

Adoption of conservation agriculture-based technologies

in the vertisols in Madhya Pradesh

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Conservation agriculture-based technologies have been adopted globally on >160 million ha, while the area under conservation agriculture in India reached around 3 million ha, mostly in the north-western plain zone. No major effort was made in central India to develop and promote conservation agriculture until the Directorate of Weed Research at Jabalpur initiated a flagship programme in 2012. Results of the last 5 years showed wonders as evident from timely sowing of crops (by June-end for rainy-season crops, October-end for mustard and chickpea, mid-November for wheat, and March-end for greengram and blackgram); increase in cropping intensity from <150% in 2012 to 300% in 2016; large savings in diesel cost, machinery repair and irrigation water; increased productivity (>10 tonne/ha/year) and profitability; and improvement in soil health. This technology has proved to be climate-resilient as it avoided burning of crop residues, puddling for rice transplanting, and ensured C-sequestration through residue recycling and zero-till cultivation. Contrary to the general belief, weed infestations reduced considerably under Conservation Agriculture compared with the conventional cultivation. This technology was accepted rapidly among the farmers of Jabalpur, Katni, Seoni, Narsinghpur and Mandla districts of Madhya Pradesh.

Key words: Adoption, Conservation agriculture, Technologies, Vertisols

CONTINUOUS adoption of the Green Revolution technologies resulted in growing concerns about natural resource degradation. It is realized that soils are getting impoverished due to imbalanced use of fertilizers, and discontinuation of traditional practices like mulching, intercropping and inclusion of legumes in cropping systems. Further, the use of organic manures, compost and growing of green manure crops has also decreased considerably due to various reasons. Similarly, water resources are under great stress due to their indiscriminate exploitation and also getting polluted due to human interferences. Burning of fossil fuels, crop residues, excessive tillage including puddling for rice

cultivation are leading to emission of greenhouse gases, which are responsible for climate change and global warming. Further, there is now a growing realization that the productivity levels are stagnating and the incomes of the farmers are reducing due to the rising cost of the inputs and farm operations. It is feared that modern cultivation practices are not sustainable in the long-run, and there is a need to change the way we do crop production on arable lands.

Conservation agriculture: A new paradigm

Conservation agriculture (CA) is considered a new paradigm in resource management for alleviating the problems associated with the so-

called modern cultivation practices. Two major innovations in the latter half of 20th century have led to a change in our thinking on crop production. These include the availability of new farm machinery and effective herbicides, which suggest that ploughing of the fields is no longer required for sowing, fertilizer placement and weeding. Zero-till based conservation agriculture has been promoted in USA and other countries of north and south America since 1970s primarily due to large-scale soil erosion problems in the rainfed ecosystem. Subsequently, the adoption was promoted with the availability of herbicide-tolerant crops from mid-1990s. These two technologies, i.e. zero tillage and

herbicide-tolerant crops have revolutionized world agriculture and grown hand-in-hand showing double-digit growth in most years, and presently adopted on 160 and 180 million ha, respectively.

Conservation agriculture involves minimum soil disturbance, soil cover with crop residues, and dynamic crop rotations, besides other suitable modifications in water, fertilizer, weed and pest management as well as farm machinery. These systems are adopted on a large-scale in USA, Canada, Brazil, Argentina, Australia and other countries of North and South America. In the Asian countries, the adoption rates are low but progressing in recent times. In India, the efforts are being made since mid-1990s, primarily for growing of wheat in the Indo-Gangetic Plains. The area under zero-till wheat reached about 3million ha in the early part of 21st century, which is now stagnant or decreasing due to operational constraints.

Weeds are the major biotic constraint in conservation agriculture, posing a great challenge towards its adoption. Presence of weed seeds on upper soil surface due to no-tillage operation leads to higher weed infestation in conservation agriculture. Herbicides are now available to deal with this problem. The modern seeding equipment like 'Happy Seeder' helps in managing weeds through retention of crop residues as mulch, besides providing efficient seeding and fertilizer placement. Outcomes of the various experiments conducted on-station as well as on the farmers' fields show that the benefits of conservation agriculture can well be taken in black cotton soils as weed menace can be managed effectively by integrating herbicides in the weed management programme.

