

Resource conservation technologies

for enhancing productivity, economics and resource use efficiency
under soybean-wheat cropping system

**A K Vishwakarma¹, B L Lakaria¹, A O Shirale¹, A L Kamble¹, R K Singh¹,
R H Wanjari¹, A B Singh¹, A O Shirale¹, K Bharti¹, Asha Sahu¹, Shinogi K C¹,
A K Biswas¹, A K Patra¹, Anupam Mishra², S R K Singh²,
Pramendra Parmar¹ and H R Nagar¹**

ICAR- Indian Institute of Soil Science, Bhopal, Madhya Pradesh 462 038

The study was conducted in a cluster of four villages namely Khamkheda, Bherupur, Kanchbavali and Kalyanpur located in two panchayats viz. Kham Kheda and Golkhedi respectively in the Huzur tehsil of Phanda block in Bhopal district. Results show that there is an overall reduction in the cost of cultivation of soybean by 15% and 10% in wheat cultivation under conservation agriculture. Results revealed that the grain yield increased by 8.67% and 6.55% as compared to conventional tillage for soybean and wheat respectively. The net profit in conservation agriculture was 40% and 25% higher as compared to conventional system in case of soybean and wheat respectively. The B: C ratio was also higher under CA (2.30 and 3.08) as compared to conventional method (1.79 and 2.50). The system productivity increased by 7.36% (wheat equivalent yield), under conservation agriculture as compared to conventional tillage and water productivity of the system increased from 1.08 kg/m³ in conventional tillage system to 1.34 kg/m³ under conservation agriculture with balanced fertilizer application, indicating a gain of 24.67% in water productivity under conservation agriculture as compared to conventional agriculture. The overall diesel consumption was reduced from 112 lit/ha under conventional agriculture to 40 lit/ha under conservation agriculture, indicating an overall reduction of 64.3% in diesel requirement for crop establishment. The overall energy equivalence of conventional system is 6306.72 MJ/ha against only 2252.40 MJ/ha under conservation agriculture. Total water requirement is reduced by 25.3% due to saving of an irrigation and less time required for irrigating the field which resulted in savings of power requirement under conservation agriculture.

Key words: Resource conservation, Productivity, Economics, Resource use efficiency, Soybean-wheat cropping system

CONSERVATION agriculture (CA) is a management system wherein soil is minimally disturbed and kept covered under crop residues. Under conventional tillage farmers tend to excessively till the soil to achieve weed free fine tilth, which resulted in destruction of soil structure, excess utilization of energy, low input use efficiency and poor economics. Recently, the whole concept of tillage practices has got changed considerably worldwide and several new concepts have been introduced. These include minimum

tillage, zero tillage, stubble mulch tillage, etc. The immediate impact of introducing minimum tillage leads to reduction in the cost of tillage due to high fuel prices. The other problems associated with conventional tillage system include low input use efficiency, erosion and natural resource degradation. Under conventional tillage systems, sowing of wheat and other seasonal crops often get delayed because of late harvesting of the previous crop and as a result less time is available for land preparation for sowing of the

subsequent crop. These delays may range between 3-6 weeks depending upon the type of soil and crop and thus compel farmers to burn crop residues for the clearing the field and to avoid delay in sowing which result in serious environmental hazards, loss of soil organic carbon and biodiversity, and decline in soil health.

These issues may be addressed by using zero till seed drills that are capable of sowing wheat and other crops in the standing residues of the previous crops without much disturbance to the soil. Repeated

tillage and use of heavy machinery results in destruction of soil structure, causes hard pan formation and promotes soil erosion from agricultural fields. Land preparation operations can be reduced by manipulating tillage operations in following two ways: a) by minimising tillage operation for land preparation activities which do not yield much economic benefits. b) Performing agricultural operations like sowing, seeding and fertilizer application together. Adoption of conservation agriculture (CA) is an integrated system of soil, water and biological management aimed to build natural resources, by maintaining and improving soil health through adoption of the principles of conservation agriculture such as no till, crop rotations and cover crops with the prudent use of inputs by optimizing yields and profits, to achieve a balance of agricultural economics and environmental benefits.

