Society for Advancement of Wheat and Barley Research
ICAR-Indian Institute of Wheat & Barley Research
Karnal - 132 001, India

Wheat and Barley Research
10(2):78-88
Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR

Research Article

Suitable wheat cultivars and seeding machines for conservation agriculture in rice-wheat and sugarcane-wheat cropping systems

RS Chhokar, RK Sharma, SC Gill, RK Singh, Vikas Joon, Mamta Kajla and Ankur Chaudhary

ICAR-Indian Institute of Wheat and Barley Research, Karnal, India

Article history
Received: 26 May, 2018
Revised : 30 July, 2018
Accepted: 01 August, 2018

Citation
Chhokar RS, RK Sharma, SC Gill, RK Singh, Vikas Joon, Mamta Kajla, Ankur Chaudhary. 2018. Suitable wheat cultivars and seeding machines for conservations agriculture in rice-wheat and sugarcane-wheat cropping system. *Wheat and Barley Research* **10**(2):78-88. doi.org/*10.25174/2249-4065/2018/80127*

****Corresponding author***
Email: rs_chhokar@yahoo.co.in
Rajender.Chhokar@icar.gov.in

Abstract

Field investigations were conducted to improve the wheat yield and profitability through identification of suitable wheat cultivars and seeding machines under conservation agriculture (CA) after rice and sugarcane. For wheat seeding under CA after rice harvest with full residue retention, Turbo Happy Seeder (THS) was more appropriate, while in sugarcane ratoon with full trash, Rotary Disc Drill (RDD) was found suitable. Based on the research farm and farmer's field experiments, the wheat grain yield was similar under conventional tillage (CT) and CA. Among 32 wheat varieties (28 aestivum and 4 durum) evaluated under timely sown conditions, no significant yield differences were observed under CT and CA. Among test cultivars, the best yielding were HD 2967, PBW 723, HDCSW 18, HI 8498, MPO 1215, UAS 428 and MACS 6222. Out these seven genotypes, three (HI 8498, MPO 1215 and UAS 428) were durum genotypes. For very late sown (20-25th January) and CA conditions after sugarcane harvest, five *aestivum* wheat varieties namely PBW 550, DBW 71, Raj 3765, WR 544 and WB 02 yielded 30.24, 33.80, 32.62, 32.46 and 27.54 q/ha, respectively. On an average, 31.8 q/ha additional wheat yield can be obtained when seeded in sugarcane ratoon using RDD. If we translate 50% sugarcane area across the wheat growing zone of India (1.0 mha) then we can have an additional wheat production of 3.2 mt/year. Both the crop establishment methods viz. no till (NT) with residue retention and conventional till (CT) wheat had similar yield levels but CA can have an additional profit of Rs 3125/ha due to reduction in tillage cost. The results clearly indicate that wheat productivity and production as well as profitability can be improved through right choice of cultivar, and seeding machinery for conservation agriculture in rice-wheat and sugarcane ratoon-wheat system.

Keywords: Crop residue; no-till; productivity; profitability; Rotary Disc Drill; sugarcane ratoon; Turbo Happy Seeder.

1. Introduction

Wheat is the second most important cereal crop in India after rice. As a sequence, rice-wheat and sugarcane-wheat are two important wheat based cropping systems. In both the cropping systems, management of crop residues is a major challenge for the growers after banning of the residue burning legally in northern India. Among the residue management options (residue retention and incorporation), retention is more economical and beneficial as lot of energy is required to incorporate the residue. Globally, residue retention and minimum soil disturbance, two components of conservation agriculture (CA) are widely accepted by the growers because of economics and sustainability issues (FAO, 2018). No- till (NT) besides reducing the tillage cost, also helps in increasing the cropping intensity because of reduction of turnaround time between crops.

Moreover, intensive tillage and agricultural practices result in the decline of soil organic matter (SOM) due to increased oxidation over time, leading to soil degradation, loss of soil biological fertility and resilience (Lal 1994; Alvarez 2005). NT minimizes SOM losses and is a promising strategy to maintain or even increase soil C and N stocks (Bayer *et al.* 2000; Alvarez 2005). NT combined with permanent soil cover, has been shown to further result in a build-up of organic carbon in the soil surface layers (Campbell *et al.*, 1996; Lal 2005). Retention of residue on soil surface besides improving soil C also has many benefits viz. conserve moisture, moderate temperature, improve microbial populations/biological activity and suppress weeds (Blevins *et al.*, 1983; Eguchi and Hirano, 1971; Unger 1991; Sharma *et al.*, 2008; Chhokar *et al.*, 2007; Chhokar *et al.*, 2012; Ram *et al.*, 2013). Also, seeding winter wheat into standing stubble provides the protection against cold temperatures due to trapped snow (Fowler and Gusta, 1978; Cox *et al.*, 1986) and in years having winter kill, NT yields higher than CT but, in years with no winter injury both the systems have similar wheat yields.

Globally, CA is practiced over 157 m.ha (FAO 2018) under different cropping systems and ecologies to address the issues of natural resource degradation, changing climate effects, shortage of labour, water and energy. For the success of CA, the most important is availability of suitable machinery for the system. Turbo Happy Seeder (THS) and Rotary Disc Drill (RDD) are two important CA machines for seeding in loose crop residue (Sharma *et al.*, 2008; Sidhu *et al.*, 2007 and Sidhu *et al.*, 2008). THS is gaining popularity in northern India for wheat sowing in rice residues. As a result of alteration in microclimate due to adoption of CA, the performance of wheat genotypes may vary in response to tillage and residue management, and specific genotypes are recommended for no-till (Chevalier and Ciha, 1986; Yang and Baker, 1991; Tillman *et al.*, 1991). Some of the researchers (Chevalier and Ciha, 1986; Hall and Cholick, 1989; Yang and Baker, 1991; Tillman *et al.*, 1991) are of the view that there is G × E/T interactions and higher yield can be achieved by selecting suitable genotypes in NT system compared to CT system. The reasons for the G × M interaction include soil mechanical impedance, diseases (type and intensity), soil temperature, anoxia, allelopathy and weed control. In contrary, some researchers studying genotype x tillage practice interaction (G × T) have generally reported a lack of interaction in field crops (Cox, 1991; Ullrich and Muir, 1986; Francis *et al.*, 1984). In Indian conditions no significant work has been done on identification of wheat genotypes for CA system. Keeping the above facts in view, the present study was designed to identify the suitable wheat genotypes and seeding machines for higher wheat grain yields and profitability under irrigated conditions of northern Indian plains under rice-wheat and sugarcane-wheat systems.

