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Natural Resource Management Technologies– An Analysis for Wheat Crop in Punjab

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ABSTRACT
Punjab state led the country's Green Revolution of the 1960s and earned for itself the distinction of becoming 'Granary of India' but this has been achieved at a great cost in terms of degradation of agricultural ecology and exhaustion of scarce natural resources. For the present study, a sample of 1100 farmers (50 from each district) of Punjab state was taken to analyse the adoption of existing resource conservation technologies (RCTs) along with their economic benefits, motivational factors, reasons for adoption/non-adoption/discontinuation for use of these RCTs for wheat crop. The results revealed that about 70 per cent farmers had adopted laser leveling of fields. About 12 per cent farmers green manured their field, 11 per cent were using zero till drill, 10 per cent opted for green manuring, and 4 per cent were applying bio-fertilizers while only one per cent had opted for bed planting of wheat. As far as area is concerned it was observed that about 54 per cent of the wheat area was laser leveled, 8 per cent was under zero till drill, 5 per cent green manured, 2 per cent sown with happy seeder and at 2 per cent bio-fertilisers were applied and merely 0.12 per cent was bed planted. Almost all the respondents had laser leveled fields in Moga and Bathinda followed by Faridkot and Sri Muktsar Sahib (98% each). In Sangrur about 17 per cent farmers had adopted happy seeder followed by Moga (14%). About 40 per cent farmers of Gurdaspur district sown wheat using zero tillage drill followed by Moga (26%). Bed planting was adopted by about 6 per cent respondents in Patiala and Sangrur. About 32 per cent respondents in Sri Muktsar Sahib followed green manuring followed by Bathinda (28%). The maximum 20 per cent respondent farmers of Tarn Taran used bio-fertiliers. However, the major constraints for adoption of the RCTs were timely availability of inputs (43.8%), finance (43.71%), technological reasons (42.20%) and general issues (40.43%). Therefore, extension workers must advocate and encourage the farmers to adopt RCTs through awareness generation trainings/demonstrations. The government should establish custom hiring centres through Self Help Groups for unemployed youth by providing subsidy and simultaneously provide solutions to constraints in adoption of these technologies.
Key words: *Resource conservation, adoption, constraints, happy seeder, laser leveller, green manuring, bed planting, zero tillage*

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INTRODUCTION

The resource conservation technologies (RCTs) primarily focus on resource savings through minimal tillage, ensuring soil nutrients and moisture conservation through crop residues and growth of cover crops, and adoption of spatial and temporal crop sequencing. Starting from the 1960s, expansion of area and intensification of rice–wheat production system based on the adoption of Green Revolution (GR) technologies, incorporating the use of high-yielding varieties, fertilizers and irrigation, led to increased production and productivity of both these crops in the Indo-Gangetic plains. However, continued intensive use of GR technologies in recent years has resulted in lower marginal returns and, in some locations to salinization, overexploitation of groundwater, physical and chemical deterioration of the soil, and pest problems. Generally the rice-wheat system has strained the natural resources in this region and more inputs are required to attain the same yield levels. The adoption of RCTs, an exponent of conservation agriculture, improves yields, reduce water consumption, and reduce negative impacts on the environmental quality. The adoption of RCTs have ensured better yield and saving of critical inputs, viz; labour, time, money, water, and wear and tear of machinery [17].

The Indian Punjab's rice-wheat cropping system plays a key role in sustaining national food security. With only 1.53 per cent of the total geographical area of the country, Punjab state produces about three per cent of rice, two per cent of wheat and one per cent of cotton of the world. Punjab led the country's Green Revolution of the 1960s and earned for itself the distinction of becoming 'Granary of India'. During 2017-18, Punjab's share in central pool was about 31 per cent for rice and about 36 per cent for wheat. Punjab realizes land productivity of more than 11 ton per hectare from wheat and paddy in one year, which is comparable to the productivity of developed countries. However, this has been achieved at a great cost in terms of degradation of agricultural ecology and exhaustion of scarce natural resources. Environmental degradation has resulted in air pollution. Withdrawal of ground water is upsetting the water balance of the state and soil and underground water is getting toxic through excessive use of chemical fertilizers and pesticides. It is, therefore, imperative now to promote alternative technologies that would help conserve the much needed but gradually depleting natural resources while boosting productivity growth in the long-run by maintaining soil health and environment. As a part of this strategy, RCTs play a major role in sustaining and enhancing the productivity of the rice-wheat system at a lower cost of production. Blending of modern technology with indigenous RCTs would help to achieve such goals with people's participation. In the recent years, a lot of emphasis has been given in resource conservation in agriculture, as a result of which a number of technologies are developed in agriculture with the ultimate objective of improving productivity and conservation of ecosystems. But the adoption rate of these technologies is not much and majority of farmers are still practicing conventional methods resulting in low productivity of crops.

