and maize-gram cropping systems were 7% and 4% in bed as compared to flatbed cultivation systems. The specific energy, MJ/ha for production of soybean, wheat, maize and gram crops in permanent bed cultivation were, 4.88, 2.91, 4.16, 2.26 as compared to 6.82, 3.35, 5.79, 3.38 MJ/ha, in conventional cultivation practices. It revealed that energy productivity i.e. energy required to produce unit kg of grain is higher in conventional cultivation as compared to bed cultivation for both the crops.

Table 1: Operational energy and energy productivity

Parameters	Permanent bed				Conventional (Flatbed)			
	Soybean	Wheat	Maize	Gram	Soybean	Wheat	Maize	Gram
Energy equivalent for tillage and sowing, MJ/ha								
Human energy Seed energy Tractor + seed drill +fuel Nitrogen Phosphorus Potassium	9.80 1029 1661 1476 683 -	9.80 1327 1661 6600 682 206	9.80 144 1661 6402 658 198	9.80 1008 1661 1327 627 -	43.51 1323 2671 1614 762 -	43.51 1617 2671 7200 737 223	43.50 294 2671 6804 693 211	43.51 1160 2671 1698 796 -
Irrigation energy, MJ/ha (3 irrigation)								
Human labour Fuel + motor		118 3775				118 3775		
Weeding and chemical , energy , MJ/ha								
Human labour Chemical	29.4 900		29.4 900	29.4 900	29 540		29.4 540	29.4 540
Harvesting and threshing energy, MJ/ha								
Human labour Tractor+ thresher +fuel	116 1086	116 1086	116 1086	116 1086	116 1086	116 1086	116 1086	116 1086
Total Energy, MJ/ha	6990.2	15841	11204	6764	8185	17587	12488	8140
Saving in energy,%	15	10	10	17	-	-	-	-
Yield, q/ha (in field)	14.3	54.48	26.91	29.98	12.0	52.49	21.54	24.04

Specific energy, MJ/kg	4.88	2.91	4.16	2.26	6.82	3.34	5.79	3.38
Energy productivity, kg/MJ	0.21	0.34	0.24	0.44	0.15	0.30	0.17	0.30

On the basis of high speed diesel consumption and inputs used for production of soybean- wheat and maize-gram cropping systems carbon foot print were assessed (Table 2 and 3). Tables revealed that carbon emission reduced 11 and 12% under permanent bed for soybean- wheat and maize-gram cropping systems as compared to flat bed

Table 2 Agricultural inputs and carbon emission for soybean-wheat cropping system

Particulars	Conventional cultivation		Permanent bed cultivation	
Inputs	Input	Carbon emission (eq. C kg/ha)	Input	Carbon emission (eq. C kg/ha)
Diesel (l/ha)	93.5	66.39	79.2	56.23
Herbicide (kg/ha)	3.2	19.6	3.2	19.6
Insecticide (kg/ha)	2.0	12.8	2.0	12.8
DAP (kg)	357	85.68	326	78.24
Urea (kg)	36	6.84	33.0	6.27
Irrigation (3 Nos)	3	15.6	3	10.58
Threshing (electric power), MJ/ha	485	8.3	528	9.05
Total C emission		215.2		192.7

Table 3 Agricultural inputs and carbon emissions for maize and gram cropping system.

Particulars	Conventional		Permanent bed	
Inputs	Input	Carbon emission (eq C kg/ha)	Input	Carbon emission (eq. C kg/ha)
Diesel (l/ha)	64.6	45.8	51.5	36.5
Insecticide (kg/ha)	2.0	12.8	2.0	12.8
DAP (kg)	354	84.96	308	73.92
Urea (kg)	120	22.8	108	20.58
Threshing (electricity, MJ)	342	5.86	427	7.31
Total C emission		172.22		151.11

Note: One litter of diesel=2.6 = 0.71kg of C Source: Gupta, 2007; 1GJ electricity emit = 17.14 kg C. CO_2; DAP 236.23 g C/kg and 57.62 g C/kg) during transport. C emission from Urea = 0.19 C/kg; C emission from herbicide 6.11kg/kg (production + transport); C emission from insecticide 6.41kg/kg (production + transport).

Conclusion

Package of equipment for bed forming cum seeding/planting, intercultural operation, chemical application, harvesting and bed shaping were modified to match the track width (1500 mm) of a 35 hp tractor and adopted for different field operations on permanent bed size of 1200 mm top width, 1500 mm bottom width and 120 mm bed height.

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. Similarly savings for maize and gram crops on beds were 75 and 13% for seeds, 6.3 and 21.8% for nitrogen, 5.9 and 6.5 % for phosphorous and 9.0 % for potassium as compared to conventional flatbed cultivation system. The energy productivity for soybean, wheat, maize and gram crops were 0.21, 0.34, 0.24 and 0.44 kg/MJ under bed cultivation as compared to 0.15, 0.30,0.24 and 0.30, M/kg under conventional system of cultivation. Reduction in carbon under permanent bed for soybean- wheat and maize-gram cropping systems were 11 and 12% as compared to convention cultivation system.

Outcome

A package of Developed rotary bed former cum seeder/planter has been commercial. M/s Tractors and Farm Equipment Ltd. (TAFE), Chennai signed a license agreement (License fee Rs 1,50,000/-) with ICAR-Central Institute of Agricultural Engineering (CIAE) Bhopal for manufacturing and marketing of rotary assisted bed maker-cum-seeder.

Activity-2

Adaptation/development of zero till intra row planter with herbicide applicator

Objective:

1. Adaptation of pre-emergence herbicide applicator as an attachment to zero till planter.
2. Performance assessment of adopted machineries/technologies for resource saving along with energy and carbon foot print.
3.

Progress

Tractor operated zero till intra row planter with pre-emergence herbicide applicator with band spraying attachment has been modified/developed for no tillage planting and application of herbicide in the field. Inverted "T" type furrow openers were mounted on the frame of machine for planting of seeds under no tillage condition. Independent seed boxes (6 Nos) having incline plate having grooves has been used to precise metering seed rate (Fig.1). The developed machine is suitable for herbicide application and simultaneously planting of wide spaced crops like maize, soybean, pigeon pea and also intra row sowing of seeds.. The specifications of developed machine are given in Table 1

Table 1 Specifications of zero till planter cum herbicide applicator

1.	Power requirement	35 hp tractor
2.	Types of furrow openers and nos. of rows	Inverted "T " type; 6 Nos.
3.	Row adjustment	250 – 750 mm
4.	Seed metering	Inclined plate having grooves on its periphery
5.	Spray pump type	Single action piston pump
6.	Nozzle type and Nos.	Flat fan nozzle, (60550) - 6
7.	Spray tank capacity	120 l
8.	Field capacity of m/c	0.4 ha/h
9.	Cost of operation	Rs 1350/ha
10	Suitable crops	Maize, soybean, pigeon pea, sorghum, cotton, groundnut

Zero till planter with herbicide applicator was evaluated on soybean and pigeon pea crops with mechanical system of weed control (control). Performance results of machines on control of weeds in soybean and pigeon pea crop are shown in Table 2. Machine covered 0.2 m strip width per nozzle (0.1 m on either side of row) at the rate of 1 kg/ha active ingredient. Inter-row and intra-row weed intensities has been observed at 21 days after sowing under blanket and control treatments. The weed intensity has reduced 80% and 78% in soybean and pigeon pea crops as compared to mechanical system of weed control.Table 2 Performance of zero till planter cum herbicide applicator

Crop	Application treatment	Weed intensity, weeds/m^2		
		Inter-row	Intra-row	Total
Soybean (Variety JS 9560, row spacing - 0.45 m)	Blanket Control	35 171	31 175	67 346
Pigeon pea (variety UPAS 120, row spacing - 0.90 m	Blanket Control	40 152	28 169	68 321

*Herbicide (ORAM-32, 30% Pendamethylene AI

Field capacity of machine was 0.4 ha/h and cost of operation Rs 1350/ha. The energy saving and reduced carbon foot print/ ha were 30% and 40% due to reduction of fuel consumption and reduction in quantity of herbicide sprayed (40-50%). The machine has resulted saving of soybean and pigeon pea seeds 40% and 60% as compared to convention herbicide application and sowing of crop using seed cum fertilizer drill. It was due to placement of seeds at required spacing and depth by the developed zero till planter cum herbicide applicator,

Activity 3

Characterization and improvement of wear of soil working components of conservation machinery

Objectives

1. To study the wear characteristic of straw-soil cutting components of selected CA Machinery.
2. To evaluate wear resistance of developed components of CA machinery in field.

Progress

The fast wearing components of agricultural machinery requires frequent replacement, which affects the work output as well as the quality of the equipment. Keeping it in mind the need of preparation of data base of material properties of critical soil engaging components of conservation agricultural machinery such as furrow opener, rotary disc of zero till drills, cutter blades used in stubble saver and residue mulcher and blade of rotovator, residue mulcher saver were selected to study. The treatment of critical components would be done by replacing with requisite materials to enhance their working. Data base on hardness, chemical composition and wear rate has been prepared on rotovator, zero till drill, blade of straw saver, blades of shredder and rotary disc. Study is in progress for data base of other components and treatment of critical components.

2.1.1.9 Establishment Method (RCER)

1. Evaluation of establishment methods for improving the productivity of rice fallows:

A long-term experiment has been initiated at the ICAR, Patna from rainy season of 2016 on silty clay loam soil. Experiment was laid out in a split-plot design and comprising of three crop establishment method *viz*. zero-till direct-seeded rice (ZT-DSR), unpuddle transplanting (UPTR) and conventional transplanting (PTR) as main-plot and five winter crops viz., chickpea (Pusa 256), lentil (HUL 57), mustard (Proagro 5111), linseed (T 397) and safflower (PBNS 12) with two reside managemepractices i.e. retaining 30% rice residue and without residues as sub-plots and replicated thrice in a split plot design. Results revealed that among crop establishment PTR recorded significantly higher grain yield (5.18 t/ha) as compared to ZTDSR (3.58 t/ha) and UPTR (2.53 t/ha). In residues management practices, paddy yield did not vary significantly. Among the preceding crops, comparatively higher.

Fig. 1. Experimental view during *Kharif* 2017 under different management practices

During the winter season, productivity of succeeding chickpea (2270 kg/ha) was lower after ZTDSR as compared to after UPTR (2458 kg/ha) and PTR (2455 kg/ha). The productivity of lentil, linseed and mustard was almost similar with respect to rice establishment methods. However, maximum yield of safflower was recorded after ZT-DSR (1667 kg/ha) as compared to

PTR (751 kg/ha) and UPTR (1160 kg/ha). Comparatively higher seed yields of winter crops was recorded in 30% residues retention as compared to no residue. Among the winter crops, system annual productivity (SREY) was recorded the maximum in rice-chickpea (12206 kg/ha) followed by rice-lentil (11560 kg/ha) and linseed (9143 kg/ha) under the PTR. Similarly, comparatively higher SREY was recorded with 30% RT than control. The similar trends were followed in case of system production efficiency during the experimentation. (Table 2)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index
Crop establishment methods				
ZTDSR	3.58	6.82	10.40	0.37
Unpuddle transplanting	2.53	4.65	7.18	0.35
Puddle transplanting	5.18	7.55	12.73	0.42
SEm±	0.26	0.64	0.81	0.02
LSD (P=0.05)	0.78	1.90	2.44	0.06
Residue management practices				
No crop residue	3.75	4.84	8.59	0.44
30% crop residue	3.77	7.84	11.61	0.33
SEm±	0.21	0.52	0.66	0.02
LSD (P=0.05)	NS	1.55	1.99	0.05
Winter crops				
Chickpea	3.88	6.96	10.81	0.37
Lentil	3.55	6.05	9.59	0.36
Safflower	3.85	6.19	10.05	0.40
Linseed	3.79	5.72	9.51	0.41
Mustard	3.76	6.78	10.54	0.36
SEm±	0.12	0.42	0.48	0.01
LSD (P=0.05)	0.34	1.20	1.40	0.03

Table 2. Winter crop yields, REY and SREY as influenced by crop establishment method, residues management practices

Seed yields (kg/ha)															
Crop establishment methods	Chickpea			Lentil			Linseed			Safflower			Mustard		
	30% RT	Control	Mean	30% RT	Control	Mean	30% RT	Control	Mean	30% RT	Control	Mean	30% RT	Control	Mean
ZT-DSR	2283	2257	2270	2240	2143	2192	1433	1220	1327	1917	1417	1667	1373	1257	1315
UPTPR	2520	2397	2458	2357	2033	2195	1193	1123	1158	1273	1047	1160	1197	1157	1177
TPR	2493	2417	2455	2503	2200	2352	1320	1250	1285	787	715	751	1460	1093	1277
Mean	2673	2449		2367	2125		1316	1198		1326	1059		1304	1208	
REY of winter crops (kg/ha)															
ZT-DSR	6481	6407	6444	6142	5876	6009	4623	3935	4279	5071	3748	4409	3543	3244	3394
UPTPR	7145	6804	8398	6463	5574	6019	3848	3623	3735	3367	2769	3068	3089	2986	3037
TPR	7077	6861	6969	6863	6032	6448	4258	4032	4145	2082	1891	1987	3768	2821	3294
Mean	7588	6952		6490	5827		4245	3865		3507	2801		3365	3117	
SREY (kg/ha)															
ZT-DSR	9941	9745	9843	9522	9125	9324	8374	7713	8044	7447	6990	7219	7639	7153	7396
UPTPR	10270	9335	9802	8776	7685	8231	6270	6427	6349	5743	5713	5728	5333	5193	5263
TPR	12437	11974	12206	12194	10925	11560	8754	9532	9143	7269	7644	7457	8926	7781	8354
Mean	9941	9745	9843	9522	9125	9324	8374	7713	8044	7447	6990	7219	7639	7153	7396
System production efficiency (kg/ha/day)															
ZT-DSR	36.8	37.5	37.1	35.7	35.4	35.5	31.6	30.4	31.0	30.4	25.2	27.8	30.4	29.6	30.0
UPTPR	37.8	35.1	36.4	32.3	29.3	30.8	23.2	24.8	24.0	19.7	20.3	20.0	20.8	20.8	20.8
TPR	44.6	44.7	44.6	44.2	41.2	42.7	31.9	36.4	34.1	24.6	30.6	27.4	34.3	31.1	32.8
Mean	42.3	40.1		37.4	35.3		28.9	30.5		24.9	25.4		28.5	27.2	

Winter crops (2017-18) view under different management practices

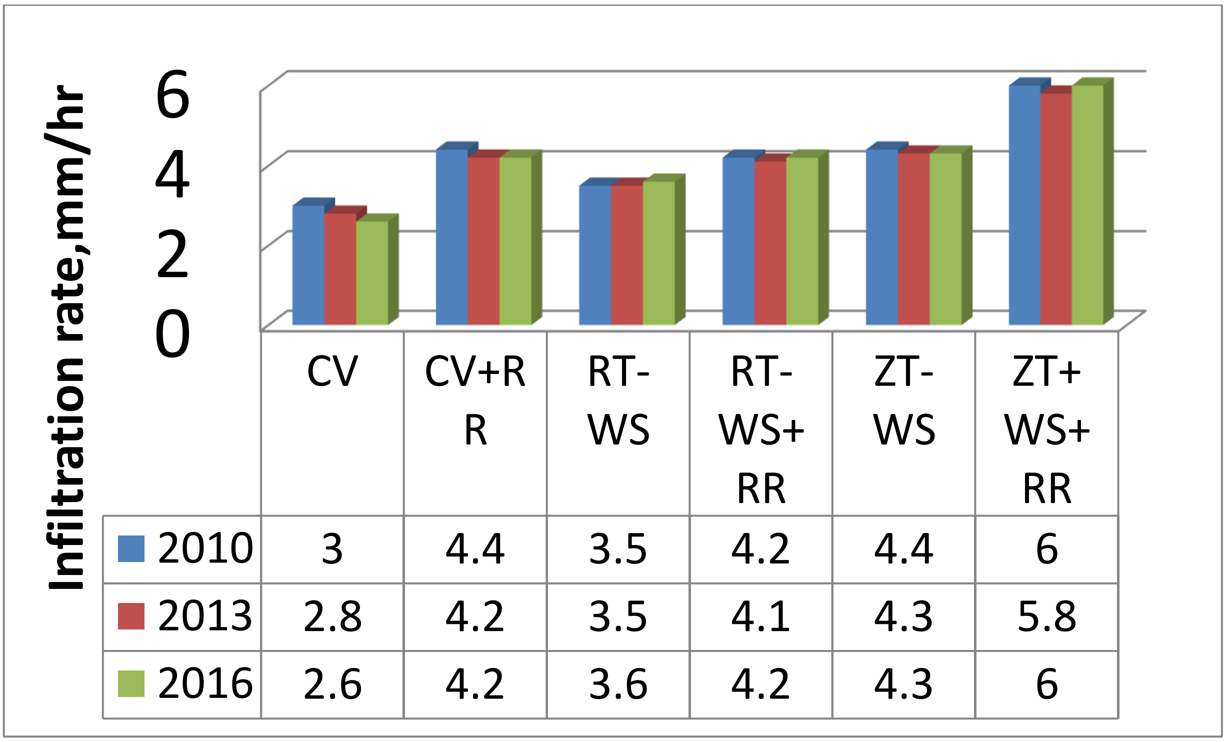
2.2 To quantify the impact of resource conservation options on the physical, chemical and biological soil health.

2.1.2.1 Soil physical properties-(CSSRI)

Infiltration rate-

1-Infiltration rate influenced by tillage and residue management. Data in figure (1) shows that infiltration rate remains lower under conventional tillage method. Maximum infiltration rate recorded in ZT wheat sowing method, where crop residue added in the plots in the form of anchors.

2-Rice crop residue incorporation before wheat crop sowing in CV+ rice residue and RT+ rice residue in both the cases, infiltration rate increased but remains lower than ZT wheat sowing with rice residue. It means that previous crop roots remains undisturbed and after decaying forms channels so through these channels, may maintained down ward water flow during observations and one think also observed that Zero tillage plots after irrigation and during heavy shower water did not accumulated. Water stagnation not recorded. These traits gives benefits to the crop growing well in good environment, resulted higher wheat productivity in comparison to conventional tillage method of wheat sowing.



	CV	CV+R R	RT-WS	RT-WS+RR	ZT-WS	ZT+WS+RR
2010	3	4.4	3.5	4.2	4.4	6
2013	2.8	4.2	3.5	4.1	4.3	5.8
2016	2.6	4.2	3.6	4.2	4.3	6

Figure (1) Effects of tillage and crop residue on basic infiltration rate after wheat harvesting.

Water stable aggregates-

1- Data given in figure (2) shows that water stable aggregates influenced by crop residue and tillage management practices.
2- Soil aggregation is the function of soil organic carbon and microbes with clay content in soil system in situ.
3- Soil aggregation recorded in higher magnitudes where crop residue added regularly in CV+ crop residue (incorporation), RT+ crop residue (incorporation) and ZT+ crop residue (anchors). Crop yield recorded higher in magnitudes where crop residue added regularly.
4- Soil aggregation may be associated with the infiltration rate means that soil aggregation promoted the infiltration and soil porosity. Water and aeration maintained properly and plant growth affected accordingly with their higher productivity.

Soil aggregation and associated carbon-

1-Results presented in figure (3) that %WSA under residue and non residue treatments behave in different ways and indicated that %WSA formation take place in 0-15 cm soil layers where crop residue added regularly and vice versa, observations were recorded in non residue treatments.

2-Soil aggregates >0.5 mm size increased in residue incorporation / anchors treatments where crop residue rice and wheat added regularly since last 9 years. It means rice and wheat residue has very good impact on soil physical condition which are responsible for providing water and aeration to the root system regularly, and in that response plants growth taking in favourable direction and ultimately yielded relatively in higher magnitudes.

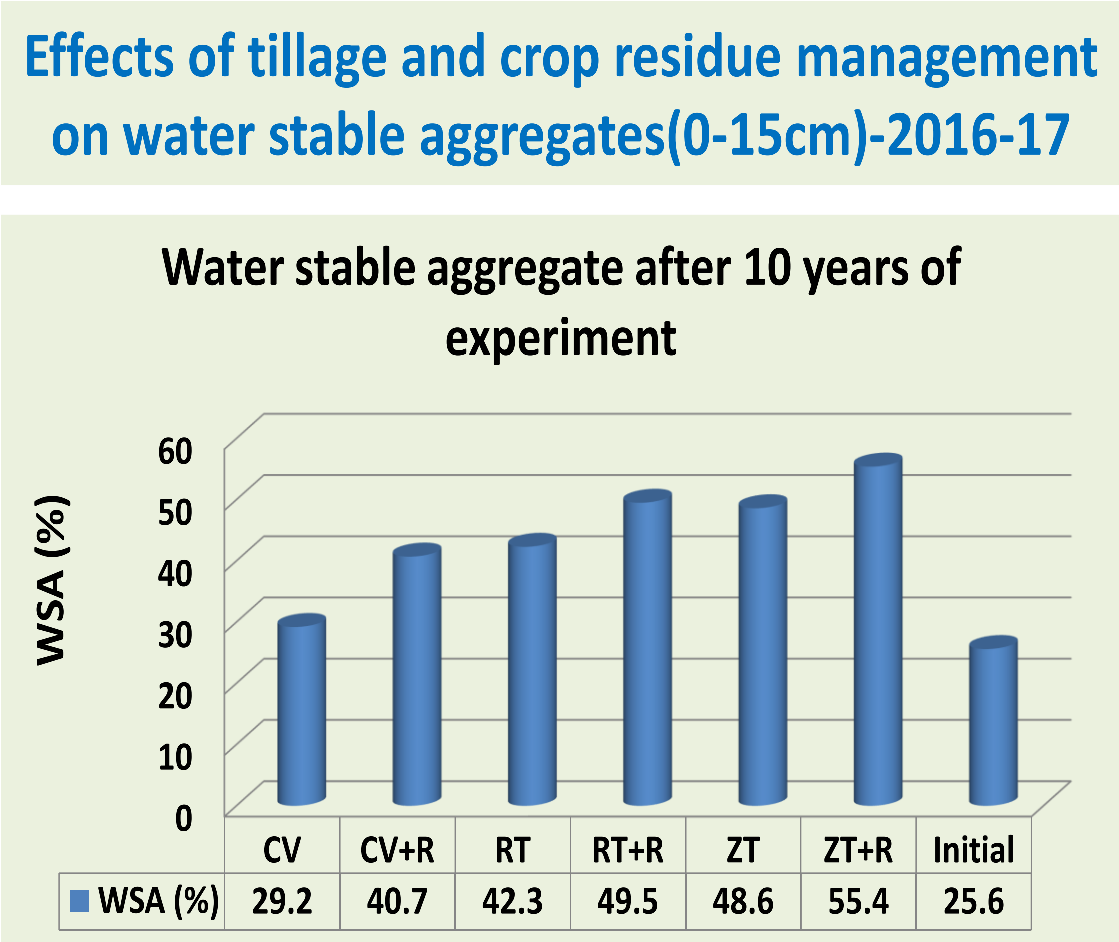


Figure 2 Effects of tillage and crop residue management on water stable aggregates (0-15cm) 2016-17

2.1.4-Water stable aggregates under different soil layers- the results are given in figure-4 revealed that:

1-WSA increased in 0-15 cm soil layer with residue management treatment and measured 17.1 % higher than non residue (NR) plots.

2-In 15-30 cm soil layer aggregates increased by 2.59%.

3- NR treatments increased the WSA% by 7.36 in 15-30 cm soil layer.

4-In residue treated plots recorded 7.15% relatively lower WSA in 15-30 cm soil layer in comparison to 0-15 cm soil layer

Figure 3 Effects of tillage and crop residue management on soil aggregates andAssocited carbon

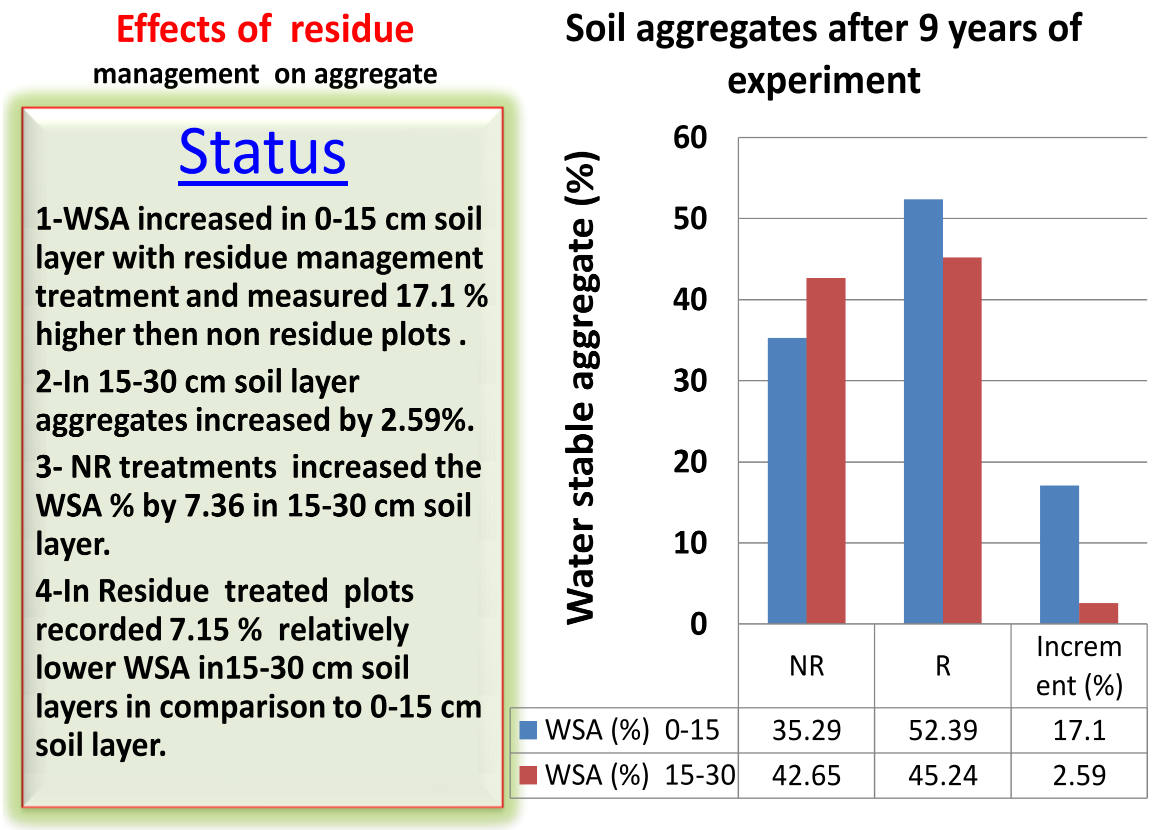


Figure 4 Effects of tillage and crop residue management on water stable soil aggregates in 0-15 and 15-30 cm soil layers

1) Physical properties of soil (CRIDA)

In sorghum-blackgram system, after five years of experimentation, organic carbon content in the soil increased significantly in different treatments with increase in the residue (more biomass) retention. Significantly higher OC (5.1 g kg^{-1}) was recorded with S2 followed by S1 (4.4 g kg^{-1}) compared to no residue retention (3.9 g kg^{-1}).The minimum tillage recorded Significantly higher OC contents (4.7 g kg^{-1}) compared to conventional tillage (4.3 g kg^{-1}). The interaction between tillage and residue retention were not significant. Residue retention treatments of previous black gram crop influenced carbon inputs to the soil. When averaged over residue retention (through sorghum stubble) treatments, it was observed that low tillage practice contributed higher amount of C inputs (1121 kg C ha^{-1}) compared to conventional tillage (1055 kg C ha^{-1}). On an average, S2 treatment contributed (1438 kg C ha^{-1}) equivalent carbon inputs followed by S1 (738 kg ha^{-1}).

Table 1 : Long term effect of conservation tillage and residue retention of previous crop on organic carbon and carbon input.

Tillage	**No residue retention (S0)**		**50% residue retention (S1)**		**S2: 100% residue retention**	
	OC (gm/kg)	C input (kg ha^{-1})	OC (gm/kg)	C input (kg ha^{-1})	OC (gm/kg)	C input (kg ha^{-1})
Minimum tillage	4.60	0	4.60	764	5.56	1479
Conventional tillage	3.90	0	4.26	712	4.80	1398
CD (0.05)						
Tillage	0.126		0.126		0.126	
Residues*	0.270		0.270		0.270	
T X R						

In Finger millet + Pigeonpea system, tillage practice *viz.*, conventional, reduced and zero tillage showed non-significant results with respect to particle density, MWHC, porosity, pH, EC and organic carbon. Conventional tillage recorded significantly lower bulk density (1.40 g cc^{-1}) as compared to reduced tillage (1.45 g cc^{-1}) and zero tillage (1.55 g cc^{-1}). Similarly, growing of cover crops also did not show significant results with pH and EC. But, growing of horse gram as cover crop showed significantly higher organic carbon (0.47 %) compared to control (0.43 %) but was on par with field bean (0.46 %). Interaction effect between different tillage and cover crop was found to be non-significant (Table 1).

Table 2: Soil physical parameters as influenced by conservation agriculture practices in finger millet+ pigeon pea intercropping (8:2)

Treatment	**Bulk Density**	**Particle Density**	**MWHC**	**Porosity**
	g/cc		**(%)**	
TILLAGE				
M1 :Conventional tillage	1.40	3.10	30.49	54.85
M2 : Reduced tillage	1.45	3.11	29.85	53.44
M3 :Zero tillage	1.55	3.23	28.77	52.08
S. Em. ±	**0.02**	**0.03**	**0.56**	**0.84**
CD (p=0.05)	**0.07**	**NS**	**NS**	**NS**
COVERCROPS				
C1: Control	1.47	3.19	29.54	53.50
C2: Field bean (HA-4)	1.46	3.16	29.21	53.69
C3: Horse gram	1.45	3.06	30.35	53.18
S. Em. ±	**0.02**	**0.03**	**0.42**	**0.74**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**

In Maize-pigeonpea system, during the entire crop growing season in 0-15 cm soil depth, the mean soil moisture content was higher in No tillage (about 5.7%) and reduced tillage (about 3.0%) as compared to the conventional tillage. Although, during initial stage of the crop growth, (30-40 DAS), slightly higher soil moisture was observed in RT and CT as compared to the NT. But as the crop stage advanced and rainfall events occurred, the trend was shifted and higher soil moisture was observed in NT and RT as compared to the CT, might be due to the formation of the crust in the CT, that restrict the water entry into the soil. The added levels of the nitrogen also decreased the soil moisture content in 0-15 cm, might be due to the good crop growth which was observed with added level of the nitrogen. The mean soil moisture content was lower by about 1.12, 2.04, and 2.83 in N75, N100, and N125 as compared to the N0 in 0-15 cm soil profile during entire crop growing period.

Similarly, the mean soil moisture content was higher in No tillage (about 8.9%) and reduced tillage (about 3.5%) as compared to the conventional tillage in 0-60 cm soil profile during entire crop growing period. The added levels of the nitrogen levels decreased the soil moisture in 0-60 cm soil depths. The mean soil moisture content was lower by about 1.01, 2.02, and 2.93 in N75, N100, and N125 as compared to the N0 in 0-60 cm soil profile during entire crop growing period.

About 6.02% and 3.07% lower bulk density was observed in No tillage and reduced tillage as compared to the conventional tillage in 0-15 soil depth. The added levels of nitrogen also reduce the soil bulk density. About 3.66% lower soil bulk density was observed in N125 treatment as compared to the NO.

