Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; SP4: 76-82

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(Special Issue- 4)
International Conference on Food Security and Sustainable Agriculture
(Thailand on 21-24 December, 2018)

Role of conservation agriculture in natural resource management for livelihood security

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Abstract
The paper focuses on conservation agriculture (CA), defined as minimal soil disturbance (zero tillage) and permanent soil cover (mulch) combined with rotations, as a more sustainable cultivation system for the future. Cultivation and tillage play an important role in agriculture. The paper describes how the benefits of conservation agriculture, zero tillage, mulch and rotations significantly improve soil properties and other biotic factors. The paper concludes that CA is a more sustainable and environmentally friendly management system for cultivating crops. Research findings of studies conducted at agronomical farm of Birsa Agricultural University on rice–wheat and maize-wheat system under conservation agriculture was taken to describe how CA practices have been used in these two cropping systems to raise production, sustainably and profitably. The paper concludes that agriculture in the next decade will have to sustainably produce more food from less land through more efficient use of natural resources and with minimal impact on the environment in order to meet growing population demands. Promoting and adopting CA management systems can help meet this goal.

Keywords: Conservation agriculture, Conventional tillage, Zero tillage, Weed.

Introduction

Livelihood security refers to the challenges of maintaining global food security and universal access to freshwater and energy to sustain livelihoods and promote inclusive economic growth while maintaining or enhancing the local and global assets and capabilities on which livelihood depend. While, livelihood is defined as adequate stocks and flows of food and cash to meet basic needs. Security refers to secure ownership of, or access to, resource and income earning activities, including reserves and assets to offset risk, ease shocks and meet contingencies. Sustainable refers to the maintenance or enhancement of resource productivity on a long term basis. A household may be enabled to gain sustainable livelihood security in many ways- through ownership of land, livestock or trees, right to grazing, fishing, hunting or gathering, through stable employment with adequate remuneration, or through varied repertories of activities. Hence, livelihoods have high reliance on natural capital and is highly vulnerable to impacts like deforestation, desertification, soil erosion, loss of soil structure, oxidation of organic matter, deterioration of soil biological health, energy crisis, declining water table, pollution, global warming, over exploitation of nonrenewable resources, frequency of fires etc.

This prompted a surge of new concepts for another shift to address these issues and increase the level of production to sustain the future food requirement of burgeoning population while conserving the natural resources and utilizing them more efficiently. The concept involves crop diversification, integrated farming systems, efficient use of inputs (water, nutrients, herbicides), use of organics, biofertilizers and bio-control agents and conservation agriculture.

Soil erosion have great impact on soil physicochemical and biological health and consequently on its structure, organic matter, nutrient availability, water holding capacity etc. which is resulting from tillage compelled to go for alternatives and to reverse the process of soil degradation. The logical approach to this has been to reduce tillage or conservation tillage and especially zero-tillage and hence concept of conservation agriculture came. Conservation agriculture (CA) aims to achieve sustainable and profitable agriculture and subsequently aims