2. Materials and Methods

Field experiments were conducted to optimize the wheat productivity by identifying suitable wheat varieties and seeding machines in rice-wheat and sugarcane-wheat systems during 2015-16 to 2017-18 at research farm of ICAR-Indian Institute of Wheat and Barley Research (IIWBR), Karnal, and at farmer's fields around Karnal, Haryana, India. The soil varied from sandy loam to clay loam in texture, alkaline in reaction, low in available N, low to medium in organic carbon and phosphorus and high in available potash. The details of the experiments conducted are as under.

2.1 Performance of wheat varieties under CT and CA systems

Three set of experiments were conducted for evaluation of wheat genotypes for CA system under rice-wheat sequence. In first experiment, eight wheat genotypes in sub plots were evaluated under two main plots of tillage crop establishment for two consecutive *rabi* season of 2015-16 and 2016-17 in strip plot design with three replications. Two tillage crop establishment methods were CT (Conventional tillage) and CA (NT with residue retention) and eight high yielding genotypes tested were HD 2967, WH 1105, HD 3086, DBW 88, PBW 550, DPW 621-50, 45th IBWSN1147 and HDCSW 18. The residue load in CA treatments was 6.0 t/ha. The sowing was done using Turbo Happy Seeder (THS) using a seed rate of 100 kg/ha on November 16, 2015 and November 5, 2016. For control of weeds sulfosulfuron + metsulfuron tank mixture was applied at 25 + 4 g/ha at 35 DAS.The crop was fertilized with 150 kg N, 60 kg P_2O_5 and 30 kg K_2O/ ha. Full P and K were applied as basal using 12:32:16 NPK mixture. NPK mixture (187.5 kg/ha) was drilled at the time of sowing. The remaining N was applied through urea as top dressing in two equal splits just before first and second irrigation at around 20 and 40 days after sowing, respectively. The crop was harvested on April 11, 2016 and April 9, 2017, during first and second year, respectively.

In another experiment, thirty-two genotypes (28 *aestivum* and 4 durum) of wheat (Table 2) were selected based on their better yielding ability across different wheat growing zone. These genotypes were evaluated for their suitability for CA system during *rabi* 2016-17. The trials were conducted across three locations comprising research farm of IIWBR (29°42'22''N; 85°40'13''E) and two locations at farmer's field viz. village Rambha (29°47'54''N; 77°00'41''E) and Taraori (29°48'26''N; 76°55'18''E). The soils of the experimental plots at IIWBR, Rambha and Taraori were sandyloam, loam and clay loam, respectively. The sowing was done with THS using a seed rate of 100 kg/ha. In this study, two different tillage management practices were CT and CA. The experimental design was strip plot with tillage in main and varieties in sub plots. The treatments were replicated thrice at IIWBR, Karnal and twice at Rambha and Taraori locations. The recommended package of practices was adopted to raise the crop. Based on the first year performance at three locations, 12 better yielding genotypes were again evaluated in third experiment conducted in strip plot design (two tillage options i.e., CA and CT systems in main plots and 12 varieties in sub plots) with three replications during the 2017-18 season at village Rambha (Table 3). The sowing was done on 26th October 2017 with THS in a combine harvested field with full rice residue. The recommended package of practices were followed and the crop was harvested on 7th April 2018 and the yield was recorded.

2.2 Demonstrations at farmer's field:

2.2.1 Comparative performance of two CA machines for seeding in to loose rice residue at farmer's field:

In Village Taraori, wheat variety HD 2967 was sown in rice residue using Rotary Disc Drill (RDD) and THS using a seed rate of 100 kg/ha. Except the sowing with either THS or RDD, all other agronomic practices were similar. Besides this, eleven demonstrations were conducted at farmer's fields in three villages namely Rambha, Taraori and Baragoan. Each demonstration consisted of one acre area divided in two equal parts as CT and CA system. For CA after combine harvesting, full rice residue was spread uniformly. For CT, residue was removed and field was well prepared using cross harrowing and cross tilling followed by cross planking. The sowing in both the conditions was done with THS using wheat cultivar HD 2967. All the recommended package of practices were followed. From each block three samples, each having a size of 4.5 m^2 (4 rows and 5 m length) were taken for recording yield.

2.2.2 Wheat seeding in sugarcane ratoon crop with full trash using Rotary Disc Drill

To explore the possibility of raising an additional wheat crop in full trash of ratoon sugarcane, the demonstrations on an area of 1.0-1.5 acre were conducted using RDD machine at two locations during 2016 and at one location during 2017 in village Bara Gaon, Karnal. The wheat cultivar PBW 550 was sown on 12th and 13th January, 2016 during first year, while during the second year, five *aestivum* wheat varieties namely PBW 550, DBW 71, Raj 3765, WR 544 and WB 02 (Fig. 2) were seeded on 24th January, 2017 using a seed rate of 150 kg/ha with RDD. Fertilizers application consisted of 120 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha. N (nitrogen) P (phosphorus) K (potassium) mixture (12:32:16) @ 187.5 kg/ha was used as basal application by drilling to meet the PK requirement. The remaining N was applied in the form of urea in two splits just before first and second irrigations. For weed control combination of sulfosulfuron + metsulfuron @ 25+ 4 g/ha was sprayed at 35-40 days after sowing and 1-2 days later irrigation was applied. The crop was harvested during first week of May during both the years i.e. 2016 and 2017. The observations were recorded on various yield and yield attributes in different experiments. The effective tillers were counted about a fortnight before harvesting in one running meter at two places in each plot and converted to per square metre. The crop was manually harvested and threshing was done by small plot thresher and after recording the yield, a random sample was taken from each treatment to evaluate 1000-grains weight (TGW).