Fig.1: Effect of tillage and nitrogen levels on mean soil moisture content in 0-15 cm soil depth

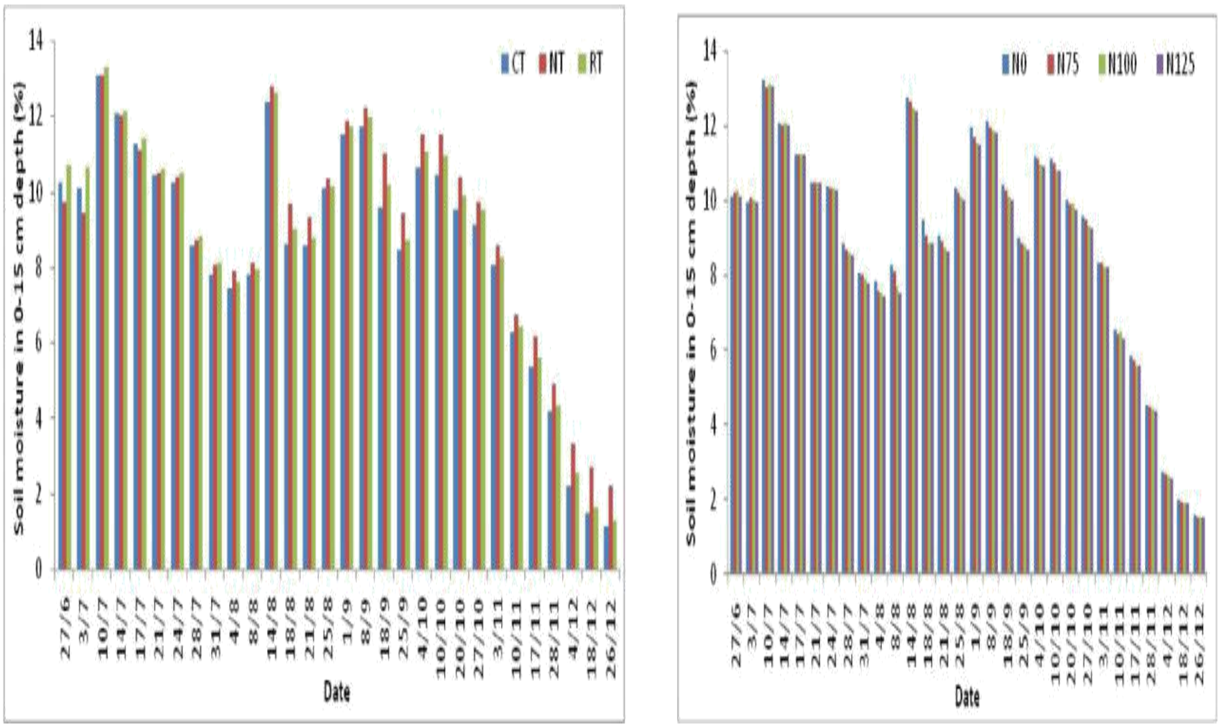


Fig. 2: Effect of tillage and nitrogen levels on mean soil moisture content in 0-60 cm soil depth

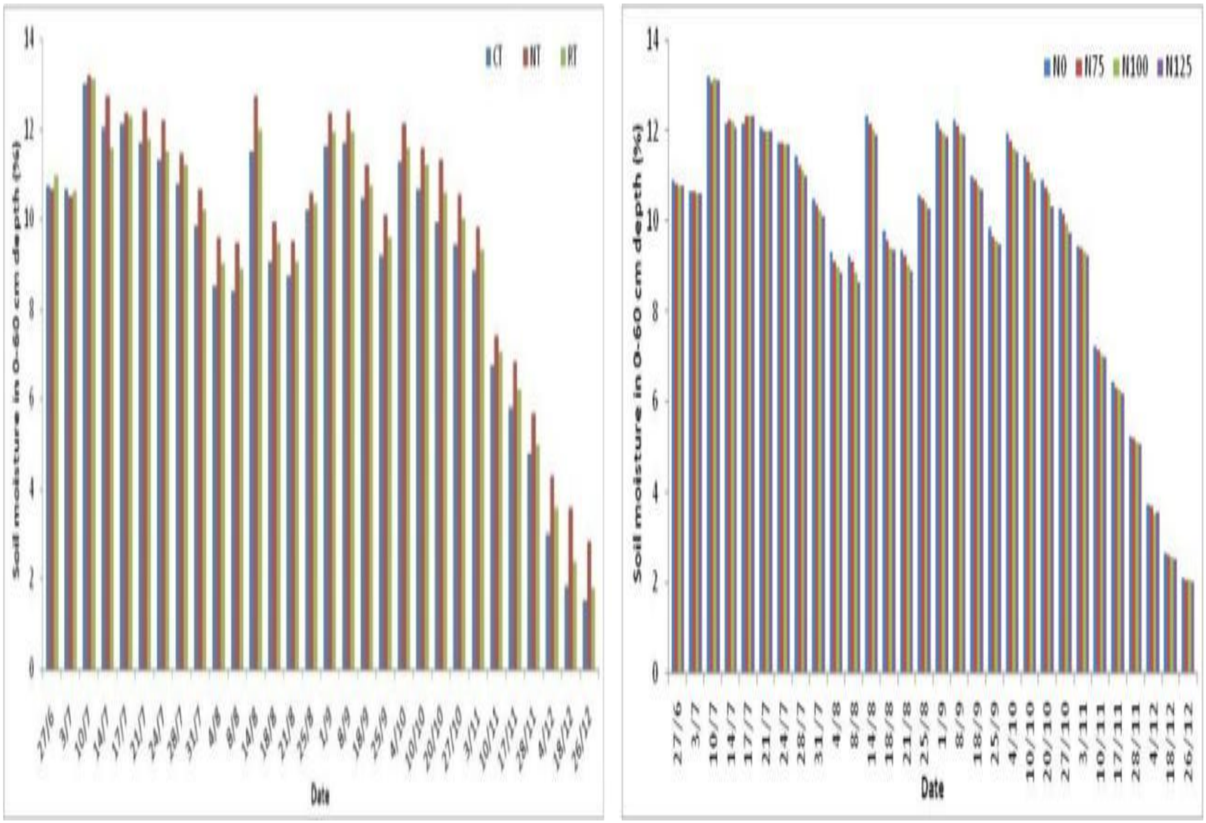
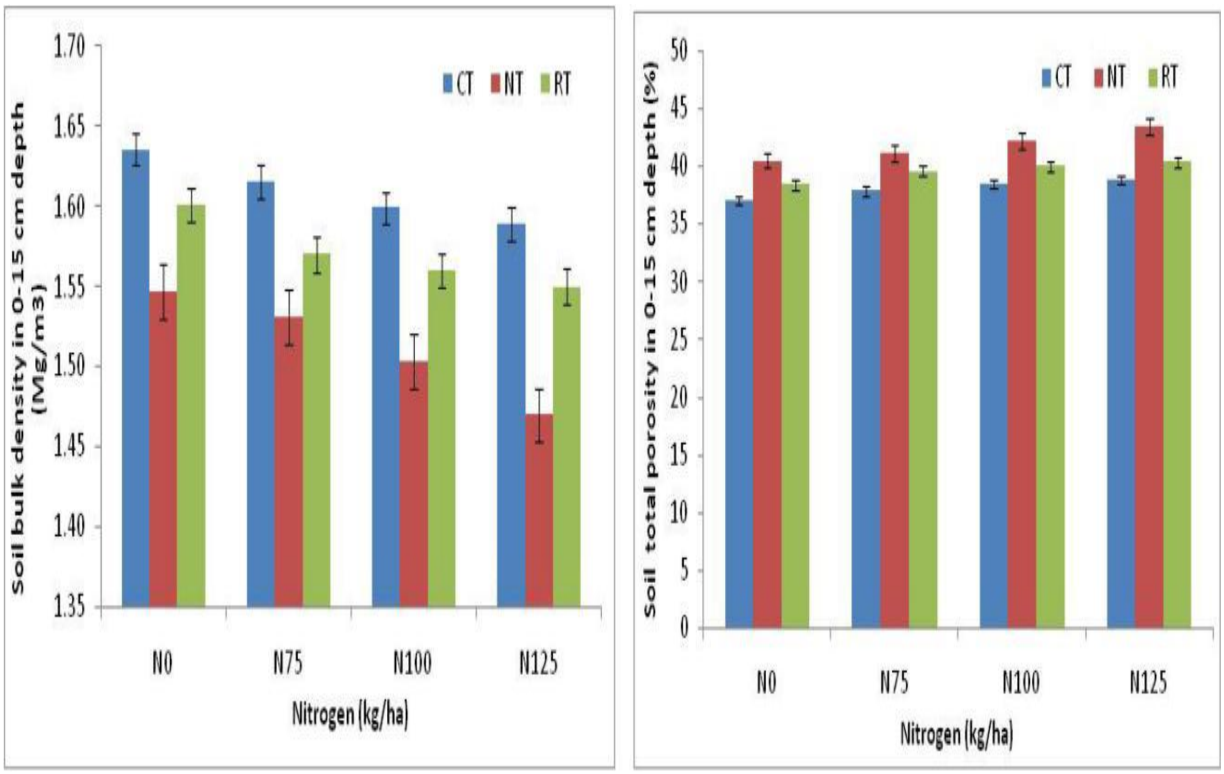


Fig 3. Effect of tillage and nitrogen levels on soil bulk density, total porosity at 0-15 cm depth



The tillage practices and nitrogen levels influenced the soil total porosity. About 9.78% and 4.99% higher soil total porosity was observed in No tillage and reduced tillage as compared to the conventional tillage in 0-15 cm depth. The added levels of nitrogen reduced the total soil porosity. About 5.77% higher soil total porosity was observed in N125 treatment as compared to the N0.

In Soybean-Chickpea system the soil moisture content decreased. The soil moisture status observed was less during flowering stage and very less during maturity stage of crop growth, it was better in all treatment combinations during vegetative stage of crop growth at the depths 0-15 and 15-30cm

Fig.4. Soil moisture content at 0-15 and 15-30 cm depth as influenced by different treatments at flowering crop growth stage

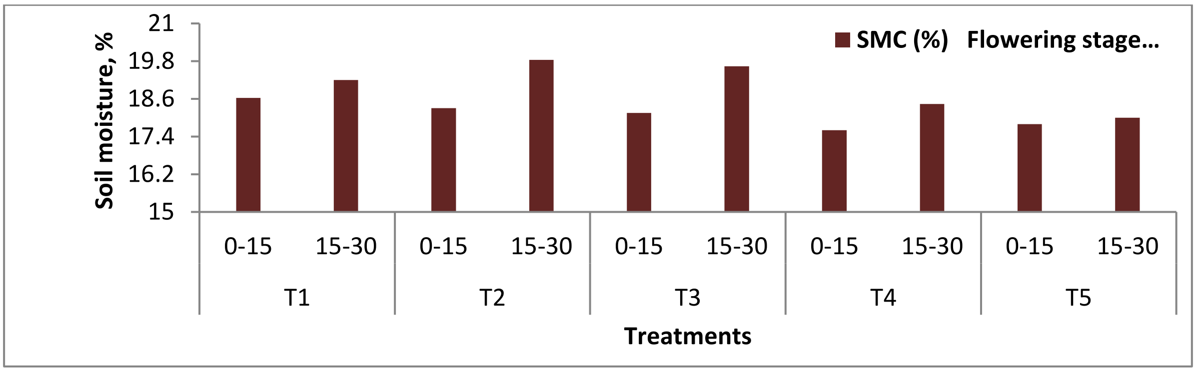
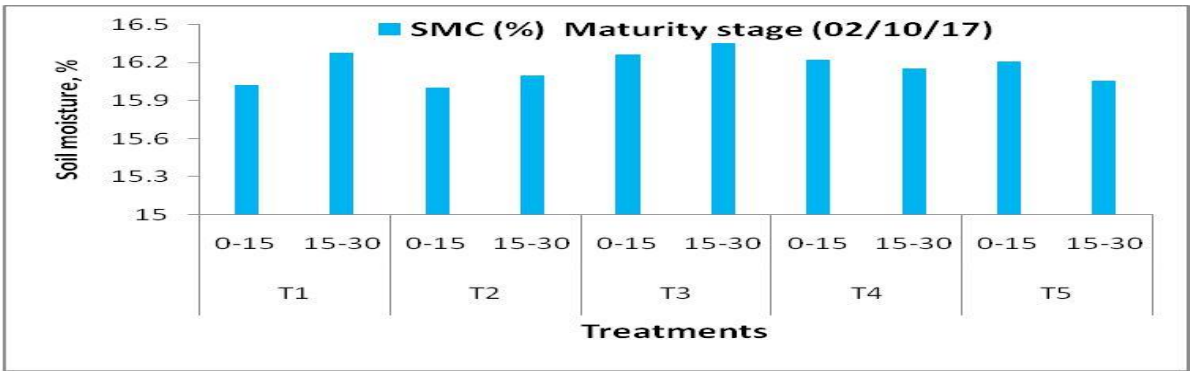


Fig.5 . Soil moisture content at 0-15 and 15-30 cm depth as influenced by different treatments at maturity crop growth stage



2) Available nutrients

In pigeonpea- castor system, after 10 years ZT recorded higher available nitrogen, potassium, phosphorus, micronutrients and total phosphorus as compared to CT and RT in 0-7.5 cm. Whereas at 15-30 cm, lower available nutrients were observed in ZT. ZT recorded higher carbon sequestration rate in 0-7.5 cm where as below 15 cm CT and RT recorded higher carbon sequestration rate. Carbon sequestration rate was negative in CT with 0 cm residue harvest height. Whereas application of residue improved the organic carbon and carbon sequestration rate in soil. Conventional tillage without residues recorded lowest OC, available phosphorus and potassium as compared to residue addition.

Conservation agriculture practices either with or without integration of insitu moisture conservation practices recorded higher available phosphorus and potassium. Among conservation agriculture practices permanent conservation furrow and permanent bed and furrow recorded higher OC, available phosphorus and potassium as compared to conservation furrow. In maize-pigeonpea system Conventional tillage without residues recorded lowest available phosphorus and potassium as compared to residue addition. Conservation agriculture practices either with or without integration of insitu moisture conservation practices recorded higher available phosphorus and potassium. Among conservation agriculture practices permanent conservation furrow and permanent bed and furrow recorded highest available phosphorus and potassium as compared to no conservation furrow.

In sorghum-black gram system, soil available N, P and K were estimated at 0-15 and 15-30 cm depth. The mineral N **(**ammonical and nitrate nitrogen) contents in the soil were significantly influenced by the residue retention. Significantly higher NH4+- N (25.15 mg kg^{-1}) and NO_3- N (36.94 mg kg^{-1}) were recorded in 100% residue retention treatment followed by 50% residue retention (21.37 mg kg^{-1}) and (28.75 mg kg^{-1}) and no residue retention (18.46 mg kg^{-1}) and (24.56 mg kg^{-1}) respectively. The results of the study on mineral nitrogen content in the soil were significantly influenced by the treatments. Minimum tillage recorded higher nitrate content but was on par with conventional tillage

Table 3 Long term effect of conservation tillage and residue retention of previous cr op on Mineral N (mg kg^{-1}).

Tillage	**S0: No residue retention**		**S1: 50% residue retention**		**S2: 100% residue retention**	
	Ammonical Nitrogen (mg kg^{-1})	Nitrate Nitrogen (mg kg^{-1})	Ammonical Nitrogen (mg kg^{-1})	Nitrate Nitrogen (mg kg^{-1})	Ammonical Nitrogen (mg kg^{-1})	Nitrate Nitrogen (mg kg^{-1})
Minimum tillage	19.24	25.66	22.18	29.44	25.49	39.09
Conventional tillage	17.68	23.46	20.56	28.05	24.82	34.80
CD (0.05)						
Tillage	NS	NS	NS	NS	NS	NS
Residues*	3.18	3.27	3.18	3.27	3.18	3.27
T X R	NS	NS	NS	NS	NS	NS

In Fingermillet+ pigeonpea system, no-significant difference was observed in soil available, phosphorus and potassium among different tillage practices. Significantly higher available nitrogen (225.62 kg ha^{-1}) was observed in horse gram as cover crop as compared to control (196.43 kg ha-1).But the available nitrogen with field bean (210.16 kg ha^{-1}) was on par with

control and horsegram as cover crop.Whereas, available soil phosphorus and potassium were non significant. Interaction between tillage and cover crops was found non-significant.

Soil physical properties (IARI)

Soil bulk density and total soil nitrogen content in bulk soils

There was no significant effect of CA (ZT, bed planting and residue retention) on soil bulk density after 5 years, both in the 0-5 cm (topsoil) and 5-15 cm soil layers (Figure1). Results clearly indicated that CA could result in comparable soil bulk density to CT in surface layers. Contrary to these results, several studies in the past reported higher bulk density under ZT in the soil surface compared with tilled. Reshaping of the beds under PNB and PBB may have increased porosity and moderated bulk density. Residue retention under ZT, PNB and PBB plots has a direct impact on soil aggregation and porosity and, in turn, inverse effect on the soil bulk density. Thus, this explains similar bulk densities under CA plots to CT plots, despite no tillage was performed for 5 years.

Core samples were taken just before wheat harvest in 2017 to determine the soil bulk density (BD) under conventional (CT) and no-tillage (NT) systems. On the surface layer (0-15 cm), BD under CT was marginally higher than NT. In the subsurface layer (15-30 cm), NT recorded 4% lower (significant at $p<0.05$) BD than CT indicating that adoption of NT practice reduces the sub-surface compaction. Conservation tillage (bed planting with ZT) had, in general, similar ($P>0.05$) TSN concentrations in both topsoil and 5-15 cm soil layer; except PBB plots which contained ~12% greater TSN concentration compared with CT plots in topsoil (Table 8). However, CA significantly ($P<0.05$) changed TSN concentrations in both layers, expect ZT+R plots in the 5-15 cm depth layer. For instance, plots under PBB+R had about 20% higher TSN concentration in topsoil than CT plots (Table 1). As a combination of bulk densities and TSN concentrations, only PBB and PBB+R plots had significantly greater TSN contents than CT plots (farmers' practice) in topsoil. However, in the 5-15 cm layer, all CA plots contained more TSN than CT. Among conservation tillage plots, only ZT plots had more TSN content/stock than CT in 5-15 cm depth layer . Soils under PBB+R had highest gain in TSN content over CT. Thus, in soil surface (0-15 cm layer) **(Table 1)**, the rate of TSN accumulation in soils under PBB+R compared to CT was ~32 kg $ha^{-1}yr^{-1}$.Greater topsoil TSN content in CA compared with CT plots could be due to: (i) more disruption of soil aggregates with CT than ZT/CA plots and (ii) improved soil aggregation under ZT/CA plots. Higher TSN concentration under CA plots in the 5-15 cm soil layer than CT plots could be due to the fact that soils of 5-15 cm had more small macro aggregates, which was the dominant soil size fraction in the 5-15 cm layer. Thus, fewer disturbances in the 5-15 cm layer could lead to more small macro aggregates and small macro aggregate-N accumulation than topsoil (0-5 cm).

Table 1. Effects of conservation agriculture on soil bulk density and total soil N content after five years of maize-wheat cropping in the north-western Indo-Gangetic Plains

Treatments	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	1.48[a]	0.93[c]	690.4[c]	1.50[a]	0.79[b]	1177.5[b]
PNB	1.48[a]	0.98[bc]	725.2[bc]	1.51[a]	0.80[b]	1208.0[ab]
PNB+R	1.46[a]	1.04[abc]	759.2[abc]	1.50[a]	0.89[a]	1335.0[a]
PBB	1.47[a]	1.09[ab]	801.9[ab]	1.48[a]	0.82[ab]	1213.6[ab]
PBB+R	1.46[a]	1.16[a]	849.7[a]	1.47[a]	0.90[a]	1315.7[a]
ZT	1.50[a]	0.96[bc]	723.0[bc]	1.53[a]	0.84[ab]	1291.3[a]
ZT+R	1.48[a]	0.99[bc]	734.8[bc]	1.51[a]	0.86[ab]	1295.6[a]
F-value	2.41	8.55	7.13	1.04	5.80	3.80

CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention. Means followed by similar lowercase letters within a column are not significantly different at $P < 0.05$ according to Tukey's HSD test.

Soil aggregation

In topsoil, micro-aggregates (0.25-0.053 mm) were the dominant fraction, which constituted~48 to 36% in soils under CT and PBB+R, respectively (Table 2). But in 5-15 cm soil depth, small macro-aggregates were dominant; with soils under PBB+R had highest proportion of that size. The PBB+R plots had significantly higher proportion of large macro-aggregates (> 2 mm) compared with CT plots in both 0-5 and 5-15 cm soil layers (Table 9). Small macro-aggregates in soils under PBB+R were also higher (by 23%) than CT. However, PBB+R plots had significantly lower (by 25%) micro-aggregate proportion than CT in topsoil. Silt + clay associated fraction proportion was similar in all plots in topsoil, but not in the 5-15 cm soil layer. The PBB+R plots had ~41% higher proportion of large macro-aggregates (>2 mm) than CT in 5-15 cm soil layer. In contrast to the topsoil, small macro-aggregates (2-0.25mm) constituted highest proportion in the 5-15 cm layer, and that fraction was higher in soils with PBB+R (by 46%) than CT. Mechanical disintegration of macro-aggregates under CT might have decreased the size of large macro-aggregates. In contrast to CT, CA (ZT+R; PNB+R and PBB+R plots) promoted macro aggregation, especially within the topsoil.

Table 2. Effects of conservation agriculture on soil aggregation after five years of maize-wheat cropping in the north-western Indo-Gangetic Plains

Treatments		Soil aggregation in the 0-5 cm layer			Soil aggregation in the 5-15 cm layer			
	Large Macro aggregates (g 100 g^{-1} soil)	Small Macro aggregates (g 100 g^{-1} soil	Micro aggregates (g 100 g^{-1} soil)	Silt + clay associated fraction (g 100 g^{-1} soil)	Large Macro aggregates (g 100 g^{-1} soil)	Small Macro aggregates (g 100 g^{-1} soil)	Micro aggregates (g 100 g^{-1} soil)	Silt + clay associated fraction (g 100 g^{-1} soil)
CT	3.7^{b}	31.0^{b}	48.1^{a}	17.2^{a}	2.62^{b}	40.8^{a}	41.4^{a}	15.2^{c}
PNB	5.2^{ab}	36.5^{ab}	41.3^{b}	17.0^{a}	3.59^{ab}	44.4^{a}	36.5^{b}	15.5^{c}
PNB+R	4.6^{ab}	35.9^{ab}	41.5^{bc}	18.0^{a}	3.66^{ab}	44.4^{a}	33.0^{bc}	19.0^{ab}
PBB	5.3^{ab}	36.7^{ab}	40.7^{bc}	17.3^{a}	3.79^{ab}	45.1^{a}	30.7^{c}	20.3^{a}
PBB+R	6.4^{a}	40.0^{a}	36.1^{c}	17.5^{a}	4.45^{a}	45.6^{a}	32.0^{bc}	18.0^{b}
ZT	4.2^{b}	38.7^{a}	40.7^{bc}	16.4^{a}	3.16^{ab}	43.1^{a}	35.7^{b}	18.0^{b}
ZT+R	4.9^{ab}	35.6^{ab}	42.0^{b}	17.5^{a}	3.27^{ab}	45.0^{a}	35.0^{b}	16.7^{bc}
F-value	4.49	4.52	9.64	0.20	4.54	0.46	8.78	9.17

CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.Means followed by similar lowercase letters within a column are not significantly different at $P < 0.05$ according to Tukey's HSD test.

4.3: Cone index

Cone penetrometer data were taken after wheat harvest in 2017 to see the compaction level under different treatment. At or near-surface layers, (<6 cm) soil resistance to penetration was lower in CT, indicating a near-surface compaction under the NT compared to the CT practice. However in the deeper layer, substantial reduction in penetration was evident under NT. A compact sub-surface zone is depicted, where NT was able to reduce the level of compaction by ~18%. A sub-surface compact layer is conspicuous in rice-wheat system across the Indo-Gangetic Plains. A reduction in sub-surface compaction, which is apparent under NT system could help in better root growth and development. This may sustain/improve the yield or realizing the yield potential of a variety. The root data in wheat (Table 3) supports this.

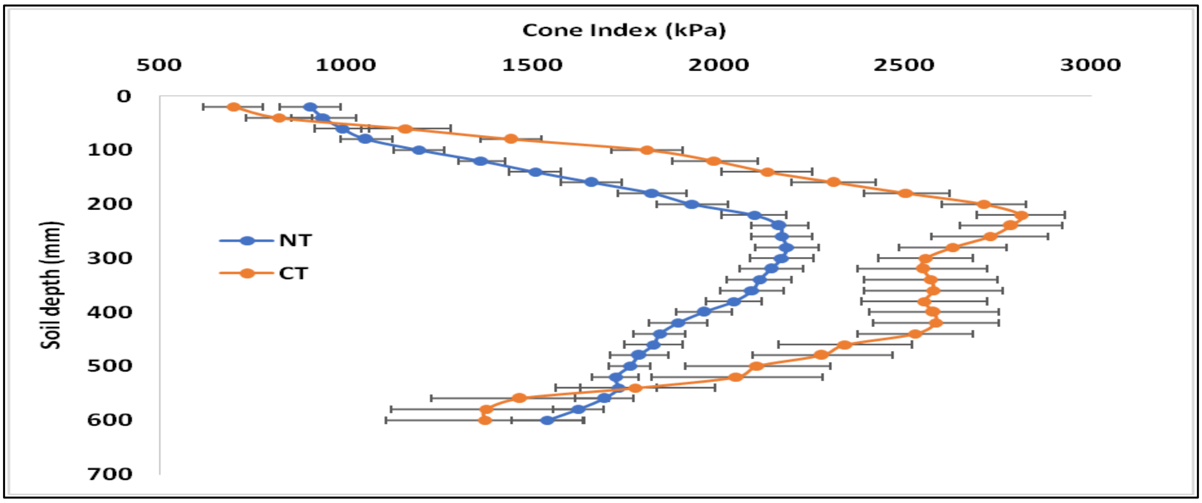


Fig.1: Penetration resistance of soil as affected by different tillage practices.

Table 3. Different root parameter of wheat as affected by NT and CT practices. Value followed by different capital letters are significantly different at p<0.05.

Soil depth (cm)	Treatment	Root length density (cm cm^{-3})	Root surface area density(cm^2 cm^{-3})	Root volume density (cm^3 cm^{-3})	Av. diameter of roots (mm)
0-15	NT-NT	82.44	11.58	0.13	0.44
	CT-CT	57.37	9.59	0.13	0.53
p-value		0.04	0.151	0.871	0.034
15-30	NT-NT	28.33	3.42	0.03	0.39
	CT-CT	10.17	1.55	0.02	0.47
p-value		0.016	0.048	0.192	0.099
30-45	NT-NT	11.65	1.78	0.02	0.50
	CT-CT	9.83	1.41	0.02	0.46
p-value		0.542	0.387	0.287	0.29

In the surface layer (0-15 cm), root length density (RLD) was higher ($p<0.05$) in NT practices (82.44 cm cm^{-3}) in comparison to CT (57.37 cm cm^{-3}). Similar trend was observed in sub-surface layer (15-30 cm), where NT recorded a huge 179% higher ($p<0.05$) RLD than the CT. Like RLD, surface area density (SAD) was also higher in NT at this layer. No appreciable difference in the root volume density (RVD) was recorded. The CT had higher average diameter of roots (0.53 mm) compared to NT (0.44 mm) in 0-15 cm layer, while in deeper layers, the difference was marginal.

4.4: Physical pool of soil organic carbon in wheat based cropping system under conservation *vis-à-vis* conventional agriculture practices

Field experiments were conducted during 2010-2016 at the research farm of the Indian Agricultural Research Institute, New Delhi to study the impact of conservation agriculture practices *vis-à-vis* conventional agriculture practices on carbon sequestration in three irrigated wheat based cropping systems i.e. cotton-wheat, pigeon pea-wheat and maize-wheat cropping systems. The treatments include **T1: Conventional Tillage (CT)**, **T2: Zero tillage -Narrow bed (ZT-NB)**, **T3: Zero tillage- Narrow bed with residue (ZT-NB+R)**, **T4: Zero tillage broad bed (ZT-BB)**, **T5: Zero tillage broad bed with residue (ZT-BB+R)**, **T6: Zero tillage flatbed (ZT-FB)** and **T7: Zero tillage flatbed with residue (ZT-FB+R)**.

After sixth year of cropping, it was observed that the contribution of micro-aggregates was the maximum among the water stable aggregate mass. In lower depths, the proportion of macro-aggregates decreases both in conservation and conventional agriculture practices (Fig. 2-10). Under CA practices, the proportion of macro-aggregates was more than the conventional flatbed system. **Retention of crop residues improved the proportion of macro-aggregates and decreased the proportion of micro-aggregates**. Among the cropping systems, maize-wheat system has highest proportion of macro-aggregates followed by pigeon pea-wheat and cotton-wheat system, whereas the proportion of micro-aggregates was maximum in the cotton-wheat system. The mean weight diameter (MWD) of water stable aggregates decreased with depth **(Table 4).** The MWD was higher under conservation agriculture practices than conventional agriculture practice at 0-5 and 5-15 cm soil depths. At 0-5 cm soil depth the maximum MWD was recorded in the Narrow bed+ residue treatment whereas in the 5-15 cm soil depth the maximum MWD was recorded in the broadbed + residue treatment. Among the cropping systems, maximum MWD was recorded in the maize-wheat system followed by pigeon pea-wheat and cotton-wheat system at 0-5, 5-15 and 15-30 cm soil depths.

Table 4. Mean weight diameter (mm) of water stable aggregates under conservation and conventional agriculture practices.

Treatment	Cotton-wheat			Pigeon pea-wheat			Maize-wheat		
	0-5 cm	5-15 cm	15-30 cm	0-5 cm	5-15 cm	15-30 cm	0-5 cm	5-15 cm	15-30 cm
Zero tillage (ZT)	0.98	0.77	0.78	0.90	0.80	0.74	0.83	0.85	0.84
ZT + Residue	1.19	0.81	0.71	1.07	0.68	0.85	0.81	1.01	0.85
BB + Residue	0.97	0.78	0.62	1.04	0.58	0.68	1.30	1.20	1.08
Broad bed(BB)	0.76	0.76	0.65	1.00	0.81	0.77	1.22	0.92	1.03
NB + Residue	0.78	0.77	0.62	1.33	0.96	0.78	1.29	0.79	0.94
Narrow bed (NB)	0.77	0.79	0.73	1.17	0.90	0.64	1.04	0.84	0.80
Flat bed	0.86	0.50	0.88	0.97	0.90	0.78	1.12	0.77	0.91

The concentration of water stable aggregate-associated carbon was higher in macro aggregates than micro-aggregates and mineral fraction irrespective of conservation and conventional agriculture practices at 0-5 cm soil depth **(Figure 11-13**). The aggregate associated carbon concentration decreases with depth. The concentration of aggregate associated carbon under CA was higher than the conventional flatbed system. Retention of residues has increased the aggregate associated carbon in all the aggregate size fractions than residue removal treatments of CA. The aggregate associated SOC concentration in pigeon pea-wheat system was at par with cotton-wheat system but superior to maize-wheat system.

Fig. 2: Aggregate mass distribution in maize-wheat system at 0-5 cm soil depth under conservation and conventional agriculture practices.

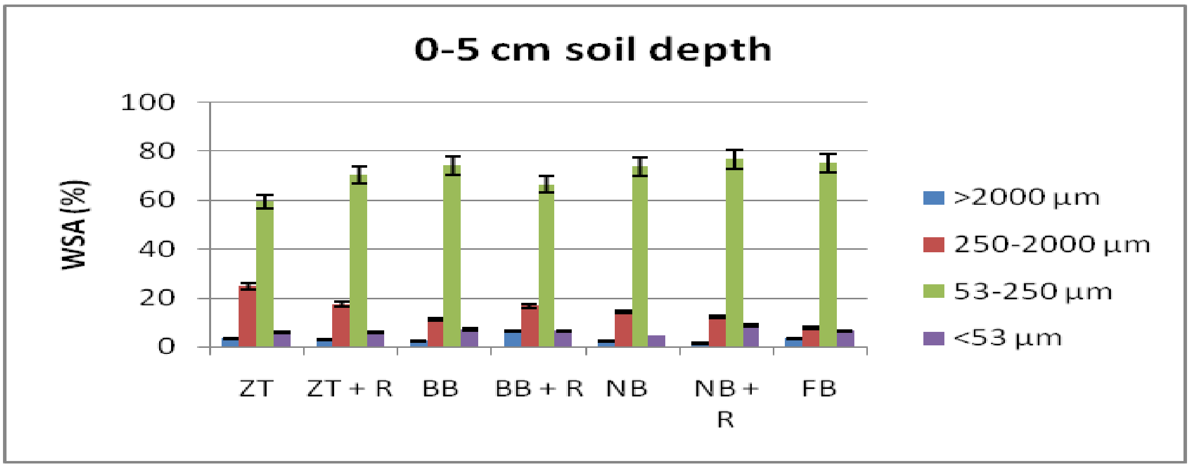


Fig. 3: Aggregate mass distribution in maize-wheat system at 5-15 cm soil depth under conservation and conventional agriculture practices

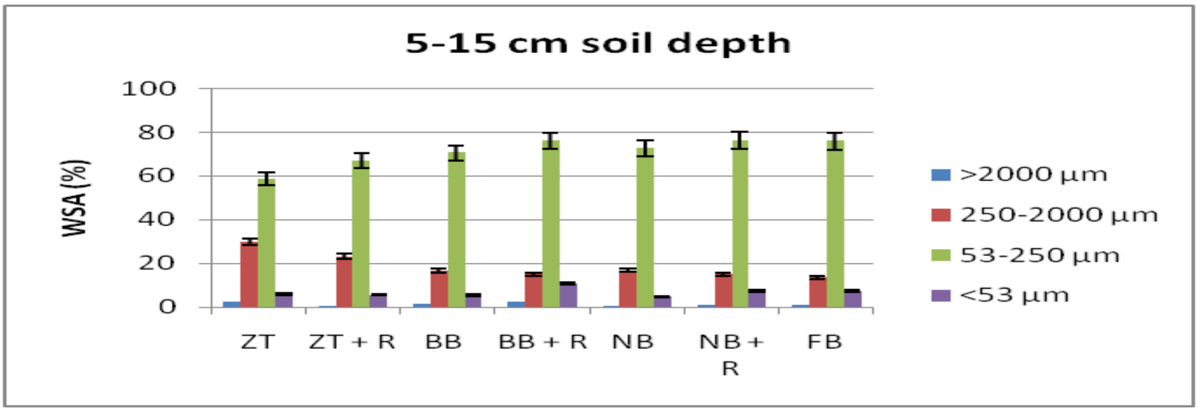


Fig. 4: Aggregate mass distribution in maize-wheat system at 15-30 cm soil depth under conservation and conventional agriculture practices

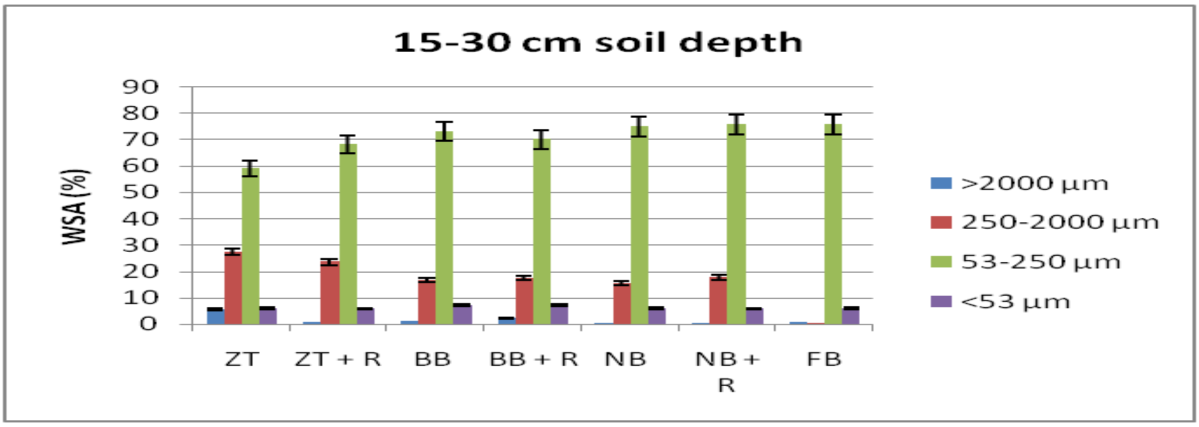


Fig. 5: Aggregate mass distribution in cotton-wheat system at 0-5 cm soil depth under conservation and conventional agriculture practices

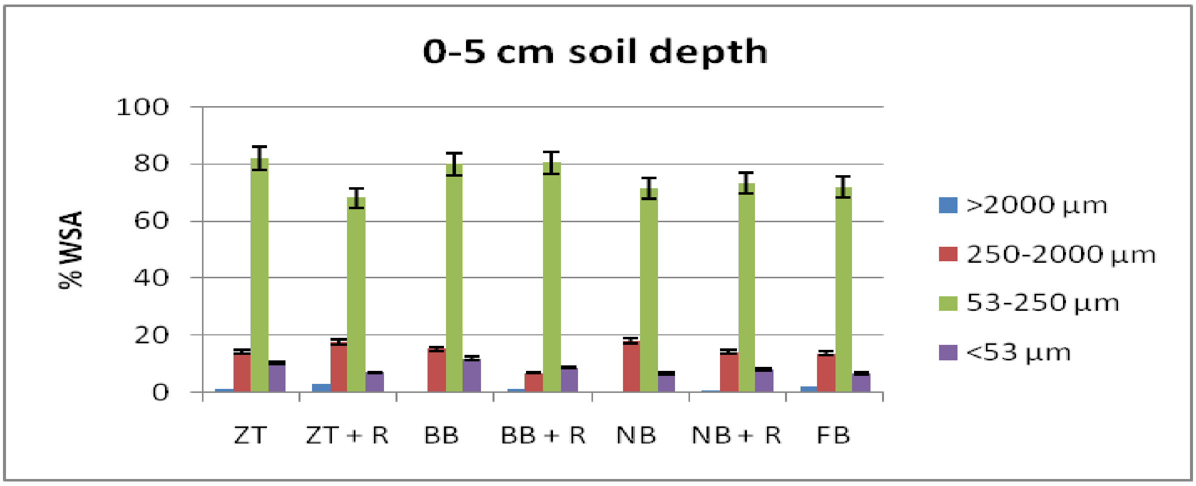


Fig. 6: Aggregate mass distribution in cotton-wheat system at 5-15 cm soil depth under conservation and conventional agriculture practices