at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations (FAO, 2012b) [2]. It is a way to combine profitable agricultural production with environmental concerns and sustainability and it has been proven to work in a variety of agroecological zones and farming systems. So Conservation Agriculture is a set of soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity. CA has proven potential to improve crop yields, while improving the long-term environmental and financial sustainability of farming. Experiences have shown that conservation agriculture method is much more than just reducing the mechanical tillage. In a soil that is not tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch. This layer protects the soil from the physical impact of rain and wind but it also stabilizes the soil moisture and temperature in the surface layers. Thus this zone becomes a habitat for a number of organisms, from larger insects down to soil borne fungi and bacteria. These organisms may create the mulch, incorporate and mix it with the soil and decompose it so that it becomes humus and contributes to the physical stabilization of the soil structure. At the same time this soil organic matter provides a buffer function for water and nutrients. Larger components of the soil fauna, such as earthworms, provide a soil structuring effect producing very stable soil aggregates as well as uninterrupted macro pores leading from the soil surface straight to the subsoil and allowing fast water infiltration in case of heavy rainfall events. Moreover, Tillage operation increases soil oxygen content leading in turn to the mineralization of the soil organic matter. This inevitably leads to a reduction of soil organic matter which is the substrate for soil life.
As the main objective of agriculture is the production of crops, changes in the pest and weed management become necessary with CA. Burning plant residues and ploughing the soil is mainly considered necessary for phyto sanitary reasons: to control pests, diseases and weeds. In a system with reduced mechanical tillage based on mulch cover and biological tillage, alternatives have to be developed to control pests and weeds. Integrated Pest Management becomes mandatory. One important element to achieve this is crop rotation, interrupting the infection chain between subsequent crops and making full use of the physical and chemical interactions between different plant species. Synthetic chemical pesticides, particularly herbicides are, in the first years, inevitable but have to be used with great care to reduce the negative impacts on soil life. To the extent that a new balance between the organisms of the farm-ecosystem, pests and beneficial organisms, crops and weeds, becomes established and the farmer learns to manage the cropping system, the use of synthetic pesticides or herbicides and mineral fertilizer tends to decline to a level below that of the original "conventional" farming system.

Research findings on CA

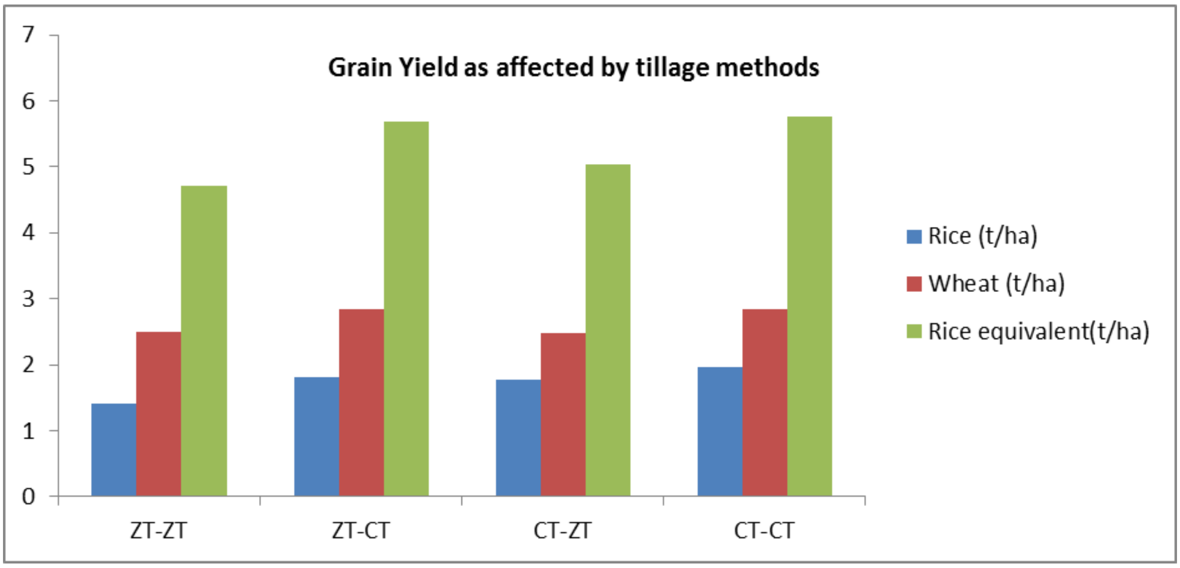
Conservation tillage in Rice-wheat cropping system

A field experiment was conducted on sandy loam soil of Birsa Agricultural University, Ranchi during 2010–11 and 2011–12 to evaluate the performance of tillage and weed-control methods on weed dynamics and productivity of rice-wheat system.