The data were subjected to analysis of variance (ANOVA) for determining the differences among the treatment means and when the F test was significant, means were compared with Fisher's protected least significant difference (LSD) test at 5% level of significance. Based on the data of different field observations, average and ±SEm were also worked out in different demonstrations. "Fischer's paired t-test" was used for comparing the significance of two treatment means. The data were pooled where the results were similar in experimentation over the years.

3. Results and discussion

3.1 Performance of wheat varieties under CT and CA systems

The perusal of data in Table1 reveals that the tillage and residue management as well as their interaction with genotypes were not significant during both the years for yield and yield attributes. However, the genotypic differences were found significant on year wise as well as on pooled basis for yield and yield attributes. Harder *et al.* (1979) had also earlier showed little or no difference in yield in a conventional vs. conservation tillage, but had significant differences among the wheat varieties. The mean wheat yields under CT and CA system were 57.89 and 56.23; 60.26 and 61.06; and 59.08 and 58.64 q/ha, respectively, during first year, second year and on pooled basis. Among genotypes, the tallest plants were of HDCSW 18 (117.5 cm) followed by 45th IBWSN1147

Table 1. Performance of wheat varieties under CA and CT in rice-wheat system

Treatments	Plant height, cm	Ear head length, cm	Tillers/m^2	Biological yield, q/ha	Yield, q/ha	1000-grains weight, g
			2015-16			
Tillage and residue management						
CT*	103.4	11.2	407.5	147.6	57.89	40.3
ZT+R (CA)**	101.2	11.3	407.2	143.4	56.23	40.6
LSD at 5%	NS	NS	NS	NS	NS	NS
Genotypes						
WH 1105	99.4	11.0	380.8	132.7	58.08	39.1
DBW 88	102.0	11.1	410.0	152.5	57.96	42.5
DPW 621-50	103.2	11.8	405.8	153.8	57.68	39.6
HD 2967	102.4	10.7	435.0	151.6	58.54	40.5
HD 3086	98.4	10.0	462.5	136.3	56.02	38.3
PBW 550	85.9	10.7	401.7	119.1	55.04	38.5
45th IBWSN1147	112.6	12.1	389.6	159.9	56.54	41.4
HDCSW 18	114.4	12.6	373.3	157.8	56.63	43.6
LSD at 5%	3.77	0.5	24.1	4.99	1.99	1.23
			2016-17			
Tillage and residue management						
CT	106.8	10.6	396.6	162.5	60.26	44.8
ZT+R (CA)	108.6	11.6	402.0	167.4	61.06	43.7
LSD at 5%	NS	0.68	NS	NS	NS	0.35
Genotypes						
WH 1105	105.1	10.8	380.4	147.7	58.96	41.7
DBW 88	105.3	10.8	404.7	172.8	59.21	42.5
DPW 621-50	110.6	11.0	401.8	169.8	60.22	44.0
HD 2967	112.7	11.1	417.5	168.7	62.72	45.0
HD 3086	103.2	9.9	435.5	159.8	59.57	44.3
PBW 550	91.4	10.4	384.6	139.8	60.80	43.5
45th IBWSN1147	112.9	12.3	386.3	179.8	59.29	45.5
HDCSW 18	120.5	12.6	383.9	181.2	64.49	47.6
LSD at 5%	2.36	0.73	NS	7.31	3.32	1.4
			POOLED			
Tillage and residue management						
CT	105.1	10.9	402.1	155.0	59.08	42.5
ZT+R (CA)	104.9	11.5	404.6	155.4	58.64	42.2
LSD at 5%	NS	0.2	NS	NS	NS	NS
Genotypes						
WH 1105	102.3	10.9	380.6	140.2	58.52	40.4
DBW 88	103.6	10.9	407.3	162.7	58.58	42.5
DPW 621-50	106.9	11.4	403.8	161.8	58.95	41.8
HD 2967	107.5	10.9	426.3	160.1	60.63	42.7
HD 3086	100.8	10.0	449.0	148.0	57.80	41.3
PBW 550	88.6	10.6	393.1	129.5	57.92	41.0
45th IBWSN1147	112.7	12.2	387.9	169.8	57.92	43.5
HDCSW 18	117.5	12.6	378.6	169.5	60.56	45.6
LSD at 5%	1.63	0.42	25.8	4.5	1.85	0.91

*CT=Conventional tillage; **R= Residue retention; CA= Conservation agriculture, ZT= Zero tillage

(112.7 cm) and both these genotypes were significantly taller than rest of the genotypes. The significantly shortest plants of PBW 550 with height of 88.6 cm were recorded. The longest ear heads were of genotype HDCSW 18 (12.6 cm) and showed significant superiority over all the other genotypes. The wheat cultivar HD 3086 had significant higher tiller density over other genotypes. The crop biomass was higher in genotypes HDCSW 18 and 45th IBWSN1147. The boldest grains were of HDCSW 18 with an average 1000-grains weight of 45.5g followed by genotype 45th IBWSN114 having 1000-grains weight of 43.4g. Among eight genotypes, during first year the highest yield obtained was of HD 2967 (58.54q/ha) which was closely followed by WH 1105 (58.08q/ha) and the lowest yield was of PBW 550 (55.04q/ha). However, during second year of study, HDCSW 18 was the top yielder with grain yield of 64.49 q/ha followed by HD 2967 having 62.72q/ha. On two year mean basis, top three genotypes in order of ranking were HD 2967 (60.63 q/ha), HDCSW 18 (60.56q/ha), and DPW 621-50 (58.52 q/ha). During 2016-17, although all the genotypes yielded better compared to 2015-16 but HDCSW 18 because of long duration variety had better performance with a mean grain yield of 64.49q/ha. The better performance of this entry might be due to early sowing leading to availability of longer growing period. The earlier results have also shown that wheat seeded during last week of October to first week of November generally gives higher yield in north western Indian plains (Ram *et al.* 2012). Therefore, the long duration varieties like HD 2967 and HDCSW 18 should be grown in last week of October under CA for obtaining higher productivity and profitability. Although PBW 550 had lower biomass and height yet it had better Harvest Index (0.46). The better yield of cultivar HDCSW 18 was due to having bolder grains.