Study area

The study was conducted in a cluster of 4 villages namely Khamkheda, Bherupur, Kanchbavali and Kalyanpur located in two panchayats *viz.* KhamKheda and Golkhedi respectively in the Huzur tehsil of Phanda block in Bhopal district. The area lies between the geographic coordinates of Latitude 23°22'16.15"N to 23°23'02.16"N and Longitude 77°24'42.01"E to 77°25'34.04"E and is on an altitude of 478-485m. The study area experiences an average annual rainfall of 1,070 mm. The soils in the cluster are deep black soil occupying an area of approximately 1,000 ha. Soybean-wheat and rice-wheat are the major cropping systems prevalent in the study area. The major problems of agriculture include poor resource utilization, residue burning, soil health, low crop yields, poor economic growth and environmental security. Farmers are practicing conventional agriculture in which

they use excessive mechanical tillage operations for land preparation (3-4) which adds significantly to the input cost of cultivation. Residue burning is another major issue in these villages which adversely affects the beneficial soil microorganism as well as ecosystem along with direct significant carbon losses. Keeping the above in view, an attempt was made to test resource conservation based interventions that can improve crop productivity, resource use efficiency and soil health.

Methodology

Farmers of the selected cluster were not aware of the resource conservation technologies prior to the implementation of the project. To sensitize the farming community, awareness camps and training programmes were organized by the project team of ICAR-IISS, Bhopal before carrying out demonstrations in a farmers participatory mode (Fig. 1). Farmers were motivated for adoption



Fig. 1. Conservation agriculture based cultivation in Khamkheda, Bherupur, Kanchbavali and Kalyanpur in Bhopal district.

of CA based cultivation of soybean and wheat, soil test based nutrient application, and retention of crop residues by organizing different interaction meets and exposure visits. Initially innovative farmers of villages under study were encouraged to adopt zero tillage and reduced tillage method of cultivation under conservation agriculture. Assessment of soil health was also carried out to determine the deficiencies of specific nutrients in the soil. The soils of the cluster were clay which are low in available N, S and Zn. STCR based approach were adopted to determine balanced nutrient requirements. Suitable machinery for sowing of crops under zero tillage, and weed and pest management practices under conservation agriculture were demonstrated on farmers' field. .

Observations

Observations on number of tillage operations, time required for different operations, cost involved, crop growth and yield parameters, economics, inputs use etc., were recorded from time to time under both conventional (farmers practice) and conservation agriculture demonstration plots. The details of the observation recorded were analysed and are presented below.

RESULTS

Comparison of cost of cultivation for soybean and wheat crop

Schedule of operations and their cost estimations under conventional and conservation agriculture in soybean- wheat cropping system were recorded and are presented in Table 1.

Analysis of comparison of cost of cultivation under conventional agriculture and conservation agriculture reveals that the cost incurred is less towards land preparation (100%) and cost of seed (20%) for both soybean and wheat; and in irrigation (16.7%) in case of wheat under conservation agriculture. However, in conservation agriculture there is an increase in cost of sowing (33.3% and 66.7%, weed management (29.7% and 66.7%) and fertilizer (30% and 19.3%) in

Table 1. A. Comparison of operations and cost of cultivation (Soybean)

Particulars	Conventional tillage number	Cost (₹)	Conservation agriculture number	Cost (₹)	Change in cost (%)
Land preparation Tillage	3	5,400	-	-	100.0
Sowing	1	1,800	1	2,400	-33.3
Seed Cost	100 kg	5,000	80 kg	4,000	20.0
Weed management	2	3,700	2	4800	-29.7
Plant Protection	2	3,000	2	3,000	0.0
Fertilizer	25:60:0 kg NPK/ha	3,000	25:60:40 kg NPK/ha	3,900	-30.0
Harvesting & threshing		3,400		3,400	0.0
Total Cost		25,300		21,500	15.0