System productivity in terms of rice equivalent yield

System productivity was affected significantly by different tillage sequences and weed-control methods (Fig 1). Maximum rice-equivalent yield was recorded in continuous conventional tillage sequence and was on par with zero tillage and conventional tillage practices in rice and wheat sequences.
Among weed management, application of recommended herbicide (butachlor 1.0 kg/ha as pre-emergence + 2,4-D 0.5 kg/ha as post-emergence in rice and isoproturon 0.75 kg/ha + 2,4-D 0.5 kg/ha as post-emergence in wheat, resulted in significantly highest rice-equivalent yield (6.34 t/ha) and was 11.80% and 63.63% higher than hand weeding and weedy check respectively.

Economics: Pooled data revealed that continuous conventional tillage sequence in rice and wheat recorded the maximumgross return (57,607/ha), net return (28,446 /ha) and benefit: cost ratio in rice–wheat cropping system and was similar to ZT-CT practices in rice and wheat sequences. Gangwar *et al*. (2006) [3] also observed higher benefit: cost ratio in rotational tillage. Among weed management, application of recommended herbicide recorded significantly maximum gross returns, net returns and benefit: cost ratio. These results confirm the findings of Singh *et al*. (2010) [14] and Mishra (2006) [10].



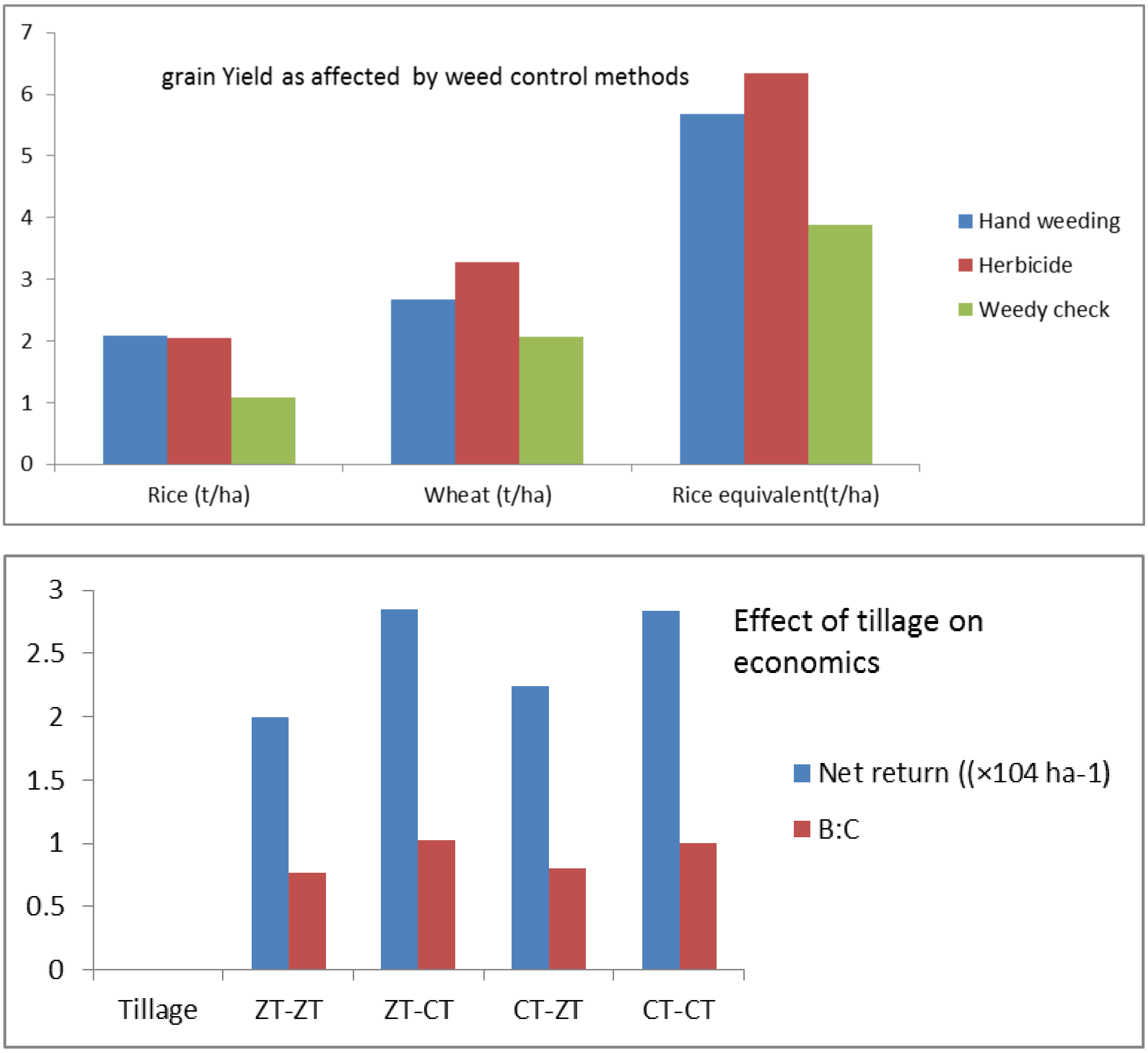


Fig 1: Effect of tillage and weed management on yield and economics of rice–wheat system (pooled data of 2 years)

Economics

Pooled data revealed that continuous conventional tillage sequence in rice and wheat recorded the maximum gross return (₹57,607 ha^{-1}), net return (₹28,446 ha^{-1}) and benefit: cost ratio in rice–wheat cropping system and was similar to ZT-CT practices in rice and wheat sequences. Gangwar *et al.* (2006) [3] also observed higher benefit: cost ratio in rotational tillage. Among weed management, application of recommended herbicide recorded significantly maximum gross returns, net returns and benefit: cost ratio. These results confirm the findings of Singh *et al.* (2010) [14] and Mishra (2006) [10].

