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Adoption status of resource conservation technologies for efficient input use in paddy in Punjab

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Abstract
Intensification of the rice-wheat system requires innovative knowledge-based technologies to ensure higher yield and the efficient use of inputs to maximize the profit of farmers with lower cultivation costs along with better resource conservation and system sustainability. As a part of this strategy, resource conserving technologies (RCTs) may play a major role. To study the use of RCTs in paddy crop in Punjab, one district was selected randomly from each agro-climatic zone of the state, and from each selected district a sample 50 farmers were selected at random constituting a total sample of 250 farmers. On an average, about 72 per cent of the sampled farmers have used laser land leveler. Only about six per cent respondents were found to be using tensiometer for irrigation scheduling in paddy. About 89 per cent of the respondents had not used LCC for application of nitrogenous fertilisers and about 93 per cent did not use DSR for paddy cultivation. Also none of the farmers transplanted paddy mechanically. All the farmers of Zone IV had used laser land leveler while about 78 per cent farmers of Zone II were doing so. In Zone V, only about 7 per cent respondents had adopted tensiometer. The adoption of LCC was poor in all the zones. About 10 per cent of the farmers of Zone I and Zone II each were using DSR. The major reason for adoption of these RCTs was their cost effectiveness, followed by saving of irrigations, reduction in insect- pest and diseases, etc. On the other hand, the major constraints in adoption and discontinuation of these RCTs were non-availability of required implements at peak time, self confidence in own practices, cost of implements, shortage of skilled persons, free electricity for irrigation and fear of theft of instruments. The study reveals vast scope for the developmental departments to intervene and improve the adoption level of RCTs by educating farmers about modern agricultural practices. To encourage the equitable and sustainable growth in adoption of these technologies, steps like encouragement of farmers by providing required machinery at subsidized rates, creating awareness about environmental consequences of excessive use of natural resources/ inputs through extension efforts along with effective transfer of technology may play a pivotal role.

Keywords: Resource, conservation, technology, adoption, laser land leveller, leaf colour chart, direct seeded rice

Introduction
Rice is staple food of more than 60 per cent of the world's population with about two-thirds of the total rice production grown under irrigation (Maclean *et al*., 2002) [13]. The rice-wheat rotation is a dominant system that contributes immensely to the food security in South Asia and India. Therefore, intensification of the rice-wheat system requires innovative knowledge-based technologies to ensure higher yield and the efficient use of inputs to maximize the profit of farmers with lower cultivation costs along with better resource conservation and system sustainability. India positions second with production of about 157 million tonnes of paddy and about 96 million tonnes of wheat (Anonymous, 2016) [1, 2]. 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' or 'India's Bread Basket'. 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 generally believed that the rice-wheat system has strained the natural resources in the Indo-Gangetic Plain region and more inputs are required to attain the same yield levels (Swarup and Singh, 1989; Kumar and Yadav, 1993; Lal *et al*., 2004) [19, 10]. 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, resource conserving technologies (RCTs) play a major role in sustaining and enhancing the productivity of the rice-wheat system at a lower cost of production. The adoption of RCTs have ensured better yield and saving of critical inputs, *viz*; labour, time, money, water, and wear and tear of machinery (Singh, 2007) [18]. 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. Similar results are obtained for paddy crop in a recent study for Kashmir (Matto *et al*., 2018) [11]. Keeping in view the above concerns, the present study was undertaken with the following objectives.

Objectives

1. To study the extent of adoption of different resource conservation technologies (RCTs) for paddy in Punjab
2. To find out various constraints faced by the farmers in adoption of new technologies
3. To suggest possible measures to increase the adoption rate of RCTs at large scale

Materials and Methods

From each agro-climatic zone of Punjab state, one district was selected randomly. Thus five districts were selected from five agro-climatic zones of the state (Table 1). Further, from each selected districts a sample 50 farmers were selected at random. Thus a total number of 250 respondent farmers constituted the sample for the study. A pre-tested questionnaire was used to collect the data through personal interview method regarding operational holding, area under different crops, different resource conservation technologies (RCTs) used by farmers, reason for adoption/non-adoption and discontinuation for use of RCTs. 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: Zone-wise sample size, operational holdings and area under paddy in Punjab