3.2 Screening of aestivum and durum wheat varieties under CT and CA systems

Thirty two wheat varieties screened at three locations (Research farm of IIWBR and two locations at farmer's field viz village Rambha and Taraori) for their suitability for CA system during 2016-17 (Table 2 and 3). At all the locations, there was no effect of tillage on yield and 1000-grains weight. Also the interaction effects were non-significant. The top six yielding varieties were MPO 1215 (62.7 q/ha), PBW 723 (62.6 q/ha), UAS 415 (61.0 q/ha), HD 2967 (60.5 q/ha), HD 2733 (60.3 q/ha) and HI 8498 (59.9 q/ha). The boldest grains were of durum variety HI 8498 with mean 1000-grains weight of 53.5 g followed by MPO 1215 (50.3 g). Among *aestivum* boldest grains were of GW366 with 1000-grains weight of 49.6 g.

Based on the results of 2016-17, 12 better yielding cultivars (Table 4) were again evaluated under CA and CT system under early sown conditions (Last week of October) during *Rabi* 2017-18. Here also, the effect of tillage as well as their interactions were non-significant for 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-grains weight of 63.9g and was followed by MPO 1215 (58.9 g) and GW 366 (56.6g). In comparison to previous year study all the varieties had heavier 1000-grains 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.

Earlier it has been reported that most of the crop breeding programs are conducted on complete/conventional tillage regimes, which limits the identification of crop genotypes responsive to conservation agriculture (Mahmood *et al.*, 2009). Some of the researchers (Hall and Cholick, 1989), obtained a significant genotype x tillage interaction for grain yield of hard red spring wheat. Contrary to this, some researchers studying genotype x tillage practice interaction (GT) have generally reported a lack of interaction in field crops (Cox, 1991; Ullrich and Muir, 1986; Francis *et al.*, 1984).

However, Herrera *et al.* 2013 using literature survey and meta-analysis compared the grain yield under NT and CT for 112 wheat genotypes (44 spring, 60 winter and 8 *durum* genotypes) across 12 locations and 24 year and reported that in most of studies, slightly higher grain yield under CT for winter (+5%) and spring (+2%) wheat. They further reported that in few studies where selection had been made under NT, the effect of tillage on grain yield

Table 2. Performance of wheat genotypes under CA and CT (2016-17)

Treatments	Yield, q/ha				1000-grains weight, g			
	IIWBR	Rambha	Taraori	Mean	IIWBR	Rambha	Taraori	Mean
Tillage & residue management								
CT*	57.8	56.6	51.7	55.3	42.1	44.3	43.1	43.1
ZT+R (CA)**	57.4	55.7	52.7	55.2	42.1	43.6	42.9	42.8
LSD at 5%	NS	NS	NS		NS	NS	NS	
Genotypes								
HD 2967	63.2	60.4	57.8	60.5	44.3	41.9	40.9	42.4
C 306	37.6	36.0	42.1	38.6	38.8	41.1	45.4	41.8
DBW 88	60.0	56.8	58.7	58.5	41.8	44.4	42.5	42.9
HS 490	40.3	40.5	42.7	41.1	42.7	45.6	47.8	45.4
HD 3171	58.8	48.8	48.9	52.2	46.3	48.0	41.5	45.3
GW 322	59.7	60.0	51.5	57.1	42.5	46.9	40.7	43.4
HI 1544	58.2	57.7	51.3	55.7	41.6	43.9	43.4	43.0
VL 907	57.4	54.5	48.9	53.6	39.0	42.1	38.1	39.7
GW 273	62.5	58.7	49.4	56.9	44.3	47.9	44.0	45.4
WH 1105	59.0	59.2	51.9	56.7	39.5	42.5	41.6	41.2
MPO 1215 (d)#	64.0	61.3	62.9	62.7	48.9	51.9	50.1	50.3
K 1006	54.1	49.0	43.8	49.0	37.7	39.5	36.5	37.9
K 307	55.4	47.2	50.1	50.9	39.6	39.6	40.5	39.9
HD 2932	59.3	59.2	55.7	58.1	39.9	40.9	41.0	40.6
UAS 428 (d)	61.3	58.6	57.2	59.0	43.2	43.8	49.1	45.4
HI 1612	52.5	51.5	41.1	48.4	43.1	43.4	42.8	43.1
HPW 349	59.5	59.0	48.4	55.7	36.9	40.5	37.1	38.2
HI 8498 (d)	59.5	60.9	59.3	59.9	50.8	53.2	56.6	53.5
HDCSW 18	60.0	56.6	48.8	55.1	43.5	42.6	48.0	44.7
HD 3086	59.9	61.2	51.0	57.4	42.8	45.6	42.3	43.6
WH 542	58.8	60.9	56.3	58.7	31.7	33.7	33.0	32.8
PBW 343	55.6	58.4	56.7	56.9	45.3	47.6	45.5	46.1
GW 366	60.3	59.4	54.7	58.2	48.5	50.8	49.4	49.6
UAS 415 (d)	61.6	60.6	60.8	61.0	46.4	47.1	47.9	47.1
PBW 723	64.0	63.4	60.3	62.6	43.0	46.8	45.1	44.9
VL 804	52.7	46.4	41.9	47.0	33.6	37.8	36.9	36.1
HD 2733	61.3	62.7	56.8	60.3	45.8	47.0	43.4	45.4
MACS 6222	59.8	58.9	53.3	57.3	43.6	44.6	45.2	44.5
45th IBWSN1147	58.9		52.2	55.6	42.8		41.0	41.9
DPW 621-50	57.8	59.5	51.4	56.3	41.3	42.4	41.5	41.7
HS 507	50.3	51.8	49.3	50.5	36.1	36.8	36.3	36.4
PBW 550	60.0		55.0	57.5	41.5		41.1	41.3
LSD at 5%	2.72	3.71	4.37		1.38	1.44	1.36	
	Interaction= NS				Interaction= NS			

*CT=Conventional tillage; **R= Residue retention; CA= Conservation agriculture; ZT= Zero tillage; #(d) durum wheat

was modified significantly by genotype. It was due to the traits associated with the emergence of vigorous seedling and resistance to a changed spectrum of diseases leading to better performance of the genotype under NT.