Conservation agriculture in maize-wheat cropping system

Another experiment was conducted on conservation agriculture in maize wheat cropping system to evaluate the effect of tillage and weed control methods on weed dynamics and productivity of maize-wheat system on sandy loam soil of Birsa Agricultural University, Ranchi during 2013–14 and 2014–15.

Effect on weeds

***Maize*:** Upasani *et al.* (2016), studying on conservation agriculture in maize – wheat sequence reported that tillage methods did not influence grassy, broad leaved and sedges as well as total weed density (Table 1). That implies zero tillage is similar to conventional tillage. The dominance of weeds under conventional and zero tillage may be because of different reasons. As under conventional tillage weed seeds which remained buried within soil might have transported up on the soil surface by soil disturbance while under zero tillage weed seeds which remained on soil surface germinated and grew resulting similar effect on weed density and dry matter at 30 and 60 DAS as that of conventional tillage. Matloob *et al.* (2015) [9] have also observed grassy weeds were much higher under zero tillage while broad-leaved weeds, especially *Trianthemum portulacastrum* dominated under continuous tillage system. Thus, the density and biomass of weeds was considerably similar under both the tillage systems. Among weed control methods, integrated weed management (IWM) performed in both the season recorded significantly reduced weed density as well as weed dry matter of all categories of weeds except grassy weeds at 30 DAS. Similar results were also observed by Bali *et al.* (2016) [1]. Verma *et al.* (2015) [16] have also suggested for getting effective control of composite weed flora, a logical combination of several weed control methods is likely to prove the most effective approach.