Agro-climatic Zone		Sampled district	Respondent farmers (No.)	Total operational holding (ha)	Area under paddy (ha)
Sub-mountain Undulating Zone	Zone I	Gurdaspur	50	303.8	238.2 (78.4)
Central Plain Zone	Zone II	Patiala	50	450.6	955.0 (84.8)
Undulating Plain Zone	Zone III	Ropar	50	703.0	382.0 (83.9)
Western Zone	Zone IV	Moga	50	333.2	200.8 (60.3)
Western Plain Zone	Zone V	Ferozepur	50	365.3	303.0 (82.9)
Overall			250	1734.1	1359.8 (78.4)

Figures in parentheses denote percentages to total operational holding of the respective Zone.

Results and Discussion

A. Status of cropping pattern and input use in Punjab agriculture

The information relating to area under different crops in Punjab indicated that with time, the cropping pattern has shifted towards rice-wheat monoculture (Table 2). Amongst *Kharif c*rops, the per cent share of area under rice in the gross cropped area has increased more than five times from 6.9 per cent in 1970-71 to about 39 per cent in 2016-17 while for other crops like sugarcane, maize, cotton, bajra, barley, pulses and oilseeds has declined with time. Also the per cent share of area under wheat increased from 40.5 to 44.5 per cent during the same time period. All this indicates that because of increased irrigation facilities in terms of rising number of tube wells (14.19 lakh in 2016-17) and highest cropping intensity (189%) paddy-wheat monoculture has replaced others crops from Punjab's cropping pattern.

Table 2: Shifts in cropping pattern in Punjab

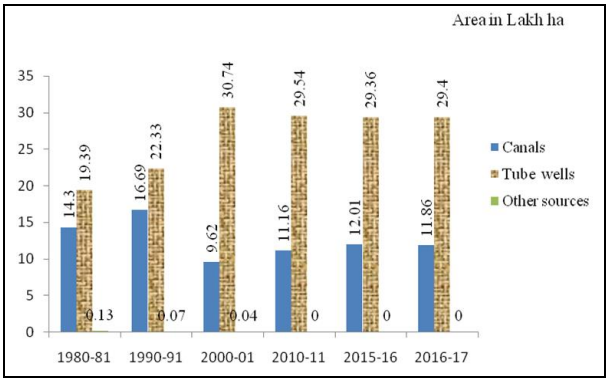
(Per cent to Gross Cropped Area)

Crop	1970-71	1980-81	1990-91	2000-01	2010-11	2015-16	2016-17
Rice	6.9	17.5	26.9	33.3	35.9	37.7	38.8
Maize	9.8	5.6	2.5	2.1	1.8	1.6	1.5
Cotton	7.0	9.6	9.3	6.0	6.10	4.3	3.6
Barley	1.0	0.9	0.5	0.4	0.2	0.2	0.1
Sugarcane	2.3	1.0	1.3	1.5	0.9	1.2	1.1
Wheat	40.5	41.6	43.6	43.4	44.5	44.5	44.3
Bajra	3.7	1.0	0.2	0.1	0.04	-	0.04
Total pulses	7.3	5	1.9	0.7	0.3	0.3	0.3
Total oilseeds	5.2	3.7	1.3	1.1	0.7	0.6	0.5

Total vegetables	0.9	1.1	0.7	1.4	2.4	2.7	1.7
Total fruits	0.6	0.4	0.8	0.4	0.9	1.1	1.0
Net sown area (000' ha)	4053	4191	4218	4250	4158	4137	4130
Gross cropped area (000' ha)	5678	6763	7502	7847	7882	7872	7823
Cropping intensity (%)	140.1	161.4	177.9	186.8	190	190	189
No. of tube wells (lakh)	1.92	6.00	8.00	10.73	13.82	14.19	14.19