Keeping in view the above concerns, the present study was undertaken to study existing resource conservation technologies (RCTs) for wheat along with their economic benefits; the extent of adoption of different RCTs for wheat in Punjab; various constraints faced by the farmers in adoption of new technologies; and to suggest possible measures to increase the adoption rate of RCTs at large scale.

MATERIAL AND METHODS

The study was carried out in Punjab state. From all the 22 districts of the state, a sample 50 farmers were selected at random. Thus a total number of 1100 respondent farmers constituted the sample for the study (Table 1). A pre-tested questionnaire was used to collect the data through personal interview method regarding operational holding, area under wheat, different resource conservation technologies (RCTs) used by farmers, reason for adoption/non-adoption and discontinuation for use of RCTs. *Mean percent score of adoption of RCTs* was calculated by multiplying total obtained score of the respondents with 100 and divided by the maximum obtainable score.

Mean percent score = (Total score obtained/Maximum obtainable score) × 100.

Further, ranks were assigned in the descending order according to the mean per cent score obtained to find out the constraints severity in order of their priority.

Secondary data were also collected from published sources like Statistical Abstract of Punjab, Agricultural Statistics at a Glance, Economic Survey, various online sources, etc. The data collected were then tabulated and analyzed by using suitable statistical measures.

Table 1: District-wise sample size, operational holdings and area under wheat crop on sample farms in Punjab, 2015-16

S. No.	District	Farmers sampled (No.)	Total operational holding (acres)	Area under wheat crop	
				Area (acres)	% to total operational holding
1	Amritsar	50	587	501.4	85.42
2	Barnala	50	637	596	93.56
3	Bathinda	50	954	844	88.47
4	Faridkot	50	1137	1075	94.55
5	FG Sahib	50	1179	906	76.84
6	Fazilka	50	1288.2	1145	88.88
7	Ferozepur	50	913.3	757.5	82.94
8	Gurdaspur	50	759.5	593	78.08
9	Hoshiarpur	50	635	349.5	55.04
10	Jalandhar	50	1641	1430.5	87.17
11	Kapurthala	50	881	758.7	86.12
12	Ludhiana	50	812.8	704.8	86.71
13	Mansa	50	562.9	506.1	89.91
14	Moga	50	833	510.5	61.28
15	Pathankot	50	463.6	387.4	83.56
16	Patiala	50	1126.5	875.8	77.75
17	Ropar	50	703	495.5	70.48
18	Sangrur	50	769.5	685.3	89.06
19	SAS Nagar	50	824	618	75.00
20	SBS Nagar	50	792.8	605.2	76.34
21	Sri Muktsar Sahib	50	1014.5	927.5	91.42
22	Tarn Taran	50	887	809.5	91.26
	Total	**1100**	**18745.9**	**16082.1**	**85.79**

RESULTS AND DISCUSSION

Of the total cropped area of the state, rice and wheat form the major share occupying about 39 per cent of the area for rice and about 45 per cent for wheat crop (Table 1).District wise analysis indicated that the share of area under rice ranged from 20 per cent of total cropped area in Hoshiarpur to about 47 per cent in Moga during 2017-18.For wheat, this range was about 41 per cent in Kapurthala to about 51 per cent in SAS Nagar. The fertiliser consumption rate has reached as high as 240 Kg per hectare which is almost double than at national level (being almost double as compared to national level of 123.4 kg/ha during 2016-17. In the state, the cropping intensity has reached as high as 190 per cent and almost whole net sown area is irrigated (99.9%).

Table 2: District wise basic information relating to agriculture, 2017-18

District	Per cent to the gross cropped area		Cropping intensity (%)	Net area irrigated (% to net sown area)	Fertiliser consumption (Kg/ha)
	Rice	Wheat			
Amritsar	41.14	42.73	196	100.0	243
Barnala	44.35	45.97	198	100.0	240
Bathinda	24.55	45.34	189	100.0	210
Faridkot	43.95	46.77	199	100.0	222
FG Sahib	44.56	43.52	196	100.0	258
Fazilka	21.31	42.83	194	100.0	209
Ferozepur	46.06	46.31	194	100.0	330
Gurdaspur	42.48	44.66	191	100.0	231
Hoshiarpur	20.29	42.65	172	100.0	217
Jalandhar	39.95	40.91	173	100.0	229
Kapurthala	43.98	41.35	195	100.0	215
Ludhiana	42.83	41.83	188	100.0	308
Mansa	25.27	46.20	186	100.0	205
Moga	47.04	44.99	200	100.0	256
Pathankot	30.77	45.05	179	100.0	333
Patiala	44.83	45.61	198	99.60	149
Ropar	26.81	46.38	186	100.0	230
Sangrur	44.05	45.98	194	100.0	206
SAS Nagar	31.31	50.51	185	100.0	274
SBS Nagar	31.55	41.71	1188	100.0	231
Sri Muktsar Sahib	34.88	46.14	187	100.0	226
Tarn Taran	45.06	47.09	196	100.0	208
State	**39.17**	**44.88**	**190**	**99.9**	**240**

Source: [3]