Table 1: Effect of tillage and weed control methods on weed density and dry matter at different crop stages of maize (Pool of 2013-14 and 2014-15)

Treatments	Weed density (no./m²)								Weed dry matter (g/m²)	
	30 DAS				60DAS				30 DAS	60DAS
Tillage Methods	Grassy	Broad Leaved	Sedges	Total	Grassy	Broad Leaved	Sedges	Total		
CT-CT	6.845 (51.5)	7.45 (68)	5.44 (35)	12.19 (159.5)	7.775 (68.5)	8.825 (89	6.075 (44.5)	13.62 (202	7.36 (57.655)	8.95 (84.235)
CT-ZT	6.61 (50)	7.435 (70)	6.01 (46)	12.335 (171.5)	8.425 (83.5)	8.65 (83.5)	6.26 (45.5)	13.9 (212.5)	7.315 (56.13)	9.45 (94.605)
ZT-ZT	9.175 (100.5)	8.17 (74	6.38 (45)	13.95 (212)	7.965 (84)	8.69 (84)	6.945 (52.5)	13.9 (220)	7.665 (62.315)	9.22 (94.45)
ZT-ZT+R	7.835 (72)	8.05 (72.5)	6.6 (51.5)	13.09 (190)	8.52 (85.5)	8.115 (79.5)	6.545 (51.5)	13.655 (217)	7.475 (59.55)	9.25 (95.405)
ZT+R-ZT+R	8.08 (81)	8.6 (86.5)	6.38 (46.5)	12.875 (189.5)	9.48 (108.5)	9.225 (97.5)	6.765 (52)	15.015 (259)	7.66 (61.72)	9.865 (107.73)
SEm	0.825	1.07	0.57	1.035	0.645	1.1	0.565	0.835	0.48	0.52
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed control										
R H --- RH	6.91 (59)	6.37 (45)	5.16 (29)	10.465 (114.5)	6.54 (44.5)	7.28 (57)	5.2 (28.5)	11.23 (130)	6.39 (41.42)	7.97 (64.03)
IWM – IWM	6.41 (44.5)	5.90 (39)	4.53 (22)	10.06 (103.5)	6.55 (44.5)	6.57 (46)	4.85 (25)	10.65 (116)	6.4 (41.33)	7.55 (57.09)
WC – WC	9.8 (109.5)	11.55 (138.5)	8.79 (83)	18.135 (335.5)	12.205 (169)	12.28 (157)	9.49 (94.5)	20.15 (421)	9.695 (95.67)	12.51 (164.43)
SEm	0.835	0.735	0.435	0.82	0.5	0.65	0.515	0.57	0.47	0.47
CD (P=0.05)	NS	2.84	1.68	3.17	1.93	2.51	1.99	2.20	1.81	2.72
Interaction										
SEm ±	0.96	1.08	0.54	0.94	0.60	1.05	0.62	0.83	1.82	NS
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	8.35	9.30

Wheat: Continuous conventional tillage (CT-CT) similar to conventional tillage performed in rainy and zero tillage in winter season (CT-ZT) recorded significantly reduced weed density of broad leaved and total weeds at 30 DAS and grassy, broad leaved and total weeds density at 60 DAS (Table 2). Similarly, conventional tillage in rainy and zero tillage in winter (CT-ZT) being on par with continuous conventional tillage CT-CT tillage sequence, significantly reduced dry matter accumulation by weeds at 30 and 60 DAS compared to other tillage sequences. Reduction in weed density and weed dry matter under conventional tillage in wheat crop has also been reported by Ramesh *et al.* (2014) [13] and Han *et al.* (2013) [4].

Table 2: Effect of tillage and weed control methods on weed density and dry matter at different crop stages of wheat (Pool of 2013-14 and 2014-15)