***Source*:** Statistical Abstract of Punjab, various issues

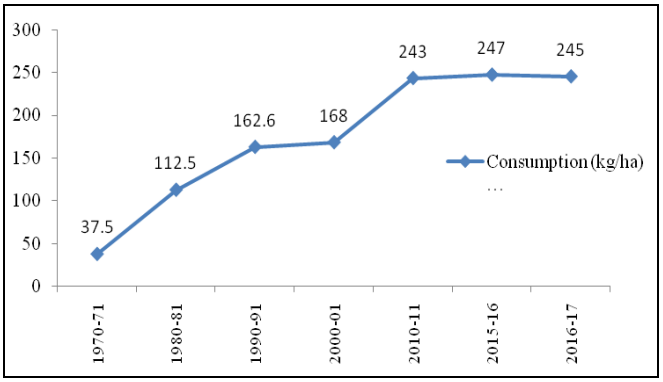
The Punjab plains in the past four decades has witnessed a boom in groundwater use and numerous important research works exist on the problem of depleting water quality and fall in water tables (Dhawan 1995; Sondhi *et al.* 2001; Ambast *et al.* 2006; Krishan *et al.* 2014; Rao *et al*., 2014; Sharma *et al*., 2014) [8, 6, 9, 15, 16]. During 1981, about 46 per cent of net area sown i.e. 19.39 lakh ha was irrigated using tube wells with rest being dependent on canal water and other sources (Fig.1). With passage of time, the share of tube wells in net irrigated area has risen to about 29.36 lakh ha (71%). Of the gross irrigated area, about 38 per cent falls under paddy and about 45 per cent under wheat during *kharif* and *rabi* seasons respectively. It may be mentioned here that 60 per cent of the world's irrigated fields are in Asia, half of which are devoted to rice production (Guerra *et al*., 1998) [7]. Irrigated lowland rice consumes more than 50 per cent of total freshwater, and irrigated flooded rice requires two or three times more water than other cereal crops, such as wheat and maize (Barker *et al*., 1998) [7]. The need for 'more rice with less water' is crucial for food security, and irrigation plays a greater role in meeting future food needs than it has in the past (Tuong *et al*., 2004) [22].



***Source*:** Statistical Abstract of Punjab, various issues

Fig 1: Source wise net Irrigated area in Punjab

Further, Punjab state ranks third at national level for fertilizer consumption per hectare (245 kg/ha) with average consumption per hectare being almost double as compared to national level of 123 kg/ha during 2016-17. This rate of fertilizer consumption was merely 37.5 kg/ha in 1970-71 (Fig 2). Paddy is sown in 30.65 lakh hectares in Punjab and controlling the use of urea could result in saving nearly Rs 200 crore. Urea consumption registered for the same is about 10 lakh tonnes which is 3.15 lakh tonnes over and above the recommended quantity (Business Standard, July 17, 2018).

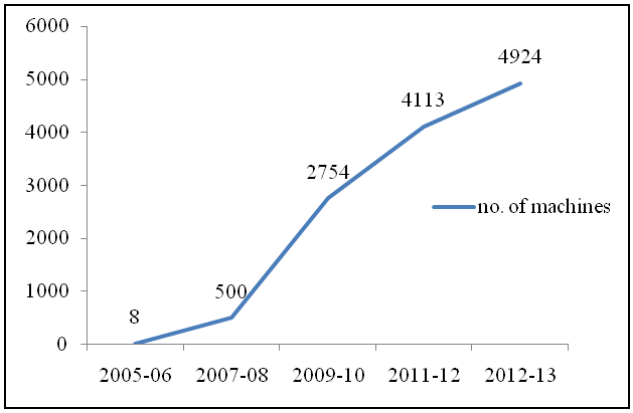


***Source*:** Statistical abstract of Punjab, various issues

Fig 2: Fertiliser Consumption in Punjab

B. Resource conservation technologies for rice cultivation in Punjab

Laser land leveler: Use of laser leveler for precision leveling of fields before puddling saves water by cutting irrigation time by 25-30 per cent. This practice also helps in increasing crop yields by improving the efficiency of applied fertilizers and herbicides. With time the number of laser levelers increased from 8 in 2005-06 to 4924 in 2012-13 covering about 30 per cent of the cropped area (Fig. 3). It may be mentioned here that out of total area of 42 lakh ha under agriculture in Punjab, 12.61 lakh ha (30.02%) is laser leveled.



***Source*:** Department of Agriculture and Farmers Welfare, Punjab

Fig 3: Increase in Number of land laser levelers in Punjab

Tensiometer based irrigation scheduling: Tensiometer is used to determine the status of water in the soil. Use of tensiometer helps in rational use of water because the crop can be irrigated as per need. Thus it saves three to four

irrigations as compared to farmer's practice of continuous flooding paddy fields without affecting the crop yield.

