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Adoption and impact assessment of weed management technologies in wheat and greengram under conservation agriculture system in central India

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ABSTRACT

Rice-wheat is the major cropping system in the Indo-Gangetic plains and is also practiced on considerable area in Madhya Pradesh. Rice-wheat production system under conventional practices involves tedious and time-consuming methods of field preparation and weed management; increases cost of production, deteriorates soil fertility, and do not offer desired benefits for increasing the grain yields. In conventional agriculture, burning of crop leftover residue has become a major challenge that leads to loss of precious plant nutrients and deteriorates environmental quality. In order to mitigate these problems, technically-feasible, economically-viable and ecologically-permissible technologies need to be essentially adopted. A technology is required to facilitate timely sowing in standing stubbles, minimize weed infestation, lower cost of production, improve fertilizer/water-use efficiency and improve soil health. To reap the benefits of conservation agriculture (CA), studies were conducted at farmers' fields in rice-wheat-greengram cropping system in black-cotton soils in Madhya Pradesh for consecutive five years. Sowing was done with Happy Seeder. Emergence of weeds from upper soil surface was effectively controlled by herbicides. Results showed that the benefits of CA can well be harnessed in black-cotton soils with rice-wheat-greengram cropping system. Retention of crop residues on soil surface provided an effective mulch cover for nutrient and moisture conservation, temperature moderation and weed control.

Key words: Adoption, Conservation Agriculture, Greengram, Herbicides, Wheat

Keeping in view the multiplicity of problems threatening present day farming in India, conservation of resources has become significant to sustain farming. Consequently there has been positive shift towards promotion of conservation agriculture (CA) throughout the world (Mertens and Jensen 2002, Melander *et al.* 2005, Sharma and Singh 2014, Bajwa 2014). The CA aims at increasing productivity and improving soil health (Fowler and Rockstrom 2001, Hobbs 2007, Giller *et al.* 2009). This practice promises better soil health than conventional tillage based agriculture (Erenstein 2003, Gowing and Palmer 2008). However, presence of weeds often down plays numerous advantages of CA (Buhler *et al.* 1994) and poses a great challenge to its wider adoption. Absence of tillage leads to presence of weed seeds on the upper soil layer which offers severe competition to the crop. Weed management in CA requires special attention with integration of several technologies such as tillage, crop establishment methods, agronomic practices, machinery *etc*. (Lafond *et al.* 2009).

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Rice-wheat is the major cropping system in the Indo-Gangetic plains (Chauhan *et al.* 2012). It is also followed in central and eastern parts of the Madhya Pradesh (MP), which is the second largest state of India having 15.1 m ha of net sown area. Crop cultivation practices in MP comprise intensive ploughing of land, removal or burning of crop residues and stubbles, fixed crop rotations, less use of organic manures, moderate use of chemical fertilizers and other pesticides including herbicides. With increasing use of combines for harvesting of rice and wheat to save time and combat problem of labour scarcity, the management of left over crop residues has become a serious problem in rice-wheat cropping system. Burning of crop residues to facilitate sowing of succeeding crop not only pollutes the environment with hazardous gases but also results in loss of precious plant nutrients from soils. Conventional rice-wheat production system involves sowing of wheat seeds in fine seedbed prepared by 4-5 tillage operations, which take 10-15 days time and incur ` 3000-4000/ha for land preparation. Such tillage operations increase the production cost with little benefit on crop yield and thus reduce the profit

margin. Thus reduction in soil fertility, scarcity of farm labour, declining water table and high cost of production of conventional agriculture require some alternative methods of wheat cultivation (Edwards and Smith 2005). The issues such as delay in sowing, severe weed infestation, crop residue management, declining factor productivity, increasing cultivation cost require urgent attention. In order to combat such problems, the technologies should be technically-feasible, economically-viable and ecologically-permissible, and should ameliorate late sowing, minimize weed infestation, minimize production cost, improve fertilizer/water-use efficiency and improve soil fertility. Resource conservation technologies have been reported to reduce cost, improve soil health and protect the environment (Chauhan *et al*. 2012). Therefore, a study was undertaken in rice-wheat-greengram cropping system to see the effect of CA technology on yield increase at farmers' field and its impact and adoption among farmers.

MATERIALS AND METHODS

This study was undertaken to manage weeds in wheat and greengram under rice-wheat-greengram cropping system under conservation agriculture in black-cotton soils of Madhya Pradesh for consecutive five years from 2012-13 to 2015-16 at farmers' fields in five localities covering 30 villages in central part of the state. These On-Farm Research (OFR) cum Demonstration trials were conducted by the ICAR-Directorate of Weed Research, Jabalpur.