The use of ground water in excess of recharge is leading to fall in water table. The water table has receded at average annual rate of 0.70 metre (m) across the state between 2008 and 2012 with a range of water table decline from 0.10 m to 4.0 m. The situation has reached alarming proportion in central Punjab. Out of 73 blocks of central Punjab, the water table has gone down beyond 20 m depth in 34 blocks. The cumulative fall in ground water in central Punjab during last three decades is more than 9 m. The Sangrur and Patiala are worst affected districts. The water table depth for Sangrur varied from 12.6 to 24.2 meters (minimum) while it was 29.5 to 33.2 m (maximum) during pre monsoon June 2007-2017 and during post monsoon period this range was 13.2 m (minimum) and 24.9 m (maximum) during October 2007-17 (Table 3). However, water table is rising in some south western parts of the state, where water extraction for irrigation purposes is limited due to its brackish and saline quality. In 2012, the Central Ground Water Authority has notified 45 blocks in state for restricting and banning the construction of new structures for extraction of ground water for any use other than drinking.

Table 3: Changes in ground water level in Punjab, 2007 to 2017

(Meter)

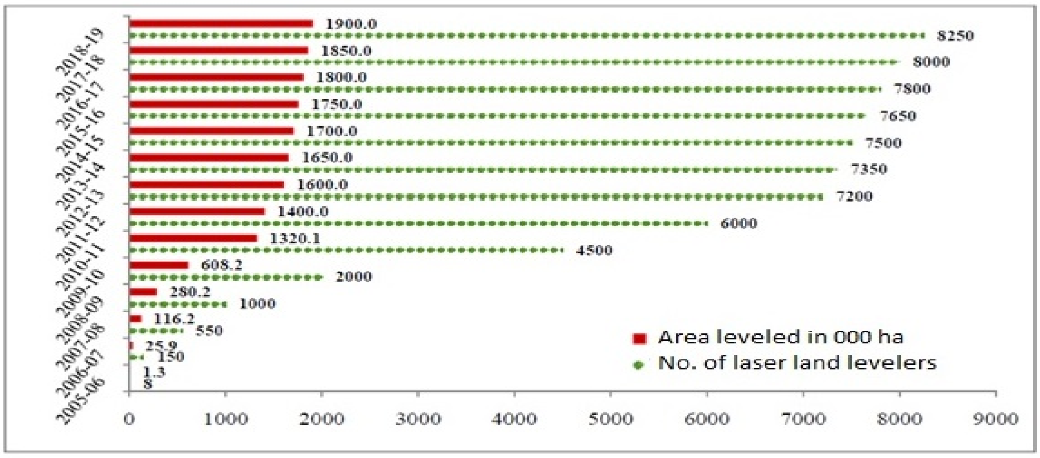
Districts	Pre Monsoon				Post Monsoon			
	June 2007		June 2017		October 2007		October 2017	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Amritsar	7.05	21.3	12.95	24.35	6.72	21.35	12.6	23.75
Barnala	13.1	21.4	23.75	33.35	13.6	23.8	24.9	34.2
Bathinda	2.8	16.85	3.5	24.4	2.65	17.51	3.9	27
Faridkot	1.85	13	4.2	15.05	1.05	14.9	3.85	16.55
FG Sahib	6.2	31.1	4.2	39	5.65	31.5	2.05	41.15
Firozpur	1.72	8.6	0.94	9.95	1.1	8.1	0.83	10.4
Gurdaspur	2.8	18.02	2.12	19.42	1.55	17.52	1.57	19.47
Hoshiarpur	1.45	22.88	9.65	26.22	1.05	21.2	3.09	26.22
Jalandhar	7.1	28.65	8	36.35	6.5	29.43	7.95	38.35
Kapurthala	4.19	27.43	10.57	28.3	4.41	28.69	10.87	32.5
Ludhiana	4.41	25.07	4.7	21.95	4.28	26.49	3.4	23.7
Mansa	4.9	16.65	3.9	26.06	5.15	17.2	2.6	25.66
Moga	11.95	29.4	21.10*	-	12.2	22.8	20.60*	-
Patiala	3.96	32	2.06	39.56	4.29	28.9	1.56	38.66
Roop Nagar	1.25	29.5	3.2	32.59	1	28.49	0.66	31.09
Sangrur	12.6	29.05	24.2	33.2	13.2	31.75	24.9	34.25
SAS Nagar	5.3	14.15	3	12.65	5.5	14	1.9	12.08
SBS Nagar	9.97	14.1	10.5	14.5	10.35	15.47	10.85	14.7
Sri Muktsar Sahib	0.47	7.05	1.5	6	0.18	6.43	0.43	5.95
Tarn Taran	6.25	16.17	7.45	21.9	6.35	16.38	8.25	22.7
Punjab	**5.06**	**20.68**	**7.63**	**22.77**	**4.88**	**20.56**	**6.87**	**23.44**

*Well changed, only one well exists in Moga district, Min.: Minimum, Max.: Maximum
Source: [3]