Treatments	Weed density (no./m²)						Weed dry matter (g/m²)	
	30 DAS			60DAS			30 DAS	60DAS
	Grassy	Broad Leaved	Total	Grassy	Broad Leaved	Total		
Tillage Methods								
CT-CT	2.00 (4.33)	2.58 (7.15)	3.20 (11.48)	1.71 (3.51)	4.58 (24.87)	4.84 (28.38)	3.13 (10.06)	2.75 (8.36)
CT-ZT	2.07 (4.71)	2.69 (7.65)	3.35 (12.36)	1.97 (4.50)	5.03 (28.81)	5.37 (33.30)	3.70 (13.97)	2.97 (9.60)
ZT-ZT	2.83 (10.14)	3.17 (10.83)	4.22 (20.97)	2.93 (10.50)	6.83 (54.96)	7.42 (65.46)	4.14 (18.29)	3.92 (17.19)
ZT-ZT+R	2.82 (9.31)	3.12 (10.48)	4.20 (19.79)	2.84 (9.93)	6.41 (46.53)	7.00 (56.46)	4.36 (19.13)	3.66 (14.61)
ZT+R-ZT+R	2.53 (7.88)	3.19 (10.38)	4.12 (18.26)	2.49 (7.28)	6.34 (42.93)	6.82 (50.20)	6.79 (65.03)	3.74 (14.48)
SEm+-	0.13	0.16	0.14	0.15	0.39	0.39	0.37	0.23 (1.58)
CD at 5%	NS	0.53	0.45	0.49	1.26	1.28	1.21	0.75 (5.14)
Weed control								
R H --- RH	1.67 (2.36)	2.36 (5.30)	2.82 (7.66)	1.60 (2.31)	4.74 (24.02)	4.97 (26.34)	4.51 (20.74	2.86 (8.50)
IWM – IWM	1.55 (2.06)	2.39 (5.47)	2.78 (7.53)	1.46 (1.89)	4.04 (16.70)	4.25 (18.59)	4.90 (40.14	2.47 (5.88)
WC – WC	4.13 (17.40)	4.10 (17.12)	5.85 (34.53)	4.10 (17.23)	8.73 (78.13)	9.65 (95.36)	3.86 (15.01	4.89 (24.16)
SEm	0.17	0.23	0.12	0.20	0.26	0.18	0.26	0.19
CD (P=0.05)	0.68	0.90	0.46	0.77	1.01	0.71	1.04	0.73
Interaction								
SEm ±	0.27	0.35	0.26	0.29	0.54	0.50	0.39	0.37
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Yield and economics

Maize: Zero tillage along with crop residue in rainy and winter seasons (ZT+R-ZT+R) being similar to zero tillage in both the seasons (ZT-ZT) and zero tillage in rainy but zero tillage along with crop residue in winter season (ZT-ZT+R) recorded significantly higher maize grain yield compared to continuous conventional tillage (CT-CT) and conventional tillage in rainy and zero tillage in winter (CT-ZT) during 2014 and pooled yield of 2013 and 2014 (Table 3). As a result ZT+R-ZT+R being similar to ZT-ZT and ZT-ZT+R recorded significantly higher gross and net return compared to CT-CT and CT-ZT during 2014 and under pooled of 2013 and 2014. The B:C ratio was maximum under ZT+R-ZT+R and was similar to ZT-ZT+R during both the years as well as when data were pooled. This may be due to saving of cost of tillage operation in zero tillage system. Similar was the findings of Marwat *et al.* (2011) [8].

Table 3: Effect of tillage and weed control methods on yield and economics of maize (Pool of 2013-14 and 2014-15)

Treatments	Yield (kg/ha)		Cost of cultivation (□/ha)	Gross return (□/ha)	Net Return (□./ha)	B:C ratio	Maize equivalent yield (kg/ha) of maize – wheat Pool of 2013 to 2014-15
	Grain	Straw					
Tillage Methods							
CT-CT	2153	4028	18990	44387	25397	2.33	11122
CT-ZT	2069	3872	18990	42646	23656	2.24	10360
ZT-ZT	2393	4282	14690	48743	34053	3.42	10341
ZT-ZT+R	2395	4202	14690	48534	33844	3.46	10478
ZT+R-ZT+R	2674	4713	14690	54248	39558	3.87	10896
SEm+-	138.98	258.99		2849.77	4891	0.15	215
CD at 5%	NS	NS		NS	NS	0.48	NS
Weed control							
R H --- RH	2499	4494	14558	50972	36414	3.63	11011
IWM – IWM	2601	4615	20914	52856	31942	2.53	11536
WC – WC	1911	3549	13758	39307	25549	3.00	9372
SEm	90.14	162.70		1832.15	2636	0.12	215
CD (P=0.05)	353.82	639		7192	10348	0.48	846
Interaction							
SEm ±	174.50	308.50		3498.62	7114	0.21	785
CD (P=0.05)	NS	NS		10487.00	21324	0.62	2355