In the first year (2012-13), trials were conducted in wheat in the Panagar block of Jabalpur on farmers' fields at 6 locations. Wheat was sown with Happy Seeder without tilling (maintaining rice stubbles in the field) along with use of glyphosate and clodinafop + metsulfuron at 60 + 4 g/ha herbicides for weed control. After the successful demonstration of the technology at farmer's fields of Jabalpur region, both wheat (10 sites) and greengram (5 sites) were sown with Happy Seeder in the same locality during 2013-14 at farmer's fields of 0.4 ha plot size. In 2015, OFR cum demonstration trial on CA based technology was extended to 5 villages and 7-8 farmers in each district in Mandla, Seoni, Narsinghpur and Katni districts of MP.

In 2015-16, about 100 more trials were laid out at 30 villages. Resource conservation technologies such as direct-seeding of rice, brown manuring with *Sesbania*, zero-till sowing of crops with Happy Seeder, residue retention on soil surface, growing of summer greengram or *Sesbania* in the crop rotation and integrated weed management technologies were demonstrated under diversified cropping systems. Wheat and greengram were grown during *Rabi* and summer with three treatments, CA with recommended fertilizers dose (RFD) and herbicide, CA with RFD and without herbicide, and farmer's practice (FP). Farmers of the locality were following conventional tillage (CT), high seed rate, imbalance fertilizer without proper weed management, the amount of which varied with the farmers/places.

Data on weed emergence and growth such as weed density/m^2 and dry weight (g/m^2) were recorded at 40 and 60 days after sowing (DAS) and grain yields were recorded at crop maturity and benefit-cost ratio of each treatment was worked out as per standard protocols.

RESULTS AND DISCUSSION

Performance of conservation agriculture technologies adopted in wheat and greengram at different localities in five districts is described below:

Jabalpur district

The OFR trials were conducted on CA and weed management during *Rabi* 2013-16 at 6 fields in wheat and 20 fields in greengram at Jabalpur district.

Effect on wheat: The ready mix of clodinafop + metsulfuron at 60 + 4 g/ha was used to control weeds in the crop in the OFR. Seed germination and establishment of wheat crop under conservation agriculture was good. The major weed flora observed was *Lathyrus sativus*, *Vicia sativa, Chenopodium album*, *Medicago denticulata* and *Melilotus alba* among broad-leaf and *Avena* sp. (wild oat) and *Phalaris minor* among grasses.

Application of RFD (120:60:40 kg N, P_2O_5, K_2O/ ha) along with herbicide (clodinafop + metsulfuron at 60 + 4 g/ha) at 30 DAS under conservation agriculture resulted in the lowest weed density and biomass and higher grain yield (4.93 t/ha), higher net income (` 54,462/ha) with higher B:C ratio (3.8) compared to farmer's practice of conventional tillage, use of higher seed rate, unbalanced fertilizer and without proper weed management (**Figure 1 and Table 1**).

Effect on summer greengram: The OFR trials were undertaken on greengram under conservation agriculture during summer 2014-2016 at twenty farmer's fields of Jabalpur district. Sowing of greengram was done with Happy Seeder just after harvesting of wheat crop without removal or burning the standing crop stubbles.

CA + post-emergence application of imazethapyr 100 g/ha effectively controlled broad spectrum of weeds and resulted in seed yield of 1.25 t/ha as compared to 0.72 t/ha under FP (CT + no weeding), and provided an additional net return of ` 13,000/ha with higher B: C ratio over FP. Use of Happy seeder saved time, favoured early sowing on residual soil moisture (visualized) and saved field preparation cost. Unlike ZT seed drill, Happy Seeder facilitated the use of wheat crop residue as mulch in the field and thereby helped in managing weeds and conserving moisture (**Figure 2** and **Table 2**).

Katni district

The OFR trials were conducted on CA and weed management during *Rabi* 2013-16 at five farmers' fields in Chitwara, Bichiya, Ghughra, Banda and Lakhapateri villages. After wheat harvest, greengram was sown on these fields.

Effect on wheat: Mean results of five sites indicated that RFD + herbicides with CA significantly reduced the weed population by 63.5% and weed dry weight by 82.4% and increased grain yield by 47.3% compared to farmers' practice (3.49 t/ha). RFD + herbicides with CA resulted in higher B:C ratio (3.44) than farmers' practice (1.81) (**Figure 1** and **Table 1**).