SUCCESS STORY

Rice-wheat is the major cropping system in the Indo-Gangetic plains, and also followed in the central and eastern parts of Madhya Pradesh. Crop production in the central plateau region is dominated by rice, soybean, maize and sugarcane in rainy season, followed by wheat, chickpea, lentil, peas and mustard

during winter. Soils cotton growing are deep black in most of the areas belonging to the vertisols. Farmers follow conventional practices like intensive ploughing of the land, clean cultivation (removal or burning of all crop residues and stubbles), fixed crop rotations, and little use of organic manures and moderate use of chemical fertilizers, and other pesticides including herbicides. Combine harvesting of most crops is followed predominantly and the crop residues are invariably burnt in many areas. Due to the rising costs of cultivation, the profit margins are generally low (` 10,000 to 20,000/ha/annum). Keeping this in view, it was felt necessary to promote the adoption of resource conservation technologies for reducing the cost of cultivation and improving soil-health, besides other environmental benefits.

Initiatives were taken since early 1990s to promote adoption of CA-based technologies in the alluvial soils of Indo-Gangetic plains primarily in rice-wheat cropping system. These programmes were mainly implemented through the CIMMYT sponsored rice-wheat consortium, which led to adoption of zero-till cultivation of wheat on nearly 3 million ha by the beginning of 21st century. However, no efforts were made in the black soil region (vertisols) of central India. Directorate of Weed Research,

Jabalpur took a major initiative and launched a flagship programme in 2012 to develop and promote technologies related to weed management in CA in the vertisols. After laser levelling of the fields, experiments were done with zero-till sowing of wheat, chickpea, mustard and maize (winter), followed by green gram (summer) while retaining the residues of previous crop *in situ*. Sowing of seed and placement of basal fertilizer was done with a specially-designed zero-till seed-cum-fertilizer drill (Happy Seeder) immediately after the harvest of previous crop with combine. Following the success of these crops, the technology was extended to rainy-season crops like rice, soybean, maize, and pigeonpea. All crops showed either the same yield or 5 to 10% higher yield under conservation agriculture than conventional farming practices (Table 1).

Simultaneously with the on-station trials, the on-farm trials in participatory mode were also undertaken in the farmers' fields of Jabalpur district from 2012 to 2013. Initially, the farmers expressed serious doubt about growing a good crop without ploughing and removing or burning of the crop stubbles. Some farmers' of Panagar block of Jabalpur were persuaded to provide their lands for demonstrating the potential of conservation agriculture technology

Table 1. Yield performance of different crops under conventional and conservation agriculture systems at the DWR farm between 2012 and 2016

Crops		Grain yield (tonne/ha)		% change under CA over conventional
		*Conventional agriculture	**CA-based practices	
Rainy season				
Rice	(10)	4.02	4.06	0.0
Maize	(12)	4.03	4.39	8.9
Soybean	(4)	0.94	1.06	11.3
Pigeonpea	(5)	2.15	2.23	3.7
Winter				
Wheat	(10)	4.19	4.56	8.8
Chickpea	(8)	1.89	2.01	6.3
Mustard	(4)	1.83	1.94	6.0
Gobhi sarson	(4)	3.97	3.72	6.3
Field pea	(4)	1.56	1.67	7.2
Summer				
Greengram	(9)	1.05	1.04	0.0

*CA-based practice involved zero-till sowing in standing residue of the previous crop, 10-15 days ahead of the farmers' practice

**Farmers practice involved burning or removal of the previous crop residues, followed by 3-4 ploughings before sowing.

CA, Conventional agriculture; DWR, Directorate of Weed Research

with an assurance that they will be compensated economically, if the technology fails to perform. Wheat was sown using a 'Happy Seeder', without tilling in the existing rice stubbles. Contrary to the general belief of the farmers, the crop showed good emergence and stand establishment. Weed population in these CA-based trials was lower compared to other trials in which the land was prepared by conventional cultivator and disc harrow. Herbicide application effectively controlled the weed flora effectively and increased yield of wheat by almost 2 when compared with cultivated by conventional practice with manual weed control.

Following the success of wheat, greengram was grown during summer (mid-April to mid-June) under Zero Tillage using Happy Seeder while retaining the residues of wheat on soil surface. A spray of glyphosate was used before sowing when there were previously growing weeds in the field. Subsequently, imazethapyr was applied at 15 to 20 days of growth. Residue mulch helped in checking moisture loss through evaporation, moderated soil temperature, prevented emergence of

weeds and improved soil-health. The crop yielded 1.01.4 tonne/ha compared with 0.7 to 0.8 tonne/ha under the conventional farmers' practice.