Honsdorf *et al.*, 2018 tested 26 CIMMYT *aestivum* and durum wheat genotypes over six years under conventional and permanent raised beds with full and reduced irrigation to clarify the importance of genotype by tillage interaction. In *aestivum* wheat, tillage by genotype interaction was significant for yield, however, no cross over effects were observed and rank changes were small. In durum wheat, genotype by tillage interaction was only significant for plant growth. They concluded that there is no need for separate breeding programme. Contrary,

Table 3. Performance of wheat varieties under early sown (26th Oct. 2017) CT and CA conditions during 2017-18

Treatments	Yield, q/ha	1000-grains weight, g
Tillage & residue management		
CT*	63.6	50.3
ZT+R (CA)**	63.3	50.4
LSD at 5%	NS	NS
Varieties		
HI 8498 (d)#	69.1	63.9
PBW 723	63.9	51.0
UAS 428 (d)	58.2	55.3
MPO 1215 (d)	57.0	58.9
UAS 415 (d)	60.2	52.8
HDCSW 18	67.6	48.1
GW 366	57.9	56.6
HD 2733	68.9	47.7
MACS 6222	63.5	46.7
GW 322	65.0	44.8
WH 542	62.6	33.2
HD 2967	67.3	45.4
LSD at 5%	2.99	1.98
	Interaction= NS	Interaction= NS

*CT=Conventional tillage; **R= Residue retention; CA= Conservation agriculture; ZT= Zero tillage; #(d) durum wheat

Trethowan *et al.*, 2009 suggested the need to breed or select genotypes to different cropping systems because of some significant genotype x tillage and genotype x cropping system interactions. These, tillage x cultivar interactions have been observed in the dryland areas depending on the amount of stubble, nutrient availability and the environmental conditions of the year influencing the disease incidence and severity.

3.3 Demonstrations at farmers field:

3.3.1 Comparative performance of two CA machines for seeding in to loose rice residue:

Wheat cv HD 2967 was tested using RDD and THS in NT, CT and CA system after rice harvest. The wheat grain yield was similar in CT and NT without loose residue when sown either using RDD or THS (Fig.-1). In the presence of rice residue, the wheat yield was slightly lower in RDD sown as there was less cutting effect of discs at few places in the field. Moreover, with THS also, some dragging of residue was observed due to moist and heavy residue load. The CA wheat yield was 48.48 and 53.70 q/ha under RDD and THS, respectively. The respective wheat yield under RDD and THS was 55.85 and 51.32 q/ha under NT without residue and 53.67 and 52.03 kg/ha under CT without residue.

The frequent blunting of front powered disc in RDD generally leads to problem in residue cutting and drilling of seed and fertilizer at appropriate depth. The performance of RDD machine can be improved by changing the front powered discs by better quality discs like Soil Razor Disc being manufactured by Ingersoll and Bellota along with increasing rpm of powered discs. The improvement in the RDD will solve the problems being faced with THS if residue is wet or need for bigger tractor of more horse power as RDD can be effectively operated with 40-45 HP tractor. However, recently the THS efficiency has been slightly improved with change of the plain flails by serrated flails (Sidhu, HS CIMMYT, BISA Ludhiana) having better cutting and beating action.

Additionally, as there is minimum soil disturbance with RDD, it can also be effectively used for cross sowing for higher productivity. Cross sowing in wheat gives the yield advantage over conventional practice (Dhiman *et al.* 1984; Jadho and Nalamwar, 1993; Chhokar *et al.*, 2017). Dhiman *et al.* (1984) reported that four wheat cultivars gave 13-18% higher grain yield when sown by disc drill in cross rows than in one direction only.

3.3.2. Comparative yield of CA and CT wheat demonstrations at farmer's fields:

Eleven CA wheat demonstrations were conducted in three villages (Baragaon, Rambha and Taraori). The wheat yield was similar in CT and CA with a mean yield of 58.8 and 58.4 q/ha, respectively (Fig. 2),

Earlier researchers (Harder *et al.*, 1979; Ram *et al*, 2013) had also showed little or no difference in yield in a conventional vs. conservation tillage. However, Walker and Rasmussen (1981) showed small increases in winter wheat yields with conservation over conventional tillage with selected cultivars. Harder *et al.*, 1979 demonstrated a strong difference among varieties in conservation tillage of winter wheat in a dry-land cropping system.

For conventional sowing, farmers generally apply different field operations and in the present study for CT we considered cross harrow, cross cultivator and cross planking followed by seed-cum-fertilizer drilling. The prevalent hire basis rates in Karnal (Haryana) for harrow, cultivator, planking and drilling are Rs 875, 875, 625 and 875/ha, respectively. Considering these costs, the tillage