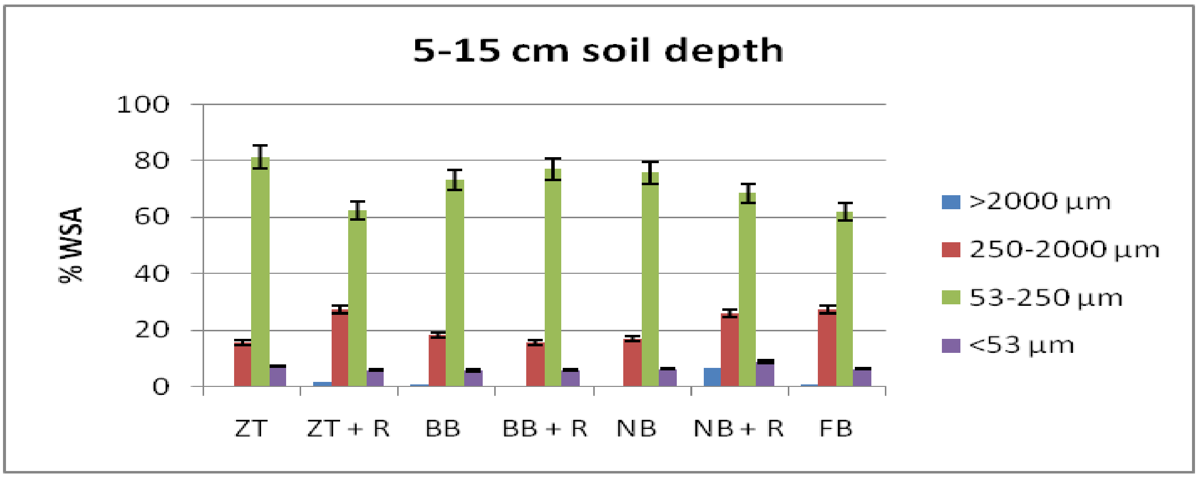


Fig. 7: Aggregate mass distribution in cotton-wheat system at 15-30 cm soil depth under conservation and conventional agriculture practices

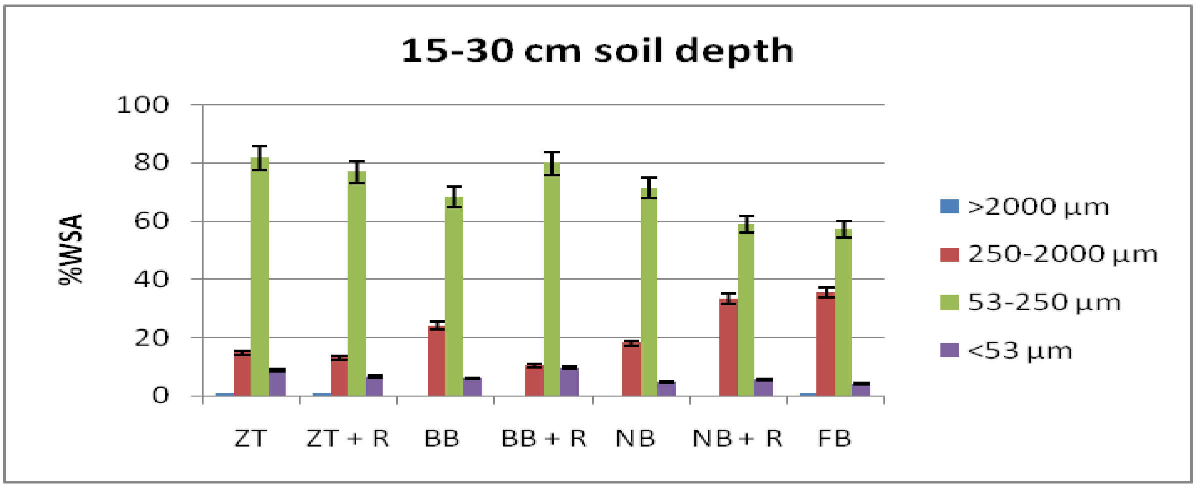


Fig. 8: Aggregate mass distribution in pigeon pea-wheat system at 0-5 cm soil depth under conservation and conventional agriculture practices

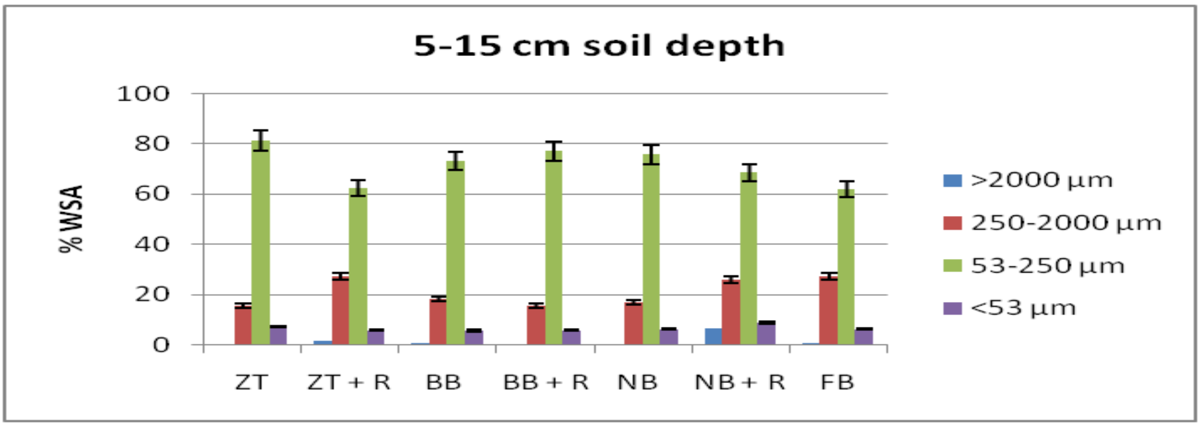


Fig. 9: Aggregate mass distribution in pigeon pea-wheat system at 5-15 cm soil depth under conservation and conventional agriculture practices

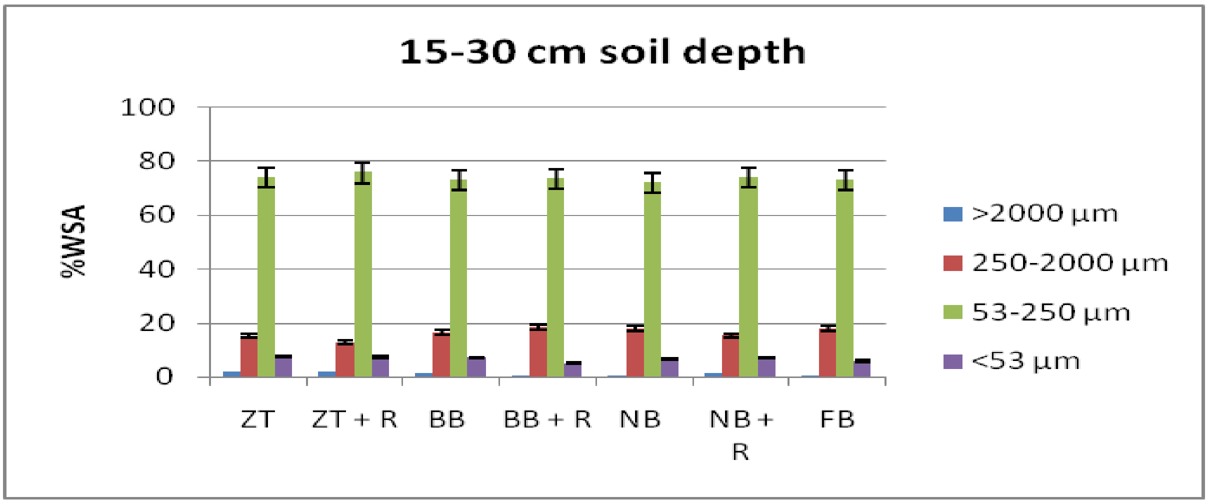


Fig. 10: Aggregate mass distribution in pigeon pea-wheat system at 15-30 cm soil depth under conservation and conventional agriculture practices

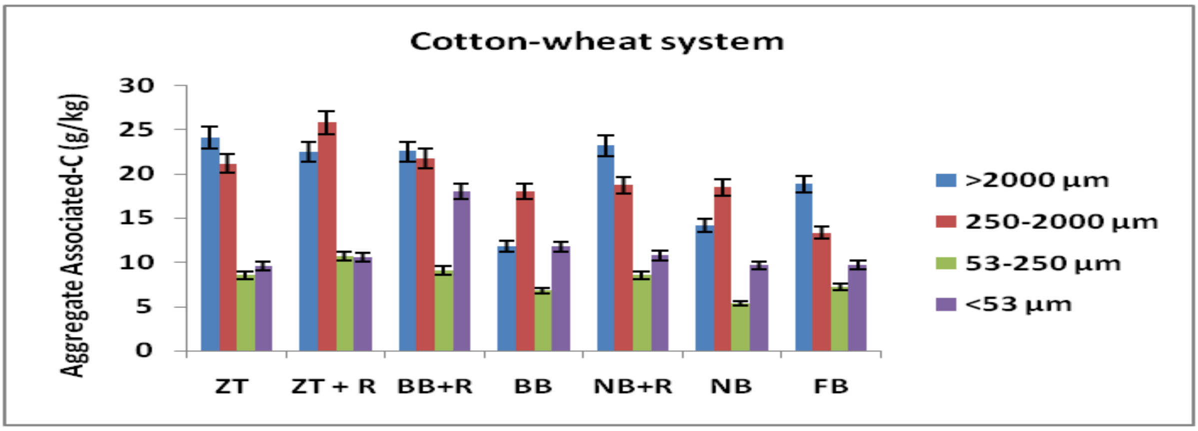


Fig. 11: Aggregate associated carbon at 0-5 cm soil depth in cotton-wheat system as influenced by conservation and conventional agriculture practices

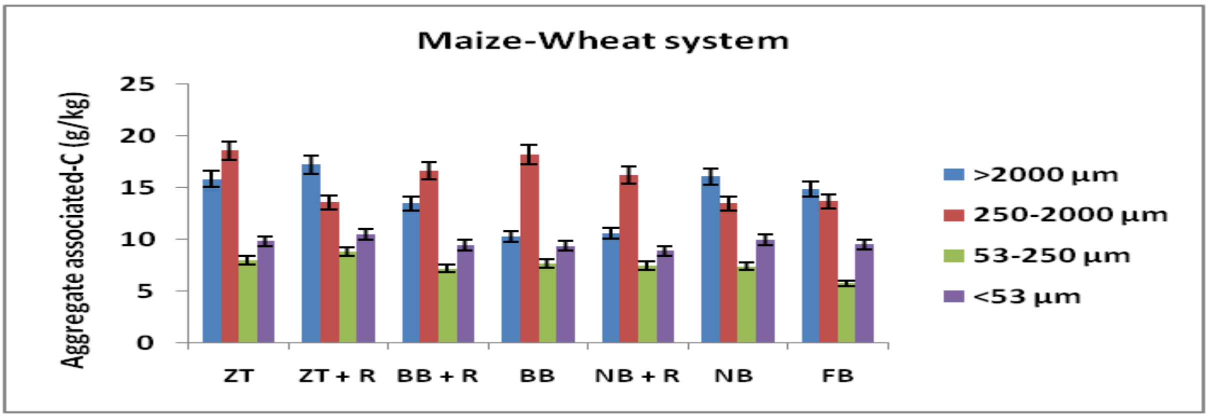


Fig. 12: Aggregate associated carbon at 0-5 cm soil depth in maize-wheat system as influenced by conservation and conventional agriculture practices

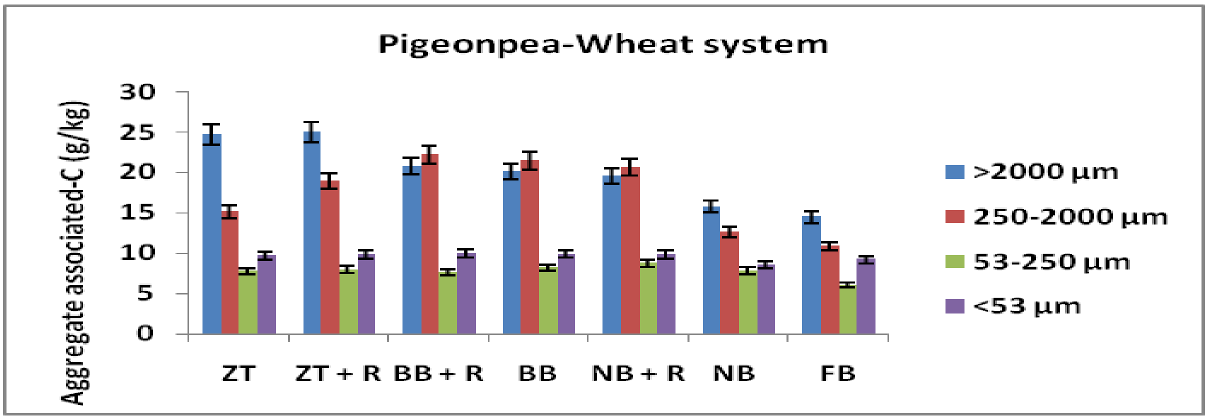


Fig. 13: Aggregate associated carbon at 0-5 cm soil depth in pigeon pea-wheat system as influenced by conservation and conventional agriculture practices

Soil physical and crop micro-environment and modelling soil hydrothermal regimes using Hydrus-2D (IARI)

In the seventh year of experiment, results showed that during wheat growth in both maize-wheat and pigeon pea-wheat systems, both PBB and PNB with and without residue retention and ZT with residue retention **reduced bulk density (BD), increased K_{sat} and improved soil water retention** at FC significantly over CT. The relationship between LAI and 1-fIPAR was found to be exponential in nature (R^2=1). Power term of the exponential was the radiation extinction coefficient (κ) which was found to be lowest in CT (0.86) and highest in PNB+R ~PBB+R (0.99). Cumulative E_p was higher by 20-50% where as T_p was lower by same amount in CT as compared to CA treatments. Residue retention in PBB, PNB and ZT increased CT_p by 6-19 % than without residue and reduced the CE_p by same amount. The results thus clearly indicated the effectiveness of crop residue as mulch in reducing evaporation.

In the seventh year of an ongoing conservation agriculture (CA) experiment, both water balance and energy balance components of pigeon pea (*Cajanas cajan*) were analysed using Hydrus-2D model. The treatments were: permanent broad bed (PBB), PBB with crop residue (PBB+R), permanent narrow bed (PNB), PNB with crop residue (PNB+R), zero tillage (ZT), ZT with crop residue (ZT+R), conventional tillage (CT).

Soil water balance components were simulated during the flowering stage (i.e. 50-75 days after sowing) and energy balance components was simulated for 10 days between 62-71days after sowing (DAS).

Results of simulated soil water balance components (Table 1) clearly indicated that cumulative root water uptake (CRWU) values of ZT (2.94 cm) and CT (3.20 cm) treatments were significantly lower than PBB (4.68 cm) treatment. Retention of crop residues in PBB, PNB and ZT treatments significantly improved their CRWU values. Similarly, cumulative evaporation (CE) from soils under different treatments were in the order: PBB (5.20 cm) ~ PNB (5.13 cm) > CT (4.80 cm) > ZT (4.50 cm) and retention of crop residues in these conservation treatments significantly reduced CE (2.69-2.80cm). In nutshell, it was observed that during simulation period, under PBB+R treatment, soil water evaporation was reduced, transpiration rate increased and soil water retention in the profile increased in comparison to conventional treatment. Besides, drainage component also increased slightly.

Looking at energy balance pattern during simulation between 62 -72 DAS period when soil was relatively wet, major fraction of total net radiation received was utilized by LE component. Results on variation of daily latent heat flux (LE) showed that its magnitude varied between 30-104 % of net radiation (R_n) in CT and 48 to 112 % in PBB+R (Fig.1). It was more than R_n when there was heavy rain. During most of the simulation period, LE followed trend similar to that of R_n. This is because of the fact that Rn is the major energy supplier for evaporation from both soil and plant surfaces. Magnitude of LE during entire simulation period was higher in PBB+R than in CT mainly because of higher value of RWU (actual transpiration) during flowering period.

Ground heat flux (G) component decreased after irrigation because of higher soil water content (SWC) of upper 0-20 cm soil which resulted in increased soil thermal conductivity and reduced temperature gradient (dT/dx). On rainy days, the magnitude of G in upward direction ranged between -12 to -5 Wm^{-2} for PBB +R and -17 to -5 Wm^{-2} for CT, which indicated that magnitude of G going upwards into atmosphere was reduced due to presence of mulch which is an insulator of heat. Similarly, on sunny days, the magnitude of G ranged between 3-13 Wm^{-2} for PBB +R and 6-14 Wm^{-2} for CT ,which again indicated that magnitude of G entering into profile was reduced due to the presence of mulch. Results thus indicated that mulch was useful in conserving soil water and moderating soil temperature fluctuations.

Table 1. Cumulative values of simulated components of soil water balance during simulation period (50-75 DAS).

Treatment	CRWU (cm)	CD (cm)	CE (cm)	RF/IR (cm)	Initial SWC (cm)	Final SWC (cm)
CT	3.20	25.34	4.80	35.50	14.10	14.50
PNB	4.53	26.10	5.13	35.50	15.40	16.34
PNB+R	5.22	25.06	2.80	35.50	16.52	18.04
PBB	4.68	27.12	5.20	35.50	15.63	15.87
PBB+R	6.20	26.07	2.69	35.50	15.85	17.89
ZT+R	5.53	26.24	3.00	35.50	15.25	16.28
ZT-R	2.94	27.35	4.5	35.50	14.50	14.80

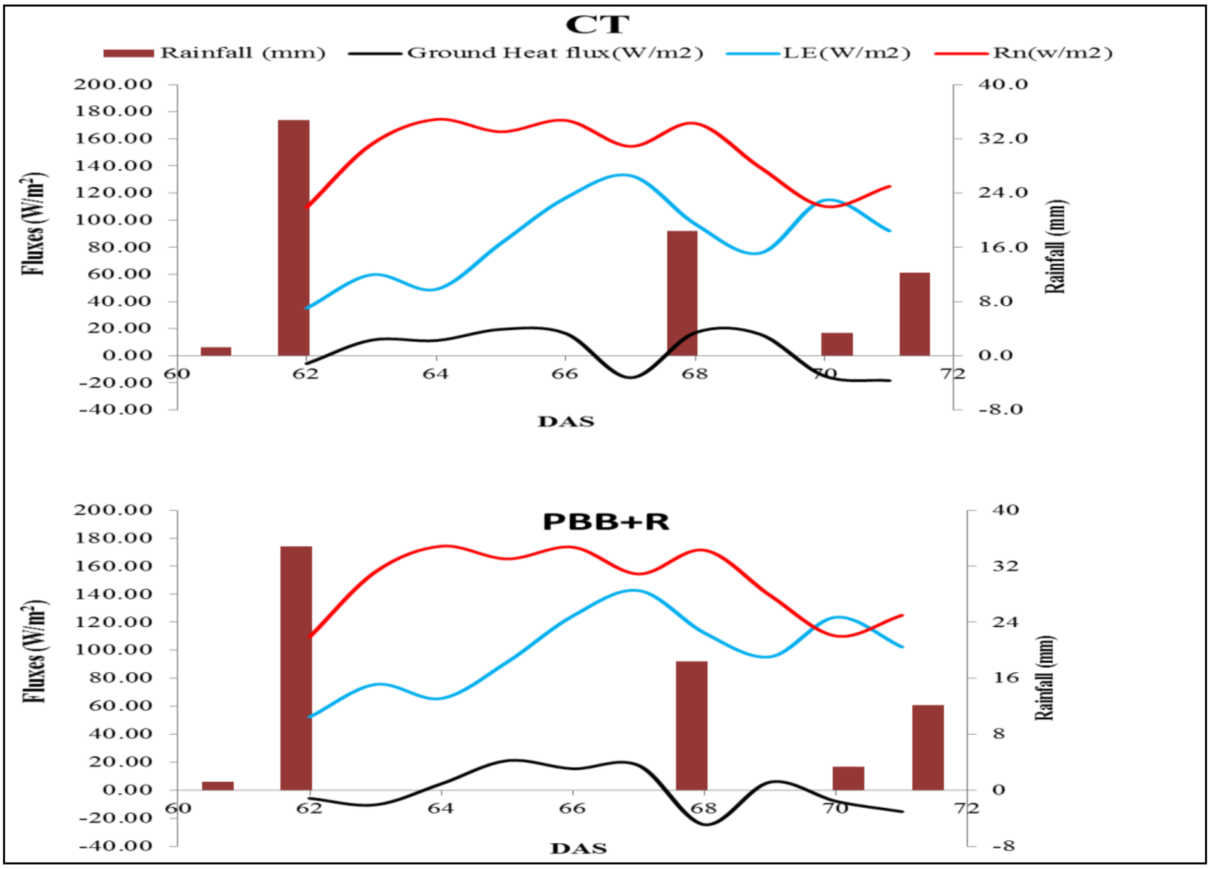


Fig. 1: Energy balance components of CT and PBB+R during simulation period (62-71 DAS)

2.1.2.2 Soil chemical properties (CSSRI)

Soil organic carbon- Soil study for the determination of soil organic carbon content was conducted after wheat crop harvesting during 2016-17 wheat season (Table 1). Soil carbon content varied under different RCTs. Soil organic carbon (g/Kg soil) recorded higher in 0-15 cm soil layer in comparison to 15-30 cm soil layer. SOC, increased in those treatments/technologies where added crop residue regularly. In 0-30 cm soil layer, SOC was 8.5 g/Kg soil in ZT +Residue anchors followed by CV+R and RT+R, respectively. Among the water management treatments, where rice residue added 100% since last 6 years, raised SOC up to 8.7, 8.0, 8.3 in ZT+100% rice residue treated technologies and correspondingly wheat crop productivity increased accordingly after improving soil fertility. The amount of SOC depends upon rate of crop residue to be added regularly per year. But in this experiment crop residue added @ 33% of total crop residue produced.

Soil carbon build up rate-

Soil carbon build up rate study conducted up to 0-120 cm soil layers. The results presented in the form of graphs with values on the graphs (figure 1), shows that carbon build up rate was greater in those technologies where crop residue added regularly. Soil carbon build up rate was higher in 0-15 cm soil layer and was statistically similar in crop residue added technologies either CV/RT/ZT plots. In 15-30 cm soil layer, it was second maximum carbon buildup rates and maximum root proliferation also observed accordingly. So, roots takes all minerals released after decomposition of organic matter in soil system. Crop productivity of wheat crop reflected in the similar fashion/manner by increasing grain and biological yield.

Table 1 Effects of crop residue and tillage operation on SOC under different RCTs in rice–wheat cropping system.

Conservation of soil organic carbon

RCTs	Soil organic carbon (g/kg soil) in 0-30 cm soil layer			
	0-15	15-30	Average (0-30)	% Increase/ Decrease over Cv
CV	6.5	4.3	5.4	-
CV+RR	8.6	6.6	7.6	40.7
RT	7.1	3.7	5.4	0.0
RT+RR	9.3	6.5	7.4	37.0
ZT	8.4	6.5	7.5	38.8
ZT+RR-1/3	9.7	7.3	8.5	57.4
ZT+RR-full	9.5	7.9	8.7	61.1
ZT+RR-full	8.9	7.7	8.3	53.7
ZT+RR-full	8.4	7.6	8.0	48.1
Range	-	-	-	37.0-61.1
Initial	0.45			

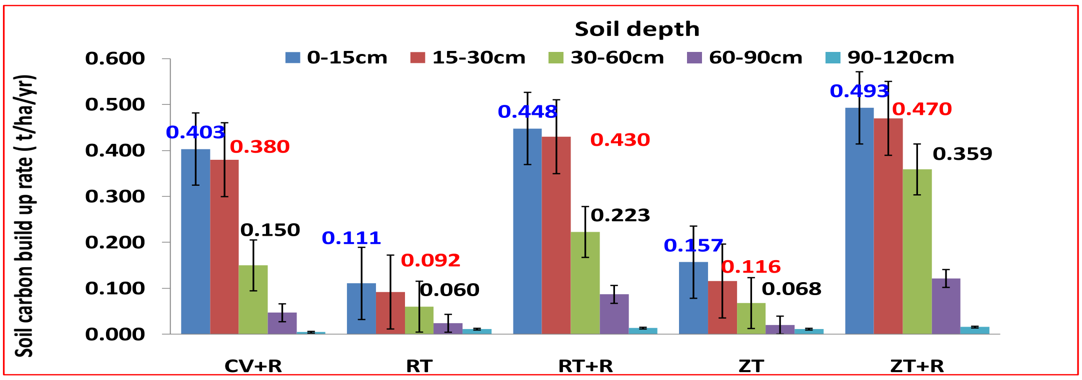


Figure (8) Effect of crop residue with tillage on soil carbon build up rate (t/ha/yr) depth wise in all treatments [CV+R = Conventional with rice residue (T_2), RT = Reduce tillage with non residue (T_3), RT+R = Reduce tillage with rice residue (T_4), ZT = Zero tillage with non residue (T_5), ZT+R = Zero tillage with rice residue (T_6)] after 10 years. Significantly different at $p<0.05$.

Figure 1 Effects of crop residue with tillage on soil carbon build up rate (t/ha/yr) depth wise under different CA technologies.

Fertility Status- Soil fertility status is given in table 2 shows that:

- —»Available nitrogen increased from 0.8% to 28.4% where crop residue incorporated/retention/mulched in 0-30 cm soil layer.
- —»Available P increased from 7.5% to 25% and K increased in range of 0.5% to 37.0%, respectively, over conventional method of rice–wheat cultivation.
- —»Similarly SOC increased up to 61% in crop residue added treatments over conventional method of rice-wheat cultivation.
- —»Higher soil microbial activity was recorded where, added crop residue regularly.
- —»Higher water stable aggregates recorded in Zero tilled soil.
- —» Higher total water stable aggregates was observed in crop residue treatments

Table. 2 Soil fertility status under different RCTs.

Changes in soil fertility status				
Soil Type	Partially Reclaimed Sodic Soil (0-15cm)			
	Initial (2006)	After 9 Years of Experiment (2015)		% increase
Soil pH 2	7.92-8.3	7.56-7.92	Cv→ZT	-
Soil EC 2	0.25dSm^{-1}	0.27 -0.32	-	-
SOC (%)	0.45	0.54-0.72	Cv→RT+R	20-60
N kgha^{-1}	96.4	123.4 -156.8	Cv→RT+R	28.0-62.7
P Kgha^{-1}	22.43	22.32 -29.83	Cv→RT+R	0.0-30.63
K kgha^{-1}	218	221.8 -301.28	Cv→CV+R	1.74-38.20
Soil texture	Sandy loam Sand= 649.4 g/kg Silt =153.0 g/kg Clay=187.6 g/kg	Sandy Loam Sand= 651.4 g/kg Silt =152.0 g/kg Clay=192.4 g/kg	–	-

Effect of trash, fertilizer-nitrogen and SORF techniques practices on soil properties (NIASM)

Surface retention of chopped trash and adoption of SORF techniques influenced the soil physical, chemical and biological properties significantly ($P \leq 0.05$) over conventional farmers' practices of trash burning and broadcast application of fertilizers. The significantly lower values of bulk density was recorded under surface retention of trash and SORF techniques (CT+SORF) as compared to trash burnt/ removed and control treatments (No-trash + No-N) in surface (0-15 cm) (Fig. 1).

However, different practices of trash, fert-N and ratoon management did not influence the soil bulk density in sub-surface (15-30 cm) soil layer.

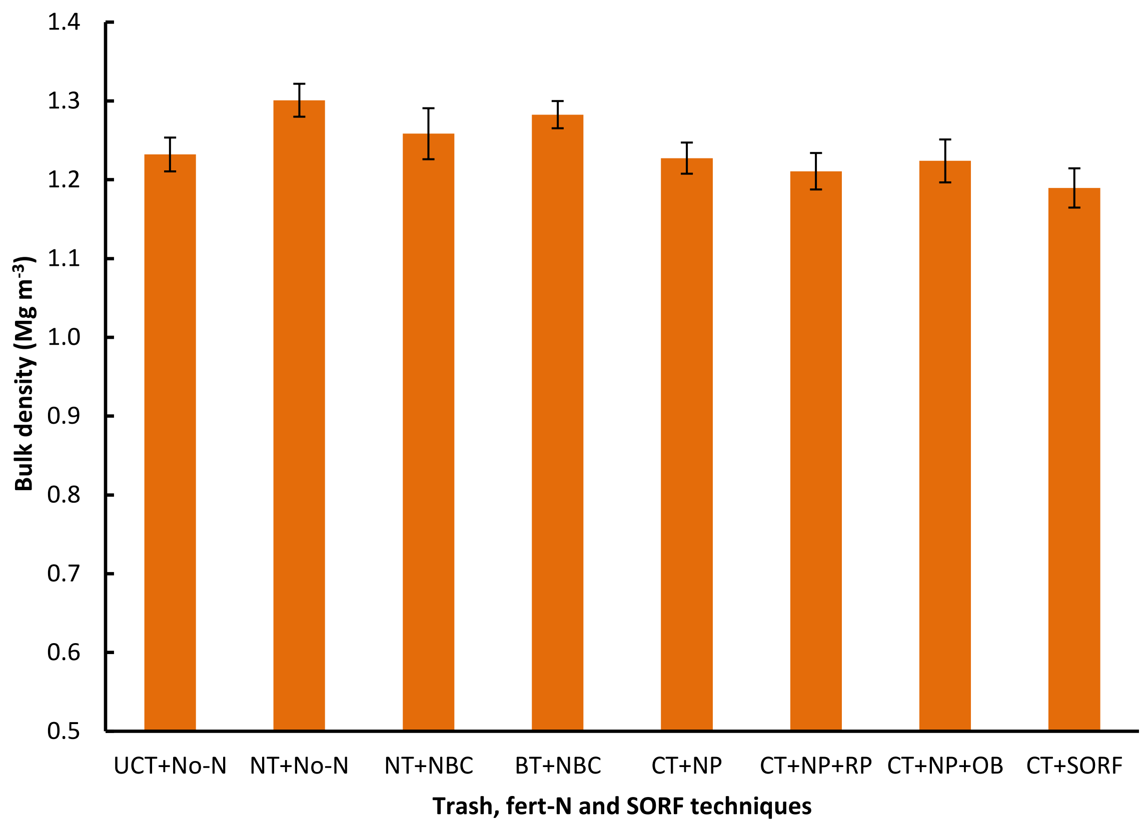


Fig. 1. Effect of trash, fert.-N and SORF techniques on bulk density in 0-15 cm soil layer.

Similarly, there was a build-up in soil organic carbon content (SOC) in 0-15 cm soil layer under the trash retained treatments. The maximum SOC content was recorded under CT+SORF treatment which was closely followed by other chopped trash + N placement treatments. Surface retention of chopped trash improved the SOC content by 5-15 % over un-chopped trash/trash removal or trash burnt treatments (Fig. 2). Surface retention of trash and other ratoon management practices did not influence the SOC content in 15-30 cm soil layer.

In addition to above, soil microbial and enzymatic activities were also influenced much due to different trash, fert-N and other ratoon management practices. At harvest, the maximum values of the soil microbial biomass carbon (MBC), Dehydrogenase (DH) activity and FDA hydrolysis were recorded under CT+SORF treatment which was closely followed by other chopped trash retained and N placement treatments (Fig. 3). Soil microbial and enzymatic activities also improved significantly with N-fertilization over N un-fertilized treatments. *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 12-25, 10-21 and 16-38 % over conventional trash burnt and broadcast application of fert-N treatments, and by 16-41, 26-46 and 23-59 % over N un-fertilized treatments, respectively.

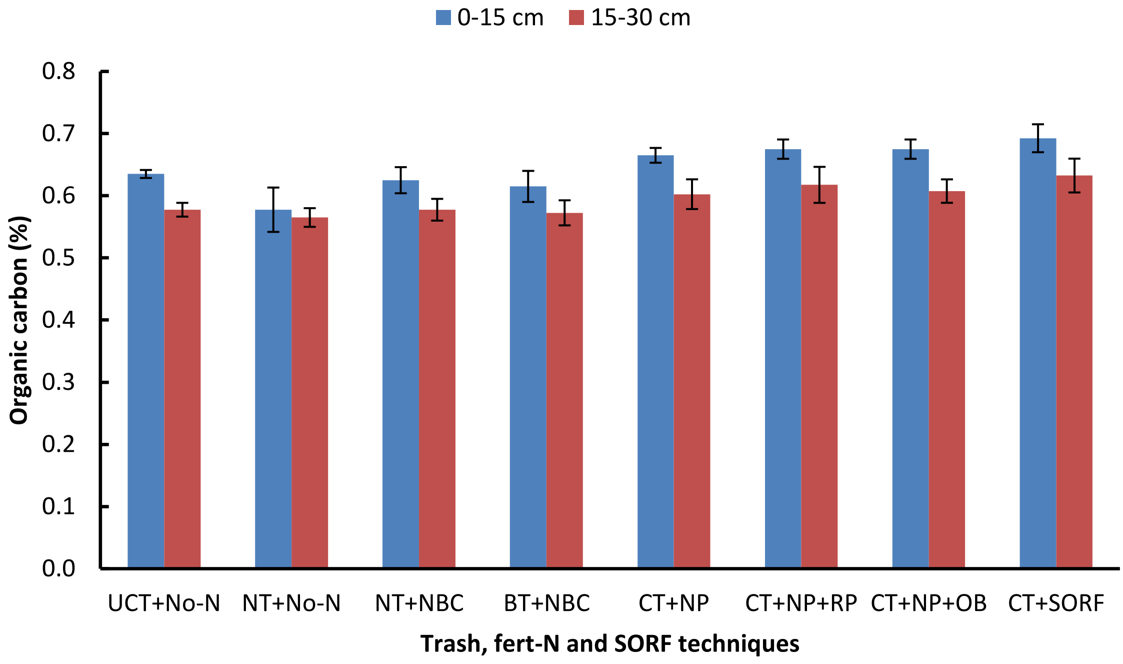


Fig. 2. Effect of trash, fert.-N and SORF techniques on organic carbon content in surface (0-15 cm) and subsurface (15-30) cm soil layers.

