J. Cotton Res. Dev. **30** (2) 185-195 (July, 2016)

Mechanization of *Bt* cotton production in northern India through front line demonstrations-Case study of directed technology diffusion

KULVIR SINGH*, SATNAM SINGH, PANKAJ RATHORE AND RAMESH KUMAR GUMBER
Agronomist, Regional Research Station, Faridkot - 151 203
**E-mail : kulvir@pau.edu*

ABSTRACT : Field evaluation was carried out in 150 demonstrations occupying an area of 487.7 ha over a period of 5 years by following farmer's practice in comparison with improved and feasible mechanical practices focused on reduction in cultivation cost along with yield enhancement. Range of increase in seed cotton yield among the improved mechanical practices over farmer's practices was 11.0-16.1, 7.25-12.3, 5.9-9.8, 5.9-8.5, and 4.8-9.7 per cent for year 2005, 2006, 2007, 2008 and 2009, respectively. Studies revealed that besides timely execution of field operations in limited time frame, introduced machinery proved beneficial as it saved not only money (US$19.8-34.3/ha) but also labor and energy as compared to its traditional counterpart leading to overall reduction in cultivation cost. As a result of this, additional returns by US$93.3-161.1/ha over the farmer's practice were recorded owing to enhanced yield. Among demonstrated implements, aeroblast sprayer, cotton planter and rotavator exhibited the highest adoption index (>80%) in the concluding study year because of wide acceptability by farmers in cotton agro ecosystems.

Key words : Adoption, farmer's practice, front line demonstrations, seed cotton yield

Agricultural mechanization can a play key role in improving production in developing countries and should be considered as an essential input to agriculture. Proper use of mechanized inputs into agriculture, both the level and appropriate choice, has a direct and significant effect on productivity, profitability of farms and quality of life of people engaged in agriculture (Clarke, 2000). Mechanization is also important in context of increasing commercialization of agriculture. Use of farm machinery in Indian agriculture needs to be increased as it can enhance output due to timeliness of operations besides increasing precision in input application (Singh *et al.*, 2012a). Cotton crop under went continuous technology shifts over period of time and thus is a test case through which changes could be examined in India (Suresh *et al.,* 2013). Moreover, mechanization of cultivation is of immense importance for decreasing cost of cotton production. As regards competitiveness in cotton markets, reducing production cost is no less a requisite than attaining a high level of productivity. Genetically modified cotton hybrids with *Bt*, acting like a biological pesticide factory offering *in situ* resistance against the bollworm complex is an cheaper alternative and environmentally benign technological solution. As a result, the area under *Bt* cotton increased to 121.9 lakh ha in 2011 with an adoption rate of 92 per cent of the Indian cotton acreage. In state of Punjab, where cotton acreage has been hovering around 4.7-5.3 lakh ha over last decade, *Bt* cotton is presently covering 94 per cent of total cotton acreage (Kranthi, 2012).Cotton wheat is most common cropping system after rice wheat being followed in this part of north India. Since April to mid May is optimum time of sowing in this region (Singh *et al.*, 2011) , therefore growers have a very limited time for sowing of cotton as most of the April month is consumed in harvesting/threshing of wheat. The agriculture particularly in north India has been primarily dependent on migrant labor especially from Bihar, Uttrakhand and Uttar Pradesh but due to certain central government initiatives such as *Manrega* which offers employment guarantee and work at local places, severe labor crunch for agricultural operations has become the major drawback in cultivating crops in this part of the country. All this necessitates for urgent mechanization of various operations so that in a limited time, various field operations may be executed and resources be properly utilized. Moreover, for broader reasons such as costly *Bt* seed and labor shortage besides timely availability, now cotton farmers have no other option than to adopt mechanization of various field operations. Keeping all these factors in mind it was decided to exhibit technology pertaining to mechanization of cotton cultivation with specific objectives of demonstrating the usefulness of the latest implements to the farmers with a view to reduce the time gap between technology generation and its adoption besides creating effective linkage among scientists and farmers.

MATERIALS AND METHODS

The main emphasis of the front line demonstrations included steps to enhance the mechanization of cotton production, where total improved package could be demonstrated. Bench mark survey was conducted before taking up the trials in the thrust areas.

Study area : This area lies in Trans-Gangetic agro climatic zone, representing the Indo Gangetic alluvial plains of Punjab {a typical representative of south western cotton belt (Zone IV)} situated around 200m above MSL. The areas lagging in adopting the mechanical cultivation were identified, adopted and regularly monitored followed by collection of data. The short and long term effect of new technology on agricultural growth parameters can be totally different and therefore, analyzing the impacts in various phases can unmask the overall effect concealed in a longer period analysis (Chand and Raju, 2009). Thus problems were identified through structured questionnaire and feedback was recorded. Hence, a total of 150 field demonstrations on mechanization of cotton cultivation spread over 487.7ha were conducted over 5 years starting from 2005 to 2009 among 3 prime cotton growing districts from south western cotton belt *i.e.* Faridkot (~30 ^{0} 40'N and 74 ^{0} 44 'E), Ferozepur (~ 30 ^{0} 55'N and 74 ^{0} 40 'E) and Mukatsar (~30 ^{0} 30'N and 74 ^{0} 43 'E)) of the Punjab state scattered over 41 villages (Table 1).