Integrated weed management (IWM) performed in maize being similar to application of recommended herbicide i.e. atrazine 1.0 kg ha^{-1} recorded significantly higher maize grain and straw yield as well as gross return due to crop received clear environment during critical period of crop weed competition and the condition was more favorable for its growth and development. Significantly lower yield under weedy check was also recorded by Pandit *et al.* (2016) [12]. While, significantly higher net return and B:C ratio was recorded under application of recommended herbicide i.e. atrazine 1.0 kg ha^{-1}. However, net return was at par with integrated weed management. The results are in agreement to the findings of Mahmoud *et al.* (2012) [7].

System productivity and profitability

Conventional tillage performed in rainy and winter seasons (CT-CT) significantly affected system yield (8019 kg ha^{-1}) and gross return (□ 120290 ha^{-1}) during 2013-14, while during 2014-15, ZT+R-ZT+R being similar to ZT-ZT+R and ZT-ZT recorded maximum net return (□ 94086 ha^{-1}) and B:C (3.57). In case of pooled analysis ZT+R-ZT+R similar to ZT-ZT+R recorded maximum B:C ratio (3.22) which was 18.01, 18.94, 9.32 and 2.80% more than CT-CT, CT-ZT, ZT-ZT, ZT-ZT+R tillage sequences, respectively owing to saving in tillage operations thus reduced cost of cultivation.

Integrated weed management (IWM–IWM) sequences in maize–wheat recorded maximum system yield as well as gross return during both the years and in pooled analysis. The increase in pooled yield was 8.19 and 28.80% and gross return was 8.19 and 28.81% than recommended herbicide (RH-RH) and weedy check (WC-WC), respectively. During 2014 and in pooled analysis IWM-IWM recorded maximum net return similar to RH-RH, which was 1.66 and 30.37% more than RH-RH and WC-WC, respectively. However, application of RH-RH in maize and wheat recorded maximum B:C ratio that was 13.35 and 16.15% more compared to IWM-IWM and WC-WC. Khaliq *et al.* (2013) [5] also reported highest net benefits were associated with the use of label herbicide dose in all tillage practices. This may be due to low cost of cultivation under recommended herbicide as compared to integrated weed management.

Soil properties

Zero tillage in rainy and zero tillage along with crop residue in winter season (ZT-ZT+R) similar to ZT+R-ZT+R recorded 5.63 pH, which was 2.31% more than initial value and 3.37% more than conventional tillage sequences. ZT+R-ZT+R also recorded 3.16 and 14.37% higher organic carbon and CO_2 respectively than initial values. ZT+R-ZT+R similar to ZT-ZT+R and CT-ZT recorded 7.76% more dehydrogenase than initial value and 26.06% more than conventional tillage sequences (CT–CT) which may be because of less soil disturbance under zero tillage bringing up favorable soil environment for soil flora and fauna to survive. This also brought up similar effects under IWM-IWM and WC-WC in enhancing soil CO_2 and dehydrogenase than initial value. According to Mutiu (2015) [11] zero or minimum tillage is beneficial to soil physical improvement as process of soil physical degradation normally sets in immediately after conventional tillage. Research reports indicate that conservation tillage, particularly under minimum tillage, is better than conventional tillage in terms of soil chemical improvement. All available reports are in agreement that soils under conservation tillage are more favoured than conventional tillage in terms of soil fauna activities and biological properties improvement. Ma³ecka *et al.* (2012) [6] have also found accumulation of organic carbon at the soil surface under reduced tillage and no tillage. The concentration of organic C in reduced tillage and particularly in no tillage, had increased significantly in the top layer (0-5 cm), by 18.3 and 26.1%, respectively, in comparison with CT.