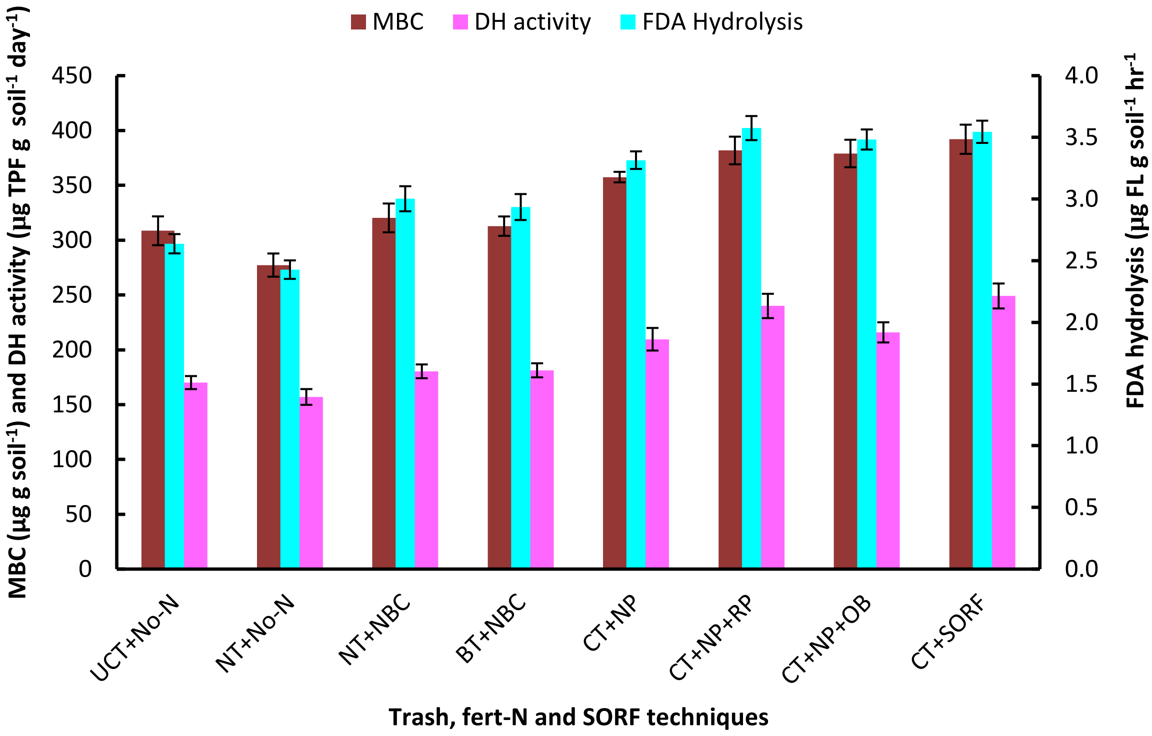


Fig. 3. Effect of trash, fert.-N and SORF techniques on soil microbial and enzymatic activities in sugarcane ratoon crop

Chemical properties (CRIDA)

Table 1: Soil chemical parameters as influenced by conservation agriculture practices in finger millet+ pigeon pea intercropping (8:2) (CRIDA)

Treatment	pH	EC (dS m^{-1})	OC (%)	Available (kg ha^{-1})		
				N	P_2O_5	K_2O
TILLAGE						
M_1 :Conventional tillage	5.05	0.01	0.46	221.52	127.89	90.58
M_2 : Reduced tillage	5.05	0.01	0.45	225.86	124.30	79.84
M_3 :Zero tillage	5.13	0.01	0.45	184.83	124.30	86.52
S. Em. ±	**0.10**	**0.001**	**0.015**	**11.60**	**4.65**	**6.02**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
COVERCROPS						
C_1: Control	5.11	0.01	0.43	196.43	121.48	84.10
C_2: Field bean (HA-4)	5.07	0.01	0.46	210.16	124.31	83.44
C_3: Horse gram	5.05	0.01	0.47	225.62	130.70	89.42
S. Em. ±	**0.06**	**0.002**	**0.011**	**7.39**	**6.13**	**5.57**
CD (p=0.05)	**NS**	**NS**	**0.03**	**22.76**	**NS**	**NS**
INTERACTIONS						
M_1C_1	5.10	0.01	0.46	205.80	116.44	80.45
M_1C_2	4.97	0.01	0.45	231.00	127.73	89.54
M_1C_3	5.08	0.02	0.48	227.77	139.51	101.76
M_2C_1	5.10	0.01	0.42	222.50	119.26	82.11
M_2C_2	5.06	0.01	0.45	218.48	123.36	74.13
M_2C_3	4.98	0.01	0.46	236.60	130.28	83.29
M_3C_1	5.12	0.02	0.41	161.00	128.73	89.72
M_3C_2	5.19	0.01	0.46	181.01	121.86	86.65
M_3C_3	5.08	0.01	0.47	212.48	122.32	83.21
S. Em. ±	**0.11**	**0.003**	**0.019**	**12.79**	**10.63**	**9.65**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 2: Available secondary and micro nutrients status in soil as influenced by conservation agriculture practices in finger millet+ pigeon pea intercropping (8:2)

Treatment	**Exchangable**		**Available**				
	Ca	**Mg**	**S**	**Zn**	**Mn**	**Fe**	**Cu**
	(meq/ 100g)		**(ppm)**				
TILLAGE							
M_1 :Conventional tillage	1.63	1.18	10.61	0.36	6.95	4.94	0.42
M_2 : Reduced tillage	1.62	1.10	9.59	0.32	6.50	4.50	0.37
M_3 :Zero tillage	1.52	1.02	9.55	0.35	6.57	4.42	0.35
S. Em. ±	**0.15**	**0.03**	**1.05**	**0.03**	**0.38**	**0.14**	**0.04**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
COVER CROPS							
C_1: Control	1.54	1.12	9.35	0.35	6.51	4.57	0.41
C_2: Field bean (HA-4)	1.58	1.08	9.52	0.33	6.51	4.64	0.35
C_3: Horse gram	1.64	1.10	10.89	0.36	7.00	4.65	0.38
S. Em. ±	**0.12**	**0.04**	**0.78**	**0.02**	**0.36**	**0.19**	**0.02**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
INTERACTION							
M_1C_1	1.64	1.27	10.87	0.33	6.14	4.61	0.46
M_1C_2	1.48	1.07	7.87	0.34	6.91	5.00	0.37
M_1C_3	1.77	1.20	13.10	0.41	7.79	5.22	0.43
M_2C_1	1.50	1.03	8.12	0.32	6.24	4.60	0.39
M_2C_2	1.85	1.13	11.38	0.30	6.11	4.48	0.35
M_2C_3	1.50	1.13	9.29	0.35	7.16	4.41	0.36
M_3C_1	1.47	1.07	9.06	0.40	7.16	4.50	0.37
M_3C_2	1.42	1.03	9.32	0.34	6.51	4.44	0.33
M_3C_3	1.67	0.97	10.29	0.32	6.05	4.33	0.34
S. Em. ±	**0.20**	**0.08**	**1.35**	**0.04**	**0.62**	**0.33**	**0.04**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

The available secondary and micronutrients were not significantly influenced by Different tillage practices and cover crops(Table 2).Similarly soil biological parameters(Table 3) *viz.*,dehydrogenase, acid phosphatase, alkaline phosphatase and urease enzyme activity were on par with each other in different tillage practices, cover crops and their interaction

Table 3: Soil biological parameters as influenced by conservation agriculture practices in finger millet+ pigeonpea intercropping (8:2)

Treatment	**Dehydrogenase (µg TPF/g per 24 hr)**	**Acid phosphatase µg PNP/g soil)**	**Alkaline phosphatase µg PNP/g soil)**	**Urease (µg NH_4/ g soil/hr)**
TILLAGE				
M1 :Conventional tillage	27.44	25.01	20.71	18.70
M2 : Reduced tillage	33.75	29.19	27.19	25.75
M3 :Zero tillage	27.31	25.65	21.15	19.31
S. Em. ±	**2.22**	**1.67**	**2.26**	**2.24**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**
COVER CROP				
C1: Control	28.45	24.72	22.45	20.45
C2: Field bean (HA-4)	28.67	26.55	21.80	19.93
C3: Horse gram	31.37	28.58	24.79	23.37
S. Em. ±	**2.03**	**1.35**	**1.87**	**2.00**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**
INTERACTIONS				
M1C1	24.43	21.23	18.43	16.43
M1C2	26.50	24.33	19.57	16.27
M1C3	31.40	29.46	24.13	23.40
M2C1	30.96	26.96	24.96	22.96
M2C2	34.76	29.08	27.08	26.76
M2C3	35.54	31.54	29.54	27.54
M3C1	29.97	25.97	23.97	21.97
M3C2	24.76	26.25	18.76	16.76
M3C3	27.19	24.73	20.71	19.19
S. Em. ±	**3.52**	**2.34**	**3.24**	**3.47**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**

3) GHG emissions

The data on GHG emissions in conservation agriculture revealed that CO_2, CH_4 and N_2O fluxes were influenced by tillage and anchored residue (residue levels 0, 30 60 cm). The CO_2, N_2O and CH_4 fluxes were measured using a vented insulated non steady state closed chamber technique. The CO_2 fluxes in different treatments ranged from 0.87 to 15.58 kg C $ha^{-1}hr^{-1}$. The cumulative CO_2 fluxes in a season ranged from 67 to 86 kg C ha^{-1} hr^{-1}. In conventional tillage, there was increase in CO_2 emissions for a period of four to five days but later it decreased. Similar increase in CO_2 emissions were observed in reduced tillage after land preparation with cultivator. Conventional tillage recorded higher CO_2 emissions in August, September, November, December and January during crop growing season of pigeon pea but in high rainfall months like June, July, October the CO_2 emissions were high in zero tillage. It was observed that when there is a continuous rainfall of high intensity, the CO_2 emissions were lower in conventional tillage as compared to zero tillage. The CH_4 and N_2O fluxes were also influenced by the tillage and residue levels. Methane absorption was observed in conventional tillage but methane emission was observed in zero tillage. Methane absorption was observed in all the tillage treatments in May, August, September, November, December and January but methane fluxes were observed in June, July and October. This may be due to high intense and also higher rainfall during these months. Higher N_2O fluxes were observed after fertilizer application. Cumulative seasonal N_2O fluxes were influenced by tillage and anchored residue heights. N_2O fluxes in conventional and reduced tillage were on par with each other but these two treatments recorded 20 % higher fluxes as compared to zero tillage. Higher CO_2 and N_2O fluxes were observed in 10 cm anchored residue height but CH_4 absorption was observed at 30 cm harvest height. The GHG fluxes were correlated with soil moisture content and soil temperature.

In pearl millet- horsegram system, significantly higher N_2O emission (g ha^{-1}) was observed in CT (544) followed by MT (509) and ZT during crop growing season .Higher N2O emission (g ha^{-1}) was observed in 125% RDF (576) followed by 100% RDF (442) and 75% RDF (362).

4). Effect of tillage and residue retention on microbial biomass carbon and carbon sequestration.

In pigeonpea-castor cropping system ZT recorded higher carbon sequestration rate in 0-7.5 cm, whereas at lower depths CT and RT recorded higher carbon sequestration rate. Carbon sequestration rate was negative in CT with 0 residues. Application of residues improved the organic carbon and carbon sequestration rate. In Sorghum-blackgram cropping system, after 4th year, it was observed that there was a significant influence of conservation tillage practices and residue retention treatments on carbon pools. In this study, labile and microbial biomass carbon in the soil varied from 331.62 to 358.16 mg kg^{-1} and 130.57 to 142.93 mg kg^{-1} respectively across the treatment combinations. Minimum tillage recorded significantly higher labile C contents (8.0%) compared to conventional tillage. Despite non significant values, the increase in MBC under minimum tillage was to the extent of 9.2% over conventional tillage. On an average, S1 and S2 residue retention treatments recorded higher contents of labile carbon viz., 8.6% and 19.4% respectively compared to no residue retention. The increase in microbial biomass carbon under S1 and S2 residue retention treatments over control was to the extent of 15.6 and 40% respectively.

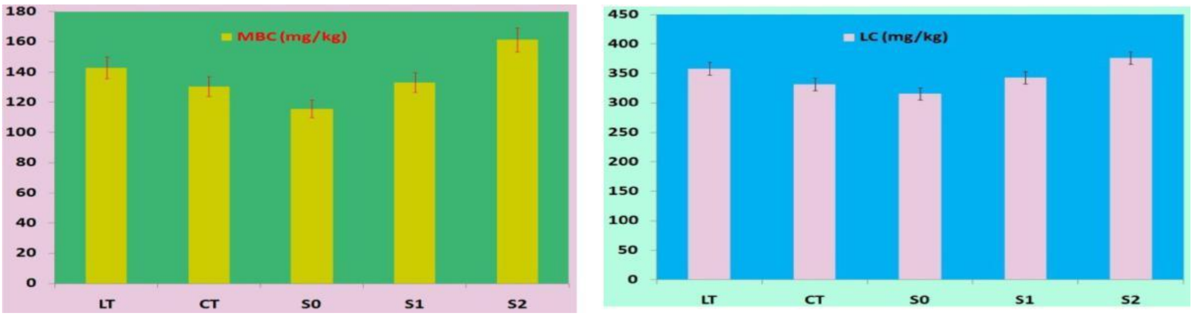


Fig1: Effect of tillage and residue retention on MBC and Labile carbon

4) Soil water and nutrient losses

In pigeonpea- castor system, the soil water nutrient losses were monitored using gauging devices. In 2017-18, the conventional tillage recorded higher soil and nutrient losses, and this was closely followed by minimum tillage.Whereas water loss was higher in Zero tillage. ZT recorded 20 % and 17 % lower soil and nutrient losses (NPK, OC) as compared to CT and RT, where as in 2016-17 ,the reduction in soil loss with zero tillage was 37 and 58 % over conventional tillage and reduced tillage. Reduction in soil loss was observed with addition of residues. 10 and 30 cm anchored residues recorded lower soil loss over 0 cm anchored residues.

In Pigeonpea – maize system, where the insitu moisture conservation treatments were integrated with conservation agriculture practices; lower soil and water loss were recorded in raised bed and conservation furrow under both CT and CA. The conservation furrow and raised bed reduced the water loss by 50 %. In CT with no residue, the runoff was 8 % of total rainfall.

6) Termite Infestation

Termite Infestation on crop residue is a major problem in rainfed alfisols. We have observed that the intensity of termite infestation differed with the type of the crop residue. Higher termite infestation was observed in maize crop residue as compared to pigeonpea and castor.

Maize residues

Pigeonpea residues

Castor residues

Fig 2: Infestation of termites on different crop residues

An experiment was conducted for the termite control at HRF with different crop residues (maize, pigeonpea, castor) with 3 treatments ie.,control, choripyriphos and cowdung. Better termite control was observed in cowdung application and chloripyriphos spary.

Control

Chloripyriphos

Application of cowdung

Fig 3: Termite Control in Maize

GHG emission and global warming potential (GWP) (IARI)

Aggregate–associated N and global warming potential

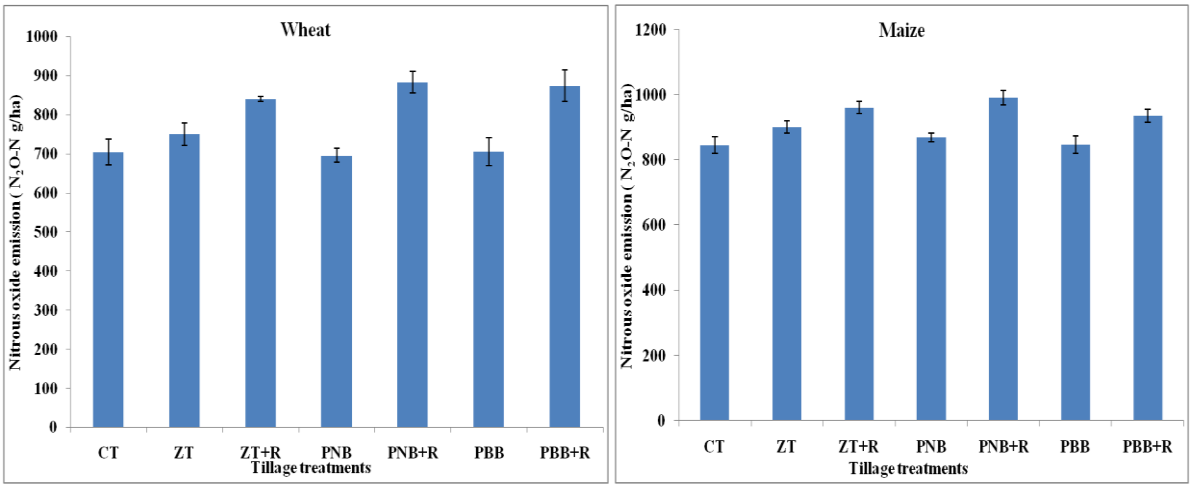
The soils under PBB+R had 37% and 9% more macro-aggregate-and micro-aggregate-associated N concentrations in topsoil (0-5 cm layer) than CT (248 and 299 kg N ha^{-1}) (Table 1). However, topsoil soil aggregation and aggregate-associated N contents of PNB+R and ZT+R were similar to CT plots. Similarly, PBB+R plots had significantly greater N concentrations and TSN stocks associated with 'silt + clay' fraction and micro-aggregates than CT in topsoil. In the 5-15 cm soil layer, an identical trend was observed. For instance, soils under PBB+R had 21% and 49% higher N concentration and TSN content associated with large macro-aggregates than CT. Overall, PBB+R and PBB plots had highest content and concentration of TSN associated with all four aggregate fractions in both layers.

Table 1. Effects of conservation agriculture on total soil N content within different soil size fractions after five years of maize-wheat cropping in the north-western Indo-Gangetic Plains

Treatments	Aggregate - associated total soil N (kg N ha^{-1}) in the 0-5 cm layer				Aggregate - associated total soil N (kg N ha^{-1}) in the 5-15 cm layer			
	Large macro aggregate-associated N	Small macro aggregate-associated N	Micro aggregate-associated N	Silt + clay associated N	Large Macro aggregate-associated N	Small macro aggregate-associated N	Micro aggregate-associated N	Silt + clay associated N
CT	29.3b	218.4c	299.0ab	109.4b	28.6c	479.6b	503.4a	178.4c
PNB	42.9ab	259.5bc	265.8b	119.9ab	40.6bc	534.1ab	445.6b	184.0bc
PNB+R	37.9b	264.5bc	280.7b	123.5ab	44.8ab	672.8a	415.8b	209.0b
PBB	43.6ab	302.3ab	329.0a	128.3a	47.1ab	523.0ab	331.0c	245.4a
PBB+R	52.9a	341.5a	290.1b	128.6a	56.9a	600.2ab	410.8b	223.7ab
ZT	30.0b	278.0b	280.7b	111.4b	35.2bc	627.6ab	403.6b	203.8b
ZT+R	36.6b	258.1bc	292.0b	119.3ab	35.9bc	646.9ab	405.7b	188.2bc
F-value	7.70	10.20	5.18	4.12	9.93	4.05	7.48	8.72

CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.

In maize, soils under PNB+R had 6% more N_2O emission than PBB+R (Figure 1). Minimum emission was observed in soils under CT, which was ~17% less than PNB+R. In the wheat crop, soils with PNB+R had highest N_2O emission (883 g ha^{-1}), which was followed by PBB+R and ZT+R. However, soils under CT had~25 and 24% lower than PNB+R and PBB+R, respectively. Thus, in the maize–wheat cropping system, N_2O emission was~21% and ~17% higher in soils with PNB+R and PBB+R, respectively, than CT. The N_2O fluxes following each split application of mineral fertilization were significantly higher in soils under ZT than CT. The temporal variation of N_2O emission data revealed that for both crops, residue retained plots had higher emission than residue removal plots. Increased N_2O emissions have been linked to increased denitrification under reduced tillage due to the formation of micro-aggregates within macro-aggregates that create anaerobic micro sites with increased microbial activity leading to greater competition for oxygen. Soils under ZT generally remained enriched with moisture and organic matter (OM).



CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.
Bars with similar lowercase letters are not significantly different at P<0.05 according to Tukey's HSD test

Fig. 1. Effect of conservation agriculture on cumulative emission of nitrous oxide in (A) maize under a maize-wheat cropping system and (B) wheat under maize-wheat cropping systems

In the maize–wheat system, highest N_2O emission was observed in PNB+R plots and least in CT plots (Fig. 2). But, PBB+R and PNB+R plots had similar CO_2 emissions to CT plots in both crops. Despite GWP of ZT+R and PBB+R plots in the maize-wheat system were ~5% higher than CT, greenhouse gas (GHG) intensities in the CT, PBB+R and ZT+R plots were similar. Thus, PBB+R practice is a better management alternative for soil N improvement (and a reduced fertilizer N dose could be adopted in future) than CT since this practice also had 36% higher stover productivity of maize and 8.2% higher straw productivity of wheat in five years in the maize-wheat cropping system and similar GHG intensity to CT plots.

In the fifth year the GWP of PBB+R treatment was 5% higher than that of CT plot among different practices adopted in the maize-wheat cropping system (Table 2). Residue retention significantly increased GWP and amount of C emission over residue removal plots. For instance, the PBB+R treatments had 12 and 13% greater GWP and CO_2 emission, respectively than the PBB treatment. But, this treatment had 23% higher crop yields than the CT treatment. As a result, the GHG intensity of PBB+R plot was similar to CT and ZT+R plots. We did not observe any significant change in GWP between the PNB and PBB plots. The GWP was lower in all the ZT plots without residue (ZT, PNB and PBB). These practices involving only ZT, but not residue retention, result in less crop productivities than their corresponding residue-retained treatments, and, hence are not sustainable.
There was increased N_2O emission but reduced CO_2 emission between the ZT and CT plots leading to GWP values that were comparable in both treatments. Among different practices, CT plots resulted in highest GHG intensity (0.255 kg CO_2 kg^{-1} grain). The PBB+R treatment had significantly lower GHG intensity (0.20-0.23 kg CO_2 kg^{-1} grain) than others. The higher GHG intensity values in CT plots indicated that higher GHG emissions were produced per kg of grain yield. The good impacts of both ZT and residue retention confirmed that CA had higher C fixation. Improved soil properties (greater aggregation and organic matter content) could lead to a higher C output in plots under resource conservation practices, apart from

PNB. Thus, the ZT and residue retention significantly decreased GHG intensity compared to CT in this region.

Table 2. Effects of conservation agriculture on cumulative seasonal nitrous oxide and carbon dioxide emissions during whole year of maize-wheat, global warming potential and greenhouse gas (GHG) intensity

Treatments	Maize N_2O-N g/ha	Wheat N_2O-N g/ha	Maize CO_2 kg/ha	Wheat CO_2 kg/ha	GWP kg CO_2 equivalent	GHG intensity (kg CO_2 equivalent kg^{-1} grain yield of maize and wheat)
CT	846[e]	705[bc]	792[bcd]	772[ab]	2320[b]	0.255[a]
ZT	901[cd]	751[b]	731[e]	719[bcd]	2255[b]	0.210[bc]
ZT+R	961[ab]	841[a]	802[abc]	800[a]	2480[a]	0.220[ab]
PNB	869[de]	696[c]	761[cde]	693[cd]	2217[c]	0.239[ab]
PNB+R	992[a]	883[a]	837[a]	751[abc]	2502[a]	0.232[b]
PBB	847[e]	706[bc]	734[e]	682[d]	2172[c]	0.202[c]
PBB+R	935[bc]	875[a]	816[ab]	747[abc]	2444[a]	0.219[ab]

F-ratio and level of significance for Greenhouse gas emissions

	Maize N_2O-N	Wheat N_2O-N	Maize CO_2	Wheat CO_2	GWP of System
Treatments	3.38*	8.27***	4.45**	3.57*	10.17***

Level of significance: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.
CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.

Means followed by similar letters within a column for management practices are not significantly different at P<0.05 according to Tukey's HSD.

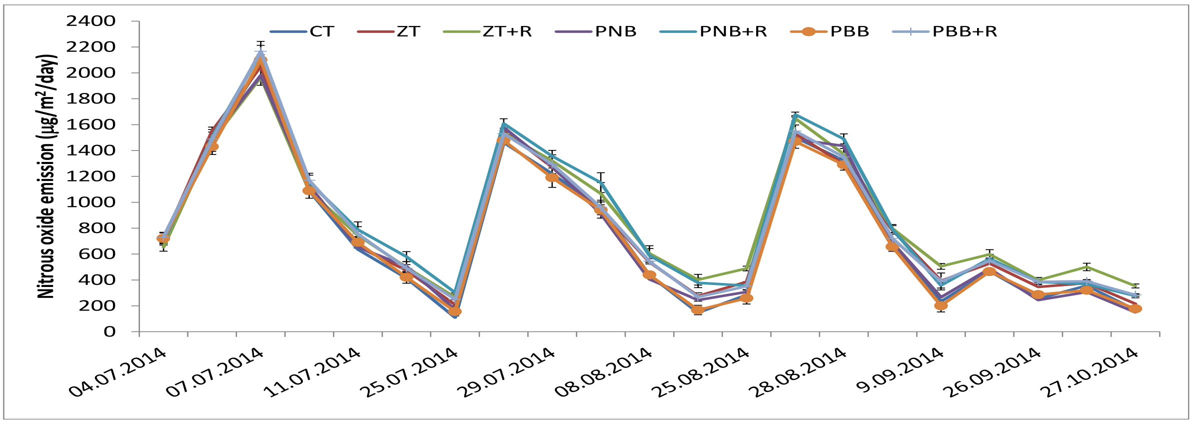
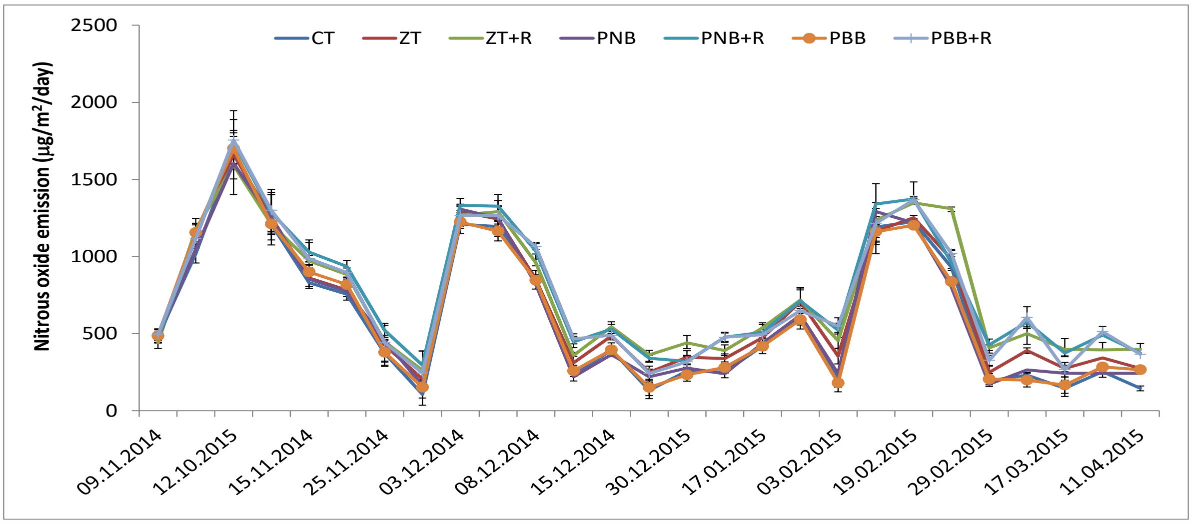


Fig. 2: Effect of conservation agriculture on temporal emission of nitrous oxide in maize under maize - wheat cropping system (including fallow period).

CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.

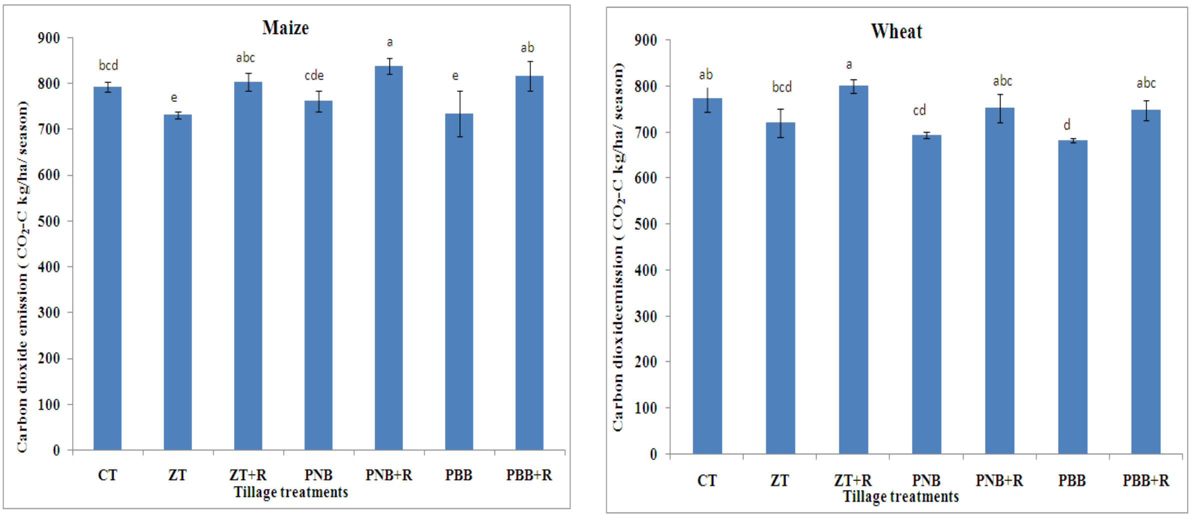
Error bars indicate standard deviations.



CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.
Error bars indicate standard deviations.

CO_2 emission

The CO_2 emission was significantly lower in the ZT plots than CT in both crops. Furthermore, the CO_2 emission was significantly higher under all residue retained plots in both crops. Highest CO_2 emissions were observed in PNB+R plots. However,both PNB+R and PBB+R treatments had similar CO_2 emissions (Figures 3). Tillage can increase emissions by mechanically breaking down soil aggregates, thereby releasing protected soil C and increasing CO_2 emissions. Higher CO_2 emission in residue retained plots might be due to the more SOC availability under residue treated plots than plots under CT. However, observed that chopped residues augmented C storage in 0-30cm soil depth layer, no matter what the tillage regime was. This improved C storage was mainly due to decreased soil CO_2 fluxes and increased conversion of C from organic residues into soil microbial biomass. The CO_2 emission in PNB+R plots was higher than CT plots in the maize crop (Figure 3A). However, in the wheat crop, soils under PNB+R had less CO_2 emission compared with CT (Figure 29B). Temperature and soil water content are the key factors that are best correlated to CO_2 emissions and microbial activity. In a semi-arid area soil water contents and temperature fluctuate widely, thereby affecting microbial activity. It can be concluded that crop residue decomposition increased CO_2 emissions in plots with residues. Again, ZT plots had more organic C than CT plots and additive effects of both processes were such that CA (ZT and residue retention) had no overall impacts on CO_2 emission.



CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.
Bars with similar lowercase letters are not significantly different at $P<0.05$ according to Tukey's HSD test.

Fig. 3. Impact of conservation agriculture on carbon-di- oxide emission in maize (A) and wheat (B) under a maize-wheat cropping system.

Global warming potential (GWP) and greenhouse gas (GHG) intensity

It was observed that in the fifth year the GWP of PBB+R treatment was 5% higher than that of CT plot among different practices adopted in the maize-wheat cropping system (Table 8). Residue retention significantly increased GWP and amount of C emission over residue removal plots. For instance, the PBB+R treatments had 12 and 13% greater GWP and CO_2 emission, respectively than the PBB treatment. But, this treatment had 23% higher crop yields than the CT treatment [grain and straw yields are reported in Das et al. (2018); five-year total stover/straw biomass yield. As a result, the GHG intensity of PBB+R plot was similar to CT and ZT+R plots. We did not observe any significant change in GWP between the PNB and PBB plots. The GWP was lower in all the ZT plots without residue (ZT, PNB and PBB). These practices involving only ZT, but not residue retention, result in less crop productivities than their corresponding residue-retained treatments, and, hence are not sustainable.

There was increased N_2O emission but reduced CO_2 emission between the ZT and CT plots leading to GWP values that were comparable in both treatments. Therefore, long-term studies are better in depicting the GHGs emission rates. They found that tillage had no significant effect on CO_2 emissions.

Among different practices, CT plots resulted in highest GHG intensity (0.255 kg CO_2 kg^{-1} grain). The PBB+R treatment had significantly lower GHG intensity (0.20-0.23 kg CO_2 kg^{-1} grain) than others. The higher GHG intensity values in CT plots indicated that higher GHG emissions were produced per kg of grain yield. The good impacts of both ZT and residue retention confirmed that CA had higher C fixation. Improved soil properties (greater aggregation and organic matter content) could lead to a higher C output in plots under resource conservation practices, apart from PNB.

Greenhouse gas emissions in rice-wheat-mungbean system

Measurement of methane, nitrous oxide and carbon dioxide emissions were carried out in rice-wheat-mungbean system under different tillage practice, residue retention, brown manuring and two levels of fertilizer application. The global warming potential was calculated and then the treatments were compared on the basis of the greenhouse gas intensity (GHGi), which is the carbon dioxide equivalent emission per unit grain yield. The lowest GHGi was observed under the triple zero-till system with 75% N application followed by 100% N application. The highest GHGi was observed in ZTDSR with brown manuring due to higher N2O emissions. (Figure 4)

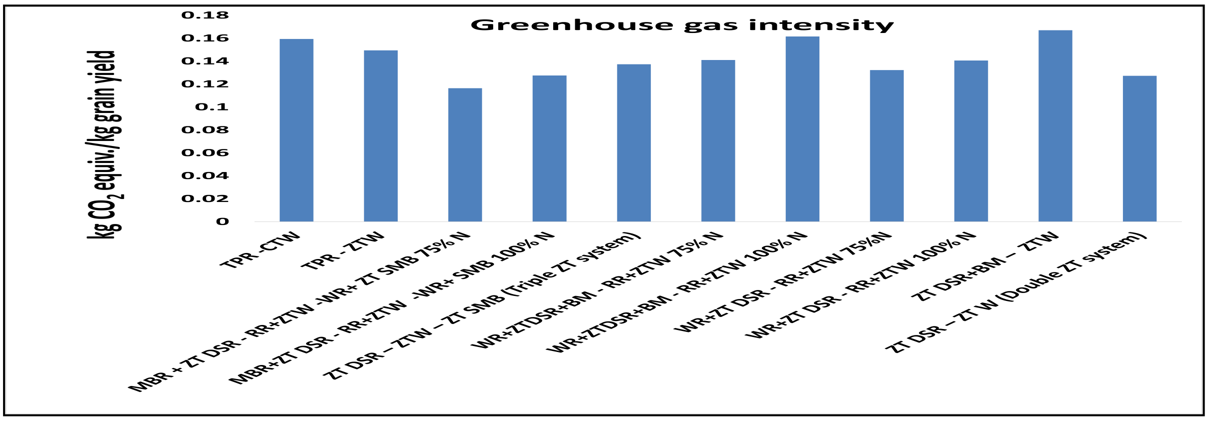


Fig. 4: Greenhouse gas intensity under various cropping system

2.1.2.3 Soil Biological Activity

Quantification of soil biological parameters in rice-mustard system (IARI)

To study the biological quality of soil under conservation agriculture with rice-mustard cropping system, soil samples were collected from conservation agriculture experiment at ICAR-Indian Agricultural Research Institute (IARI) farm after 6 years of rice-mustard cropping system from eight treatments viz. zero tillage direct seeded rice (ZTDSR)-zero tillage mustard (ZTM), zero tillage direct seeded rice (ZTDSR) + brown manuring (BM) -zero tillage mustard (ZTM), mustard residues (MR)+ZTDSR –rice residues (RR)+ZTM, MR+ZTDSR+BM+RR-ZTM, mungbean residues (MBR)+ZTDSR-ZTM-zero tillage summer mungbean (ZTSMB), MBR+ZTDSR-RR+ZTM-MR+ZTSMB, transplanted rice (TPR)-ZTM and TPR- conventional tillage mustard (CTM) at different stages of crop growth. Soil samples were analyzed for different biological attributes of soil quality *viz.* microbial biomass carbon, dehydrogenase, acid and alkaline phosphatase and aryl sulphatase activity of soil. Results showed that dehydrogenase activity after harvesting of rice was highest with MBR+ZTDSR-ZTM+RR-ZTSMB treatment (320 µg TPF g^{-1} soil $24h^{-1}$) and lowest was with TPR-CTM treatment (213 µg TPF g^{-1} soil $24h^{-1}$) (Fig.1 and 2). It was found that the treatment MBR+ZTDSR-ZTM+RR-ZTMB with three zero tillage and mung bean & rice residues showed highest microbial biomass carbon and enzyme activity irrespective of growth stage.