Resource Conservation Technologies used for wheat in Punjab

Laser Land Leveler (LL): Application of LL has the potential to increase crop yield with less use of water, energy and fertilizer inputs as compared with the traditional land leveling practice [1] and [12]. Laser land leveling in wheat fields reduced irrigation time by 10 to 12 hours per ha per season and yield increased by 7 to 9 per cent [5]. The rice-wheat system in a hectare of laser leveled field required 754 KWH less electricity for irrigation per year compared to a traditionally leveled field. With time the number of laser land levelers has increased from just eight in 2005-06 to 8250 in 2018-19 covering about 28 per cent (19 lakh ha) of the cropped area in Punjab (Fig. 1)

Fig. 1: Adoption of laser land leveling technology by Punjab farmers over time



Source: [3 and 4]

Happy Seeder (HS): The happy seeder is a tractor mounted machine developed by PAU, Ludhiana that cuts and lifts rice straw, sow wheat into the bare soil, and deposits the straw over the sown area as mulch. It therefore allows farmers to sow wheat immediately after their rice harvest without the need to burn any rice residue for land preparation. The wheat crop can be sown in standing stubbles of rice which avoids the preparatory tillage of the field and the crop can be sown 7-10 days earlier as compared to traditional method of sowing. By using this HS technology, the input cost can be saved worth up to Rs.1110 per hectare leading to higher net returns upto Rs. 1015 along with improvement in the physical properties over longer period of time over the normal sown wheat (Table 4).

Table 4: Comparative economics of wheat sown with happy seeder vis-à-vis conventional sowing

Particulars	Method of wheat sowing		Difference
	Happy Seeder	Conventional	
Total Cost incurred (Rs /ha)	14290	15400	-1110
Yield (Qtl/ha)	50.4	49.7	+0.7
Net returns (Rs /ha)	58790	56665	+1015
Benefit-cost ratio (B:C Ratio)	4.11	3.67	+0.44

Source: [8]

With time, use of HS for wheat sowing has increased as the number of happy seeders increased from mere 11 in 2008 to 1640 in 2017 and to about 7 times in 2018 (11377) due to provision of subsidy by the state government to discourage paddy straw burning. As a result, wheat area under HS technology has increased from 280 ha in 2008 to 25600 ha in 2017 and abruptly increased to 4.74 lakh ha in 2018 forming about six per cent of the total state cropped area (Fig. 2a and Fig. 2b).

Fig. 2a: Adoption of happy seeder by Punjab farmers over time

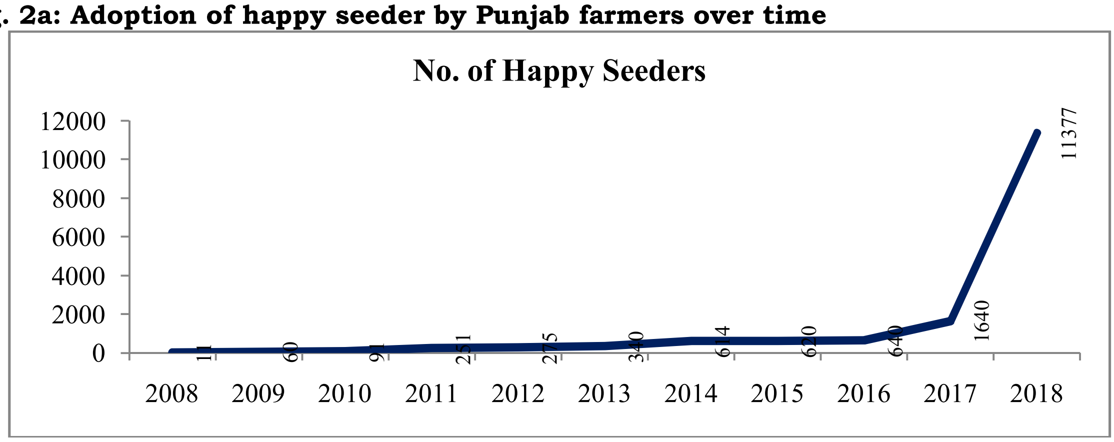
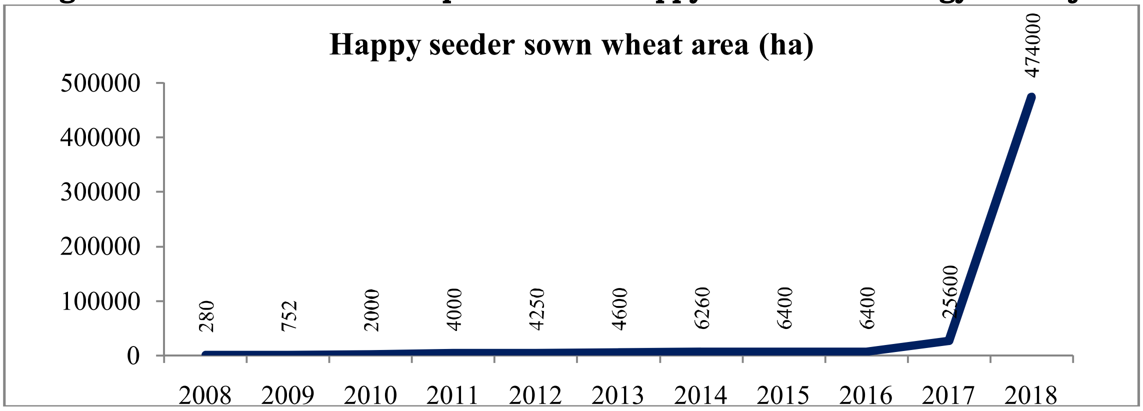