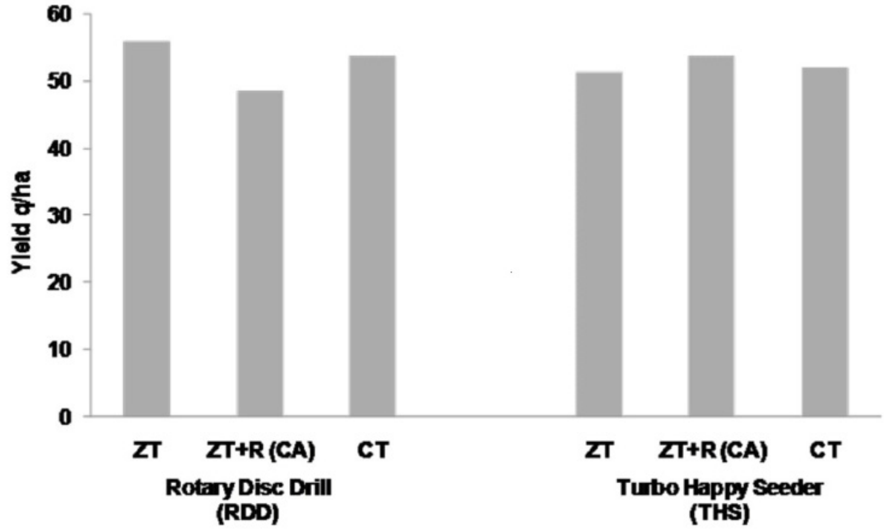

Fig. 1. Comparative performance of two CA machines (RDD and THS) for wheat seeding after rice harvest

and seeding expenditure for CT is Rs 5625. On custom hire basis, wheat seeding charges with THS are Rs.2500/ha. Thus compared to CT, CA saves on land preparation and seeding costs by about Rs. 3125/ha besides significant energy and time saving.

3.2.3 Wheat seeded in sugarcane ratoon crop with full trash using Rotary Disc Drill

As far as sowing in sugarcane ratoon is concerned, tyne drilling is not feasible and the feasible option is RDD as it has front powered disc followed by double disc for drilling seed and fertilizers in the slits created by powered discs.

During first year, the average wheat (cultivar PBW 550) yield recorded was 34.3 q/ha (32.7 and 35.8 q/ha) from the very late sown (Mid-January) wheat (Fig. 3).

During second year, the very late sown wheat (24^{th} January, 2017) had an average grain yield ranging from 27.5 to 33.8 q/ha. The maximum yield was recorded with wheat variety DBW 71 followed by Raj 3765 and WR 544. Between two timely sown varieties (PBW 550 and WB 02), PBW 550 yielded more. The better yielding varieties had better 1000-grains weight. Besides wheat, greengram can also be seeded using the RDD in sugarcane ratoon (Fig. 4). The growing

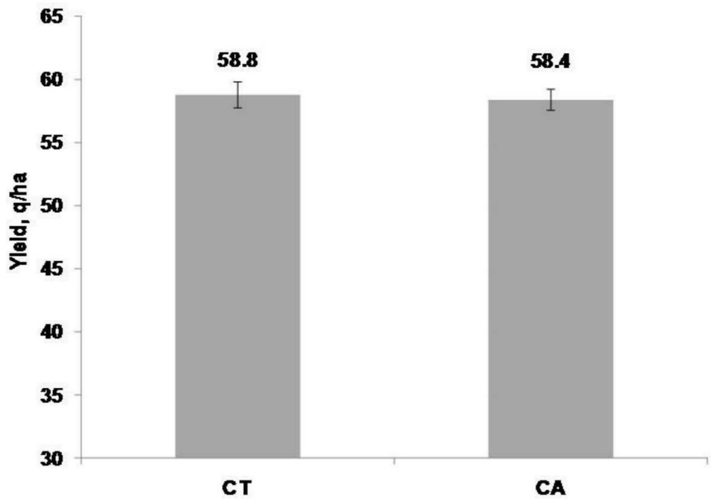

Fig. 2. Wheat yield under CA and CT system in rice-wheat system (Average of 11 field demonstrations).Vertical bars represent ± SEM. Means are not significantly different at P=0.05 using "Fischer's paired t test"

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 improve the wheat and pulse production. The total sugarcane area in India is about 4.5 m ha and 50% area is in three states namely Haryana, Punjab and UP. Of total area, about 50% is under ratoon. If we target the sugarcane ratoon area of about 1.0 m ha in three states (Haryana, Punjab and UP) for seeding wheat then we will have an additional wheat production of about 3.2 m MT considering the average wheat yield of 3.2 t/ha. After wheat harvest if there are any gaps in sugarcane crop stand then by adopting gap filling farmers can harvest the bumper yield of sugarcane also, Moreover, this will promote the CA with better environmental health by reducing the pollution with no straw/trash burning along with efficient use of inputs.

Adoptions of CA based technology not only reduce the cost of cultivation and increases profit but also enhances the soil quality, i.e. soil physical, chemical and biological conditions (Verhulst *et al.*, 2010; Ram *et al.*, 2013). Thus CA can help in arresting and reversing the natural resource degradation. Due to multifarious benefits of CA, its area has steadily increased worldwide to cover about ~11% of the world arable land (157mha) (FAO, 2018).

The benefits of CA in terms of yield advantages may not be in short term but if adopted for a long term, then can expect yield benefits. Zheng *et al.*, 2014 have reported that the longer the experimental duration (>5 years) of CA, the higher was the magnitude of the increase in crop yield. Contrary, the potential negative effects were observed where NT without residue is adopted for longer period in some situations.

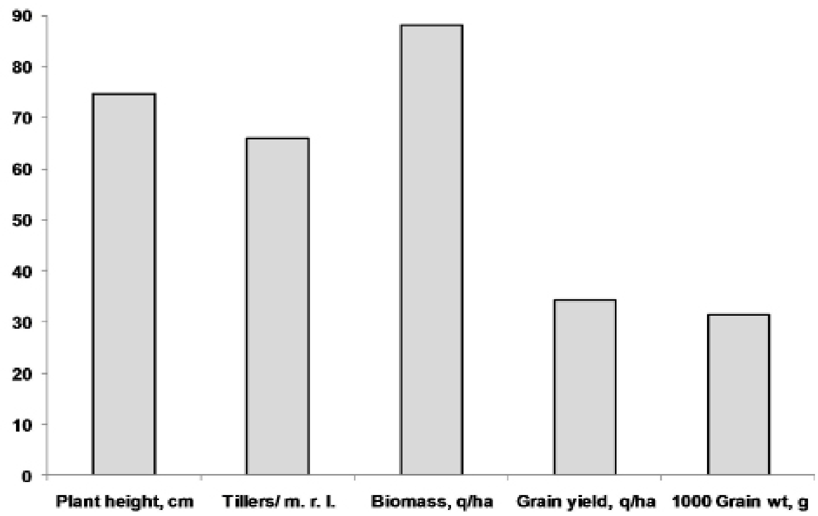

Fig. 3. Performance of late sown CA wheat cv. PBW 550 in sugarcane ratoon (Average of two locations)