Leaf Colour Chart: Leaf Colour Chart (LCC) developed by Punjab Agricultural University, Ludhiana is an ideal tool to optimize nitrogen use irrespective of soil nitrogen supply and its source. Judicious and timely application of urea using the LCC helps to save 10-15 per cent fertiliser (Sharma *et al*. 2008) and thus reduces the incidence of insect pest attack.

Direct Seeded Rice (DSR): To save water, reduce labour requirement, and mitigate greenhouse gas emission, DSR is a feasible alternative to conventional puddle transplanted rice with good potential. DSR is a cost effective alternative leading to similar yields under good weed control and water management practices.According to Pandey and Velasco (2005), low wages and adequate availability of water favour transplanting, whereas, high wages and low water availability favors DSR.

Mechanical transplantation of rice: Using machine for transplanting reduces the burden of the farmer because of less labour requirement. Time saving, achieving uniform spacing and plant density, placing of single seedling is possible and uniform depth of transplanting of seedlings is possible with this method.

C. Adoption of Resource Conservation Technologies in Punjab

It was observed that at state level during 2016-17, about 71 per cent of the net area sown is irrigated by tube wells only with an average productivity of 4149 kg/ha rice with fertilser consumption of 245 kg/ha (Table 3).

Table 3: Status of irrigation, fertilizer consumption and productivity of rice in Punjab, 2016-17*

Zone	Cropping Intensity (%)	Area irrigated (Lakh ha)		Fertilizer consumption (kg/ha)	Productivity of rice (kg/ha)
		Total area irrigated	Area irrigated by tube wells		
Zone I	191	209	188 (89.96)	293.7	3185
Zone II	197	256	255 (99.61)	270.5	4243
Zone III	183	81	79 (97.53)	308.0	4528
Zone IV	198	193	193 (100.0)	290.5	4585
Zone V	194	218	155 (71.10)	332.5	4229
Punjab	189	4126	2940(71.26)	245.0	4149

***Source*:** Statistical Abstract of Punjab, 2017

Figures in parentheses are percentages to total area irrigated in the respective zone.

*Data pertains to selected district of respective zone

Zone-wise data analysis indicated that whole area in Zone IV was irrigated using tube wells while it was 99.6 per cent, 97.53 per cent, 90 per cent, 89.96 per cent and about 71 per cent for Zone II, zone III, zone I and Zone V, respectively. Though paddy occupied more than 41 per cent of gross irrigated area in all the Zones but it was the maximum for Zone IV with highest productivity of 4585 kg/ha. On the basis of fertilizer use, Zone V was leading with per hectare consumption of 332.5 kg/ha which was much higher than the other zones.

Analysis of data relating to use of different RCTs indicated that about 72 per cent of the sampled farmers were using laser land leveler on about 55 per cent of the total operational holdings (Table 4). About 21 per cent of those have used laser leveler only when demonstrated by PAU or Department of Agriculture while about 51 per cent had actually adopted it themselves. Only about six per cent respondents were using tensiometer for applying irrigation to paddy on only about 0.02 per cent of paddy area and majority of them i.e. about 4 per cent had used it as a demonstration conducted by PAU or State Department of Agriculture. About 89 per cent of the respondents had not used LCC for application of nitrogenous fertilisers and another about 93 per cent did not use DSR for paddy cultivation. Also none of the selected farmers were using machines for paddy transplantation.

Table 4: Status of adoption of resource conservation technologies/ practices in Punjab

S. No.	Technology/ Practice	Per cent farmers				Per cent area under technology/ practice
		Used as a demonstration of PAU, Dept. of Agriculture, etc.	Used at their own level	Total	Farmers who have not used the technology/ practice	
1	Laser Land Leveler	20.80	51.20	72.00	28.00	54.54*
2	Tensiometer	4.40	1.60	6.00	94.00	0.02**
3	Leaf Colour Chart	10.00	1.20	11.20	88.80	0.11**
4	Direct Seeded Rice (DSR)	4.40	2.00	6.40	93.60	0.04**
5	Mechanical Transplanting of Rice	Nil	Nil	Nil	100.0	0.0**

* Percentages to the total operational holding

** Percentages to the total area under paddy

It has been observed that all the selected farmers of Zone IV have used laser land leveler on custom hiring basis (Table 5).