Fig. 2b: Area under wheat crop sown with Happy Seeder technology in Punjab



Source: [4] and [18]

Zero tillage (ZT): Cost effective technology of reducing tillage is important for a number of reasons. The cover of crop residue helps prevent soil erosion by water and air thus conserving valuable top soil. Soil structure improves because heavy machinery (which causes soil compaction) is not used and soil tilt is not tampered artificially. The net income has been found higher in ZT method for wheat, mainly due to lower cost of production i.e. Rs 26124 per hectare (saving 6.68 per cent human labour, 46.30 per cent machine labour and 17.65 per cent irrigation water) compared to that in conventional method leading to higher benefits (Table 5). It leads to saving of irrigation water, reduction in production cost, less requirement of labour and timely establishment of crops, resulting in improved crop yield and higher net income ([15] and [9]).

Table 5: Comparative economics of wheat cultivation with zero tillage technology vis-a-vis conventional sowing

Particulars	Method of wheat sowing		Difference
	Zero tillage technology	Conventional sowing	
Total cost incurred(Rs./ha)	26124	29935	-3811
Yield (Qtl/ha)	54.7	53.7	+1.0
Net income (Rs./ha)	34057	29135	+4922
Benefit-cost ratio (B:C Ratio)	2.3	1.98	+0.32

Source: [20]

Ridge/Bed planting (BP): Ridge/Bed planting in wheat saves water in contrary to flooding method. It helps in judicious use of fertilizers and also makes intra cultural operations easier leading to better crop growth and development and thus higher yields. Better tillering and crop growth contributed towards 12 per cent higher wheat grain yield and saving of 30-35 per cent water with ridge-furrow planting in comparison with the farmer practice of flat planting [11]. Furrow-irrigated raised-bed planting of wheat provides additional options to generate alternate sources of productivity growth through intercropping of high value vegetable crops and thus contribute to high water productivity, profitability and long-term sustainability [16 and 13].

Green manuring (GM): Green manuring is the ploughing under or soil incorporation of any green manure crops while they are green or soon after they flower. GM improves the soil fertility, adds nutrients and organic matters, improves the soil structure and soil aeration, helps to control insect/mite pests, nematodes and diseases, helps to control weeds, promotes habitat for natural enemies and increases soil's biodiversity by stimulating the growth of beneficial microbes and other soil organisms.GM thus improve soil physical, chemical, and biological properties and consequently crop yields, increases biological security by decreasing some of the problems associated with intensive cropping systems, including decreased weed, disease, and insect problems ([10] and [19]). It improves the soil health by fixing atmospheric N and partially supplementing the use of inorganic fertilizers.

Use of bio-fertilizers (BF): Bio-fertilizers contain different types of fungi, root bacteria or other microorganisms. They form a mutually beneficial or symbiotic relationship with host plants as they grow in the soil. Bio-fertilizers increase the nitrogen and phosphorus available to plants more naturally than other fertilizers and they have been universally identified as important renewable source of plant nutrients. Application of bio-fertilizers and half NPK in wheat increased net returns significantly with higher benefit-cost ratio upto 2.81 as compared to 50 per cent NPK alone (B:C ratio 2.71) as shown in Table 6.

Table 6: Comparative economics of wheat cultivation by using bio-fertilizers vis-à-vis chemical fertilizers

(000 Rs/ha)

Fertilizer type	Cost	Gross returns	Net Returns	B:C ratio
Control (unfertilized)	10.78	23.74	12.96	2.20
Use of chemical fertilizer				
50% NPK	11.95	32.38	20.43	2.71
100% NPK (recommended dose)	13.07	39.35	26.28	3.01
Use of bio-fertilizers				
50% NPK + Azotobactor	12.27	33.30	21.03	2.71
50%NPK + Azospirillum	12.27	33.26	20.99	2.71
50%NPK + Proteus	12.27	33.93	21.66	2.77
50%NPK + Kurthia	12.27	34.43	22.16	2.81
50%NPK + Klebsiella	12.27	33.57	21.30	2.74

Source: [6]

This was due to significantly higher straw yield and numerically higher grain yield ([7], [6], [14] and [2]). The recommended dose of chemical fertilizers was most effective for improving productivity, grain quality and profitability of durum wheat cultivation (B: C Ratio of 3.01). Thus, poor farmers with low investing capacity on fertilizer may opt for integrated use of bio-fertilizers with lower rate of chemical fertilizers for getting higher net returns.