B. Comparison of operations and cost of cultivation (Wheat)

Particulars	Conventional Tillage Number	Cost (₹)	Conservation agriculture Number	Cost (₹)	Change in cost (%)
Land preparation Tillage	3	5,400	-	-	100.0
Sowing	1	1,800	1	3,000	-66.7
Seed Cost	100 kg	4,300	80 kg	3,440	20.0
Weed management	2	3,000	2	5,000	-66.7
Plant Protection	2	3,000	2	3,000	0.0
Fertilizer	120:60:0 kg NPK/ha	5,500	120:60:40:10 kg NPKZn/ha	6,560	-19.3
Irrigation	5	12,000	4	10,000	16.7
Harvesting & threshing		5,000		5,000	0.09
Total Cost		40,000		36,000	10.0

soybean and wheat respectively. Despite increase in the cost of some of the inputs, there is an overall reduction in cost of cultivation of soybean by 15% and 10% in wheat cultivation under conservation agriculture (Table1) mainly owing to the savings in costs involved in land preparation.

Crop productivity under soybean-wheat cropping system

The yield analysis shows that conventional agriculture resulted in 15 q ha¹ seed yield of soybean, while

adoption of conservation agriculture increased the seed yield to the extent of 16.30q/ha, which was 8.67% higher as compared to conventional tillage. Similarly, under conventional agriculture wheat grain yield was 47.50q ha⁻¹ which increased to 50.61 q ha⁻¹ under conservation agriculture, which was 6.55% higher as compared to conventional tillage (Table 2).

Economics of soybean-wheat cropping system

The net profit increased from ₹

Table 2. Yield, economic returns and water productivity (kg/m³) in Soybean- wheat cropping system

A. Crop performance	Soybean			Wheat		
	CT	CA	CA benefits over CT (%)	CT	CA	CA benefits over CT (%)
Yield (q/ha)	15.00	16.30	8.67	47.50	50.61	6.55
B. Economic indicators						
Cost of cultivation (Rs./ha)	25,300	21,500	-15.02	40,000	36,000	-10.00
Net income (Rs./ha)	20,000	28,000	40.00	60,000	75,000	25.00
B:C ratio	1.79	2.30	28.49	2.50	3.08	23.20
C. System productivity (WEY) and water productivity under conventional and zero tillage						
Particulars	Crop productivity (kg/ha)		System productivity (WEY)		Water productivity	
	Soybean	Wheat	kg/ha	% change	(Kg/m ³)	% change
Farmers practice CT	1500	4750	7750		1.08	
Zero tillage	1630	5061	8320	7.35%	1.34	24.67%

Table 3. A. Energy consumption in land preparation and sowing

Particulars	Consumption Farmers practice	Consumption CA	Change (%)
Ploughing once (5 hrs/ha)	40 litres	Nil	100.0
2 times cultivator (3 hrs/ha)	48 litres	Nil	100.0
Sowing (3 hrs/ha) (4 hrs/ha)	24 litres	40 litres	-66.7
Total diesel consumption/ha	112 lit	40 lit	64.3
Energy equivalence (A)	6,306.72 MJ	2,252.40 MJ	64.3
Saving in energy consumption	-	4,054.32 MJ	
<i>B. Energy consumption for irrigation application in wheat</i>			
Time required for one irrigation	30	28	6.7
Electricity consumption /hr	3.72 units of electricity	3.72 units of electricity	
Energy consumption /hr	44.38 MJ	44.38 MJ	
Energy consumption/ irrigation	1,331.10 MJ	1,242.63 MJ	6.6
No. of irrigation	5	4	20.0
Total Energy consumption (B)	6,655.50 MJ	4,970.50 MJ	25.3
Saving in energy consumption	-	1,685.00 MJ	
Total energy consumption (MJ)(A+B)	12,962.22 MJ	7,222.90 MJ	
Total saving in energy consumption (MJ)	-	5,740.36 MJ	44.3