Table 5: Adoption of laser land leveler in Punjab

Zone	Per cent farmers who used the technology/ practice			Per cent farmers who have not used the technology/ practice	Per cent area under the technology*
	Used as a demonstration of PAU, Dept. of Agriculture, etc.	Used at their own level	Total		
Zone I	64.0	6.0	70.0	30.0	9.30
Zone II	2.0	76.0	78.0	22.0	44.78
Zone III	8.0	34.0	42.0	58.0	25.32
Zone IV	30.0	70.0	100.0	0.0	100.0

Zone V	0.0	70.0	70.0	30.0	48.83
Overall	20.8	51.2	72.0	28.0	54.54

Figures are percentages to the total sample size
* Percentages to the total operational holding

About 78 per cent farmers of Zone II were doing so and 76 per cent of them had adopted it on their own level covering about 45 per cent of paddy area. About 70 per cent farmers each from Zone I and Zone V had adopted laser leveler but in former it was done on only about 9 per cent area which was demonstrated by PAU or Department of Agriculture while in the latter actual adoption (on their own will) had taken place on about 49 per cent paddy area.

Table 6: Adoption of tensiometer in Punjab

Zone	Percent farmers who used this technology/ Practice			Percent farmers who have not used the technology/ practice	Percent area under the technology*
	Used as a demonstration of PAU, Dept. of Agriculture, etc.	Used at their own level	Total		
Zone I	14.00	0.00	14.00	86.00	0.07
Zone II	8.00	0.00	8.00	92.00	0.01
Zone III	0.00	0.00	0.00	100.00	0.00
Zone IV	0.00	0.00	0.00	100.00	0.00
Zone V	0.00	8.00	8.00	92.00	0.04
Overall	4.40	1.60	6.00	94.00	0.02

Figures are percentages to the total sample size
* Percentages to the total area under paddy

About 94 per cent of the respondents were not using tensiometer for irrigating paddy fields and none of the farmers of Zone III and Zone IV has adopted it while in Zone V about 7 per cent had actually adopted it on 0.04 per cent of paddy area (Table 6).

Table 7: Adoption of Leaf Colour Chart for paddy crop in Punjab

Zone	Percent farmers who used this technology/ practice			Percent farmers who have not used the technology/ practice	Percent area under the technology*
	Used as a demonstration of PAU, Dept. of Agriculture, etc.	Used at their own level	Total		
Zone I	30.00	2.00	32.00	68.00	0.36
Zone II	20.00	0.00	20.00	80.00	0.09
Zone III	0.00	2.00	2.00	98.00	0.04
Zone IV	0.00	0.00	0.00	100.00	0.00
Zone V	0.00	2.00	2.00	98.00	0.04
Overall	10.00	1.20	11.20	88.80	0.11

Figures are percentages to the total sample size
* Percentages to the total area under paddy

In Zone II and Zone I, about 8 and 14 per cent of the farmers used tensiometer respectively only as demonstration. Again the adoption of LCC was poor as only about 11 per cent of the respondents were using it to apply fertilisers to the paddy crop covering only about 0.11 per cent of the paddy area (Table 7). None of the Zone IV farmers were using LCC while about 2 per cent of farmers of Zone III and Zone V were using it covering about 0.04 per cent paddy area each. Only in Zone II and Zone I about 20 and 30 per cent farmers respectively used LCC as demonstration on about 0.09 and 0.36 per cent of area under paddy cultivation.

Table 8: Adoption of Direct Seeded Rice (DSR) technology in Punjab

Zone	Percent farmers who used this technology/ practice			Percent farmers who have not used the technology/ practice	Percent area under the technology*
	Used as a demonstration of PAU, Dept. of Agriculture, etc.	Used at their own level (Actual adoption)	Total		
Zone I	6.00	4.00	10.00	90.00	0.03
Zone II	6.00	4.00	10.00	90.00	0.07
Zone III	2.00	0.00	2.00	98.00	0.01
Zone IV	8.00	0.00	8.00	92.00	0.07
Zone V	0.00	2.00	2.00	98.00	0.01
Overall	4.40	2.00	6.40	93.60	0.04

Figures are percentages to the total sample size
* Percentages to the total area under paddy

Direct seeded rice technology was used by about 7 per cent of the farmers covering only about 0.04 per cent area by respondents (Table 8). About 10 per cent of the farmers of Zone I and Zone II each were using DSR with majority of them i.e. about 6 per cent only when demonstrated. In Zone IV, about 8 per cent of the farmers were again using DSR demonstrations and this figure was about 2 per cent for Zone III farmers while in Zone V about 3 per cent farmers had actually adopted DSR on their own though covering only about 0.01 per cent of paddy.