Adoption of RCTs for wheat in Punjab

During the study period, it was observed that about 60 per cent of the selected farmers had adopted laser leveling of fields themselves while about 10 per cent were made aware about the LL by Punjab agricultural University, Ludhiana and Department of Agriculture and Farmers Welfare, Punjab (Table 7). Similarly about 8 per cent respondents were using zero till drill at their own level and about 2 per cent used it as a demonstration by different departments. About 10 per cent of them opted for green manuring and about 3 per cent were aware of it. About 54 per cent of the operational holdings were laser leveled followed by 5 per cent being green manured and about 2 per cent being using bio-fertilizers. Of the wheat area under sample, about 8 per cent was cultivated using zero till drill followed by about 5 per cent being green manured, about 2 per cent each sown using happy seeder and using bio-fertilizers and only 0.12 per cent was bed planted.

Table 7: Status of adoption of RCTs for wheat in Punjab

(Per cent to the total sample size)

S. No.	RCT technology/ practice	As a demonstration of PAU, Deptt. of Agriculture, etc.	Adopted at their own level	Total adoption	Farmers who have not used the technology/ practice	% area under technology/ practice
1	Laser Land Leveler (LL)	9.98	59.70	69.68	30.32	54.02*
2	Happy Seeder (HS)	2.83	2.12	4.95	95.05	1.84**
3	Zero Till Drill (ZT)	2.20	8.33	10.53	89.47	7.69**
4	Bed Planting (BP)	0.47	0.63	1.10	98.90	0.12**
5	Green Manuring (GM)	2.91	9.90	12.80	87.20	4.99*
6	Bio-fertilizers (BF)	0.31	4.01	4.32	95.68	1.75*

** Percentages to the total operational holding*

*** Percentages to the total area under wheat*

Further district wise analysis of data for use of different RCTs in Punjab revealed that there existed full adoption of LL technology in Bathinda and Moga districts (Table 8) while it was more than 95 per cent for Muktsar and Faridkot (98% each) and Mansa (95.7%) and it was below 50 per cent for Ropar (42%) and Barnala (44%). For all other districts the numbers of adopters were below it. In case of happy seeder, highest share of adopter respondents (17.2%) belonged to Sangrur only while it ranged from 2 to 10 per cent for other districts.

The highest number of respondents following zero tillage in wheat was about 40 per cent for Gurdaspur followed, six per cent respondents of Patiala followed bed planting, 32 percent from Muktsar adopted green manuring and only 20 per cent respondents of Tarn Taran used bio-fertilisers. Analysis of data related to the major motivating factors behind adoption of these RCTs in wheat indicated that in case of laser leveller technology, though all the respondents had adopted laser leveling in Moga and Bathinda but only 70 and 78 per cent of them respectively had adopted it on their own level (Table 9) while those doing so in Mansa were the highest being about 93 per cent followed by Faridkot and Muktsar (90% each). For happy seeder, about 11 per cent of the selected farmers used it on their own with rest about 6 per cent using it as demonstration by PAU or Department of Agriculture. In Fazilka about 7 per cent followed by Kapurthala (6.35%) had adopted happy seeder as demonstration only. Gurdaspur respondents were highest in number to opt for zero tillage on their own (14.94%) as well as demonstrations (5.75%).

Table 8: District-wise adoption of different RCTs for wheat in Punjab

(Per cent farmers to total sample size)

S. No.	District	LL	HS	ZT	BP	GM	BF
1	Amritsar	85.92	5.63	8.45	-	11.27	2.82
2	Barnala	44.00	-	-	-	2.00	-
3	Bathinda	100.00	2.00	12.00	-	28.00	4.00
4	Faridkot	98.00	6.00	14.00	-	12.00	2.00
5	FG Sahib	62.00	6.00	-	-	12.00	-
6	Fazilka	83.64	7.27	5.45	-	30.91	7.27
7	Ferozepur	70.00	2.86	14.29	-	7.14	10.00
8	Gurdaspur	70.00	10.00	40.00	2.00	20.00	6.00
9	Hoshiarpur	62.00	-	2.00	2.00	16.00	-
10	Jalandhar	72.00	-	10.00	2.00	-	-
11	Kapurthala	84.13	6.35	-	-	-	-
12	Ludhiana	62.00	2.00	6.00	-	12.00	10.00
13	Mansa	95.71	2.86	8.57	-	17.14	7.14
14	Moga	100.00	14.00	26.00	-	10.00	-
15	Pathankot	-	-	2.80	-	4.67	-
16	Patiala	78.00	10.00	20.00	6.00	16.00	8.00
17	Ropar	42.00	2.00	4.00	-	4.00	14.00
18	Sangrur	86.21	17.24	20.69	5.75	10.34	4.60
19	SAS Nagar	54.00	-	6.00	2.00	2.00	-
20	SBS Nagar	58.00	-	-	-	24.00	-
21	Sri Muktsar Sahib	98.00	2.00	12.00	-	32.00	2.00
22	Tarn Taran	72.00	10.00	24.00	4.00	24.00	20.00
	Total	**69.68**	**4.95**	**10.53**	**1.10**	**12.80**	**4.32**