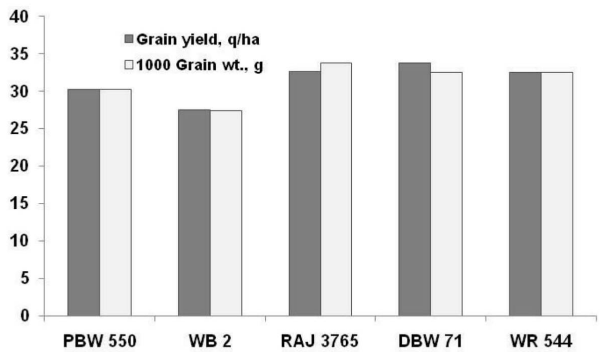

Fig. 4. Performance of varieties under late sown conditions in sugarcane ratoon with residue sown using RDD

Generally, straw retention improves aggregate stability, reduces soil erosion, and increases the infiltration and conservation of soil water, thus enhancing soil productivity (He *et al.*, 2009; He *et al.*, 2011; Li *et al.*, 2007). Additionally, straw retention directly increases the input of organic matter and nutrients into soil, in turn improving soil nutrient availability for crop growth (Qin *et al.*, 2010; Wang *et al.*, 2008; Liu *et al.*, 2010). Thus, it would be better to apply NT plus straw mulching to avoid potential negative effects of NT on crop yield. These observations mainly pertain to CA practiced under rainfed conditions. But for irrigated system like rice-wheat, no negative effect has been observed for the past 15 years of continuous NT without residue at ICAR-IIWBR, Karnal (Unpublished data).

On the basis of present studies it can be concluded that the wheat genotypes performing better under CT also performed better in NT indicating no significant G × T interaction. Therefore, for G × T interaction it is must to breed genotypes under NT conditions. So unless cultivars not developed for NT, it is less likely to have interaction. Development of suitable genotypes for CA system will further strengthen the sustainability of production systems over a long term basis by addressing the emerging challenges of resource degradation, climate change and food security. In this ensuing *rabi* season of 2017-18, farmers adopted CA wheat had lesser infestation of *Phalaris minor* in comparison of neighbours adopted CT sowing. In future this technology can be utilized for management of herbicide resistant *Phalaris minor*. Moreover, in rice-wheat system, THS was found efficient in seeding under conservation agriculture. Whereas, RDD machine with its unique mechanism was more suitable at the moment for seeding wheat in sugarcane ratoon and can open the window for increasing wheat area in sugarcane belt of northern plains. Moreover, it can be effectively utilized in other system like Pigeon pea-Wheat or cotton-wheat rotations. However, if front rotary discs are improved then RDD may also be suitable for rice-wheat system. Keeping in view the benefits of CA in terms of reduced tillage cost (Rs. 3125/ha) with similar yield need to be popularized in various wheat based system for better productivity and profitability as well as healthy environment.

Acknowledgments

This work was undertaken as a part of the ICAR-Consortia Research Platform Project on "Conservation Agriculture" and we thankfully acknowledge the financial assistance received under this project. We also gratefully acknowledge the support received from the Director, ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana, India for conducting this research.

References

1. Blevins RL, MS Smith, GW Thomas and WW Frye. 1983. Influence of conservation tillage on soil properties. *Journal of Soil and Water Conservation* **38**: 301–307.
2. Chhokar RS, RK Sharma, GR Jat, AK Pundir and MK Gathala. 2007. Effect of tillage and herbicides on weeds and productivity of wheat under rice-wheat growing system. *Crop Protection* **26**: 1689-1696.
3. Chhokar RS, RK Sharma, SC Gill and Raj Kumar. 2017. Influence of tillage, cultivars, seed rate and planting geometry on wheat yield. *Journal of Wheat Research* **9(2)**:19-22
4. Chhokar RS, S Singh, RK Sharma and M Singh. 2009. Influence of straw management on *Phalaris minor* control. *Indian Journal of Weed Science* **41**: 150-156.
5. Cox DJ, JK Larsen and LJ Brun. 1986. Winter survival response of winter wheat: Tillageand cultivar selection. *Agronomy Journal* **78**: 795-801.
6. Cox DJ. 1991. Performance of hard red winter wheat cultivars under conventional-till and no-till systems. *North Dakota Farm Research* **48**: 17-20.
7. De Vita P, E Di Paolo, G Fecondo, N Di Fonzo and M Pisante 2007. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. *Soil and Tillage Research* **92**: 69-78.
8. Dhiman SD, DN Sharma and MS Kairon. 1984. Cross sowing of wheat, beneficial technique. *Haryana Agricultural University Journal of Research* **14**: 460-464.
9. Eguchi H and J Hirano. 1971. Effect of combinations of tillage and non-tillage, straw mulching and fertilization on weed communities in rice-wheat cropping. *Weed Research (Japan)* **12**: 36-39.
10. FAO 2018. CA Adoption Worldwide, Food and Agriculture Organization of the United Nations,-CA website: http://www.fao.org/ag/ca/6c.html
11. Fowler DB and LV Gusta. 1978. Winter cereal production in Saskatchewan: Oats, barley, triticale, wheat, and rye. Division. of Extension and Communication Relations, University of Saskatchewan, Saskatoon, Canada, Publication Number 264.
12. Fredrick JR and HG Marshall. 1985. Grain yield and yield components of soft red winter wheat as affected by management practices. *Agronomy Journal* **77**: 495-499.
13. Hall EF and FA Cholick. 1989. Cultivar × tillage interaction of hard red spring wheat cultivars. *Agronomy Journal* **81**: 789-792.
14. He J, HW Li, RG Rasaily, QJ Wang, GH Cai, YB Su, XD Qiao and LJ Liu. 2011. Soil properties and crop yields after 11 years of no tillage farming in wheat–maize cropping system in North China Plain, *Soil and Tillage Research* **113**: 48–54.
15. He J, NJ Kuhn, XM Zhang, XR Zhang and HW Li. 2009. Effects of 10 years of conservation tillage on soil properties and productivity in the farming–pastoral ecotone of Inner Mongolia, China, *Soil Use and Management* **25**: 201–209.
16. Herrera JM, N Verhuist, RM Trethowan, P Stamp and B Govaerts. 2013. Insights into Genotype X tillage interaction effects on the grain yield of wheat and maize. *Crop Science* **53**: 1845-1859.
17. Jadho SL and RU Nalamwar. 1993. Response of wheat (*Triticum aestivum* L.) genotypes to planting methods and manual weeding. *Indian Journal of Agronomy* **38**: 382-385
18. Jat, ML, RK Jat, P Singh, SL Jat, HS Sidhu, HS Jat, D Bijarniya, CM Parihar and R Gupta. 2017. Predicting yield and stability analysisof wheat under different crop management systems across agro-ecosystems in India. *American Journal of Plant Sciences* **8**: 1977-2012.