Effect on summer greengram: Greengram sown with Happy Seeder after harvest of wheat and application of RFD and herbicide imazethapyr 100 g/ha resulted in appreciably good seed yield (1.26 t/ha) with B:C ratio of 3.90 (**Figure 2** and **Table 2**).

Mandla district

In Mandla district also, OFR trials were conducted on wheat at 8 farmers' fields and greengram at 6 farmers' fields in Bhawal, Bejegaon, Lalipur, Gujarsani and Harratikur villages during *Rabi* 2013-16.

Effect on wheat: Farmer's practice was compared with CA and RFD but without weed management and CA with RFD and weed management with herbicides. Mean of 8 trials revealed that CA with RFD and herbicide based weed managment significantly reduced the weed population and dry weight compared to farmers' practice and produced 20% higher grain yield (4.2 t/ha) than farmers' practice. The B:C ratio of with CA alongwith RFD and herbicide application was also higher (3.16) than that obtained from farmers' practice (**Figure 1** and **Table 1**).

Effect on summer greengram: Greengram sowing with Happy Seeder and weed control by application of imazethapyr 100 g/ha resulted seed yield of 1.35 t/ha with B:C ratio of 3.63 (**Figure 2** and **Table 2**).

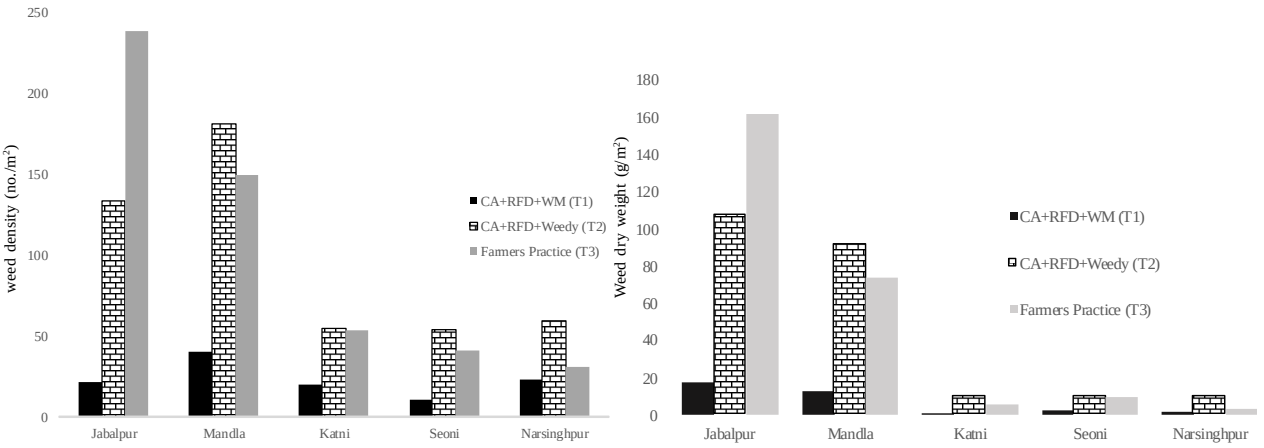

Figure 1. Effect of conservation agriculture on weed density and weed dry weight in wheat at different locations during *Rabi* 2013-16

Table 1. Productivity of wheat (t/ha) under conservation agriculture in OFR during *Rabi* 2013-16 (average of 29 farmer's fields)

Treatment	Jabalpur		Mandla		Katni		Seoni		Narsinghpur	
	Grain yield	B:C ratio	Grain yield	B:C ratio	Grain yield	B:C ratio	Grain yield	B:C ratio	Grain yield	B:C ratio
CA + RFD + WM	4.93	3.80	4.20	3.16	5.14	3.44	5.05	3.44	4.10	3.46
CA + RFD + weedy	3.51	2.90	3.30	2.87	4.34	3.15	2.91	2.15	2.76	2.68
Farmers practice	3.22	2.22	3.50	2.30	3.49	1.81	2.83	1.78	3.75	2.40

CA-Conservation agriculture; RFD- Recommended fertilizer dose; WM: weed management

Narsinghpur district

Effect on wheat: To discourage burning of crop residues of paddy after its harvest, wheat was sown with Happy Seeder in the standing crop residues without any tillage operation at 5 locations at farmers' fields during *Rabi* 2013-2016. Application of ready mix combination of clodinafop + metsulfuron at 60 + 4 g/ha at 25 DAS in wheat effectively controlled weeds and produced higher grain yield (4.10 t/ha) and B: C ratio (3.46) compared to farmers' practice which yielded 3.75 t/ha of grain with B:C ratio of 2.40 (**Figure 1 and Table 1**).