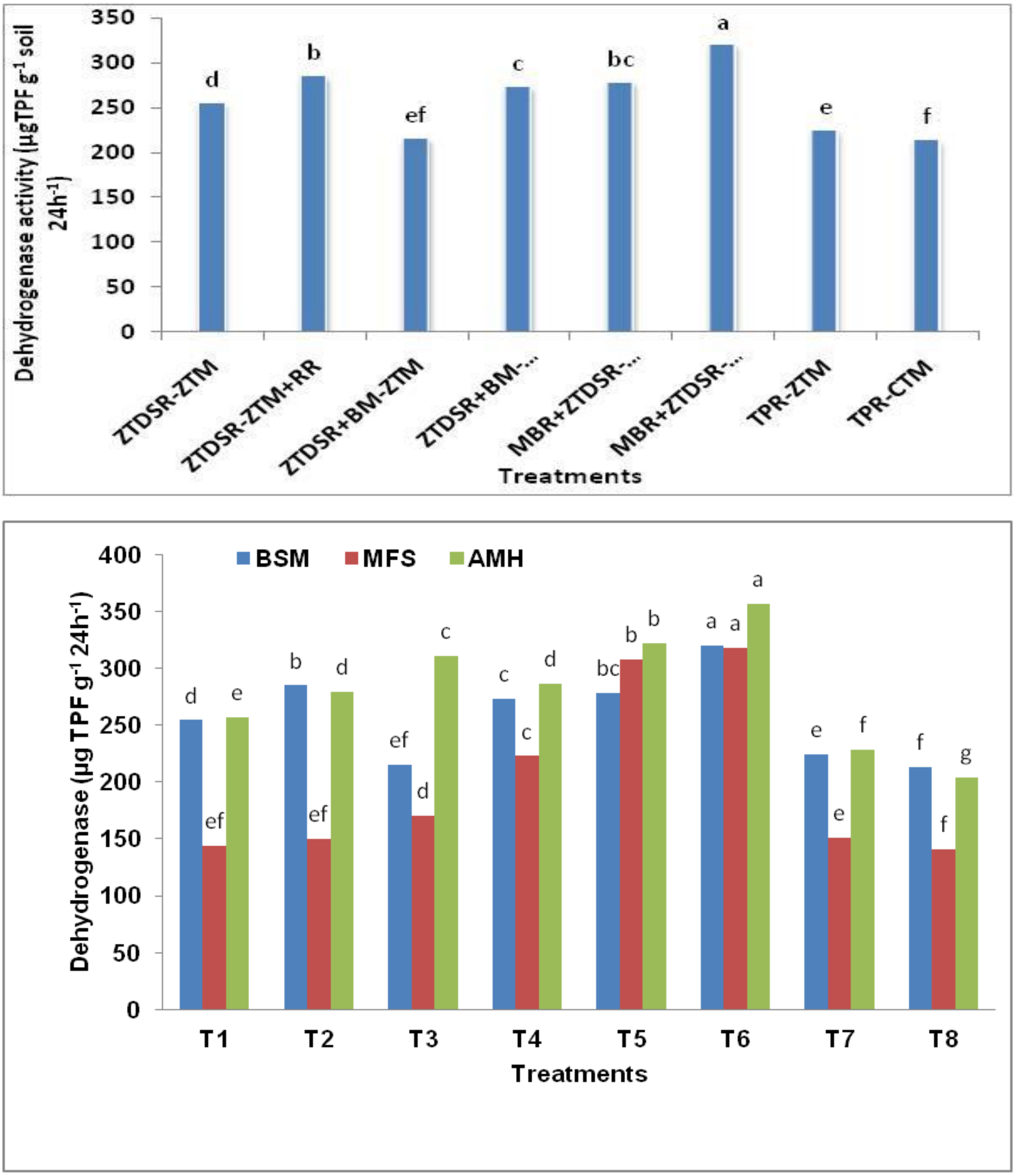
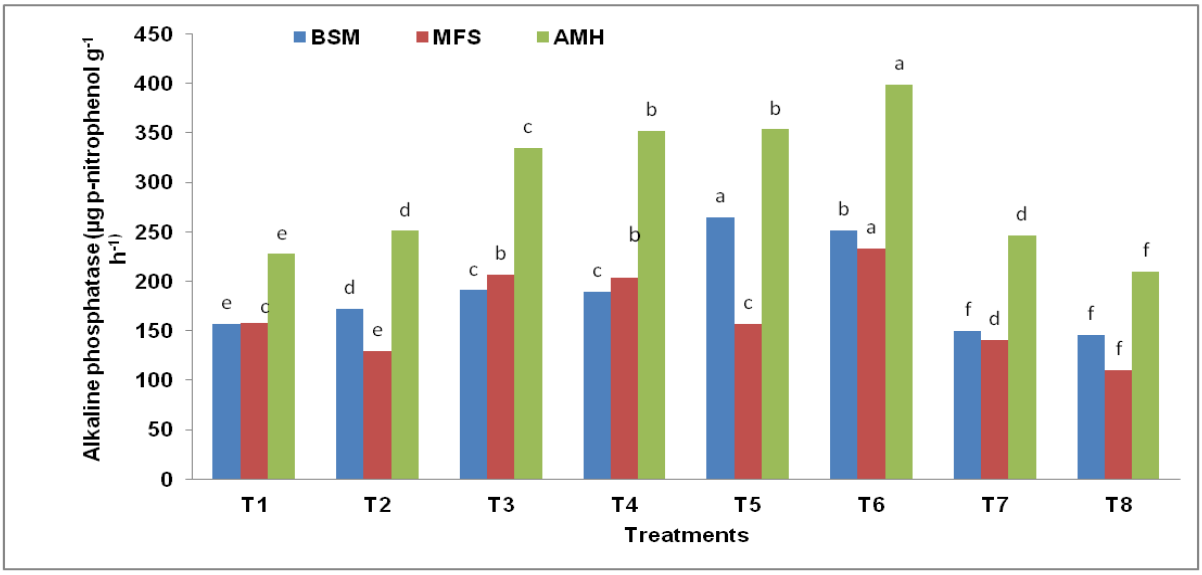


Fig.1. Dehydrogenase activity (ug TPF g^{-1} 24 h^{-1}) in rice

T1: ZTDSR-ZTM, T2: ZTDSR-ZTM+RR, T3: ZTDSR+BM-ZTM, T4: ZTDSR+BM-ZTM+RR, T5: MBR+ZTDSR-ZTM-ZTMB, T6: MBR+ZTDSR-ZTM+RR-ZTMB, T7: TPR-ZTM, T8: TPR-CTM BSM: before sowing of mustard, MFS: mustard flowering stage, AMH: after mustard harvest

Fig. 2: Dehydrogenase activity (ug TPF g^{-1} 24 h^{-1}) at different crop growth stages



T1: ZTDSR-ZTM, T2: ZTDSR-ZTM+RR, T3: ZTDSR+BM-ZTM, T4: ZTDSR+BM-ZTM+RR, T5: MBR+ZTDSR-ZTM-ZTMB, T6: MBR+ZTDSR-ZTM+RR-ZTMB, T7: TPR-ZTM, T8: TPR-CTM BSM: before sowing of mustard, MFS: mustard flowering stage, AMH: after mustard harvest

Fig. 3: Alkaline phosphatase activity (ug p-nitrophenol g^{-1} h^{-1}) at different crop growth stages

5.2: Soil enzyme activities and plant available nitrogen in soil

The treatment MBR+ZTDSR-ZTM+RR-ZTMB with zero tillage and mung bean and rice residues showed highest enzyme activity irrespective of growth stage. All the enzyme activity was lowest at mustard flowering stage than before sowing and after harvesting of mustard.

The PBB+R treatment resulted in ~44 and 66% higher DHA and FDA in the topsoil (0-5 cm) than CT **(Table 1)**. Similarly, in 5-15 cm soil depth/layer, it contained~36 and 100% higher DHA and FDA than CT. However, CA had no impacts on MBN in both soil layers. Residue retention under ZT and PNB plots significantly affected DHA in the topsoil compared to residue removal plots, but not for PBB+R versus PBB **(Table 1)**.

However, in case of FDA activity, a completely reverse trend was observed in topsoil. There were no differences in both enzyme activities in both soil layers among CA practices. In general, residue retention had significant impacts on NO_3-N and NH_4-N in both soil layers (**Table 2**). Ammonium-N and NO_3-N concentrations in both soil layers were higher in soils under all CA plots (PBB+R, PNB+R and ZT+R) than CT.

As soils were sampled during growth period of the wheat crop, the topsoil enzyme activities and topsoil microbial biomass N data were correlated with emissions of GHG during wheat. Results indicated that topsoil dehydrogenase activity was significantly correlated ($r = 0.426$, $n = 21$, $p<0.05$) with CO_2 emission and with N_2O emission($r = 0.770$, $n = 21$, $P<0.01$) during wheat (2014-15). However, topsoil (0-5 cm depth) FDA activity was only significantly correlated ($r = 0.616$, $n = 21$, $p<0.01$) with N_2O emission. Similarly, topsoil MBN concentration was not correlated with CO_2 emission, but with N_2O emission ($r = 0.485$, $n = 21$, $P<0.01$).The increased NO_3-N and NH_4-N data in the CA plots revealed faster turnover of aggregate-N in the CA plots than the CT or ZT plots. The faster mineralization of the immobilized N might have also contributed to higher plant available N under CA compared with CT/ZT plots.

The topsoil NO_3-N and NH_4-N concentrations were also correlated with N_2O emission during wheat. Results indicated that NO_3-N was significantly correlated ($r = 0.807$, $n = 21$, $p<0.01$) with N_2O emission and NH_4-N was also positively correlated ($r = 0.768$, $n = 21$, $P<0.01$) with N_2O emission during wheat. The results of the present research indicated that unlike CT, the CA practices increased oxidative and reductive capacity of soil with residue retention, causing increased release of plant available N.

The increased N turnover also increased N_2O emission from the CA plots due to the constant coupled nitrification-denitrification processes. Higher surface DHA and FDA resulting from CA practices might have occurred owing to OM accumulation through crop residues that could increase microbial activity in soil. Dehydrogenase activity and FDA exist as an essential part of soil microbial life. It is worth noting that crop residues and ZT were more favorable to the overall biological activity of the soil compared to CT practice. In the present research, CA plots brought about a significantly higher soil DHA and FDA than CT.

Table 1. Effect of conservation agricultural practices on selected soil enzyme activities and microbial biomass nitrogen after five years of maize-wheat cropping

Treatments	Dehydrogenase activity* (ug TPF g^{-1} 24 h^{-1})		FDA activity (µg fluorescein $g^{-1}hr^{-1}$)		Microbial biomass N (mg kg^{-1})	
	0-5 cm	5-15 cm	0-5 cm	5-15 cm	0-5 cm	5-15 cm
CT	14.2c	13.3b	181.7c	125.2c	90.8a	77.8a
PNB	15.1bc	13.3b	243.4b	216.7ab	111.5a	88.2a
PNB+R	20.9a	16.4ab	272.1ab	217.7ab	132.5a	111.5a
PBB	16.7bc	14.1b	251.2b	205.2b	108.9a	98.5a
PBB+R	20.4ab	18.0a	301.4a	250.1a	145.2a	119.3a
ZT	17.2bc	13.6b	237.6b	175.9b	121.9a	95.9a
ZT+R	21.7a	14.6ab	272.1ab	215.6ab	137.4a	103.7a
F-value	9.80	5.73	20.44	18.86	2.23	1.65

CT = Conventional tillage; PNB = Zero tillage (ZT) with planting on permanent narrow beds; PNB+R = PNB with residue retention; PBB = ZT with planting on permanent broad beds; PBB+R = PBB with residue retention; ZT = Zero tillage; ZT+R = ZT with residue retention.
Means followed by similar letters within a column for management practices are not significantly different at P<0.05 according to Tukey's HSD.

Table 2. Effect of conservation agricultural practices on nitrate and ammonium after five years of maize-wheat cropping in the north-western Indo-Gangetic Plains

Treatments	NO_3-N (mg kg^{-1} soil)		NH_4-N (mg kg^{-1} soil)	
	0-5 cm	5-15 cm	0-5 cm	5-15 cm
CT	25.6c	37.6c	9.5b	3.5c
PNB	28.3c	39.9abc	11.1b	4.8bc
PNB+R	35.7ab	44.9ab	16.3a	6.5b
PBB	25.8c	37.8c	10.5b	5.0bc
PBB+R	41.3a	46.1a	19.3a	12.4a
ZT	29.8bc	38.8bc	10.2b	6.6b
ZT+R	37.9a	43.2abc	16.3a	10.6a
F-value	20.87	6.66	14.72	43.99

Quantification of Carbon Sequestration, Green House Gas Emissions (NO_2 and CO_2) and Soil Quality Changes under the Practice of Conservation Agriculture(IISS)

The deteriorating soil health coupled with production fatigue poses a great threat to Indian agriculture. A long term (10 years) resource conservation experiment was evaluated for changes in soil chemical and biological properties under rice-wheat cropping system. Soil samples were collected from ongoing long-term experiment on resource conservation technology conducted at CSSRI, Karnal. All together 10 treatment combinations comprising of conventional, reduced and no tillage were evaluated with and without residue for changes in soil pH, organic carbon, water soluble carbon, available phosphorus and potassium and dehydrogeanse activity in 0-5 and 5-15 cm of soil depths.

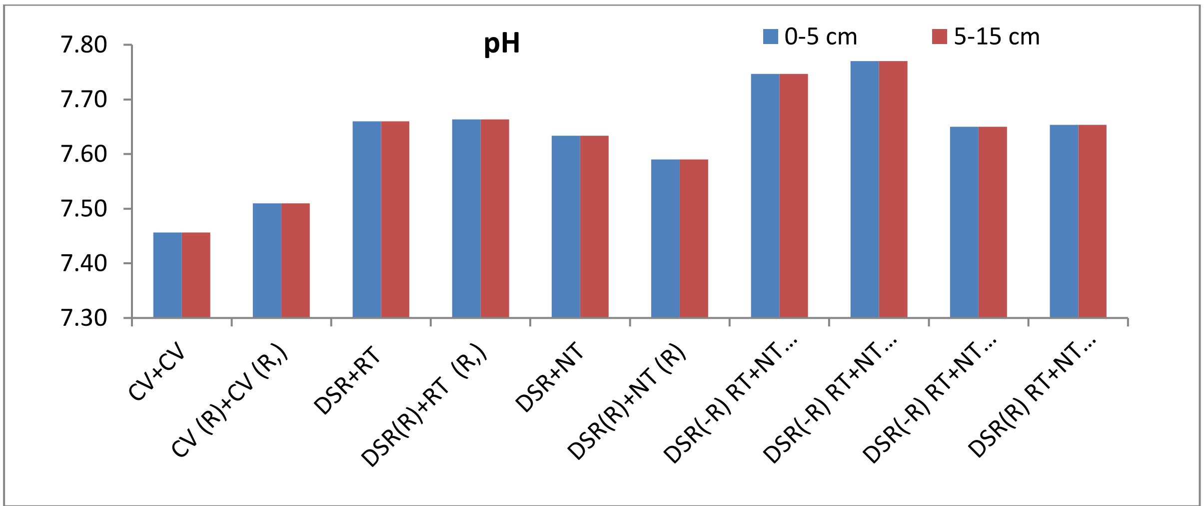


Fig 1. Effect of different resource conservation measures on changes in soil pH

It was observed that soil pH was significantly affected by different treatments. Lowest soil pH of 7.46 was recorded under the treatment of conventionally tilled rice and wheat plot. It was followed by treatment T_2 (7.51) where 1/3rd of rice and wheat residues were incorporated along with conventional tillage. Adoption of direct seeding of rice and reduced tillage or zero tillage in wheat resulted in increase in soil pH. Highest pH of 7.77 and 7.75 was recorded under the treatment of T_7 (direct seeded rice without wheat residue retention and no tilled wheat with 100% rice residue retention along with drip irrigation) and T_8 (direct seeded rice without wheat residue retention and no tilled wheat with 100% rice residue retention along with surface irrigation), respectively (Fig 1). It could be concluded that retention of residue on soil surface in general led to the increase in soil pH whereas incorporation resulted in decrease in soil pH

Highest concentration of soil organic carbon (8.8 g/kg) was recorded in 0-5 cm of soil depth in treatments of zero tilled rice (direct seeded) and wheat plots which retained of 1/3rd residue of the previous crop. However, it fails to improve soil carbon concentration (5.4 g/kg) in 5-15 cm of depth. Direct seeded rice without wheat residue in reduced tillage followed by zero tilled wheat with entire rice residue retention maintained higher concentration of soil organic carbon (7.6 g/kg) in both 0-5 and 5-15 cm of soil depths (Fig 2.).

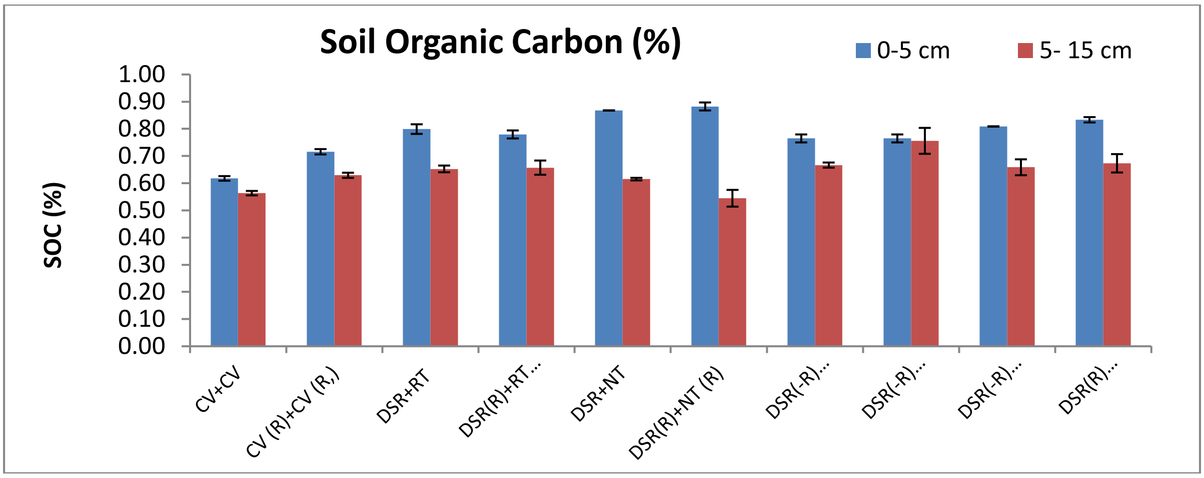


Fig 2. Effect of resource conservation measures on concentration of soil organic carbon (%)

However, the trend for water soluble carbon was different. It was observed maximum (107.5 mg/kg) under the treatment of conventional rice transplanting after wheat residue incorporation (1/3) followed by conventional wheat sowing after 1/3rd of rice residue incorporation. This treatment was found to be at par with the treatment of direct seeded rice without wheat residue in reduced tillage followed by zero tilled wheat with entire rice residue retention. In all the treatments water soluble carbon was higher in 0-5 cm of soil depth in comparison to 5-15 cm of soil depth. However, in treatments of zero tilled rice and wheat plots, concentration of water soluble carbon was higher (75 mg/kg) in 5-15 cm of soil depth in comparison to 0-5 cm of soil depth (45 mg/kg) (Fig 3).

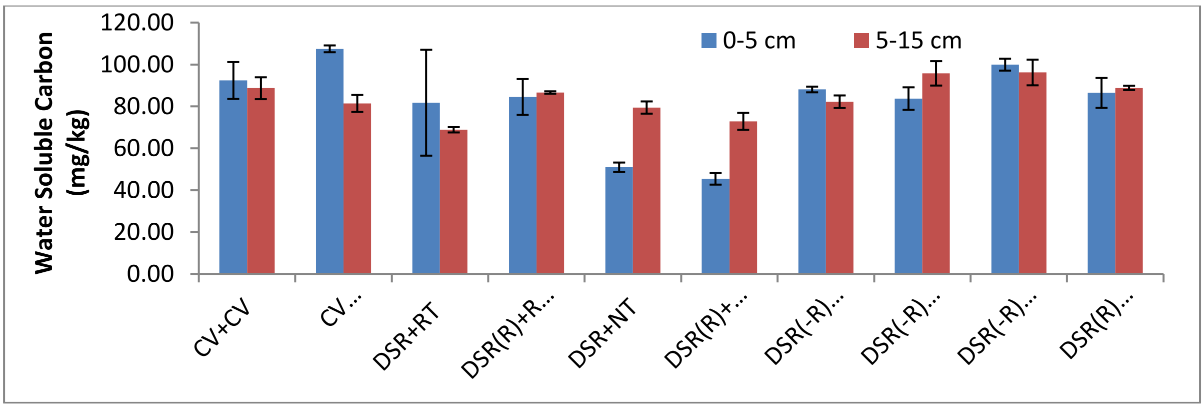


Fig 3. Effect of resource conservation measures on concentration of water soluble carbon (mg/kg)

The trend for ammonium acetate extractable potassium was found similar to water soluble carbon. In general available potassium was higher in plots receiving higher input of residues. Here also, treatments of zero tilled rice and wheat failed to maintain higher level of potassium (240 kg/ha) in soil. It was observed that conventional tilled rice and wheat plots with 1/3 rd of residue incorporation (both rice and wheat) maintained higher concentration of exchangeable potassium (333 kg/ha) in soil. Treatments of direct seeded rice without wheat residue in reduced tillage followed by zero tilled wheat with entire rice residue retention also maintained higher level of potassium in soil (Fig 4.).

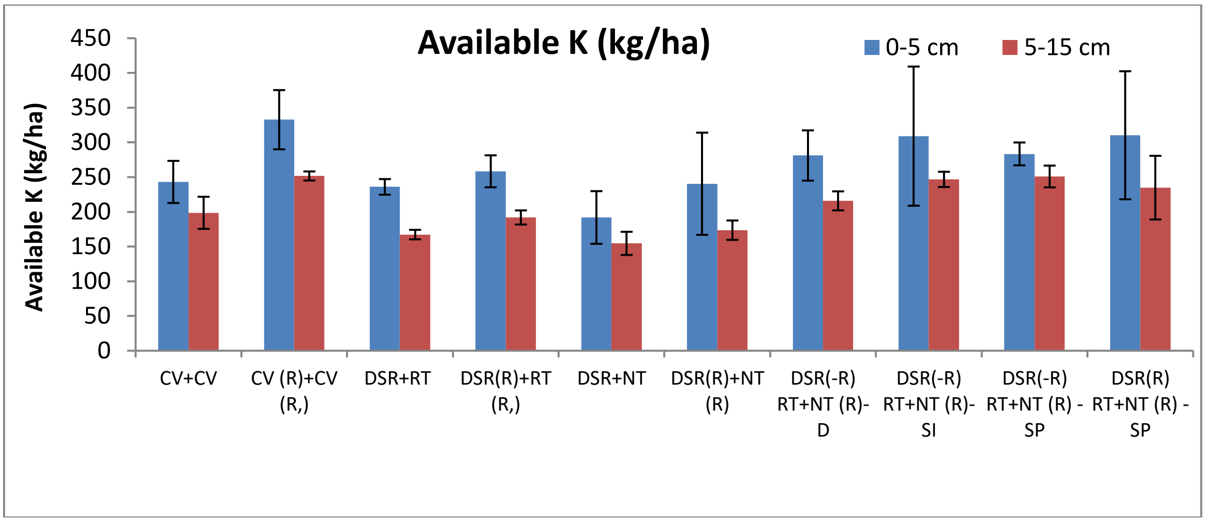


Fig 4. Effect of resource conservation measures on concentration of water soluble carbon (mg/kg)

In case of available phosphorus, conventionally tilled plot along with 1/3 rd of residue incorporation maintained maximum concentration in 0-5 cm of soil depth. It was observed that plots where residues were either retained or incorporated, significantly improved status of available P in soil. Dehydrogenase activity also followed the same trend. It was significantly higher (152 µg TPF/g soil/day**)** in treatment of conventionally tilled plot along with 1/3 rd of residues incorporation. This was followed by treatment of direct seeded rice without wheat residue in reduced tillage followed by zero tilled wheat with entire rice residue retention (Fig 5.). It could be inferred from the present work that soil health could be maintained or improved by any practice which facilitate retention or incorporation of residues irrespective of tillage practice.

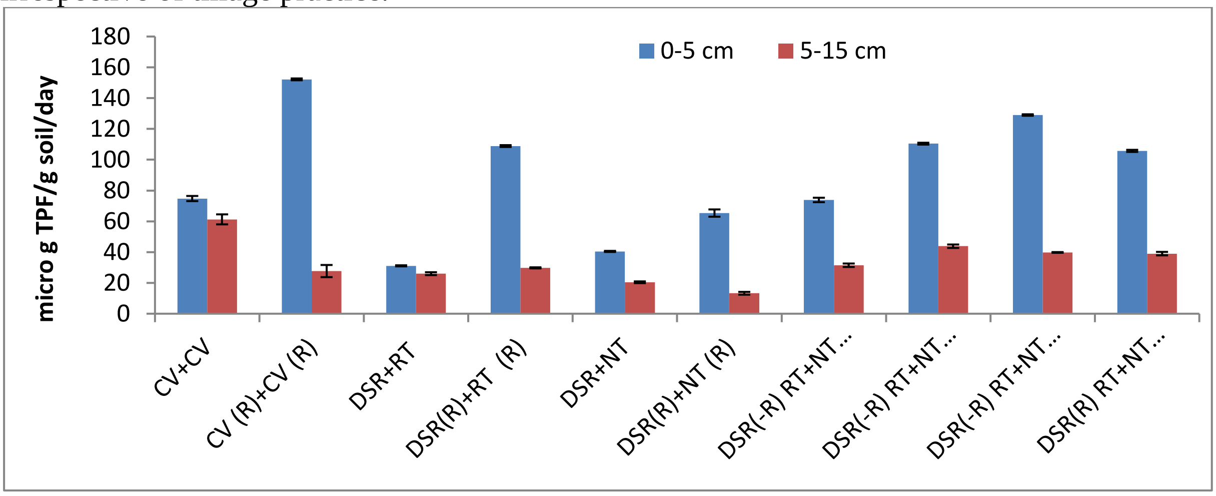


Fig 5. Effect of resource conservation measures on dehydrogenase activity in soil

Fluorescein diacetate (FDA) hydrolysis assays can be used to measure enzyme activity produced by microbes in a sample. A bright yellow glow is produced and is strongest when enzymatic activity is greatest. Fluorescein diacetate activity was found maximum (77.52 µ g/g of soil) in treatment (T_{10}) of DSR with wheat residue (33%) incorporation in reduced tillage followed by wheat in zero tillage with rice residue retention (100%) (Fig 6). In treatment of (T_2) of Conventional rice transplanting after wheat residue incorporation followed by wheat sowing after rice residue incorporation (33%) recorded higher FDA activity in sub-soil (5-15 cm) in comparison to surface soil (0-5 cm).Similar trend was recorded in T_1 where conventional rice transplanting and wheat sowing was done. FDA activity was found lower in treatment of direct seeded rice and zero tillage in wheat with and without residue retention.

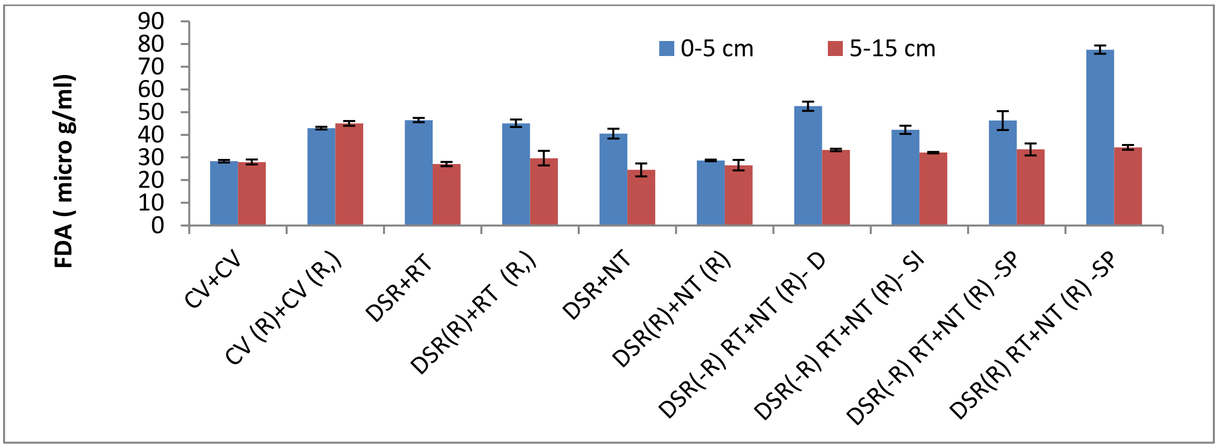


Fig 6. Effect of resource conservation measures on FDA activity in soil

Role of weedicides in conservation agriculture (CA) on N_2O production is less understood. Experiments were carried out to evaluate N_2O production from soybean and maize cropping system under zero tillage (Fig 6). The treatments were none (hand weeding), pre emergence weedicide (pendimethalin 1 kg ha^{-1}) and post emergence weedicide (imazethapyr 0.1 kg ha^{-1} for soybean, atrazine 1 kg ha^{-1} for maize) applications. Soil samples were collected from 0-10 cm, 10-20 cm, and 20-30 cm depths and were incubated at 60% moisture holding capacity (MHC) and 100% MHC. N_2O production, abundance of eubacterial 16S rRNA gene, nitrifying bacterial amoA gene, and nitrifying archaeal amoA genes were estimated. N_2O production, and microbial gene abundance were high in maize than soybean. N_2O production decreased with soil depth. N_2O production started immediately after incubation, this reflected active nitrification in the field soils. N_2O production peaked during 10-15 days and then stabilized. This trend of N_2O production was due to log phase and stationary phase of microbial growth. Potential N_2O production was high in maize than soybean. Probably this was due to high level of N fertilizer amendment to maize than soybean Abundance of eubacteria and nitrifying bacteria were high at the top (0-10 cm) soil and declined with depth. Contrastingly, the nitrifying archaeal gene abundance increased with soil depth. Study highlighted that weedicides in conservation agriculture may enhance N_2O production and the associated microbial population. Microbial abundance was in the range of 0.15 x 10^7 g^{-1} soil to 3.10 x 10^7 g^{-1} soil. Similarly, in maize bacterial gene abundance of eubacteria, ammonia oxidizing bacteria and ammonia oxidizing archaea were estimated from the soil samples in terms of number of gene copies g^{-1} soil Abundance of eubacteria and ammonia oxidizing bacteria was high in 0-10 cm and low in sub-soils (10-20 cm and 20-30 cm). In soybean the eubacterial gene copies abundance ranged from 1.25 x 10^7 g^{-1} soil to 7.83 x 10^7 g^{-1} soil. Ammonia oxidizing bacterial gene copies varied from 0.07 x 10^5 g^{-1} soil to 7.37 x 10^5 g^{-1} soil in soybean. In maize nitrifying bacterial gene abundance varied from 0.22 x 10^5 g^{-1} soil to 25 x 10^5 g^{-1} soil. Contrastingly, ammonia oxidizing archaeal gene abundance increased with soil depth, and weedicide application. Gene abundance of archaea was high in maize than soybean. Archaeal gene abundance varied from 0.57 x 10^4 g^{-1} soil to 9.27 x 10^4 g^{-1} soil. Abundance of microbial gene copies followed as post emergence.> pre emergence> hand weeding. Study suggested that weedicide application enhanced nitrification and N_2O production by stimulating nitrifiers population. When soils were incubated at 100% moisture holding capacity, N_2O production was mostly carried out by nitrifying archaea (fig 8.). Intensive use of weedicides in no till conservation agriculture may stimulate nitrification and N_2O production.