20,000 ha⁻¹ under conventional tillage system to ₹ 28,000 ha⁻¹ under conservation agriculture which was 40% higher as compared to conventional system in case of soybean and was ₹ 60,000 ha⁻¹ and ₹ 75,000 ha⁻¹ under conventional tillage system and conservation agriculture, respectively for wheat, which was 25% higher. The B: C ratio analysis shows that it was also higher under CA (2.30 and 3.08) as compared to conventional method (1.79 and 2.50) which was 28.49 and 23.20% higher in case of soybean and wheat crops respectively (Table 2).

System productivity

In terms of system productivity crop performances under conventional and zero tillage were compared and the results were converted in terms of wheat equivalent yield to determine the system productivity. A positive correlation between zero tillage and crop yield under soybean-wheat cropping system was recorded. The system productivity increased by 7.36% (wheat equivalent yield), under conservation agriculture as compared to conventional tillage (Table 2).

Water productivity

Water productivity is a measure of performance expressed as the ratio of output to input. Crop water productivity was calculated as the ratio of amount of marketable produce (kg grains) to the amount of input needed to produce that output

(m³ water). The water productivity of the system increased from 1.08 kg/m³ in conventional tillage system to 1.34 kg/m³ under conservation agriculture with balanced fertilizer application, indicating a gain of 24.67% in water productivity under conservation agriculture as compared to conventional agriculture (Table 2).

Energy consumption in tillage operation by tractor Soybean – wheat system Land preparation and sowing

Data presented in Table 3 revealed that there is 100% reduction in energy consumption for ploughing and land preparation under conventional agriculture. However there is 66.7% increase in diesel consumption for sowing operation under conservation agriculture. The overall diesel consumption was reduced from 112 lit/ha under conventional agriculture to 40 lit/ha under conservation agriculture, indicating an overall reduction of 64.3% in diesel requirement for crop establishment. The overall energy equivalence of conventional system is 6306.72 MJ/ha against only 2252.40 MJ/ha under conservation agriculture. This saving in diesel requirement corresponds to an overall saving of 64.3% in energy required for crop establishment.

Irrigation

It has been observed that there is less time required for irrigation application under conservation

agriculture (28 hr/ha) as compared to conventional tillage (30 hr/ha) using a 5 hp submersible pump, which resulted in net saving of energy requirement by 6.6%. The total water requirement is reduced by 25.3% due to saving of an irrigation and less time required for irrigating the field which resulted in savings in terms of power requirement under conservation agriculture.

Conclusions

CA offers a new paradigm for agricultural research and development different from the conventional one which mainly focuses at achieving specific food grain production targets in adopted villages. Application of resource conservation technologies in the study region for resource conservation and enhancing sustainability, safe disposal of crop residues, improving soil health and reducing cost of cultivation have been found beneficial. The results of the participatory demonstrations clearly indicated that there are number of advantages associated with adoption of conservation agriculture. The main benefits of the technology include time and fuel saving by avoiding number of tillage operations. It results in reduced labour cost and significant reduction in cost on land preparation by reducing diesel requirement thus leading to higher profits. Zero tillage also results in faster application of irrigation and thus saving water, time and energy. Crop residues left in the field acts as a mulch and conserve moisture in the soil for longer period of time which result in increased water productivity. The study has been successful in convincing farmers for accepting conservation agriculture practices in Vertisols of Central India. Some of the progressive farmers have started adopting conservation agriculture in different cropping systems. Despite several advantages, the main disadvantage of the technology includes machinery intensive practice and requirement of high power tractors for sowing in vertisols.

¹ICAR-IISS, Bhopal, ²ICAR-ATARI, Jabalpur.
Corresponding email: Anand.vishwakarma@icar.gov.in