Seoni district

In Seoni district, OFR trials were conducted on wheat at 5 farmers' fields and greengram at 10 farmers' fields during *Rabi* 2013-16.

Effect on wheat: In Happy Seeder sown plots, application of RFD (120:60:40 N, P_2O_5, K_2O kg/ha) and post emergence (POE) herbicide (clodinafop + metsulfuron at 60 + 4 g/ha) resulted in higher mean grain yield (5.05 t/ha) and B:C ratio (3.44) over farmers' practice (2.83 t/ha and 1.78, respectively) (**Figure 1 and Table 1**).

Effect on summer greengram: Under CA with recommended fertilizer dose (20:60:40 kg N, P_2O_5 and K_2O/ha) and post-emergence application of herbicide (imazethapyr at 100 g/ha), greengram produced higher mean seed yield (1.70 t/ha) and B: C ratio (2.82) over farmers' practice (0.88 t/ha and 1.31, respectively) (**Figure 2 and Table 2**).

Better crop emergence, lesser number of weeds under CA, RFD and with or without herbicide based weed management resulted in higher yield (4.0-4.5 t/ha) than conventional practices (2.4-3.0 t/ha). The lower production costs and higher yields increased benefit cost ratio under CA system. Precision land leveling can reduce the labour requirement by 75 per cent in wheat in comparison to traditional leveled fields (Jat *et al.* 2009).

Yield loss models are generally used to estimate the effect of weeds on yield at an early growth stage of crop development before they have a distressing effect on crop. Data of weed density of all locations were used to fit a crop yield model to estimate the effect of weeds on wheat yield. A linear function as suggested by Dew (1972) was used to express the relationship between crop yields and weed density in wheat crop. It is given by

$$Y = a + bx$$

Where, y is the crop yield, x is the weed density, a is the intercept at $x = 0$, and b is the regression coefficient.

The model suggests reduction in grain yield with increase in weed density (**Figure 3**). With each unit (number) power of 10 increase in weed density/m^2, the wheat yield will decrease by 0.586 t/ha.

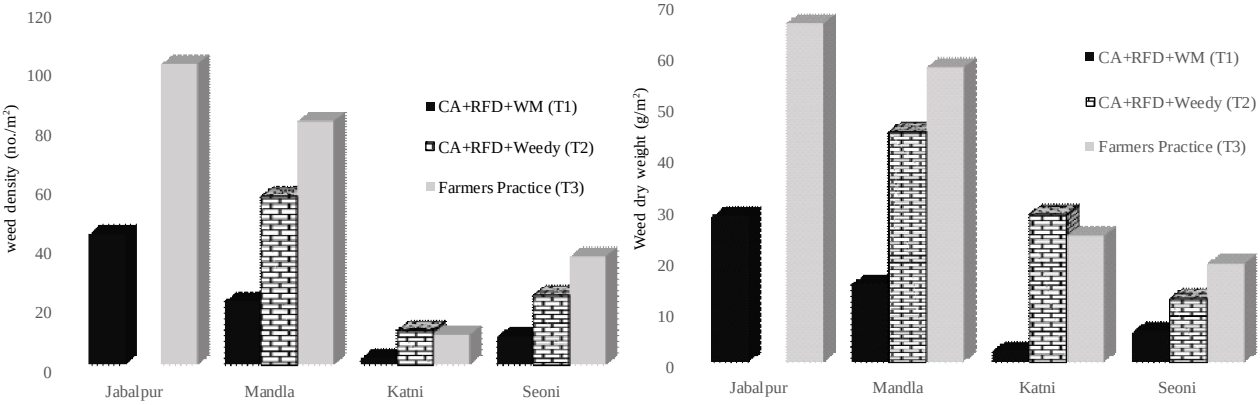

Figure 2. Effect of conservation agriculture on weed density and weed dry weight in summer greengram during 2013-16 (average of 41 farmer's field)

Table 2. Productivity of greengram (t/ha) under conservation agriculture during summer 2013-16 (mean of 41 locations)

Treatment	Jabalpur		Mandla		Katni		Seoni	
	Seed yield	B:C ratio	Seed yield	B:C ratio	Seed yield	B:C ratio	Seed yield	B:C ratio
CA + RFD + WM	1.25	2.94	1.35	3.63	1.26	3.90	1.70	2.82
CA + RFD + weedy	-	-	1.03	3.09	0.95	3.32	1.35	2.44
Farmers practice	0.72	1.43	0.89	2.18	0.87	2.10	0.88	1.31