After getting significant results in 2012-13, a large number of OFR trials were undertaken in a participatory mode from 2013-14 in different locations around Jabalpur (Gosalpur, Shahpura, Kundam, Bankhedi and Majholi). Sowing of rice in rainy season, wheat in winter and greengram in summer was done on 1 acre (0.404 ha) area in each farmers' field. From 2014 onwards, the OFR trials on CA-based technology were extended under *Mera Gaon, Mera Gaurav* programme in the adjoining districts, viz. Mandla, Seoni, Narsinghpur and Katni. In each district, 5 villages and 8 to 10 farmers from each locality were identified and selected. Resource conservation technologies such as direct-seeding of rice, brown manuring with *Sesbania*, zero-till sowing of crops, residue retention on soil surface, growing of summer legumes like greengram or *Sesbania* in the crop rotation, and integrated weed management technologies were demonstrated in diversified cropping

systems. About 100 OFR trials were laid out in 25 villages of the 5 districts of Madhya Pradesh during 2015-16 (Table 2).

Performance of all crops sown at the optimum time under conservation agriculture was far better than the delayed-sown crops under conventional farmers practice. The increase in grain yield ranged from 9 to 36% in rice, 27 to 50% in wheat, and 33 to 80% in greengram. Besides, there was considerable saving of resources and thereby increase in net profit.

Conservation agriculture-based technology like zero-till sowing of crops in the presence of residue of the previous crop with improved weed management practices has proved to be the most promising technology in the vertisols of Madhya Pradesh. This technology has spread in several thousand hectares and the Happy Seeder machines are now in great demand in the area. Farmers accepted this technology as it saves time, provides good weed control, maintains soil moisture status, and improves soil fertility, besides being environment friendly.

MAJOR CONCLUSIONS

Based on the on-station trials at the research farm of Directorate of Weed Research and on-farm trials on the farmers' fields of 5 districts of Madhya Pradesh over the last 5 years, following broad conclusions were drawn:

- Equal crop yields were recorded under zero-till (with or without residue) and conventional till conditions in the first two cropping-cycle.
- Beneficial effects of residue retention under zero-till condition were apparent from the third cropping-cycle.
- Control of most weed species was successfully achieved following integrated approach involving use of herbicides.
- There was no major shift of weed species towards perennial weeds over the 5-year.
- Sowing of most crops was possible with Happy Seeder under crop residue load up to 6 tonne/ha.
- Systems approach involving suitable

Table 2. Performance of zero-till sown crops in OFR trials in different districts of Madhya Pradesh during 2015-16

District / villages / crops (Trials)	Grain yield (tonne/ha)		% change over FP
	*CA-based practice	**Farmers' practice (FP)	
<i>Jabalpur (villages: Bharda, Nipaniya, Nibhora, Neelkheda, Repura, Katangi and Chanti)</i>			
Rice (8)	3.7–4.0	3.2–3.4	16–18
Wheat (16)	3.8–4.2	3.0–3.2	27–34
Greengram (9)	0.9–1.3	0.6–0.8	50–62
<i>Mandla (villages: Bhawal, Bijegaon, Gojarsani, Lalipur, and Harratikur)</i>			
Rice (10)	3.9–4.3	3.0–3.2	30–34
Wheat (17)	4.2–4.4	3.2–3.4	29–31
Greengram (12)	1.0–1.2	0.7–0.9	33–42
<i>Narsinghpur (villages: Baglai, Khamariya, Simariya, and Kushiwara)</i>			
Rice (7)	3.5–4.2	2.6–3.5	20–34
Wheat (8)	4.0–4.4	3.7–4.0	8–10
<i>Katni (villages: Banda, Bichhiya, Chhitwara, Ghughra, and Lakhapateri)</i>			
Rice (8)	4.5–4.7	4.1–4.3	9-10
Wheat (10)	4.8–5.1	3.4–3.7	38-42
Greengram (8)	1.1–1.3	0.8–0.9	38-44
<i>Seoni (villages: Ghughri Nagar, Khoot Khamariya, Nagan Deori, Dongargaon and Salaiya)</i>			
Rice (7)	4.1–4.4	3.4–3.6	20–22
Wheat (12)	4.2–5.0	2.8–3.7	35–50
Greengram (5)	1.2–1.7	0.8–0.9	50–80

Figures in parentheses indicate number of trials

*CA-based practice involved zero-till sowing in standing residue of the previous crop, 10-15 days ahead of the farmers' practice

**Farmers practice involved burning or removal of the previous crop residues, followed by 3-4 ploughings before sowing.

adjustment of sowing date, seed rate, basal fertilization, early first irrigation, uniform residue spreading, pest management etc. was required.