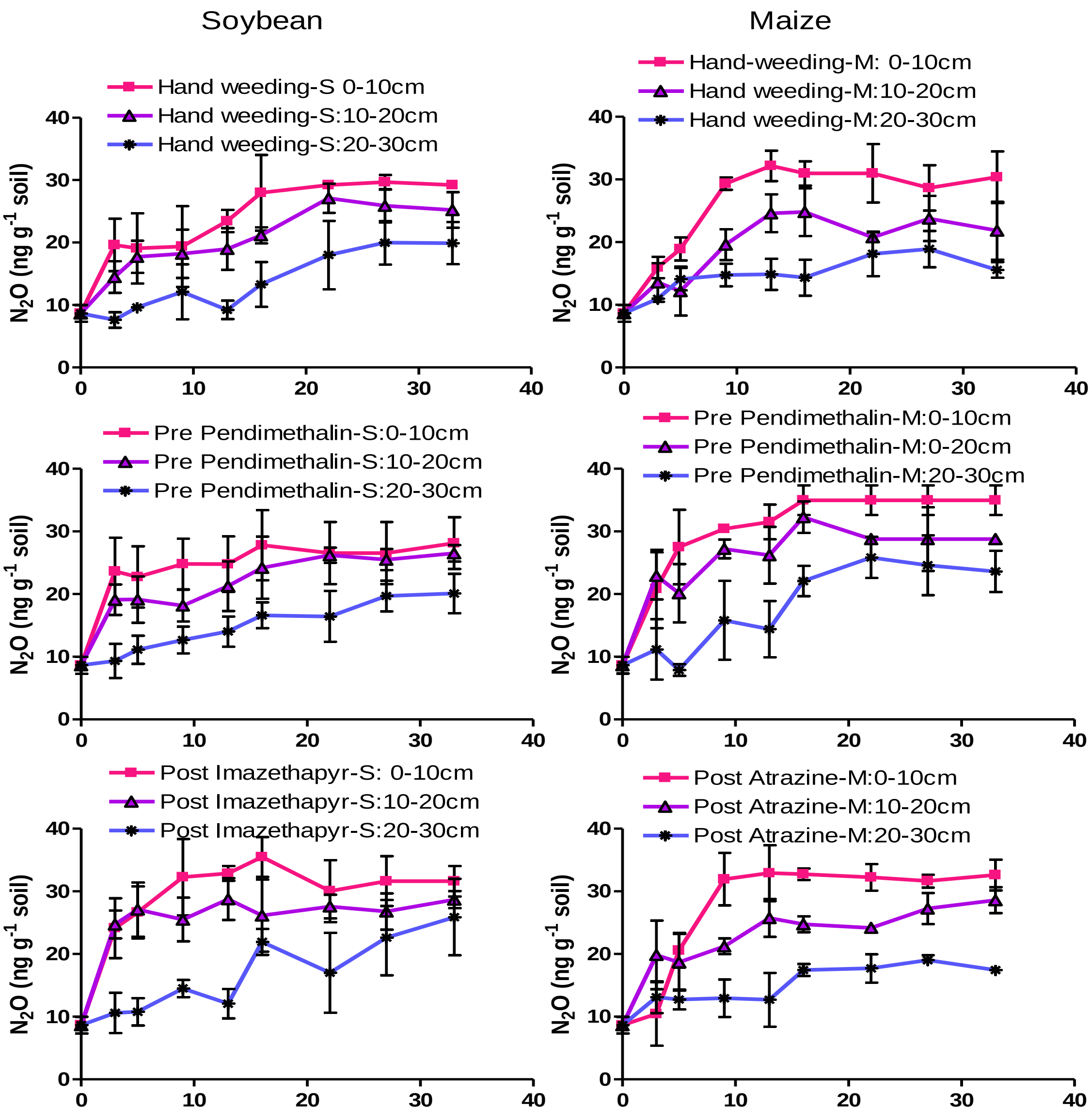


Fig 7. Influence of herbicide on N_2O production under conservation agricultural practices. Soils were collected from fields of maize (right panel) or soybean (left panel) at different depths. N_2O production measured at different days of incubation. Weedicide treatments were hand weeding, pre emergence pendimethalin, post emergence imazethapyr (for soybean) or atrazine (for maize). Each data point

represents arithmetic mean with standard deviation as error bar of three replicated observations. X axis represents incubation period (day) and Y axis represents N_2O (ng N_2O produced g^{-1} soil).**

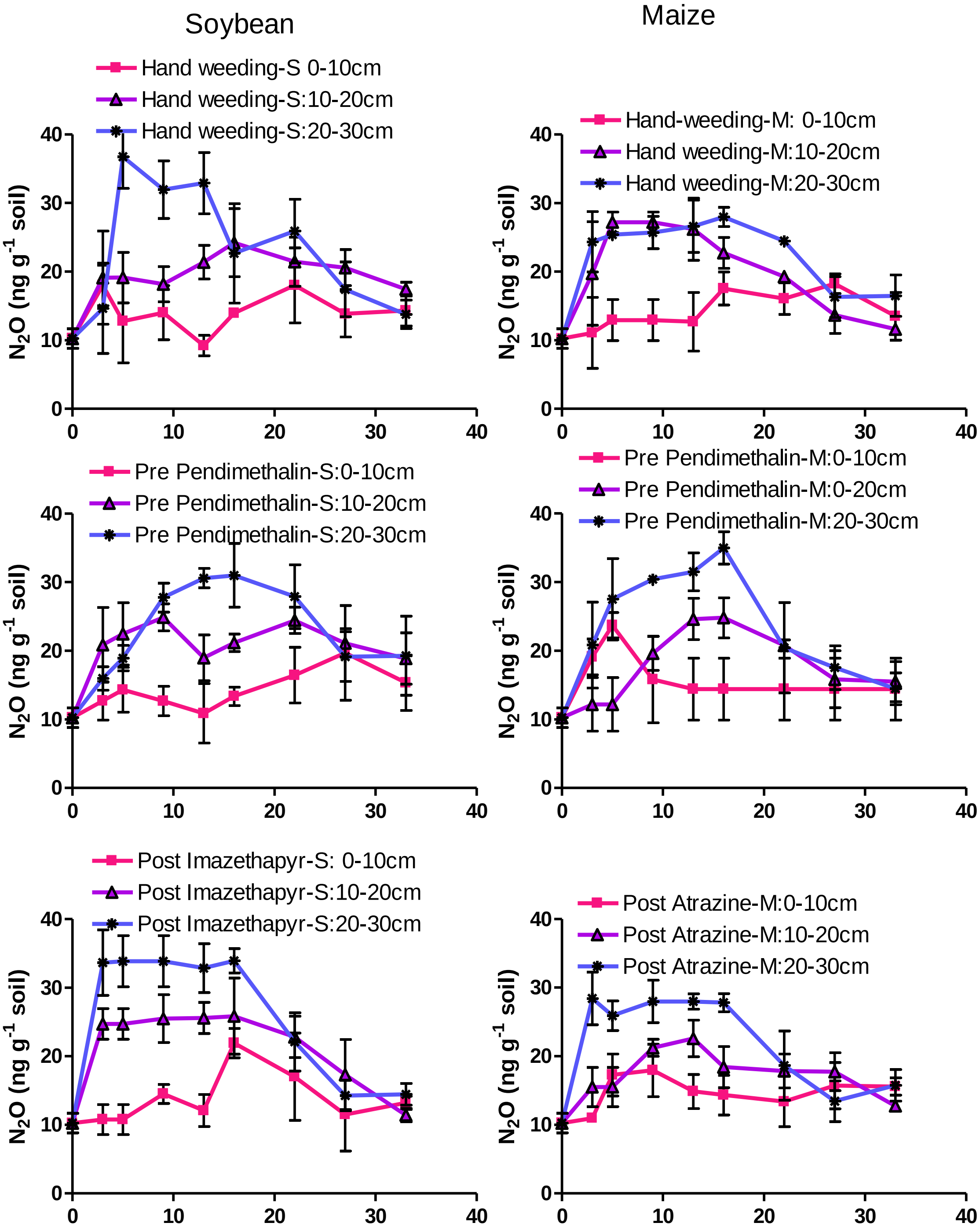


Fig 8. N_2O production from soil under flooded condition.

Soils from different depth were incubated under flooded condition amended. Herbicides were applied to the crops as conservation agricultural practice. Weedicide treatments were hand weeding, pre emergence pendimethalin, post emergence imazethapyr (for soybean) or atrazine (for maize). Each data point represents arithmetic mean and standard deviation as error bar of three replicated observations. X axis represents incubation period and Y axis represents N_2O (ng g^{-1} soil).

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

On-Farm trial:

Demonstration of Conservation Agriculture (CA) technologies in farmer's field (NRRI)

A field demonstrated in farmers field of Jajpur was conducted in which multicrop planter was used for sowing the rice in *kharif* season. Multicrop planter was used successfully for dry direct seeding in farmer's field by opening a slight slit in the soil for seed soil contact without tillage operation (Fig1). Rice seed was used @ 40 kg/ha. Row to row distance along with optimum plant population was maintained. Test variety was Pooja. Compared to farmers practice 3.7% higher grain yield was recorded in CA plot (Table 1). During harvesting, 30 % residue was retained in the field itself. Spraying of herbicide (Glyphosate was done for killing the weeds before green gram sowing in *rabi*season(Fig 2). In *rabi* season green gram (variety IPM 2-3) was sown (Fig 3). Rice residue was retained and sowing was done by multicrop planter by following minimum tillage. The green gram yield was also 3.8% higher in green gram sown in CA plots compared to farmers practice (Table 2). System productivity of rice-green gram system was 3.7% higher in CA plots compared to farmer's practice (Fig.4)

Table 1: Rice plant parameters and grain yield in different treatments in farmer's field

Treatments	Plant height (cm)	Tillers/m^2	Tiller number/m^2	Panicle length (cm)	Panicle wt. (g)	Grains/panicle	Grain yield (t/ha)	Straw yield (t/ha)
CA component	116.1	257.7	201.1	4.3	2.81	125.3	.6	6.6
FP	117	260	193.3	3.6	2.72	124.3	5.4	6.7

Table 2: Plant parameters and grain yield of green gram in different treatments in farmer's field

	PH (cm)	NoP/m^2	NoPD/plant	NoS/pod	PL (cm)	NoRN/plant	RL (cm)	Grain yield (qt/ha)
FP	33.7	60.7	10.6	10	7.3	9	9.9	5.2
CA	30.5	63.3	9.6	10.4	7	8.6	9.2	5.4

PH-plant height (cm), NoP/m^2-No.of plant/m2, NoS/Pod- No. of seed/pod, PL- pod length (cm), NoRN/plant- no. of root nodules, RL-root length (cm)

Fig 1. Rice is being sown using multicrop planter by following by following the minimum tillage in CA plot

Fig 2. Spraying of herbicide (Glyphosate) for weed control before sowing of green gram

Fig 3. Green gram in CA plot with rice residues still visible in the field.

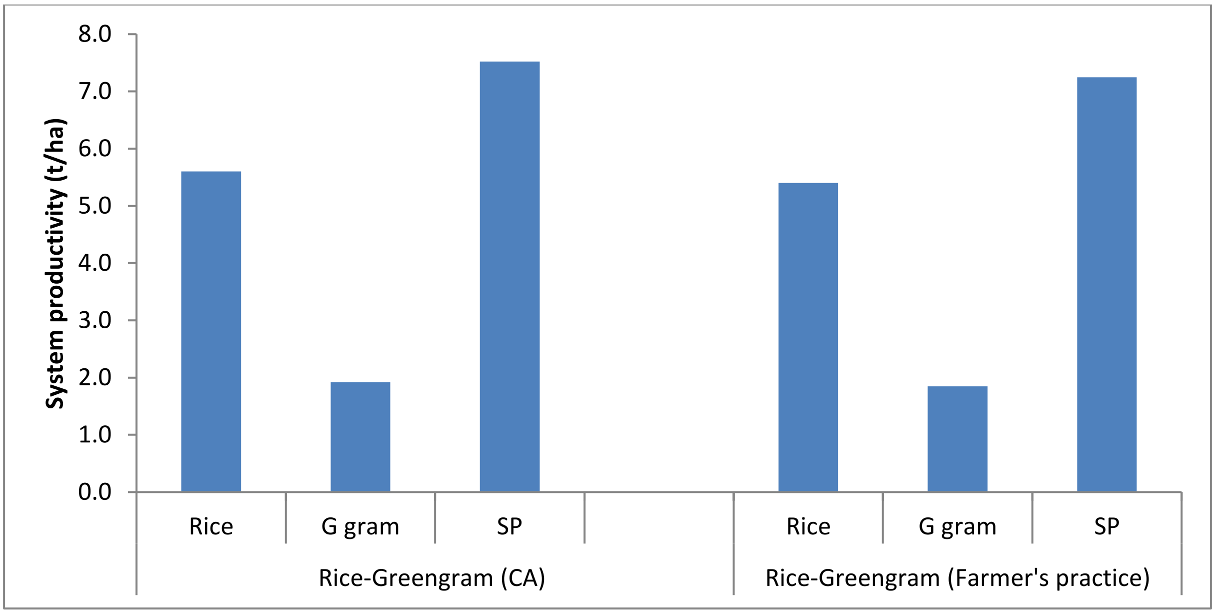


Fig 4. System productivity in CA vs Farmer's practice in Jajpur

Demonstration of best between conservation technologies, developed at CSSRI, Karnal in rice–wheat cropping system – (CSSRI)

The Agri- CRP project- CRP on Conservation Agriculture in farmers' participatory mode during June 2015 has been started. The promising conservation technologies developed at CSSRI, Karnal under rice-wheat cropping system has been demonstrated at farmer's field at four sites. Technical programme of rice–wheat cropping system demonstrated at farmer's field is given below in table (1&2).

Table 1 Cropping system, soil type, water quality and area under different offsite experiment on farmers fields.

Cropping system	Soil type	Water quality	No. of demons.	Area (ha)	Location
Rice-wheat	Sodic/saline	Saline/Sodic/ Fresh	4	1.6	Karnal, Kaithal, Panipat
Total			**4**	**1.6**	

A total of 4 demonstrations at four different locations representing diverse sites with soil and water quality described in table 1 under rice-wheat cropping sequence were carried out in farmers' participatory mode in collaboration with respective district KVKs to evaluate, validate and refine (if required) the technological interventions. The details are as under: The following technical programme is totally under investigation at farmers fields in 4 villages under different CA techniques, were taken as per the technical programme (Table-2) under testing different tillage, residue management, and water management specially micro irrigation methods.

Table. 2 Technical programme of best conservation technologies at farmers fields for the demonstration during 2015-2017.

Rice-Wheat Cropping System		
S. No	**Symbol**	**Treatments**
T_1	CV	Conventional –Prevailing farmers practices-(rice-TPR and wheat with Rotavator)
T_2	CV+ RR	TPR with wheat residue incorporation (1/3 part)-ZT wheat with rice residue mulch/anchored
T_3	TPR(DGM)- ZT Wheat	Rice transplanting after sesbania green manuring-ZT wheat with rice residue mulch/anchored
T_4	DSR-ZT wheat	Direct seeded rice with wheat residue incorporation-ZT wheat with rice residue mulch/anchored with sprinkler irrigation method
Whereas, CV+RR = conventional with wheat and rice residue; TPR (DGM)-ZT Wheat =Zero tillage wheat followed by rice transplanting before dhaincha green manuring; DSR-ZT wheat=Zero tillage wheat after DSR (direct seeded rice) and CV=Conventional wheat sowing.		
Experimental area= one acre (4000 m^2). Package and practice:–recommended package and practice followed (150:60 N:P) for rice and wheat crop, respectively. Variety: wheat –KRL 210 and Rice: Basmati CSR 30.Farmers practice:-Rice:- harrow 2 times, tiller = 2times, leveling =2 times, laser leveling=one time/year and puddling with harrow residue management: - 1/3 of total that is 15-20 cm above from soil surface.		

2 Results -

2.1 Rice Crop: - The results recorded under different CA technologies at farmers fields are presented accordingly.

- Layout of CA technologies at farmer's field for the demonstration of micro irrigation methods along with CA techniques. The results presented revealed that :
- The Rice variety basmati CSR 30 was grown in direct seeded (DSR) and transplanted (TPR) conditions.
- DSR with 50% tillage with CSR 30 basmati rice experiment was laid out along with the farmer practice (TPR) for the demonstration.
- The recommended Nitrogen 90 kg ha^{-1}, phosphorus 60 kg ha^{-1} and potash 40 kg ha^{-1} and Zinc (24 kg zinc sulphate ha^{-1}) were applied.
- Irrigation was applied in DSR after 4/5 days interval with surface method at the depth of 6.0 cm.
- Irrigation was scheduled when soil surface dry with small cracking, irrigation was made at 4/5 days interval during the crop.

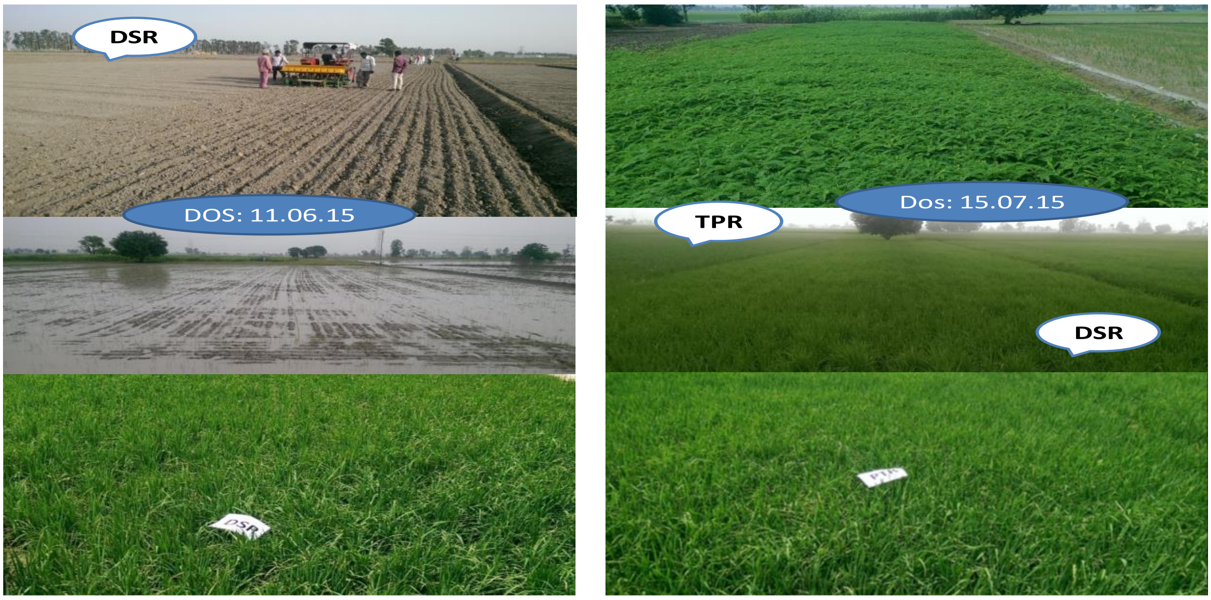
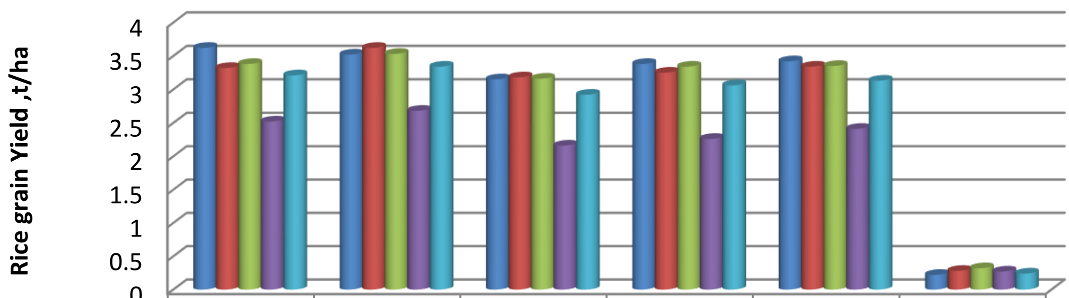


Figure1: Field view of DSR and TPR during kharif season at farmers fields.

1.1Crop yields under different RCTs from demonstration fields during rice 2017

- **Results-**The grain yield of Basmati CSR 30 recorded with different magnitudes under different soil and water quality (fig. 2).
- During rice kharif season 2017 results indicates that CA technologies, tested at farmers fields, found that dhaincha green manuring with TPR found better in comparison to other CA technique by increasing grain yields by 0.13 tha^{-1}.
- This technique is feasible only where availability of irrigation water is not a problem.
- However, where availability of irrigation water is a problem, DSR techniques with mini sprinkler irrigation method observed statistically equal grain yield with TPR rice cultivation system.



	TPR	TPR(GM)	DSR	DSR+Sprl	Mean	CD(0.05)
Shambhali	3.62	3.52	3.15	3.38	3.42	0.22
Geong	3.32	3.62	3.18	3.25	3.34	0.28
Bahupur	3.38	3.53	3.16	3.34	3.35	0.32
Kaith	2.52	2.68	2.16	2.26	2.41	0.27
Mean	3.21	3.34	2.92	3.06	3.13	0.24

Figure.2) Productivity potential of rice under different crop establishment techniques during kharif rice 2017 at farmers' field.

- Rice grain yield in Shambhli village (karnal) recorded statistically higher, in comparison to kaith village in Panipat district, where soil and water both are problematic. In this village TPR with green manuring was better.
- Higher grain yield of basmati CSR 30 was in DSR in comparison to farmer practices at four sites on farmer's field.
- Maximum grain yield was 4.57 tha^{-1} in DSR with sprinkler irrigation system in Bahupur village where water quality was 2.5 RSC and and EC 2.80 dS/m. However in Kaith and Geong village's rice grain yield recorded 3.66 and 3.55 tha^{-1} respectively, which was similar to each other but was statistically lower than Bahupur village.
- However, in Shambhali village of Karnal district, basmati CSR 30 grain yield was also high in its magnitudes under sprinkler irrigation system in comparison to conventional TPR, TPR after sesbania green manuring, and DSR techniques. There was better soil and water quality relatively.
- In DSR avoiding puddling, not required irrigation, saved the labour, diesel, irrigation water, electricity and saving of time, resulting coverage of more area under rice through DSR techniques.
- Salt tolerant variety (CSR 30 basmati) performed well under higher RSC water and yielded upto 3.62 tha^{-1} in DSR technique. DSR in reduced tillage under sprinkler irrigation yielded similar grain yield in comparison to TPR technique (Figure-1).

2.1.2 The site wise results of rice 2017 on economic analysis basis

i) **Shambhali village** –data shows in table 3 that rice economic analysis of Shambhali village experiment, indicates that all the CA are economically better than farmers practice. B:C ratio at Shambhali village varied from 2.85 to3.32. It means that all the CA practices are economically feasible, means have economic potential. DSR with mini sprinkler irrigation system, recorded highest B:C ratio 3.2 and feasible with some problems..

Table. 3 Economic analysis of different CA techniques at Shambhali village during 2017 kharif season.

Economic analysis of rice crop cultivated at SHAMBHALI village-1 during 2017 kharif season					
RCTs	**Grain yield, Kg/ha**	**Cost of cultivation (Rs)**	**Gross income (Rs)**	**Net income (Rs)**	**B:C ratio**
TPR(CV)	3.62	44560	133940.0	89380.0	3.0
TPR+DGM	3.52	45650	130240.0	84590.0	2.85
DSR	3.15	37646	116550.0	78904.0	3.10
DSR-SPRL	3.38	40146	125060.0	84914	3.16
SEM±	0.09	-	-	-	-
CD at 0.05	0.22	-	-	-	-
Rice 2017 MSP was Rs. 37000 per tonne.					
Cost of cultivation includes-operational cost					

ii) Geong village- data shows in table 4 of rice crop experiment at Geong was economically analyzed and found that B:C ratio varied from 2.93 to 3.12. DSR rice cultivation practice observed better with sprinkler irrigation system with higher B:C ratio (3.16) followed by

DSR with surface irrigation method. Similar grain yield was recorded under DSR and TPR cultivation. Lower cost of cultivation was observed under DSR treated plots.

Table. 4 Economic analysis of rice under different CA techniques at Geong village during 2017 .

Economic analysis of rice crop cultivated at GEONG village-2					
RCTs	**Grain yield, Kg/ha**	**Cost of cultivation (Rs)**	**Gross income (Rs)**	**Net income (Rs)**	**B:C ratio**
TPR (CV)	3.32	44560	122840	78280	2.08
TPR+DGM	3.62	45650	133940	88290	2.93
DSR-surface irrg.	3.18	37646	117660	80014	3.12
DSR-SPRL	3.25	40146	120250	80104	2.99
SEM±	0.11				
CD at 0.05	0.28				
Rice 2017 MSP was Rs. 37000/ tonne					

iii) BAHUPUR village- data presented in table 5 of rice crop experiment during 2017, was economically analysed and found that B:C ratio varied from 2.81 to3.10. DSR rice cultivation practice observed better because of low cost of cultivation, while in DSR with mini sprinkler irrigation method observed higher B:C ratio (3.08). DSR with surface irrigation method and sprinkler irrigation method are feasible.

Table. 5 Economic analysis of rice under different CA techniques at Bahupur village during 2017 kharif season.

Economic analysis of rice crop cultivated at BAHUPUR village-4					
RCTs	**Grain yield, Kg/ha**	**Cost of cultivation (Rs)**	**Gross income (Rs)**	**Net income (Rs)**	**B:C ratio**
TPR(CV)	3.38	44560	125060	80500	2.81
TPR+DGM	3.53	45650	130610	84960	2.86
DSR	3.16	37646	116920	79274	3.10
DSR-SPRL	3.34	40146	123580	83434	3.08
SEM±	0.13				
CD at 0.05	0.32	-			
Rice 2017 MSP was Rs. 3700 per quintal.					
Cost of cultivation includes-operational cost .					

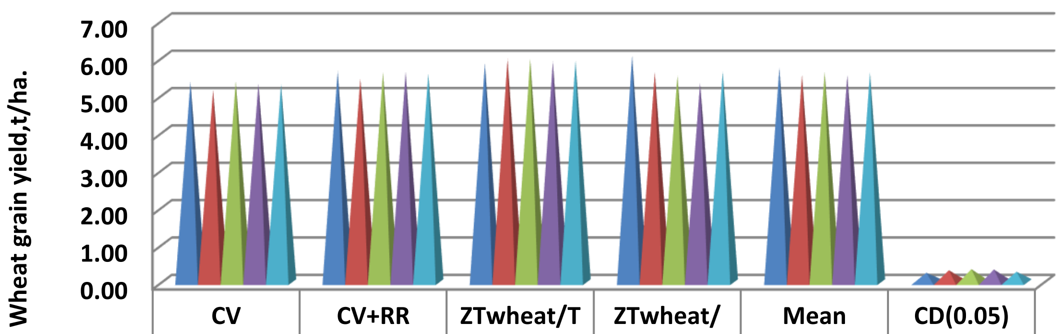
iv) **Kaith village** –results shows in table 6 of kaith village, in Panipat district observed lesser grain yield it was because of poor quality of soil and irrigation water. B:C ratio varied from 2.09 to 2.17. DSR cultivation practice observed better with sprinkler irrigation system with higher 2.08 B:C ratio. It was found better because of lesser irrigation water requirement which may reduced the salt loads accordingly.

Table 6 Economic analysis of rice under different CA techniques at Kaith village during 2017 kharif season.

Economic analysis of rice crop cultivated at KAITH village-3					
RCTs	**Grain yield, Kg/ha**	**Cost of cultivation (Rs)**	**Gross income (Rs)**	**Net income (Rs)**	**B:C ratio**
TPR(CV)	2.52	44560	93240	48680	2.09
TPR+DGM	2.68	45650	99160	53510	2.17
DSR	2.16	37646	79920	42274	2.12
DSR-SPRL	2.26	40146	83620	43474	2.08
SEM±	0.10	-	-	-	-
CD at 0.05	0.27	-			
Rice 2017 MSP was Rs. 3700 per quintal.					
Cost of cultivation includes-operational cost.					

2 Wheat crop: - The result recorded under different CA technologies is presented in tables and graphs accordingly.

2.1 Rabi-2016-17-Wheat Crop: Wheat (Cv KRL-210) was sown at four sites in rice – wheat cropping system on one acre land adopting four techniques, e.g. farmers practice, wheat in conventional tillage with rice residue and zero tillage wheat after green manuring of sesbania (residual effect of DGM),wheat in zero tillage with rice residue under sprinkler irrigation system. The recommended package and practices were followed. Nitrogen 150 kg ha^{-1}, phosphorus 60 kg ha^{-1} and potash 40 kg ha^{-1} and Zinc (24 kg ha^{-1} zinc sulphate) were applied. Irrigation applied with surface irrigation method except mini sprinkler irrigation method.



	CV	CV+RR	ZTwheat/TPR(DGM)	ZTwheat/DSR	Mean	CD(0.05)
Shambhali	5.37	5.65	5.86	6.07	5.74	0.25
Geong	5.14	5.45	5.98	5.62	5.55	0.32
Bahupur	5.38	5.62	5.98	5.54	5.63	0.35
Kaith	5.32	5.63	5.92	5.34	5.55	0.34
Mean	5.30	5.59	5.94	5.64	5.62	0.28

Figure (3) wheat grain yield at different villages under different improved conservation practices during rabi season 2016-17.

Whereas, CV+RR = conventional wheat with rice residue; ZR-TPR (DGM) Wheat =Zero tillage wheat followed by rice transplanting before dhaincha green manuring; ZT wheat- DSR= Zero tillage wheat after DSR (direct seeded rice) and CV=Conventional wheat sowing.

The data presented in figure 3 shows that residual effect of sesbania green manuring was observed in wheat under zero tillage with rice crop residue, yielded 5.94 tha^{-1}, followed by wheat in conventional with rice residue, it was better with 12.08% higher grain yield than conventional wheat (farmers practice). The average wheat grain yield was 5.30 tha^{-1}, in conventional practice which was significantly lower than other improved techniques.In Shambhali village yielded higher (where fresh water given for irrigation) in comparison to saline and alkali irrigation water. The results presented in figure 10 shows that rice residue and dhaincha green manuring improved the wheat grain yield in comparison to farmers practice in saline and alkali environment. Crop residue improved the wheat grain yield as it maintained soil hydro thermal regime in favour of plant growth and production.

2.2 in Rabi-2017-18-Wheat Crop: - Results will be presented after crop harvesting and data processing for calculation, interpretation etc.

13- Output during period under report (Self explanatory)

(A) Special attainments/innovations

1- Irrigation water and urea nitrogen saving in sprinkler irrigation method in both rice–wheat
2- cropping sequence.
3- Special attainment was given to chemical weed management in DSR under different crop establishment techniques.
4- Electricity saving along with irrigation water.
5- Mini sprinkler irrigation method may be feasibility in both rice and wheat cropping system.

On-Farm Research (OFR) trials of weed management technologies at farmers' field in rice-wheat-greengram under conservation agriculture at different locality of Jabalpur (DWR)

ICAR-Directorate of Weed Research, Jabalpur has demonstrated conservation agriculture based technologies through on-farm research (OFR) trials cum demonstration at Patan and Bargi blocks of Jabalpur district of Madhya Pradesh.

On-farm research was conducted at five village's *viz*. Podi, Ponia, Khera Ramkhidia, Boria, Bhiloda in Patan block of Jabalpur, where rice and blackgram were sown during *kharif* 2017. Weed management in crops grown under CA with recommended fertilizer dose (RFD) and no weed control, CA with recommended dose of fertilizer (RDF) and improved weed management practices (bispyribac sodium 25 g/ha in rice at 20 DAS and imazethapyr 100 g/ha at 20 DAS in blackgram) were compared with farmers conventional practice. In the OFR, crops were sown with the help of happy seeder machine keeping previous crop residues as such in the field.

In the OFR of rice cv 'MTU 1010', it was found that the highest weed density and weed dry biomass was recorded in farmers practice (74.7 no./m^2 and 40.3 g/m^2, respectively) whereas, conservation agriculture with recommended fertilizer with weed management has 46% lower density and 55.4% lower weed dry biomass (**Table 1**). It was also recorded that plants in conservation agriculture with recommended fertilizer with weed management has 11.5% taller, 4.1% more panicle/m running row, resulting 13.8% higher grain yield (3.96 t/ha). Higher grain yield and lower cost of cultivation help to obtain better net return (Rs. 37938/ha) and B: C ratio (2.56).

Table 1. Performance of rice cv MTU 1010 with or without herbicide under CA practice during *Kharif* 2017 (n=3)

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Plant height (cm)	No. of panicle /m row	Grain yield (t/ha)	Gross return (Rs)	Net return (Rs)	B:C ratio
Farmers practice	74.7	109.4	55.4	102.0	254.0	3.48	54589	22964	1.73
CA with RFD and weed management	40.3	48.8	-	113.7	264.3	3.96	62203	37938	2.56

Values are the average of three farmers; CA: Conservation agriculture; RFD: Recommended dose of fertilizer; Herbicide: Bispyribac-Na 25 g/ha at 20 DAS

In the OFR of rice cv 'Kranti', the highest weed density and weed dry biomass was recorded in farmers practice (55.7 no./m^2 and 92.3 g/m^2, respectively) whereas, conservation agriculture with recommended fertilizer with weed management has 57% lower weed density and 63.6% lower weed dry weight (**Table 2**). It was also recorded that plants in conservation agriculture with recommended fertilizer with weed management has 12.7% taller, 4.9% more panicle/m running row, resulting 20% higher grain yield (4.57 t/ha). Higher grain yield and lower cost of cultivation help to obtain better net return (Rs. 47521/ha) and B: C ratio (2.96).

Table 2. Performance of rice cv Kranti with or without herbicide under CA practice during *Kharif* 2017 (n=3)

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Weed control efficiency (%)	Plant height (cm)	No. of cobs/m^2	Grain yield (t/ha)	Gross return (Rs)	Net return (Rs)	B:C ratio
Farmers practice	55.7	92.3	63.6	122.7	239.0	3.81	59864	28239	1.90
CA with RFD and weed management	23.7	33.6		138.3	250.7	4.57	71796	47521	2.96

Values are the average of three farmers; CA: Conservation agriculture; RFD: Recommended fertilizer dose; Herbicide: Bispyribac-Na 25 g/ha at 20 DAS

In blackgram, the major weed flora observed was *Commelina communis*, *Echinochloa colona*, *Aternanthera sessilis*, *Mullogo pentaphylla*, *Convolvulus arvesnsis* etc. Weed density and dry biomass in blackgram was recorded significantly lower in CA+RFD with imazethapyr 100 g/ha at 20 DAS treated plots than the farmers practice. The maximum plant height and number of pods/plant, seeds/pod and yield of seeds and haulm was significantly higher in CA+RFD with imazethapyr. More yield over farmers practice resulted higher gross and net return and B: C ratio.

At Bargi locality, OFR trials were conducted at five villages, *viz.* Silua, Sagda, Devri, Rosara and Pipariya Charghat during *kharif* (2017) in rice and maize, and weed management in crops grown under CA with recommended fertilizer dose (RFD) and no weed control, with recommended dose of fertilizer (RDF) and improved weed management practices were compared with farmers conventional practice. The sowing of crops under CA practice was done using happy seeder machine without removal of previous crop residues.

In rice, OFR trials were undertaken on weed management in direct-seeded rice under CA. The major weed flora observed was *Echinochloa colona*, *Commelina communis*, *Cyperus iria* and *Alternanthera sessilis*. The recommended weed management and fertilizer dose practices were compared with farmers practice. As compared to farmers practice, application of recommended fertilizer dose (120:60:40 N, P_2O_5, K_2O Kg/ha) along with herbicide (bispyribac sodium 25 g/ha at 20 DAS) effectively reduced the weed density and dry biomass by 72.8 and 77.6%, respectively (**Table 3**). This treatment also produced higher plant height (70.8 cm), panicles (94.3 /m row), panicle weight (3.39 g) and number of grains/panicle (137.3). The grain yield (3.89 t/ha) and net return (Rs 40345 /ha) was also higher in CA with RFD and herbicide in comparison to farmers practice (2.95 t/ha).