Among weed control methods, WC-WC and IWM-IWM performed similar in enhancing soil CO_2 and dehydrogenase. Weedy check recorded 4.53, 5.34 and 13.27% higher CO_2 and 0.79, 0.31 and 7.56% higher dehydrogenase than initial value, IWM - IWM and RH-RH, respectively.

Hence, it can be concluded that in maize-wheat system zero tillage sequences with or without residue is more beneficial than conventional tillage. Application of recommended herbicide in maize and wheat is more profitable to farmers while, integrated weed management sequences in maize–wheat is the second profitable method for controlling weeds and attaining higher yield.

Conservation Agriculture, understood in this way, provides a number of advantages on global, regional, local and farm level

- It provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora (including wild life) in agricultural production systems without sacrificing yields on high production levels. As CA depends on biological processes to work, it enhances the biodiversity in an agricultural production system on a micro as well as macro level.
- No till fields act as a sink for CO_2 and conservation farming applied on a global scale could provide a major contribution to control air pollution in general and global warming in particular. Farmers applying this practice could eventually be rewarded with carbon credits.
- Soil tillage is among all farming operations the single most energy consuming and thus, in mechanized agriculture, air-polluting, operation. By not tilling the soil, farmers can save between 30 and 40% of time, labour and, in mechanized agriculture, fossil fuels as compared to conventional cropping.
- Soils under CA have very high water infiltration capacities reducing surface runoff and thus soil erosion significantly. This improves the quality of surface water reducing pollution from soil erosion, and enhances groundwater resources. In many areas it has been observed after some years of conservation farming that natural springs that had dried up many years ago, started to flow again. The potential effect of a massive adoption of conservation farming on global water balances is not yet fully recognized.
- Conservation agriculture is by no means a low output agriculture and allows yields comparable with modern intensive agriculture but in a sustainable way. Yields tend to increase over the years with yield variations decreasing.
- For the farmer, conservation farming is mostly attractive because it allows a reduction of the production costs, reduction of time and labour, particularly at times of peak demand such as land preparation and planting and in mechanized systems it reduces the costs of investment and maintenance of machinery in the long term.
- Disadvantages in the short term might be the high initial costs of specialized planting equipment and the completely new dynamics of a conservation farming system, requiring high management skills and a learning process by the farmer. Long term experience with conservation farming all over the world has shown that conservation farming does not present more or less but different problems to a farmer, all of them capable of being resolved.

Constraints for adoption of conservation agriculture

- Availability of appropriate sowing implements for conservation agriculture is one of the limiting factors for small and marginal farmers of Jharkhand.
- Demand of crop residues for conservation agriculture is restricted because of its utilization as fodder for cattle.
- Crop residues are burned, by farmers particularly of west UP, Punjab and Haryana for early vacating fields and timely sowing of succeeding crops.
- Farmers are unaware about practicing conservation agriculture. Availability of skilled and scientific manpower for managing conservation agriculture systems. Strengthened knowledge and information sharing mechanisms are needed.
- Awareness of knowledge about the potential of CA among leaders, extension agents and farmers to practices in conservation agriculture, including planting and harvesting, water, nutrient and weed management, diseases and pest control etc. needed.
- A mental change in attitudes of farmers, technicians, extensionists and researchers for operations towards sustainable production systems like no tillage is necessary.
- The need to develop the policy frame and strategies is urgent to promote CA in the region.

Conclusions

From different experiments conducted at Jharkhand, it was observed that performance of zero tillage was as good as conventional tillage in reducing weeds as well as in attaining higher yield. However, zero tillage is cost effective due to savings in tillage operations, thus conservation agriculture directly involve in enhancing livelihood on sustainable basis. However there is need to change the mind set and attitude of farmers of Jharkhand state who have been doing conventional tillage since long.

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