CA-Conservation agriculture; RFD- Recommended fertilizer dose; WM: weed management

Table 3. Cost of production (`/ha) and gross income (`/ha) in wheat and greengram

Treatment	Jabalpur				Mandla			
	Wheat		Greengram		Wheat		Greengram	
	Cost of production	Total income	Cost of production	Total income	Cost of production	Total income	Cost of production	Total income
CA + RFD + WM	19,563	74,025	19,850	58,395	20,500	65,286	21,550	78,150
CA + RFD + weedy	17,625	52,665	-*	-*	18,000	51,617	19,750	62,100
Farmers practice	22,875	48,405	23,400	33,631	24,375	56,102	24,650	53,640

CA: Conservation agriculture; RFD: Recommended fertilizer dose; WM: Weed management; *Related data not recorded

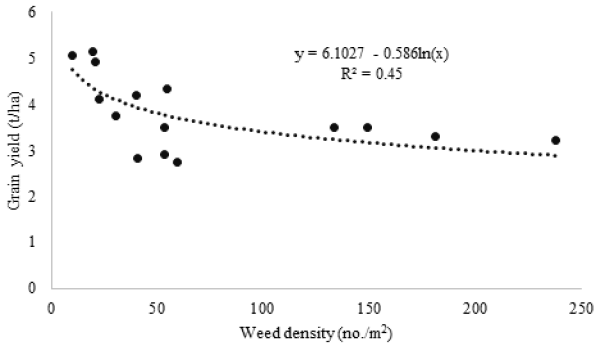

Figure 3. Fitting of linear model for estimating wheat crop yield as a function of weed density

Economic impact of CA

Production cost varied from ` 22,875 to ` 24,375 per ha in case of wheat and ` 23,400 to ` 24,650 per ha in case of greengram under farmers' practice (conventional tillage). Cost of production under CA based treatment varied from ` 19,563 to ` 20,500 per ha for wheat crop and ` 19,850 to ` 21,550 per ha for greengram. Higher benefit cost ratio obtained in CA based weed management than farmers' practice in wheat and greengram indicated effectiveness of CA based technology for effective weed management and yield enhancement (**Table 3**).

Impact of CA technologies on farming community

OFR-cum-demonstrations have been successful in convincing the farmers about the benefits of conservation agriculture. As a result the area under zero tillage has been rapidly increasing and previous practice of crop residue burning has been stopped to a greater extent. The CA based technology has made significant impact on farmers of the Jabalpur, Mandla, Narsighpur, Katni and Seoni districts and surrounding region and has now spread to more than 2000 ha of land in MP state within a span of 5 years. Farmers were impressed with the performance of the greengram in summer season also. They have realized the benefits of CA in terms of saving in cost of field preparation and labour, time and conservation of soil moisture.

Constraints towards adoption of CA technology

Conservation agriculture has the potential to break productivity barriers, sustain natural resources and offer better environmental health and, therefore has been widely accepted by farmers in developed countries (Bolliger *et al.* 2006, Triplett and Warren 2008). Despite several benefits, adoption of CA systems by farmers in central India is still in its infancy as they require a total paradigm shift from conventional agriculture with regard to crop management. CA technologies are essentially herbicide- (Lafond *et al.* 2009), machine- and knowledge-driven. Weed composition differs from farm to farm. Small-seeded weeds proliferate well under CA and have to be controlled by special measures (Chauhan *et al.* 2006, Sosnoskie *et al.* 2006). There is, thus need to explore these opportunities in a site-situation-specific manner for local adaptation.

Results of the present study comprising large number of OFR conducted at farmers' fields in various districts of Madhya Pradesh of central India, reveals that conservation agriculture retains crop residues in soil surface which act as mulch to improve nutrient availability and soil structure, and restrict the moisture loss from soil surface, retains nutrients in soil otherwise lost through burning of crop residues. Successful introduction of greengram as summer crop and use of CA technology offers additional income and improvement in soil fertility. With the availability of farm machinery for ease of sowing and better residue management and herbicides for efficient weed management, intensification of rice-wheat-greengram cropping system is feasible at lower environmental cost and enhanced income. These OFR trials will motivating the other farmers of the locality and nearby to adopt conservation agriculture in larger area. Increased number of demonstrations and training and capacity building of the stakeholder are required in other part of the state to boost the confidence level of the farmers and convince them to adopt conservation agriculture technology.

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