Table 3. Performance of rice with or without herbicide under CA practice during *Kharif* 2017

Treatment	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Plant height (cm)	No. of panicle /m row	Panicle weight (g)	No. of grains/ panicle	Grain yield (t/ha)	Gross return (Rs)	Net return (Rs)	B:C
Farmers practice	113.8	162.8	51.6	56.1	2.86	107.8	2.95	45725	15075	1.49
CA with RFD and without herbicide	128.5	203.6	51.0	46.8	2.40	91.8	2.39	37045	19495	2.11
CA with RFD and herbicide	31.0	36.5	70.8	94.3	3.39	137.3	3.89	60295	40345	3.02

Values are the average of four farmers; CA: Conservation agriculture; RFD: Recommended fertilizer dose; Herbicide: Bispyribac-Na 25 g/ha at 20 DAS

In maize, the major weed flora observed was *Commelina communis*, *Echinochloa colona*, *Aternanthera sessilis*, *Mullogo pentaphylla*, *Convolvulus arvesnsis* etc. Weed density and dry weight in maize grown with recommended fertilizer (120:60:40 N, P_2O_5, K_2O kg/ha) and herbicide (atrazine 1000 g/ha *fb* tembotrion 120 g/ha at 30 DAS) under CA was 72.6 and 91%, respectively lower than farmers practice (**Table 4**). Plants under the plots received recommended fertilizer and advanced weed management practice under CA were taller and had more number of cobs/m^2. The grain yield of maize was 6.08 t/ha in CA practice with improved weed management technique (**Table 4**). As compared to the farmer practice, the higher net return (Rs 63340) and B: C (3.72) ratio were recorded with the same treatment.

Table 4. Performance of maize with or without herbicide under CA practice during *Kharif* 2017

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	Plant height (cm)	No. of cobs/m^2	Grain yield (t/ha)	Gross return (Rs)	Net return (Rs)	B:C ratio
Farmers practice	139.8	122.7	164	10.9	5.07	72248	37247	2.06
CA with RFD and without herbicide	95.0	156.4	158	10.4	3.54	50445	32145	2.76
CA with RFD and herbicide	38.3	10.7	176	11.6	6.08	86640	63340	3.72

Values are the average of four farmers; CA: Conservation agriculture; RFD: Recommended fertilizer dose; Herbicide: Atrazine at 1000 g/ha as PRE *fb* tembotrion 120 g/ha at 30 DAS

At Jharkhand and Chhattisgarh (RCER)

Evaluation of CA practices on productivity of winter crop in Hill and Plateau Region (Jharkhand and Chhattisgargh)

Field experiment was conducted during 2017-18 at farmer's field at two locations viz., Chene, Ranchi (Jharkhand) and Condora, Jaspur (Chhattisgargh). The CA practices comprised of zero-tillage transplanted rice with mulch (ZTT-M), ZTT rice without mulch (ZTT-NM), direct seeded rice with mulch (DSR-M), DSR without mulch (DSR-NM) and farmer's practice without mulch (FP-NM) were superimposed on winter crops like lentil (KLS-218), mustard (Pusa-26) linseed (BAU 06-03) and safflower (PBNS-12) after rice harvest. Paddy straw used as mulch @ 5 t/ha.

Experimental Site 1: Chene village, Namkum, Ranchi (Jharkhand)
Chene, Block: Namkum, Distt. Ranchi (Jharkhand)

(I) Effect of different CA practices on yield of rice

Three rice establishment methods *viz*., direct seeded rice (DSR), zero-tillage transplanted (ZTT) compared with farmers' practices of puddle transplanted (FP-T) were evaluated at farmer's field at Chene village in the Namkum block of Ranchi (Jharkhand) during *Kharif* - 2017. The results on plant parameter and yield attributed are depicted in Table 1. The numbers of tillers per plant were significantly higher in DSR (6.9) rice. The number of panicles per metre row was found significantly higher in FP-T (52.23). Comparatively higher number of grains per panicle was significantly higher in FP-T (122.67) than other methods of rice establishment. The highest significant number of filled grains per panicle (117.6) and grain filling percentage (89.88 %) were recorded in FP-PTR. The grain yield was significantly higher (5.84 t/ha) in FP-T than other rice establishment methods. The harvest index was not influenced by the CA practices.

Table 1. Effect of different CA practices on yield of rice

Treatments	No. of tillers / plant	No. of panicle / meter row	Panicle length (cm)	No. of grains/ panicle	No. of filled grains/ panicle	No. of chaffy grains/ panicle	Grain filling (%)	Grain yield (t/ha)	Harvest index
DSR	6.90	46.80	22.73	116.00	99.73	9.60	89.08	4.95	0.48
ZTT	5.03	45.23	19.73	105.43	98.19	9.24	88.73	4.37	0.57
FP (PTR)	6.43	52.23	23.90	122.67	117.60	14.40	89.88	5.84	0.52
SEm±	0.152	0.112	0.119	1.532	0.644	0.943	0.25	0.28	0.003
C.D. (P=0.05)	0.472	0.35	NS	4.773	2.007	2.937	NS	0.86	NS

DSR: Direct-seeded rice; ZTT: Zero till transplant; FP: Farmers practice, PTR: Puddle transplant rice

The soil organic carbon was significantly higher in ZTT (0.55 %) and DSR (0.49 %) compared to Farmer's practice. The soil pH, available Nitrogen and phosphorus contents in post harvest soil were found to be non-significant. However, the available potassium content was significantly higher (113.9 kg/ha) in DSR as compared to other rice establishment methods (Table 2).

Table 2: **Effect of different CA practice on soil fertility status of post-harvest soils of rice in Jharkhand**.

Treatments	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
FP-T	4.51	0.42	172.0	13.50	90.84
DSR	4.76	0.49	164.6	13.71	113.91
ZTT	4.61	0.55	174.5	14.74	100.22
SEm ±	0.069	0.016	2.80	0.54	3.870
LSD (P=0.05)	NS	0.049	NS	NS	11.922

In another experiment, four rice genotypes *viz.*, Lalat, IR-64, Naveen & Sahbhagi were evaluated with different conservation agricultural practices as zero tillage transplanted (ZTT) and zero tillage with direct seeded rice (ZT-DSR) compared with farmer puddle transplanted practices (FP-T), at farmer's field of village Chene, block-Namkum, Ranchi (Jharkhand) in *kharif* - 2017. Higher number of tillers/plant (10.1) was recorded in ZT-DSR, However, there is no significant difference among the CA practices and genotypes. Significantly higher numbers of panicle/row (49.6) was recorded in FP-T while genotypes sahabhagi recorded highest numbers of panicle/row (55.0).The interaction effect of genotypes and CA practices were found significant.

The panicle length showed non-significant effect among CA, genotypes and their interaction. The number of grains /panicle was found maximum in FP-T (130.5) and Naveen genotype (142.7).The interaction of ZTT and Naveen recorded highest number of grains per panicle (148.6). The highest number of filled grains (112.3) was recorded in FP-T and Naveen (118.2) among the CA practice and rice genotypes, respectively. The grains filling percentage per panicle was also recorded maximum in ZTDSR (89.3 %) while, IR-64 recorded significantly highest grain filling percentage of 86.2%. The interaction of FP-T with Lalat registered significantly highest grain filling percentage of 91.2 % compared to other treatment combinations (Table 3). The grain yield (4.89 t/ha) was significantly highest in FP-T over ZTDSR and ZTT. Rice genotypes were on a par for grain yield and harvest index.

Table 3. Effect of different CA practices and rice genotypes on growth and yield attributes

Treatment	No. of tillers / plant	No. of panicle/ meter row	Panicle length (cm)	No. of grains / panicle	No. of filled grains / panicle	No. of chaffy grains /panicle	Grain filling percentage (%)	Grain yield (t/ha)	Harvest index
CA practice									
C1:ZTDSR	10.1	48.5	23.5	124.3	109.6	18.6	89.3	4.01	0.52
C2: ZT Transplant	9.0	46.8	22.8	117.3	91.8	19.5	78.8	4.43	0.54
C3: FP	10.0	49.6	23.0	130.5	112.3	20.7	86.9	4.89	0.53
SEm (±)	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0.19	0.0
LSD (P=0.05)	NS	1.6	NS	1.9	1.8	1.4	1.6	6.5	NS
Genotypes									
V1: Naveen	9.4	45.3	23.6	142.7	118.2	29.3	82.9	4.43	0.53
V2: Lalat	9.6	44.2	22.8	126.6	106.2	22.9	85.4	4.59	0.54
V3: IR 64	9.3	48.7	23.6	114.3	97.6	13.0	86.2	4.30	0.54
V4: Sahabhagi	10.4	55.0	22.5	112.5	96.3	13.1	85.6	4.42	0.52
SEm (±)	0.2	0.2	0.2	0.4	0.3	0.2	0.3	0.22	0.0
LSD (P=0.05)	NS	0.7	NS	1.1	0.9	0.5	0.7	NS	NS

The chemical analysis of post-harvest soils of rice shown in Table 4. The effect of different CA practices on pH and available P (kg/ha) was found non-significant. The organic carbon was recorded significantly higher (0.54%) in DSR practice compared to Farmer Practice. However, the organic carbon was found non-significant between DSR and ZTT. The available N content was significantly higher in ZTT (173.7 kg/ha) compared to Farmer's practice (151.2 kg/ha). Similarly, the available K was significantly higher in ZTT (107.5 kg/ha) and DSR (103.5 kg/ha) compared to Farmer practice. The rice genotypes did not significantly influence the available pH, organic carbon, N, P and K content in post harvest soils. Comparing the interaction effect, the highest available N and K content of 190.4 and 117.0 kg/ha, respectively was recorded in the treatment combinations of C3V1 (Rice cv. Naveen grown under ZTT). The interaction effect of different CA practices and genotypes on pH, organic carbon and P was found significant.

Table 4. Effect of different CA practice on soil chemical parameters in post-harvest soils of different rice genotypes in Jharkhand.

Treatment	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
CA practice					
C1: Farmer practice	4.62	0.41	151.2	13.0	90.5
C2: ZTDSR	4.78	0.54	163.0	12.4	103.5
C3: ZTT	4.71	0.51	173.7	13.5	107.5
SEm ±	0.066	0.04	4.69	0.80	3.8
LSD (P=0.05)	NS	0.11	13.76	NS	11.1
Genotypes					
V1: Naveen	4.68	0.47	166.6	14.4	104.3
V2: Lalat	4.74	0.49	159.6	12.9	104.6
V3: IR 64	4.79	0.51	157.4	12.2	94.7
V4: Sahabhagi	4.61	0.48	166.9	12.4	98.4
SEm ±	0.076	0.04	5.42	0.93	4.4
LSD (P=0.05)	NS	NS	NS	NS	NS

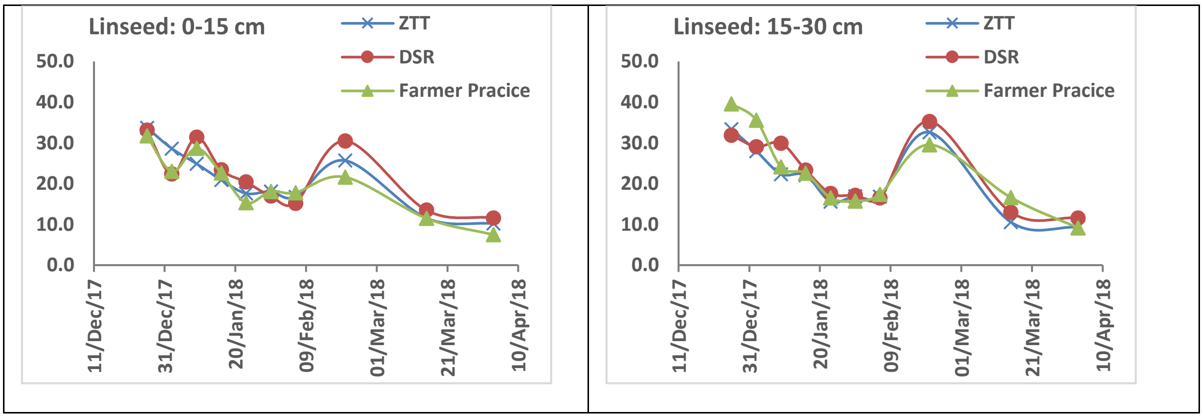
NS= Non-significant

The winter crops like lentil, mustard, linseed and safflower were grown in rice-fallows under different CA practices. Results revealed that lentil and safflower did not germinate due to high moisture content in soil after rice harvest. The grain yield of mustard was significantly influenced by different CA practices (Table 5). The highest grain yield was recorded in DSR-NM (3.07 q/ha), which was on a par with DSR-M (3.05 q/ha). The CA practices of DSR-M, DSR-NM and ZTT-M was significantly higher grain yield over farmer’s practice (FP). Similarly, grain yield of linseed was recorded the highest of 2.23q/ha with DSR-M and was found significantly superior over farmer’s practice. The mulched treatments of CA practice i.e. ZTT-M and DSR-M recorded 5 and 16.7%; respectively increase in grain yield over ZTT-NM and DSR-NM, respectively.

Table 5. Effect of different CA practices on yields parameters of winter crops

CA practices	Mustard			Linseed		
	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)
ZTT-M	2.77	4.05	6.82	1.51	2.98	4.49
ZTT-NM	2.43	4.35	6.78	1.45	2.92	4.37
DSR-M	3.05	8.05	11.10	2.23	3.74	5.97
DSR-NM	3.07	6.38	9.45	1.91	3.39	5.29
FP-NM	1.92	4.22	6.13	1.15	3.78	4.93
LSD ($p \leq 0.05$)	0.73	2.67	2.81	0.30	0.47	0.62

Soil moisture variability in winter crops: After the rice harvest, soil moisture content was very high in all the experimental plots. In 0-15 cm depth, soil moisture varied from 31.7 to 45.6% while at 15-30 cm depth, it ranged between 31 to 42.1% among CA practices and winter crops. In linseed plots, soil water gradually decreased and it reached to critical level in first week of February 2018. Irrigation was applied when soil water content was 16.8, 15.2 and 17.8% in ZTT, DSR and farmers' practice, respectively. In case of mustard,one critical irrigation was applied in first week of February when soil water content reached 17.8, 18.2 and 17.1% in ZTT, DSR and farmers' practice. Application of one critical irrigation maintained optimal moisture conditions in crop root zone leading satisfactory growth and yield from these crops. Among the CA practices, soil moisture under DSR plots was comparatively higher than ZTT and farmers' practice (Fig. 1).



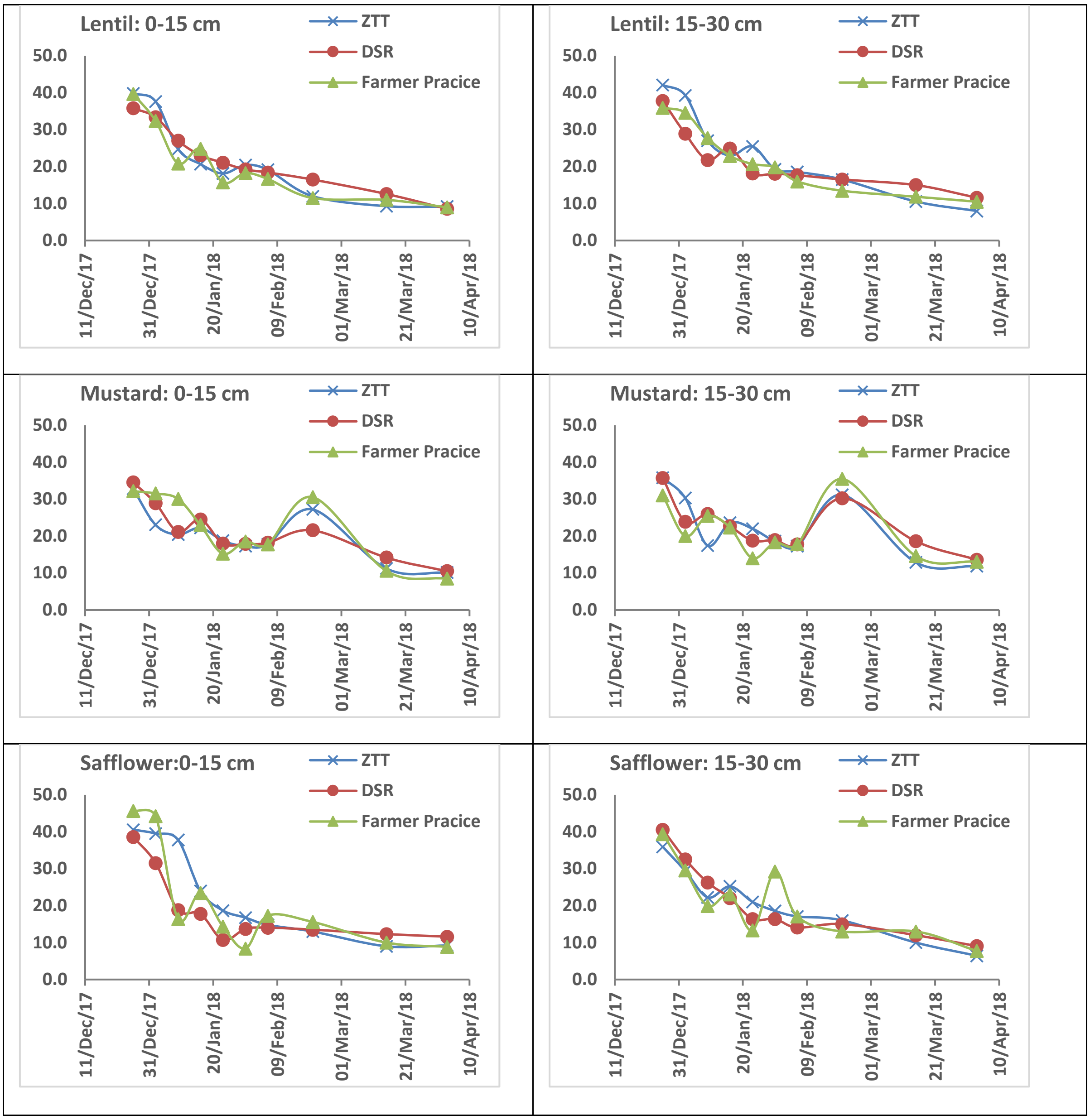


Fig.1.Soil moisture variability in winter crops under different CA practices during experimentation

Fig 2. Performance of winter crops under different CA practices at Chene, Jharkhand

Conjunctive use of Pond water levels: A pond having size of 20 mx16 m x 3 m having storage capacity of 482 m^3 was constructed to provide the life saving irrigation to winter crops. The water level of pond was recorded at regular interval using a gauging staff to assess seepage and evaporation loses from the pond. Analysis revealed that seepage loss and evaporation loss from pond was noted @ 11.7 and 3.3 mm/day, respectively (Fig 3). At this rate of water loss pond reduces to half of the capacity by 3rd week of February. At this stage, the stored water can be used to apply one critical irrigation to the cropping area of 1 acre. This analysis revealed that there is need of pond lining so that the irrigation potential of these water harvesting ponds can be improved.

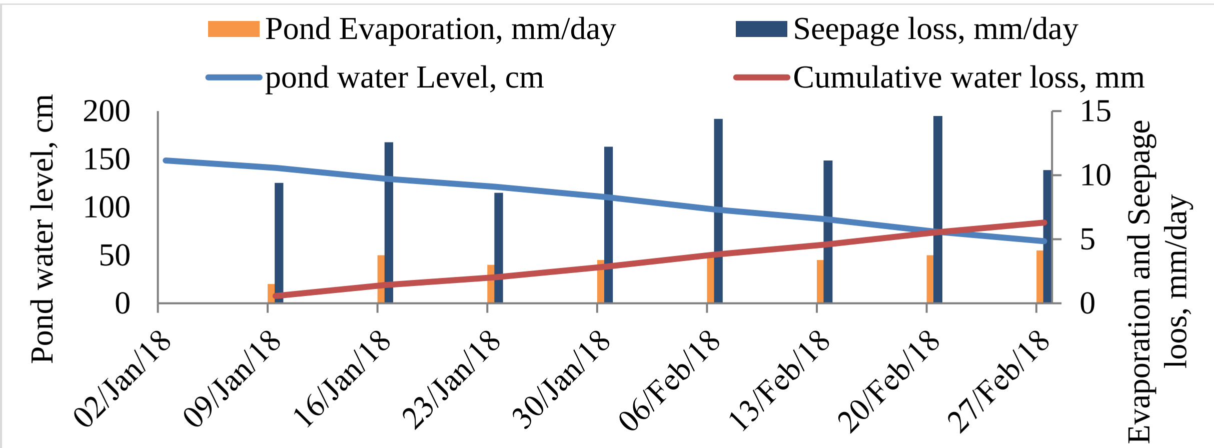


Fig.3. Seepage and evaporation loss of pond during experimentation

Experimental Site 2: Kandora village, Block: Kunkuri, Jashpur (Chhattisgarh)

(I) Effect of different CA practices on yield of rice (*Kharif* 2017)

Three rice establishment methods *viz*., direct seeded rice (DSR), zero-tillage transplanted (ZTT) compared with farmers practices of transplanted (FP-T) were evaluated at Kandora village of Kunkuri block, Jashpur (Chhattisgarh) in *kharif* 2017. Results revealed that significantly higher number of tillers/plant was recorded in FP-T (7.8) followed by DSR (6.1) and ZTT (5.6) respectively (Table 1). Significantly higher number of filled grains/panicle was recorded in FP-T (105.4). Higher panicle length was also recorded in FP-T (24.40 cm) than other methods of rice establishment. Significantly higher grain filling percentage was recorded in FP-T (92.4) method of rice establishment. Significantly, the highest grain yield was recorded in FP-T (3.07 t/ha) followed by DSR (2.36 t/ha), and the lowest in ZTT (2.05 t/ha).

Table 1. **Effect of different CA practice on yield of rice at Kandora village of Kunkuri block, Jashpur**

Treatment	No. of tillers/ plant	No. of panicle/ meter row	Panicle length (cm)	No. of grains/panicle	No. of filled grains/ panicle	No. of chaffy grains/ panicle	Grain filling (%)	Grain yield (t/ha)	Harvest index
DSR	6.1	34.9	21.9	94.2	76.9	17.+0	82.1	2.36	0.543
ZTT	5.6	36.8	23.1	96.9	76.2	20.8	79.5	2.05	0.519
FP	7.8	42.4	24.4	105.4	96.6	9.3	92.4	3.07	0.536
LSD (P=0.05)	0.363	0.336	0.334	0.39	0.318	0.249	0.329	0.37	0.004

The soil chemical parameters in post harvest soil of rice are depicted in Table 2. The soil organic carbon among the CA practice (DSR and ZTT) was non-significant, but when compared with farmer's practice, it was found significant. The highest organic carbon content was 0.52 % in DSR while 0.39% in farmer's practice. The available Nitrogen content in post harvest soil was found non-significant among the conservation agriculture practice. However, the highest available N content was 178.3 kg/ha in ZTT. The DSR practice recorded significantly highest available P (13.36 kg/ha) over farmer's practice. The available potassium was significantly highest of 129.7 kg/ha in DSR compared to other rice establishment methods. The pH was found non-significant among the CA practice on post-harvest rice soil.

Table 2: Effect of different CA practice on soil fertility status of post-harvest soils of rice (Cv Lalat) in Chhattisgarh.

Treatments	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
FP-transplanted	4.46	0.39	166.5	10.93	109.0
DSR	4.63	0.52	170.4	13.36	129.7
ZTT	4.53	0.51	178.3	12.56	120.3
LSD (P=0.05)	NS	0.056	NS	1.94	12.12

(I) Evaluation of Rice genotypes under different CA practices in different crop rotations

Four rice genotypes *viz*., Lalat, IR-64, Sahbhagi and Naveen were evaluated with different conservation agricultural practices as zero tillage transplanted (ZTT), zero tillage with direct seeded rice (ZT-DSR) and transplanted farmer practices (FP-T) and were evaluated at farmer's field of village at Kandora village of Kunkuri block, Jashpur (Chhattisgarh) in *Kharif* 2017. Significantly highest number of tillers/plant was recorded in FP-T (7.89) where as, IR-64 genotype of rice recorded the highest number of tillers/plant (7.28) than other genotypes. Significantly higher number of grains/panicle was recorded in FP-T (128.06), whereas among genotypes, Naveen recorded significantly the highest of 127.08 followed by Sahabhagi (124.97). Significantly the highest number of grain filling percentage was recorded in ZTDSR (87.2) and found at par with FP-T. Naveen recorded highest grain filling percentage of 88.5 %. The interaction of FP-T with IR-64 genotype recorded highest grain filling percentage of 93.87 % and was at par with ZTDSR-Naveen. Higher grain yield of 3.16 t/ha recorded in FP-T, while 'Naveen' recorded 3.02 t/ha. The impact of CA practice and genotypes on biological yield and harvest index was non-significant.

Table 3. Effect of different CA practice on the yield attributing characters of rice genotypes

	No. of tillers / plant	No. of panicle / meter row	Panicle length (cm)	No. of grains / panicle	No. of filled grains / panicle	No. of chaffy grains / panicle	Grain filling percentage (%)	Grain yield (t/ha)	Harvest index
CA practice									
C1:ZTDSR	7.09	37.16	23.26	120.93	105.48	15.45	87.18	2.47	0.55
C2: ZT Transplant	6.25	33.50	22.58	120.23	94.43	25.80	78.72	2.37	0.56
C3: FP	7.89	34.16	23.97	128.06	110.48	17.59	86.21	3.16	0.53
C.D. at	1.41	1.61	1.12	1.53	1.49	1.80	1.59	5.26	NS

5%									
Genotypes									
V1: Naveen	7.07	32.47	23.34	127.08	112.51	14.57	88.45	30.18	0.56
V2: Lalat	6.79	30.70	22.92	120.33	101.74	18.59	84.50	26.46	0.55
V3: IR 64	7.28	35.38	24.12	119.91	100.19	19.72	83.57	24.80	0.55
V4: Sahabhagi	7.18	41.21	22.69	124.97	99.40	25.57	79.62	25.21	0.54
C.D. at 5%	NS	0.70	0.14	0.61	0.56	0.92	0.68	NS	NS

The winter crops like lentil, mustard, linseed and safflower were grown in rice-fallows under different CA practices. Safflower is not yet harvested. Results revealed that grain yield of lentil were significantly influenced by different CA practices (Table 4). The highest grain yield was recorded with ZTT-M (2.68 q/ha) but being at par with FP-NM (2.16 q/ha). Higher grain yield was observed in mulched treatment as compared to non-mulch under ZTT and DSR. The highest grain yield of 4.39 q/ha was noted with ZTT-M. Similarly, highest linseed grain yield of 2.74 q/ha was recorded with DSR-M and noted significantly better than DSR-NM and FP-NM.

Table 4. Effect of different CA practices on yield parameters of winter crops

CA practices	Lentil			Mustard			Linseed		
	Grain yield (q/ha)	Straw yield (q/ha)	Bio. yield (q/ha)	Grain Yield (q/ha)	Straw yield (q/ha)	Bio. yield (q/ha)	Grain Yield (q/ha)	Straw yield (q/ha)	Bio. yield (q/ha)
ZTT-M	2.68	2.49	5.17	4.39	9.09	13.48	2.49	4.92	7.41
ZTT-NM	1.70	2.47	4.17	2.87	7.65	10.52	2.47	4.86	7.33
DSR-M	1.57	2.74	4.30	2.12	4.84	6.96	2.74	3.41	6.15
DSR-NM	1.26	1.55	2.81	1.74	3.44	5.18	1.55	3.35	4.90
FP-NM	2.16	1.97	4.12	3.39	6.12	9.51	1.97	3.90	5.87
LSD ($p \leq 0.05$)	0.86	0.74	1.32	1.75	3.49	5.05	0.74	0.94	0.96

Fig. 4. Performance of winter crops under different CA practices at Kandora, Chhattisgarh

Demonstration of best bet CA technologies at farmers' fields (NIASM)

Total four field demonstrations were conducted with SORF machine at farmers' fields during the year 2017-18 (Fig. 1). Four treatment combinations including three methods of trash management (open burning of trash (BT) and retention of trash in the field as such (UCT) or after chopping (CT) with a trash cutter), two methods of fertilizer application (broadcast (FBC) as is the farmer's practice, placement with SORF machine along with off-barring, root pruning and stubble shaving practices). The 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 farmers' practices of ratoon management (BT+FBC). Surface retention of chopped trash and employing of SORF techniques (CT+SORF) improved the cane yield by 19-27 % over burnt trash and broadcast application of fertilizers (Fig. 2).

Fig. 1. Demonstration of SORF machine at farmer's fields.

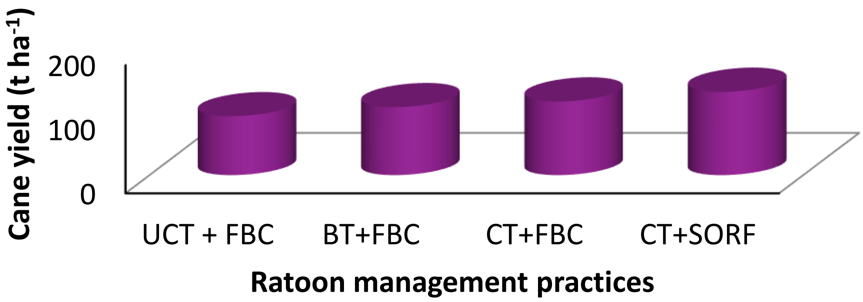


Fig. 2. Average cane productivity under different ratoon management practices at farmers fields.

Adapting and mainstreaming available best bet location Specific conservation agriculture practices (CRIDA)

Experiments were conducted in different cropping systems (Table 1) on both KVK farm as well as farmers fields to demonstrate the advantage of reducing tillage practices and residue retention**.**

1. Cowpea-Finger millet (ML-365)cropping system

Experiments were conducted in Horse gram- finger millet and Cowpea- finger millet system on vertisols at KVK Tumkuru.on vertisols at KVK Tumkuru.

Traditional systems	Fallow finger millets system
Proposed cropping sequence	**Cowpea-Finger millet (ML-365)/ Horse gram-Finger millet (ML-365)**
T1-Farmers Practice	Sowing of Finger millet in August (Two ploughing + One harrowing)
T2-Minimum Tillage	Sowing of Cow pea/ Horse gram in June (One pre sowing passing tractor drawn cultivator followed by harrowing. Cow pea/ Horsegram) and Sowing of Finger millet with seed drill in August.
T3-No tillage	No till for both the crops.

Results: Ragi ML-36

1. Farmer: Vishveshwariah, D.Nagenahalli, Koratagere, Taluk, Tumakuru District.

Treatments	Plant Height (cm)	No. of fingers / Plant	Fodder Yield (kg/ha)			Seed Yield (kg/ha)		
			Cowpea	Horsegram	Mean	Cowpea	Horsegram	Mean
T1	94	11	3725	3640	3683	2650	2520	2585
T2	83	10	3450	3410	3430	2550	2405	2478
T3	74	9	3010	3160	3085	2300	2310	2305

2.Farmer: Ranganath, D.Nagenahalli, Koratagere, Taluk, Tumakuru District.

Treatments	Plant Height (cm)	No. of fingers / Plant	Fodder Yield (kg/ha)			Seed Yield (kg/ha)		
			Cowpea	Horsegram	Mean	Cowpea	Horsegram	Mean
T1	87	10	3615	3545	3580	2450	2500	2475
T2	84	10	3235	3125	3180	2350	2450	2400
T3	77	9	2950	2705	2827	2250	2300	2275

3.Farmer: KVK, Hirehalli, Tumakuru Taluk, Tumakuru District.

Treatments	Plant Height (cm)	No. of fingers / Plant	Fodder Yield (kg/ha)			Seed Yield (kg/ha)		
			Cowpea	Horsegram	Mean	Cowpea	Horsegram	Mean
T1	98	11	3840	3706	3773	2700	2650	2675
T2	87	10	3570	3345	3457	2630	2485	2557
T3	82	10	3350	3100	3225	2480	2210	2345

In farmers field of D.Nagenahalli, Tumakuru District and field of KVK there was significant difference in plant height, fodder yield and seed yield of Ragi ML-365 in all three treatments. The cover crops viz. horse gram and cowpea failed due to dry spells in July and August 2017

Ragi Ml-365

2. Rice-Field pea cropping System

In the trials conducted on Paddy-pea system at Sonitpur, two methods of paddy cultivation - pea sowing were tested. The results of the study revealed that DSR paddy matured 10 days earlier to transplanted paddy in both KVK Farm and farmer's field. Yield and yield attributes were higher in transplanted paddy as compared to DSR in both farmers fields and KVK farm, this higher yields in transplanted paddy is may be due to lower weed competition in transplanted paddy but the benefit: cost ratio was higher in DSR than transplanted rice due to lower cost of cultivation in DSR than transplanted rice.

Direct seeded paddy at farmers field

Transplanted paddy at farmers field

Table 1: Yield and yield attributes of *Sali* paddy (var.TTB 404) under DSR and transplanted methods of cultivation.

	KVK farm		Farmer field	
Parameters	DSR with drum seeder	Transplanted	DSR with drum seeder	Transplanted
Plant height (cm)	125.3	128.1	121.5	123.2
No. of effective tiller/plant	5.4	6.1	4.7	5.5
Panicle length (cm)	23.1	22.6	21.1	21.8
Grains/panicle	141.4	158.5	132.9	161.2
Duration (Days)	133	145	131	148
Yield (q/ha)	41.09	53.0	38.75	46.3
Cost of cultivation (Rs/ha)	23700.00	30900.00		

Gross Return (Rs/ha)	47,904.00	61800.00		
Net Return (Rs/ha)	24,204.00	30900.00		
B : C	2.02	2.00		

Table 2 : Yield and yield attributes of Field Pea (var.Prakash) under zero tillage and relay methods of cultivation. (Location; KVK, Farm, farmer's field**)**

	KVK, Farm		**Farmers field**	
Parameters	**Zero tillage pea**	**Relay pea**	**Zero tillage pea**	**Relay pea**
No. of branches	3.6	2.9	3.4	2.7
Nos. of pod/branch	7.5	5.3	7.0	5.4
Nos. of seed/pod	6.5	6.0	5.7	6.2
1000 seed weight	155 g	150.2	151 g	149.5
Yield (q/ha)	8..75	5.5	7.90	5.3

Table 3: Cost of cultivation of *Field pea* (var. Prakash) under Zero tillage and relay methods of cultivation.

Parameters	Zero tillage pea	Relay pea
Gross Cost (Rs/ha)	14500.00	12900.00
Gross Return (Rs/ha)	41625.00	29000.00
Net Return (Rs/ha)	27125.00	16100.00
B : C (Gross return/gross cost)	2.53	2.33

The yield and yield attributes of zero tillage pea were higher in KVK, farm and farmers field condition than conventional relay pea after transplanted paddy. This may be due to better and early establishment of pea under zero tillage condition.