The major reason for adoption of RCTs for paddy cultivation were observed to be was the cost effectiveness of these technologies which helped in applying farm inputs judiciously followed by lesser irrigations required leading to efficient use

of water, time saving, reduction in insect- pest and diseases due to judicious use of inputs, reduction in damage to soil which is caused when paddy is grown by conventional method of puddling and few were also aware of environment friendliness of these technologies (Table 9). On the other hand, the majority of the farmers who were not following these RCTs had a major constraint of non-availability of required implements at peak time. Most of them had a view that adoption of RCTs will only add to the cost of cultivation as they felt that they are already more experienced. The farmers felt the cost of implements required e.g. laser land leveler, mechanical transplanter, etc. are too costly and there was lack of credit facility for an individual farmer.

Table 9: Reasons for adoption and non-adoption of RCTs in paddy crop in Punjab

S. No.	Reasons for adoption and non-adoption of RCTs	Ranks given by the respondents
a) Reasons for adoption		
1	Cost saving/judicious use of inputs	I
2	Efficient use of water	II
3	Time saving	III
4	Low incidence of insect-pests and diseases	IV
5	No damage to soil structure	V
6	Environment friendly	VI
b) Reasons for non-adoption/discontinuation		
1	Unavailability at peak time	I
2	Not required for small holdings	II
3	High cost of implement/ no credit facility	III
4	Lack of knowledge to use	IV
5	Shortage of labour	V
6	Confidence in their own decisions	VI
7	Irrigation based on electricity timings and visual observations	VII
8	More care and repeated observations are required	VIII
9	Varietal variations in leaf colour/ difficulty in using	IX
10	Fear of theft of tensiometer	X

Also shortage of skilled persons at required time was another constraint for operating the machinery. The respondents felt themselves to be better judge based on their own experience rather than wasting time on repeated observations. Moreover, the differences in plant physiology such as the leaf colour varies with variety, if is difficult to make proper decision to use the fertilizer with the help of LCC. Further, electricity for irrigation was available free of cost, so they did not bother about using water judiciously. Fear of theft of instruments like tensiometer from the field was also one of the reasons for its non adoption.

Conclusions

Adoption of resource conservation technologies is one the most suitable alternate strategy to mitigate the climate change and achieve the target of sustainability. However, respondents in the conventional method reported main reasons for non-adoption of the RCTs encompassing different constraints such as lack of fellow farmers, lack of credit facilities, lack of own funds to buy costly new machines and non-availability of implements or machinery at peak time. Therefore, researchers must advocate and encourage the farmers to adopt the resource conservation technologies and simultaneously provide solutions to constraints in adoption of these technologies and thereby strengthen the farmers to cope up with the present situation of changing climate. To encourage the equitable and sustainable growth in adoption of these technologies following suggestions may help to a great extent:

- Keeping in view the multifaceted merits of the RCTs, the farmers may be encouraged through providing required machinery at subsidized rates in the beginning or making the required instruments available at cheap rates through the help of agricultural department or the co-operative societies and public-private partnership.
- The whole range of existing farm management practices need to be evolved, evaluated and matched in the context of new systems. The guidelines for the different farm operations to use different RCTs may be published and provided to the farmers free of cost for proper crop management and judicious input use.
- More field demonstrations may be conducted by the agricultural scientists on the farm conditions to demonstrate various practices needed to be evolved in the technology adoption. More exhibitions may be arranged to make the farmers familiar to the technology and remove any doubts and misperceptions from their minds.
- Awareness should be created about environmental consequences of excessive use of natural resources/ inputs like fertilisers through extension efforts. The extension network should be streamlined for effective transfer of technology with wide spread publicity through electronic and print media.
- Improvement in coordination among various stakeholders (research, extension service, farmers, service providers, agricultural machinery manufacturers, etc.) for transfer of technologies may play a pivotal role in accelerating adoption of these interventions.

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