Bed planting was opted by farmers on their own level by about 5 per cent respondents in Sangrur while about 6 per cent farmers of Patiala opted it as demonstrations only. About 26 per cent respondents in Muktsar followed green manuring at their own level with rest 6 per cent using it as demonstration while the share of adopters using green manure as demonstration was about 13 per cent in Fazilka. The maximum 14 per cent respondent farmers of Tarn Taran used bio fertiliers at their own as well as demonstration.

Table 9: District-wise to adoption of different RCTs in wheat crop by the farmers at their own level and as a demonstration of different institutions in Punjab

(Per cent farmers to total sample size)

District	LL		HS		ZT		BP		GM		BF	
	D	O	D	O	D	O	D	O	D	O	D	O
Amritsar	1.41	84.51	5.63	-	1.41	7.04	-	-	-	11.27	-	2.82
Barnala	-	44.00	-	-	-	-	-	-	-	2.00	-	-
Bathinda	22.00	78.00	2.00	-	2.00	10.00	-	-	4.00	24.00	-	4.00
Faridkot	8.00	90.00	4.00	2.00	-	14.00	-	-	-	12.00	-	2.00
FG Sahib	2.00	60.00	2.00	4.00	-	-	-	-	2.00	10.00	-	-
Fazilka	14.55	69.09	7.27	-	3.64	1.82	-	-	12.73	18.18	1.82	5.45
Ferozepur	-	70.00	-	2.86	-	14.29	-	-	-	7.14	-	10.00
Gurdaspur	64.00	6.00	4.00	6.00	16.00	24.00	2.00	-	10.00	10.00	-	6.00
Hoshiarpur	-	62.00	-	-	-	2.00	-	2.00	-	16.00	-	-

Jalandhar	-	72.00	-	-	-	10.00	2.00	-	-	-	-	-
Kapurthala	63.49	20.63	6.35	-	-	-	-	-	-	-	-	-
Ludhiana	-	62.00	-	2.00	-	6.00	-	-	-	12.00	-	10.00
Mansa	2.86	92.86	1.43	1.43	-	8.57	-	-	5.71	11.43	-	7.14
Moga	30.00	70.00	8.00	6.00	10.00	16.00	-	-	6.00	4.00	-	-
Pathankot	-	-	-	-	-	2.80	-	-	4.67	-	-	-
Patiala	2.00	76.00	8.00	2.00	-	20.00	6.00	-	4.00	12.00	-	8.00
Ropar	8.00	34.00	2.00	-	-	4.00	-	-	4.00	-	-	14.00
Sangrur	1.15	85.06	5.75	11.49	5.75	14.94	1.15	4.60	1.15	9.20	-	4.60
SAS Nagar	6.00	48.00	-	-	-	6.00	-	2.00	-	2.00	-	-
SBS Nagar	-	58.00	-	-	-	-	-	-	-	24.00	-	-
Sri Muktsar Sahib	8.00	90.00	2.00	-	2.00	10.00	-	-	6.00	26.00	-	2.00
Tarn Taran	-	72.00	4.00	6.00	10.00	14.00	-	4.00	4.00	20.00	6.00	14.00
Total	**9.98**	**59.70**	**2.83**	**2.12**	**2.20**	**8.33**	**0.47**	**0.63**	**2.91**	**9.90**	**0.31**	**4.01**

D: Demonstration by PAU, Ludhiana and Department of Agriculture and Farmers Welfare, Punjab
O: Adoption at farmers own level

It was observed that whole area operated by the respondent farmer was laser levelled in Moga and Bathinda due to full adoption by them (Table 10). About 91 per cent of operational area in Faridkot followed by about 85 per cent area in Fazilka and about 82 per cent in Muktsar was leveled using laser leveler. On the higher side about 5 per cent area under wheat crop was sown using happy seeder in Sangrur, another about 39 per cent was zero tilled in Gurdaspur, about 0.7 per cent was sown using bed planting method in Sangrur and Patiala each. About 13 per cent of the operational holdings were green manured in Sri Muktsar Sahib and Hoshiarpur and about 12 per cent operating area was applied bio fertilizers in Tarn Taran.