19. Kassam A, T Friedrich, F Shaxson and J Pretty. 2009. The spread of Conservation Agriculture: Justification, sustainability and uptake. *International Journal of Agricultural Sustainability* **7**(**4**): 292–320

20. Li HW, HW Gao, HD Wu, WY Li, XY Wang and J He. 2007. Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. *Australian Journal of Soil Research* **45**: 344–350.

21. Liu EK, BQ Zhao, XR Mei, HB So, J Li and XY Li. 2010. Effects of no-tillage management on soil biochemical characteristics in northern China. *Journal of Agricultural Sciences* **148**: 217–243.

22. McLeod JG, CA Campbell, Y Gan, FB Dyck and CL Vera. 1996. Seeding depth, rate and row spacing for winter wheat grown on stubble and chemical fallow in the semiarid prairies. *Canadian Journal of Plant Science* **76**: 207–214.

23. Michael NH, J Mulvaney, RP Singh, K Ammar Juan Burgueno, B Goverts and N Verhuist. 2018 Genotype by tillage interaction and performance progress for bread and durum wheat genotypes on irrigated raised beds. *Field Crops Research* **216**: 42-52.

24. Qin SP, XH He, CS Hu, YM Zhang and WX Dong. 2010. Responses of soil chemical and microbial indicators to conservational tillage versus traditional tillage in the North China Plain. *European Journal of Soil Biology* **46**: 243–247.

25. Ram H, G Singh, GS Mavi and VS Sohu. 2012. Accumulated heat requirement and yield of irrigated wheat (*Triticum aestivum* L.) varieties under different crop growing environment in central Punjab. *Journal of Agrometeorology* **14**: 147-153.

26. Ram H, Y Singh, KS Saini, DS Kler and J Timsina. 2013. Tillage and planting methods effects on yield, water use efficiency and profitability of soybean–wheat system on a loamy sand soil. *Experimental Agriculture* **49**: 524-542

27. Sharma RK, RS Chhokar, ML Jat, S Singh, B Mishra and RK Gupta. 2008. Direct drilling of wheat into rice residues: experiences in Haryana and Western Uttar Pradesh. *In* Permanent beds and rice-residue management for rice-wheat systems in the Indo-Gangetic Plain, Humphreys E and Roth, CH (eds), *Proceeding of a workshop held in Ludhiana, India, 7-9 Sept., 2006, ACIAR Proceedings No.* **127**: 147-158.

28. Sidhu HS, M Singh, E Humphreys, Y Singh, B Singh, SS Dhillon, J Blackwell, VM Bector and S Singh. 2007. The happy seeder enables direct drilling of wheat into rice straw. *Australian Journal of Experimental Agriculture* **47**: 844-854.

29. Sidhu HS, M Singh, J Blackwell, E Humphreys, V Bector, Y Singh, M Singh and S Singh. 2008. Development of Happy Seeder for direct drilling into combine harvested rice. *In* Permanent beds and rice-residue management for rice-wheat systems in the Indo-Gangetic Plain, Humphreys E and Roth, CH (eds), *Proceeding of a workshop held in Ludhiana, India,* 7-9 Sept., *2006, ACIAR Proceedings No.* **127**: 159-170.

30. Thierfelder C and PC Wall. 2009. Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. *Soil and Tillage Research* **105**(**2**): 217-227

31. Trethowoan R, Y Manes and T Chattha. 2009. Breeding for improved adaptation to conservation agriculture improves crop yields, *In Proceedings 4th World Congress on Conservation Agriculture*, 4-7 Feb 2009, New Delhi, India.

32. Unger PW. 1991. Organic matter, nutrient and pH distribution in no- and conventional-tillage semiarid soils. *Agronomy Journal* **83**: 186-189.

33. Verhulst, N., B Govaerts, E Verachtert, A Castellanos-Navarrete, M Mezzalama, P Wall, J Deckers and KD Sayre. 2010. Conservation Agriculture, Improving Soil Quality for Sustainable Production Systems? *In*: R Lal and BA Stewart (Eds.), *Advances in Soil Science: Food Security and Soil Quality.* CRC Press, Boca Raton, FL, USA, pp. 137-208.

34. Wang QJ, YH Bai, HW Gao, J He, H Chen, RC Chesney, NJ Kuhn and HW Li. 2008. Soil chemical properties and microbial biomass after 16 years of no-tillage farming on the Loess Plateau, China. *Geoderma* **144**: 502–508.

35. Winter SR and AD Welch. 1987. Tall and semidwarf wheat response to dryland planting systems. *Agronomy Journal* **79**: 641–645.