- Physico-chemical and biological properties of soil showed improvement in the 3rd cropping cycle.
- Conservation agriculture appears to be the most promising technology for vertisols (black cotton soils) and can revolutionize crop cultivation in central India.

Conservation agriculture is a highly specialized technology, requiring optimum conditions and utmost care for its successful adoption. It is essential to follow all the principles of conservation agriculture in a holistic manner coupled with other precautionary measures. Failure of conservation agriculture-based farming at some locations may be due to the following reasons.

- Lack of assessment of the time period between conversion of native vegetative and no-till adoption.
- Lack of knowledge or experience on how to manage crops with no-tillage techniques.
- Lack of a systems approach when eliminating tillage.
- No-tillage was performed with bare soil conditions or with insufficient crop cover with crop residues.
- Lack of experience of the machine operator at seeding.
- Inadequate no-tillage machinery, leading to poor plant establishment
- Poor control of weeds and other pests.
- Nitrogen fertilization may not have been adjusted during the first few years of applying no-tillage technology.
- No-tillage implemented on an extremely degraded and/or eroded soil.
- Inadequate crop rotation diversity.

Consortia research platform on CA

Indian Council of Agricultural Research has launched a Consortia Research Platform on Conservation Agriculture from 2015, which is a major step for developing, capacity building and adoption of these resource conserving technologies.

The Directorate Weed Research (DWR), Jabalpur has taken lead in developing and promoting weed management in conservation agriculture in diversified cropping systems in the black soil region of Central India. The Directorate Weed Science Research has converted its research farm of 150 acres (60.6 ha) with conservation agriculture-based technologies, and now taken up the task of disseminating these technologies on the farmers' fields on a large-scale. Needless to say that the technology is spreading fast for growing wheat and chickpea in winter and greengram in summer. Adoption rates are higher in these crops than rainy season crop like rice, which require a greater precision for proper stand establishment and timely weed control. The crop needs to be sown by mid-June with basal fertilization (two-thirds, N and full P and K), 20-25 kg seed/ha, and use of suitable herbicides before sowing, after sowing and at month of growth. There is a growing demand for suitable farm machinery like Happy Seeder, which can do sowing, place fertilizer and also work under residue conditions. Undoubtedly, this technology has the potential for revolutionizing crop cultivation in Central India, for which, greater collaborative efforts are needed by different institutions, state departments, and other agencies concerned with agricultural development.

WAY FORWARD

Conservation agriculture-based technologies were developed and adopted in rice-wheat cropping systems mostly in the light-textured soils of north-western India. Limited work has been done in the heavy-textured black cotton soils of central India. However, adoption of these technologies at the research farm of Directorate Weed Science Research and farmers' fields of Jabalpur region showed great promise for promotion of these technologies in other areas of the state. Further, large areas in Madhya Pradesh remain seasons fallow during both rainy season and winter due to various operational constraints. Summer also remains virtually fallow due to open cattle

grazing but has a lot of potential for cultivation of summer pulses like greengram and blackgram. There exists a large scope for bringing these areas under profitable cropping systems with the adoption of conservation agriculture-based technologies. There is required to be coordinated effort involving multi-stakeholders to make the farmers aware and demonstrate these technologies on a large-scale.

There is a need for analysis of factors affecting adoption and acceptance of zero tillage cultivation among the farmers. Lack of information on the effects and interactions of minimal soil disturbance, permanent residue cover, planned crop rotations and integrated weed management, which are key CA components, can hinder CA adoption. This is because these interactions can have positive as well as negative effects depending on regional conditions. The positive impacts should be exploited through systems research to enhance CA crop yields. Information has mostly been generated on the basis of research trials, but more on-farm-level research and development is needed. Farmers' involvement in participatory research and demonstration trials can accelerate adoption of conservation agriculture.

SUMMARY

There is immense scope to promote this technology in the vertisols of central India, for which initiatives must be taken: (i) adopt conservation agriculture-based technologies on-station fully, (ii) large scale demonstrations/on-farm research trials, (iii) trainings and exposure visits to farmers and other stakeholders, (iv) collaboration with multi-stakeholders, (v) subsidy on new farm machinery, (vi) incentives for not burning crop residues, (vii) easy availability of custom hiring services, (viii) good quality and easy availability of herbicides, (ix) policy support, and (x) skill developments especially in farm machinery.

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