Table10: District wise area under different RCTs for wheat in Punjab

S. No.	District	LL*	HS**	ZT**	BP**	GM*	BF*
1	Amritsar	77.00	1.70	3.20	-	3.70	0.80
2	Barnala	28.30	-	-	-	0.50	-
3	Bathinda	100.00	0.20	7.10	-	7.10	0.70
4	Faridkot	90.90	0.60	10.10	-	4.00	0.70
5	FG Sahib	35.80	5.70	-	-	1.00	-
6	Fazilka	85.00	0.60	1.20	-	11.60	4.50
7	Ferozepur	34.90	1.10	11.10	-	1.60	1.60
8	Gurdaspur	53.10	1.50	38.80	0.20	7.90	2.80
9	Hoshiarpur	27.60	-	4.30	0.60	12.60	-
10	Jalandhar	25.10	-	4.10	0.10	-	-
11	Kapurthala	76.80	8.90	-	-	-	-
12	Ludhiana	25.40	0.10	8.60	-	3.30	4.30
13	Mansa	56.50	1.10	5.70	-	5.90	2.30
14	Moga	100.00	6.90	10.80	-	13.20	-
15	Pathankot	-	-	4.10	-	3.60	-
16	Patiala	44.80	1.50	12.60	0.60	4.90	3.30
17	Ropar	25.30	0.40	4.40	-	1.10	4.60
18	Sangrur	62.70	4.90	18.50	0.70	3.70	0.90
19	SAS Nagar	46.60	-	1.90	0.30	0.50	-
20	SBS Nagar	24.20	-	-	-	6.40	-
21	Sri Muktsar Sahib	82.40	0.40	13.20	-	12.80	1.50
22	Tarn Taran	65.30	3.00	10.50	0.30	9.10	11.80
	Total	54.00	1.80	7.70	0.10	5.00	1.80

* Per cent to the total operational holding, ** Per cent to the total area under wheat)

Constraints in adoption of RCTs in wheat crop in Punjab

On an average, the major constraint in adoption of RCTs for wheat was related with input supply including major reasons like unavailability of required technology at peak time (86%), scarcity of skilled labour (75%) and others like requirement of more fertilizers, continuous power supply, unavailability of bio-fertilizers in market (Table 11). Another major constraint was related to economics with high cost of technology (71%), high labour cost (66%), additional cost involved for use of technology on small holdings (59%), maintenance and custom hiring charges, lesser bi product obtained and fear of yield loss. Major technological constraint was of difficulty in using the technology (70%), lack of knowledge about new technology (50%), more incidence of rats and weeds, difficulty in cultivation and shortage of time. other general reasons like confidence in own decision due to long experience (79%), time shortage (66%), lack of habit (39%), disinterest in land leased in from others and difficulty in changing the habit of sowing wheat in well prepared field.

Table 11:Constraints in adoption/continued use of RCTs in wheat crop in Punjab

Constraint	Mean Per cent Score	Rank
A. Technological constraints		
Difficulty in using (Skill)	70	I
Lack of knowledge about techniques	50	II
High incidence of weeds and rats	36	III
Difficulty in making bunds/hard pan of soil for zero till drill	29	IV
Lack of time due to intensive cropping pattern	26	V
B. Input supply constraints		
Unavailability at peak time	86	I
Scarcity of skilled labour	75	II
Inadequate/irregular irrigation facilities	37	III
High requirement of manures and fertilizers	36	IV
Erratic power supply	35	V
Requirement of high power tractors	23	VI
Lack of availability in local market (especially bio-fertilizers)	15	VII
C. Economic constraints		
High cost of implement/ no credit facility	71	I
Labour intensive/repeated observations required	66	II
Additional charges for small holdings	59	III
Additional charges for maintenance as slippage of belt	35	IV
Fear of low yield	33	V
High custom hiring charges	27	VI
Less wheat straw production due to less tillering in zero till drill	15	VII
D. General constraints		
Landon lease so no interest	36	I
Shortage of time	66	II
Confidence in their own decisions/low risk bearing ability	79	III
Lack of habit to adopt new technology	39	IV
Like sowing in well cultivated soil	36	V
Un-necessary and useless botheration of making beds	21	VI
Old age	6	VII
Overall Constraints		
Input supply	43.86	I
Economic	43.71	II
Technological	42.20	III
General	40.43	IV

CONCLUSIONS AND POLICY IMPLICATIONS

Adoption of RCTs is one the most suitable alternate strategy to mitigate the climate change and achieve the target of sustainability. Therefore, researches must advocate and encourage the farmers to adopt the resource conservation technologies and simultaneously provide solutions to constraints in adoption of these technologies.

Technological interventions

- The farm machinery which assists in conservation agricultural practices such as Happy Seeder, etc. should be made available at village level cooperatives and ensure their timely availability to the farmers.
- Improvement/modifications in existing technologies may be carried out to meet varied requirements

Capacity building and awareness generation

- Organizing training of farmers for awareness generation through mass and print media.

- Establishment of custom hiring centres through Self Help Groups of unemployed youth by providing subsidy
- Demonstration of RC technologies

POLICY INTERVENTIONS

Because of superiority of RCTs over the conventional practices in terms of cost saving and efficient inputs-use, there is a need to internalize the RCTs in their totality by applying plans and strategies based on local dynamics. There is need of policy formulations for dissemination and wider adoption of these RCTs

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