Implements

Sowing of Pearlmillet with CRIDA

zero seed drill machine

Redgram sown on maize residue (2015)

Bed Planter

Demonstrations at farmers field: (IIWBR)

Five CA wheat demonstrations were conducted in three villages (Bara gaon, Rambha and Taraori) in rice-wheat system. Wheat cultivar HD 2987 was sown using a seed rate of 125 kg/ha using the Turbo Happy seeder. The mean wheat yield was similar in CA (60.56 q/ha) and CT (60.81 q/ha) system.

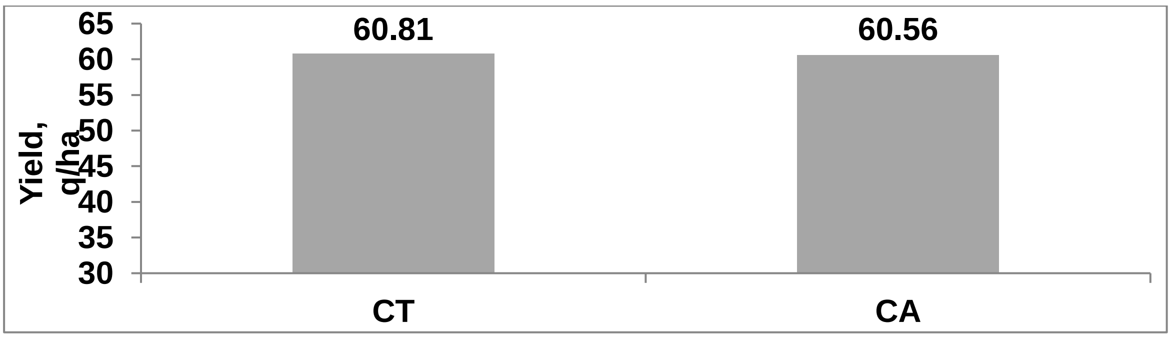


Fig.1. Comparative performance of CA and CT system of wheat seeding (Mean of five demonstrations)

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

Under "Mera Gaon Mera Gaurav" scheme in Village Bara Gaon, two field were selected for seeding of wheat and greengramin ratoon crop of Sugarcane. 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 production. Moreover, this will promote the conservation agriculture with better environmental health by reducing the pollution with no straw/trash burning.

Seeding of greengram in sugarcane ratoon using Rotary Disc Drill

Field demonstration(IARI)

Under this project various program like training on zero-tillage practices, direct seeded rice practices and diversification of cropping pattern were organized during the month of September, 2017. The training program was conducted in village Mumtazpur, Gurgaon district where about 120 farmers belonging to Mumtazpur, Lokhra, Bokharkha and Hedahedi participated. 90 farmers from village Sanghel and Jaysinghpur under Mewat District participated in the training programme as well.

1:Paddy

Demonstration on direct seeded rice was conducted in Bokharkha, Heraheri and Sanghel Villages. But the rate of adoption was poor owing to a few undesirable climatic conditions like heavy rain just after sowing, improper soil condition etc. However, some farmers were able to gain high production under DSR in Bokharkha due to higher fertility in the soil condition. The comparative study of DSR and conventional is given in Table 1. With the same variety of Rice (Pusa 1121) cultivated by five farmers, different results were observed. The practice of DSR showed yield which was comparable with conventional systems, but a higher Benefit Cost Ratio. The results clearly elucidated that the cost involved in DSR systems is less than conventional systems, with a higher net income.

Table 1Comparative overview of conventional and DSR systems

Name of farmers	Village	Crop	Practice	Variety	Yield (t/acre)	Total cost(Rs./acre)	Gross Income(Rs./acre)	Net Income(Rs./acre)	BCR
Dataram	Bokharkha	Rice	DSR	Pusa 1121	1.6	15265	48000	32735	2.14
Rajender	Hedahedi	Rice	DSR	Pusa 1121	1.2	15700	36000	20300	1.29
Tezprakash	Sanghel	Rice	DSR	Pusa 1121	1.3	16500	39000	22500	1.36
ShivKumar	Sanghel	Rice	Conventional	Pusa 1121	1.6	22765	48000	25235	1.10
Rajendre	Hedahedi	Rice	Conventional	Pusa 1121	1.4	21750	42000	20250	0.93

2: Cotton

A training programme on cultivation of raised bed cotton was conducted in Mumtazpur village where about 80 farmers participated and around 60 farmers were mobilized to grow cotton. In Mumtazpur Village 35 farmers were asked to cultivate cotton on 55 acres of land, in Heraheri Village 27 farmers cultivated the crop on 36 acres of land and in Lokra Village, cultivation was carried out on 20 acres of land by 12 farmers. (Table 2)

Table2. Adoption of raised-bed cotton

Practice	Other adopted village	Number of farmers	Area(Acre)
Raised bed cotton	Mumtazpur	35	55
	Heraheri	27	36
	Lokra	12	20

In Lokra Village, the cotton variety **Rashi** was cultivated, which led to a yield of 10 quintal per acre, with a BCR of 0.8. In Heraheri Village, the **Shriram** cotton variety provided a yield of 10 quintal/acre with a BCR of 0.78. (Table 3)

Table 3. Yield and net income from cotton cultivation in raised bed

Farmers Name	Village	Crop-variety	Intervention	Yield quintal /acre	Total Cost (Rs./acre)	Gross income (Rs./acre)	Net Income (Rs./acre)	BCR
Ashok	Lokra	Cotton -**Rashi**	Raised bed cotton	10.00	22200	40000	17800	0.80
Rajender	Heraheri	Cotton - **Shriram**	Raised bed cotton	10	22450	40000	17550	0.78

3: Wheat

Among the participants, 60 farmers from Mumtazpur and 28 farmers from Sanghel village respectively were provided with seeds for conducting demonstration on zero tillage wheat practices. In Mumtazpur, all three interventions i.e., zero-tillage, raised bed and conventional were carried out for three varieties of the crop (Table 4). In Sanghel village only Zero Tillage was practised.

Table 4. Demonstration of wheat under different practices in 2017-18

Place of demonstration/Intervention	Intervention	Variety	Demonstration/Intervention	Area under Intervention (Acre)	No. Of farmers
Mumtazpur, Haryana	Zero tillage	HD-2967	38	38	38
		HD- 3086	9	9	9
		HD-3117	10	10	10
	Raised bed	HD-2967	10	6.5	10
		HD-3086	5	2.0	5
	Conventional	HD-2967	2	2	2
Sanghel, Haryana	Zero tillage	HD-2967	22	22	22
		HD-3117	2	2	2
		WR-544	10	10	10

Zero tillage was also practised in other adopted villages to increase farmer outreach and awareness for this sustainable farming practice. The intervention was met with ample support from the farmers who came out in huge numbers. (Table5) In Heraheri Village, 160 farmers joined hands to cultivate 550 acres of land with Zero tillage. In Lokra, 100 farmers carried out the practice on 160 acres of land. Farmers from Turkapur, Ujina and Jaisinghpur also keenly participated in the demonstration.

Table 5. Comparative Analysis of agriculture interventions in Wheat in 2017-18

Intervention	Variety	Yield (Q/acre)	Net Income (Rs)	BCR
Zero-tillage	HD-2967	17.5	18800.00	3.043
	HD-3117	17	18050.00	2.973
	WR-544	16.5	13160.00	2.424
Conventional	HD-2967	16	12950.00	2.024
	HD-3117	15.5	12000.00	1.938
	WR-544	15	10900.00	1.832

Table 6 illuminates the benefits of zero tillage with HD- 3117 as compared to conventional practice. In Mumtazpur Village, per acre yield of wheat was 27 quintal, with less total cost and higher gross income with an impressively high BCR of 3.52. The same crop sown under conventional systems in Mumtazpur and Sanghel showed lower yield per acre (24 and 23 quintals) with higher cost and lesser income for farmers. This led to lower BCR in the conventional systems (2.01 and 1.87 resp.). This firmly establishes the benefits of Zero Till Practice over conventional Method. These experiments have proven that ZTW is a game changer to have higher yield, higher income and lesser costs to the farmers.

Table 6. Productivity of some of the farmers during 2017-18

Name of farmer	Village	Crop	Practice	Variety	Yield (q/acre)	Total cost (Rs./acre)	Gross income (Rs./acre)	Net income (Rs./acre)	BCR
Jogender	Sanghel	Wheat	Zero-tillage	HD-2967	24	10400	41640	31240	3.00
Shiv kumar	Sanghel	Wheat	Zero-tillage	HD-2967	23	9350	40250	30900	3.30
Ratiram	Sanghel	Wheat	Zero-tillage	HD-3086	22	9600	38170	28570	2.97
Dataram	Bokharkha	Wheat	Zero-tillage	HD-3086	26	9750	45110	35360	3.62
Shispal	Mumtazpur	Wheat	Raised-bed	HD-3086	24	10800	41640	30840	2.85
Deewan	Mumtazpur	Wheat	Zero-tillage	HD-3117	27	10350	46845	36495	3.52
Rajender	Hedahedi	Wheat	Zero-tillage	HD-2967	24	12300	41640	29340	2.38
Ragveer	Mumtazpur	Wheat	Conventional	HD-3117	24	13800	41640	27840	2.01
Yogesh	Sanghel	Wheat	Conventional	HD-3117	23	13900	39905	26005	1.87

Fig. 1. Interaction with farmers on site

Fig. 2. ZT Broad Bed wheat

Fig. 3. Demonstration on Zero Tillage

Fig. 4. Raised bed wheat

Fig. 5. Demonstration on Direct Seeded Rice

Demonstration of Best-Bet Conservation Agriculture Practices on Farmers' Fields in Vertisols of Central India. (IISS)

Farmer field experiments were conducted in a participatory mode in villages Khamkheda, Rasla Khedi, Raipur and Karod khurd data for various growth and yield attributes were recorded under different tillage modules. Among different tillage modules tested zero tillage has proved to be best among various modules with soybean. The experiments conducted during rabi season are harvested and data compilation work is under progress.**Farmer Field Data 2018 (Kharif)**

Crop- Soybean

Treatment	**Plant height at harvest**	**Pods/plant**	**Grain yield q/ha**	**Straw yield q/ha**
ZT	40.06	20.50	5.95	9.90
RT	39.66	19.66	5.23	9.58
CT	39.26	20.83	4.63	9.08
FP	38.33	18.33	4.06	8.99

2.1.4 Capacity building and knowledge management for accelerated adoption of conservation agriculture machinery

CIAE

Field days

Field days on CA machineries were organized on 17/10/2018, 13/12/2018 and 28/02/2018. Total 244 farmers from various villages of Bhopal districts of Madhya Pradesh participated in the field day (Table 1). The participants were briefed on updates of C A technologies and covered cultivation. They were given in hands on training including demonstrations of improved conservation agricultural machineries (laser land leveler, happy seeder, pre-immergence herbicide applicator with inclined plate planter, zero till drill and strip till, pipe less drainage system, hand operated dibblers and other agricultural machineries.
The leaflet on CA machinery and CIAE, Naveen sickle were also distributed to all the farmers to make them aware about the CA machinery and practices.

Trainings and Demonstration

Operational trainings on conservation agricultural machinery like laser leveler, no till drill, happy seeder, rotary disc bed farmer cum seeder planter, stubble saver (rotary chopper cum spreader), rotary slit till drill and laser land leveler.were conducted at the Institute to the 230 farmers of Chhatishgarh, Madhya Pradesh, Andhra Pradesh, Maharashtra, Rajashthan, Gujrat

(Table 1). Machinery included for the operational trainings were Similarly other training programmes were also conducted as listed in Table-1

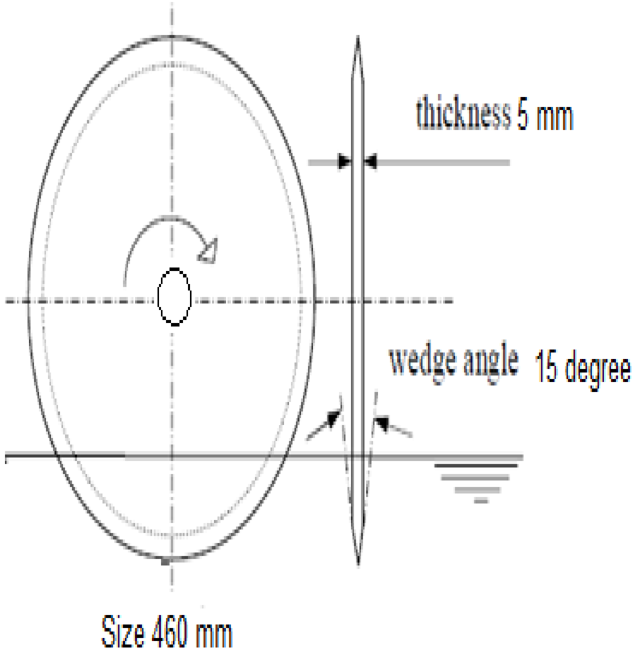
Field demonstration of laser leveler, zero till drill and rotary strip no till drill to the farmers

Refinement/fine tuning of existing CA machinery
Refinement/development of rotary disc to enhance the hardness

Table-1 Trainings and demonstration programme organized under CRP on CA

Date of Training/ demonstration	Nos. of Farmers	State/Villages
CA trainings		
21 -23/09/2017	60 Farmer	Chhatishgarh, MP,Andhra Pradesh , Maharashta, Rajashthan ,Gujrat ,Uttara Khand
4 - 6/10/2017	42 Farmer	Madhya Pradesh, Rajashthan
1 - 3/11/2017	52 Farmers	Bhiar, Uttar Pradesh
6 - 8/12/2017	76 Farmer	Bihar,Odisha,Chhatishgarh,UP and Madhya Pradesh
2 - 4/01/2018	81 Farmers	M.P. and Maharashtra
20-22/02/2018	76 Farmers	M.P., U.P. Maharashtra, Bihar and Gujrat
15-17/03/2018	80 Farmers	Bhopal, Madhya Pradesh
Field days		
17/10/2018 and	122 Farmers	Bhensoda, Ratatalkhajuri, Kochhi Barkheda, Eitkhedi, Ishlam Nagar, Mastipura, Imaliya, Lambakheda, Shyamalpur, Golkhedi, Neemkheda
13/12/2018	120 Farmers	Karond Khurd, Khamkheda, Manikhedi, Gharetiyadagi, Manakund, Sukha Nipaniya, Dewal Khedi, Bankhedi, Kardhai, Ratatal, Manikhedi.
28/02/2018	10 Scientists/technical	IIWBR, Karnal, IISS, CIAE, Bhopal

Database of critical components of CA machines has been prepared for properties (chemical composition, hardness, tensile strength, toughness, percentage elongation, and microstructure. ing the hardness testing of samples of rotary disc it has been found that not a single sample has confirm the Indian Standard for hardness and material compositions To Reduce the wear and enhance the disc heat treatment austenized, socking followed by quenching and tempering of has been conducted for obtaining proper combinations of mechanical and tribological properties. EN 8 having carbon, 0.45% and Mn, 0.9 % has been used to enhance the hardness of cutting edge of disc. Retrofitting of refined/developed discs has been done with the rotary no till drill an d long duration testing of machine was conducted under field conditions. The machine has performed satisfactorily on heavy residue condition for direct sowing of wheat crop after harvesting of paddy.



2.1.4.1 Publications

CRIDA

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- **Das, T. K.** 2017. Conservation agriculture in cereals systems in India: productivity, profitability and sustainability. **Souvenir (ISBN 978-93-84553-04-3).** Third International Conference on Bio-Resource and Stress Management, 8-11 November, 2017, Jaipur, Rajasthan, India. 36-40.

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CSSRI

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1.2 Research papers Communicated-

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- Ranbir Singh, D.K.Sharma, P.K.Joshi and Renu Kumari (2016) Long-term effect of direct seeded and transplanted rice on water productivity, natural resource saving and their economics in reclaimed alkali soil environment. **Field crop and research.**

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(i) Published –

j.kchj flg¡ 2011 Lqk/kjh Ålj {kkjh; Hkwfe esa /kku -xsgw¡ Qly pdz dk izcU/ku ,oa lalk/ku laj{k.k **d`f'k fdj.k** (4):8-9

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(ii) Communicated-

1&j.kchj flag] vkj0 ,l0 f=ikBh],l0 ds0 pkS/kjh] Mh0 ds0"kekZ]ih0 ds0 tks"kh],l0ds0"kekZ]]iznhi Ms0]Mh0ih0"kekZ] ,oa xqjcpu flag (2013) {kkjh; okrkoj.k esa /kku dh lh/kh cqvkbZ }kjk vf/kd "kq)] vk; vkSj izkd`frd lalk/kuksa dh cpr& **[ksrh**

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- **QOokjk flapkbZ fof/k ls Lqk/kjh gqbZ Ålj Hkwfe;ksa esa /kku &xsgw¡ Qly iz.kkyh }kjk ikuh ,oa ukbVªkstu dh cprA**

IIWBR

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Chhokar R.S., R.K. Sharma, S.C. Gill, RK Singh, Vikas Joon, Mamta Kajla and Ankur Chaudhary. 2018**.** Suitable wheat cultivars and seeding machines for conservation agriculture in rice-wheat and sugarcane-wheat cropping systems. Wheat and Barley Research 10 (2): 78-88.

Bulletin

Kumar Anuj, R.K Sharma, **R.S. Chhokar** and G.P Singh. 2016. Fasal Avsesh prabandhan kee chunotiya avm upay. Vistar Bulletin 59, ICAR-IIWBR, Karnal.

RCER

Publications:-

- Kumar R, Mishra JS and Hans H.2018.Enhancing the productivity of rice fallows area of Eastern India through inclusion of pulses. *Indian Farming: In Press.*
- Kumar R, Mishra JS, Rao KK, Kumar R, Singh SK and Bhatt BP. Evaluation of crop establishment techniques in rice-fallows of Eastern Indo-Gangetic Plains. *In. Abstracts, National seminar on Organic Waste Management for Food and Environmental Security during 8-10 Feb. 2017 held at Bhopal* and organized by ICAR- Indian Institute of Soil Science & Indian Society of Soil Science (Bhopal Chapter), Bhopal-462038, Madhya Pradesh.
- Mishra JS and Kumar Rakesh. 2017. Zero tillage options for establishment of pulses in rice-based cropping system. Farm Mechanization for increasing pulse productivity: *In Press.*
- Mishra JS and Kumar.2017.Conservation tillage and weed management in small holder Agriculture: Issues and Opportunities. *Current Advances in Agricultural Sciences* **9** (2):186-189.
- Mishra JS, Kumar Rakesh, Kumar R, Rao KK, Singh SK, Idris M, Jha BK, Naik SK, SS Mali and Bhatt BP. 2016. Evaluation of pulses and oilseed under different crop establishment methods in rice-fallows of Eastern India. Paper ID No. IAC-2016/Sym-.XII/107). *4th International Agronomy Congress on "Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge*" held during November 22–26, 2016 at New Delhi, India.

NIASM

List of Publications

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

1. Choudhary, R.L., Wakchaure, G.C., Minhas, P.S. and Singh, A.K. 2017. Response of Ratoon Sugarcane to Stubble Shaving, Off-barring, Root Pruning and Band Placement of Basal Fertilisers with a Multi-purpose Drill Machine. *Sugar Tech***19**(1):33–40. (NAAS rating: 6.83)

(ii) Popular articles:

1. आर.एल. चौधरी, ए.के. सिंह, जी. सी. वाकचौरे, महेशकुमार, पी.ए. काले, के. के. कृष्णानीऔरएन. पी. सिंह। 2018 ।गन्नेसेअधिकमुनाफेकेलियेबहुउद्देशीयमशीन।*खेती (दोगुनीकृषकआयविशेषांक)* 2018(1): 57–59

Technical folders:

1. **Choudhary, R.L.,** Singh, A.K., Wakchaure, G.C., Minhas, P.S., Krishnani, K.K. and Singh N.P. 2018. SORF: A Multi-purpose Machine for Ratoon Sugarcane. Boon for farmers and environmental protection. Technology Folder No.: 25 (2018), ICAR-National Institute of Abiotic Stress Management, Malegaon, Baramati- 413 115, Pune, Maharashtra, India.
2. **चौधरी, आर.एल.,**सिंह, ए.के., वाकचौरे, जी.सी., मिन्हास, पी.एस., कृष्णानी, के.के., नांगरे, डी.डी., काले, पी.ए. और सिंह, एन.पी. 2017. सोर्फ: ऊस खोडव्याच्या व्यवस्थापनासाठी एक बहुउद्देशीय औजार.*तकनीकी फ़ोल्डर क्रमांक: 14 (2017)*, संरक्षण कृषि संशोधन मंच, भाकृअनुप-राष्ट्रीय अजैविक स्ट्रैस प्रबंधन संस्थान, मालेगांव, बारामती, पुणे - 413 115, महाराष्ट्र, भारत.
3. **चौधरी, आर.एल.,**सिंह, ए.के., वाकचौरे, जी.सी., मिन्हास, पी.एस., कृष्णानी, के.के., पटेल डी.पी. और सिंह, एन.पी. 2017. सोर्फ: पेड़ी गन्ने के लिये एक बहुउद्देशीय मशीन.*तकनीकी फ़ोल्डर संख्या: 12 (2017)*, संरक्षण कृषि अनुसंधान मंच, भाकृअनुप-राष्ट्रीय अजैविक स्ट्रैस प्रबंधन संस्थान, मालेगांव, बारामती, पुणे - 413 115, महाराष्ट्र, भारत.

4. **Choudhary, R.L.,** Singh, A.K., Wakchaure, G.C., Minhas, P.S., Krishnani, K.K. and Singh N.P. 2017. SORF: A Multi-purpose Machine for Ratoon Sugarcane. *Technical Folder No.: 11 (2017)*, Consortia Research Platform on Conservation Agriculture, ICAR-National Institute of Abiotic Stress Management, Malegaon, Baramati- 413 115, Pune, Maharashtra, India.

(iii) Papers presented at scientific meetings:

- **Choudhary, R.L**., Kumar, M., Wakchaure, G.C., Singh, Y., Krishnani, K.K. and Singh, N.P. In-situ trash and nutrient management for improving resource-use efficiency, productivity and soil health in sugarcane cropping system. In: *Abstracts, National Conference on Organic Waste Management for Food and Environmental Security*, 8–10 February, 2018, ICAR-Indian Institute of Soil Science, Bhopal, India. pp. 66-67.
- **Choudhary, R.L**., Kale, P.A., Kumar, M., Wakchaure, G.C., Krishnani, K.K. and Singh, N.P. Innovation in sugarcane ratoon management to improve cane productivity and environmental quality. In: *Proceedings, International Symposium on Sugarcane*

Research Since Co 205: 100 Years and Beyond, 18–21 September, 2017, ICAR-Sugarcane Breeding Institute, Coimbatore, India. pp. 620-621.

- **Choudhary, R.L**., Kale, P.A., Pondkule, R.G., Kumar, M., Wakchaure, G.C., Meena, K.K., Krishnani, K.K. and Singh, N.P. Innovation and scope in summer mungbean cultivation for sustainable diversification of sugarcane cropping system in peninsular India. Oral presentation in the "*National symposium on Advances in Agriculture through Sustainable Technologies and Holistic Approaches"* held at Panjim, Goa during 15–17th February, 2017.
- **Choudhary, R.L.,**Minhas, P.S., Wakchaure, G.C., Krishnani, K.K., Rajagopal, V., Kumar, M., Meena, R.L. and Singh, N.P. Response of ratoon sugarcane to fertiliser-nitrogen application methods and trash management practices in semi-arid tropical region of India. Oral presentation in the "*International Conference on Climate Change Adaptation and Biodiversity: Ecological Sustainability and Resource Management for Livelihood Security"* held at Port Blair, Andaman & Nicobar Islands, India during 8–10th December, 2016.
- **Choudhary, R.L.,**Minhas, P.S., Pondkule, R.G., Kale, P.A., Wakchaure, G.C., Kumar, M., Saha, S. and Singh, N.P. 2016. Root growth and cane yield of ratoon sugarcane under the combined effect of stubble shaving, off-barring, root pruning and placement of basal dose of fertilisers with surface retention of trash. Poster presented in the "*4th International Agronomy Congress on Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge"* held at Indian Agricultural Research Institute, New Delhi, India during 22–26th November, 2016.

(iv) Chapters in Books/Training Manuals:

1. Choudhary, R.L., Kumar, M., Singh, Y., Meena, K.K., Krishnani, K.K. and Singh, N.P. 2018. Conservation agriculture in sugarcane based cropping systems: the beginning. In: *Advanced Training on Detection, Identification and Application of Microbially Derived Biomolecule for Alleviation of Salinity Stress in Crop Plants*. (Meena, K.K., Krishnani, K.K., Sorty, A.M., Bitla, U.M. and Singh, N.P. Eds.). Training Manual, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, India. Pp. 158-169.
2. Choudhary, R.L., Kumar, M., Rane, J., Kumar, P., Harisha, C.B. and Krishnani, K.K. 2018. In-situ Root Phenotyping through Mini-rhizotron Technique. In: *International Training on 'Advanced Training on Application of Plant Phenomics Tools for Assessing Responses of Crop Plants to Drought and High Temperature'*. (Rane et al., and Singh, N.P. Eds.). Training Manual, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, India. Pp. 158-169.
3. Choudhary, R.L., Kumar, M., Kumar, S., Ram, H. and Kumari, A. 2017. Potential of conservation agriculture in drought stress management in crop plants. In: *Climate Change and Sustainable Agriculture*. (Kumar, P.S., Kanwat, M., Meena, P.D., Kumar, V. and Alone, R.A. Eds.). New India Publishing Agency, New Delhi. pp. 103–142.

4. Choudhary, R.L., Wakchaure, G.C. and Minhas, P.S. 2017. New Prototype of Off-bar, Root Pruner-cum Fertilizer Drill Machine for Improving Nitrogen-use Efficiency and Productivity of Sugarcane Ratoon Crop. In: *Sustainable Farming and Soil Health Management*. (Arora, S. and Bhan, S. Eds.). Soil Conservation Society of India, New Delhi. pp. 297–309.
5. Choudhary, R.L., Wakchaure, G.C., Kumar, M., Singh, Y., Krishnani, K.K. and Singh, N.P. 2017. Conservation agriculture in sugarcane cropping system: a way towards climate smart production system. In: *Climate Smart Agriculture for Enhancing Crop and Water Productivity under Abiotic Stress Conditions*. (Wakchaure, G.C., Gaikwad, B.B., Meena, K.K., Singh, Y., Nangare, D.D., Choudhary, R.L. and Singh, N.P. Eds.). Training Manual, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, India. Pp. 1–7.
6. Choudhary, R.L. and Krishnani, K.K. 2017. Climate smart machinery for sugarcane ratoon management. In: *Climate Smart Agriculture for Enhancing Crop and Water Productivity under Abiotic Stress Conditions*. (Wakchaure, G.C., Gaikwad, B.B., Meena, K.K., Singh, Y., Nangare, D.D., Choudhary, R.L. and Singh, N.P. Eds.). Training Manual, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, India. Pp. 8–10.
7. Choudhary, R.L., Kumar, M., Wakchaure, G.C., Singh, Y., Krishnani, K.K. and Singh, N.P. 2017. Conservation agriculture in sugarcane cropping systems: challenges and opportunities. In: Recent Advances in Abiotic Stress Management for Climate Smart Agriculture. (Singh, Y., Bal, S.K., Nangare, D.D. Kumar, M and Singh, N.P. Eds.). Training Manual, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, India. Pp. 77–87.

(v) Awards:

1. Dr. R L Choudhary, Scientist SS (Agronomy) has been awarded Best Oral Presentation Award for his research paper entitled "Innovation and scope in summer mungbean cultivation for sustainable diversification of sugarcane cropping system in peninsular India" in the National symposium on *"Advances in Agriculture through Sustainable Technologies and Holistic Approaches"* held at Panjim, Goa during 15–17 February, 2017.

(vi) Manuscripts under preparation:

1. 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 "Crop-Environment Interaction". (*Communicated*)

NRRI

Research paper above 6 rating with title and journal-

Banwari Lai; A. K. Nayak; B. B. Panda; P. Bihari; PriyankaGautam; R. Tripathi; M. Shahid; P. K. Guru; D. Chatterjee; U. Kumar (2018). Assessment of N_2O emission and soil health in maize under zero tillage. Environmental Monitoring and Assessment .

Presentation in seminar symposia

Dinesh Kumar Marapi, B.B. Panda, G.K. Shrivastava, A.K. Nayak, R. Tripathi, Md. Shahid, Jagadish Jena, HaramohanRath, D. Mohabhoi, P. Dash and J. Panigrahi (2018). Effect of tillage and residue mulching on productivity of rice – maize cropping system. Extended Summaries: 3rdARRW International Symposium, February 6-9, 2018, Cuttack, India. p. 307.

CIAE

Research paper above 6 rating with title and journal: Nil

Research paper below 6 rating

1. Singh KP, Saha KP, Singh Dushyant, Singh CD, Singh RC, Tripathi H, Bhushana Babu V. 2016. Performance Evaluation of Tractor Operated Raised Bed Former-cum-Seeder for Maize– Chickpea Cropping Sequence. *Journal of Agricultural Engineering*, 52 (1), 1-8.
2. Singh C D; R C Singh; K. P. Singh and Ramadhar Singh (2016). A sensor network for monitoring soil moisture and temperature under permanent bed in vertisol. International Journal of Innovative Studies in Science and Engineering Technology (IJISSET), Vol. 2 (9): pp 8-12. Impact factor 0.6
3. Singh, Dushyant, Nandede, B.M; Singh, A.K. and Singh R.S. (2018). Effect of heat treatment on wear rate of different agricultural grade steels and associated cost. Economics Affairs, 63(1): 203-208.

Review papers Nil

Popular article. 3

Technical bulletins

- Singh, R S; K P Singh; Vivek Walke; A K Dubey; K P Shaha and R C Singh (2016). Energy foot prints in production agriculture. Technical bulletin No. CIAE/ AMD/ 2016/196. Pp. 56.
- Singh R.S; R C Singh; PS Tiwari; SK Garg; AK Dohre and D K Dwevedi (2016). Broad bed former cum seeder: Praticool JalWayu Me Ak Safal Upyogi Krishi Yantra. Tech. Bulletin No. CIAE/NICRA/2016/201, pp. 09.
- Singh R C; Dushyant Singh; Sonam Sarvaiya and Anjana Yadav (2016). Balate Parivesh me Saranskhan Kheti Ki Jarurat. Leaflet No. CIAE/CA/2017/207.pp 02.

Presentation in seminar symposia

- Singh, R. C; Sangeeta Lenka and C D Singh (2016) “Interactive effect of conservation tillage and manure on soil aggregation, yield and energy requirement for soybean and wheat in vertisol”. Paper presented in 50th ISAE Annual Convention and Symposium on Agricultural Engineering in National Building: Contribution and Challenges, held at OUA&T Bhubaneshwar, during 19-21th January, 2016.
- C D Singh, R C Singh and K P Singh (2016) “Telemetry based soil moisture sensor networks for monitoring of wheat plants under permanent raised bed in vertisols” in 50th ISAE convention held at OUAT, Bhubaneswar on 19-21 January 2016. ISAE-2016/FMP/ESA-20, page 158.

- Singh, R. C. (2016). “Adoption/development of Conservation agricultural Machinery” Paper presented in Interaction meeting cum training program for consortia partners of CRP on CA, held at ICAR-CIAE, Bhopal dated 29th March 2016.

DWR

Papers Published

Papers reviewed in peer reviewed journals/proceedings:-

- Choudhary, V.K. and Singh, P.K. 2017. Crop residue management for improving soil and crop productivity in cereal based cropping system. In: Souvenir National Conference on Managing soil health for sustainable and nutritional food production. 28-29 October, 2017 at JNKVV, Jabalpur. Pp.107-115.

Papers presented at scientific meetings:

- Presented paper on “Enhancing soil and crop productivity in mid hills through residue management in rice-toria cropping system” on National Conference on “Managing soil health for sustainable and nutritional food production”. 28-29 October, 2017 at JNKVV, Jabalpur organized by GVK Society Agra.
- Presentation made on “Technologies for weed management” during 24th Zonal Workshop of KVKs at Burhanpur on 24-26 November 2017.

Research paper:

- Singh, V.P., Barman, K.K., Singh, P.K., Singh, R. and Dixit, A. 2017. Managing weeds in rice (*Oryza sativa*) - wheat (*Triticum aestivum*)-greengram (*Vigna radiata*) system under conservation agriculture in black cotton soils. *Indian Journal of Agricultural Sciences* 87(6): 739-745.
- Singh, P.K., Sondhia, S., Dubey, R.P., Sushilkumar, Kumar, B., Gharde, Y. and Choudhary, V.K. 2017. An analysis on adoption and impact of conservation agriculture technology in conjunction with weed management in wheat and greengram in central India. *Indian Journal of Weed Science*. 49(1):23-28.
- Sharma, A.R., Mishra, J.S. and Singh, P.K. 2017. Conservation agriculture for improving crop productivity and profitability in the non-Indo-Gangetic region of India. *Current Advances in Agricultural Sciences* 9(2):178-185.
- Sondhia S. and Singh, P.K. 2018. Bio-efficacy and monitoring of terminal residue of pendimethalin in field soil and plants at farmers field following an application to the chickpea. Journal of Environmental Monitoring and Assessment (Communicated)

Extension folder:

- Choudhary, V.K., Singh, P.K., Gharde, Y., Chauhan A. and Kumar Santosh. 2018. Sanrakshit kheti se visham paristhiti ka samadhan pp. 1-6. Published by ICAR-Directorate of Weed Research, Jabalpur.
- Choudhary, V.K., Singh, P.K., Chethan C.R., Subhash Chander, and Kumar Santosh. 2018. Fasal Avseshon ka samuchit prabandhan pp. 1-6. Published by ICAR-Directorate of Weed Research, Jabalpur.

Popular article:

- Sharma, A.R., Singh, P.K. and Gharde Yogita. 2016. Adoption of conservation agriculture based technologies in Jabalpur. ICAR News, New Delhi (Ist issue of 2016, pp-24-25).
- Singh, P. K., Sondhia Shobha and Gharde Yogita 2017. mUur d`f"k ,oa e`nk LokLF; gsrq

Qly vo'ks"k izca/ku] [ksrh if=dk 70 (8) pp- 7-11

- Kanthale, A.K., Singh, R., Jaggi, D. Choudhary, V.K., Chethan, C.R. and Singh P.K. 2016-2017. Sanrakshit krishi ka mrida swasthay par prabhav. *Trin Sandesh*. 12: 86-87.
- Kanthale, A.K., Chauhan, A., Choudhary, V.K. and Chethan, C.R. 2016-2017. Mrida sourikaran: kharpatwar niyantran ki ek rasayan mukt taknik. *Trin Sandesh*. 12: 4-6.

Workshop cum Field day

- Workshop-cum field day was organized on weed management in conservation agriculture on 27th March 2018, where 185 farmers were benefitted.