Demonstration details and data collection : The term demonstration plot was used for the exhibited improved technology (IT), whereas farmer's practice (FP) was considered to be synonym with check plot. Each demonstration was conducted in a minimum area of 0.4ha or more. Adjacent to the demonstration, there was a check plot of 0.4ha or more where conventional practices popular among cotton growers were followed to make valid comparison from the data generated. These demonstrations were exhibited in an area of 91.4, 64.8, 26.5, 194.6 and 110.4 ha for year 2005, 2006, 2007, 2008 and 2009, respectively with the intervened technology details as elaborated further (Table 2). The improved implements were provided by Punjab Agricultural University free of cost, though farmers had to use tractor for utilizing them. Except for the demonstrated technology, quantity and quality of all other critical inputs such as fertilizer, irrigation, plant protection was kept uniform in all the plots so as to ensure that differences in yield from different demonstrations could be primarily attributed only due to sole effect of implement(s) used. An impact analysis for individual implement was also recorded in the light of reduction in cost of cultivation, saving of time and labor and awareness of modern technology or other advantages (Table 5). To work out the technology and extension gaps and also the technology as

Table 1. Year wise number of demonstrations, area, villages and districts covered

Sr. No.	Year	Number of demonstrations	Area (ha)	Villages covered and number	District(s)
1	2005	50	91.4	Chahil, Srawan Wale, Ranjitgarh, and Faridkot local **(4)**	Faridkot and Mukatsar
2	2006	18	64.8	Arain wala, Kamiana and Chahil **(3)**	Faridkot
3	2007	17	26.5	Arain wala, Kamiana,Chahil and Vander Jatana **(4)**	Ferozepur
4	2008	40	194.6	Devi wala, Madhok,Veerewala, Chak khiwe wala, Doad, Arain wala, Vandarjatana, Chahil, Jaitu, Himmatpura, Kamiana, Pakhi kalan, Mishri wala, Fatehgarh Sabrah Bargarhi, Rameana, Ratti rori, Sukhan wala and Abohar **(19)**	Faridkot and Ferozepur
5	2009	25	110.4	Machaki mal Singh,Madhok, Vandarjatana, Chahil, Pakhi kalan, Mishri wala, Jalaleana, Sukhan wala, Khara, Kattian waly and Abohar **(11)**	Faridkot and Ferozepur
Total	**150**	**487.7**	-	-	

well as adoption indices, the following formulae have been used.

i) Technology gap = Potential yield - Demonstration yield

ii) Extension gap = Yield from improved practice/ demonstration - Yield from Farmer's practice

iii) Technology index = 100 X (Yi* - Yi)/Yi*

Where Yi * = Potential yield of ith crop, Yi = Demonstration yield of ith crop

iv) Adoption index = (Ai/ Pi) X 100

Where Ai = adoption score obtained by the farming community for ith crop

Pi = possible maximum score of ith crop.

Here the list of technologies used in raising cotton crop was collected and each one was assigned a score of one. Adoption index in the studies was recorded for two subsequent years after the introduction of new mechanical technology into an area and then average was worked out for interpretation.

Statistical analysis : The data on inputs used for raising crop was collected for working out monetary parameters and economic feasibility of the exhibited technology was also worked out. The SCY data from IT and respective FP over the years was analyzed using SAS Proc t-test to test the significance.

RESULTS AND DISCUSSION

SCY (kg/ha) of the front line demonstration trials (Improved Technology *i.e.* IT) and farmer's practice (FP) and also the potential yield has been compared to estimate the yield gaps, which have been further categorized into technology and extension gaps. Thereafter, technology and adoption indices have also been worked out and discussed in the light of results obtained. Since few of the technologies were introduced later in 2008 and hence could not be demonstrated in the initial study years, therefore data has been discussed separately in a year wise fashion.

Year 2005: A total of 12 demonstrations were conducted on aeroblast sprayer and 38 on disc harrow and cotton planter. Both IT's had a significant and positive effect over the respective FP for yield improvement (Table 3). Demonstrations on aeroblast sprayer indicated an increase of 16.1 per cent in SCY over the FP. The increase in SCY to the tune of 11.0 per cent was observed for demonstrations on cotton planter and disc harrow over FP. There was an additional return of US$143.7/ha by using aeroblast sprayer while disc harrow and cotton planter lead to

Table 2. Details of demonstrations on mechanization of *Bt* cotton production

Sr. No.	Improved Technology (IT)/ Implement demonstrated	Farmer's Practice (FP)	*Area (ha) and demonstrations	Field operations accomplished
Year 2005				
1	Aeroblast sprayer	Back mounted hand operated knapsack sprayer	34 (12)	Application of pesticides and nutrients
2	Disc harrow and cotton planter	Cultivator and manual dibbling	57.4 (38)	Seed bed preparation and seed placement
Year 2006				
1	Aeroblast sprayer	Back mounted hand operated knapsack sprayer	14.4 (1)	Application of pesticides and nutrients
2	Disc harrow and cotton planter	Cultivator and manual dibbling	22 (6)	Seed bed preparation and seed placement
3	Rotavator and cotton planter	Cultivator and manual dibbling	28.4 (11)	Seed bed preparation and seed placement
Year 2007				
1	Disc harrow and cotton planter	Cultivator and manual dibbling	7.3 (6)	Seed bed preparation and seed placement
2	Rotavator and cotton planter	Cultivator and manual dibbling	19.2 (11)	Seed bed preparation and seed placement
Year 2008				
1	Aeroblast sprayer	Back mounted hand operated knapsack sprayer	34 (1)	Application of pesticides and nutrients
2	Cotton planter	Manual dibbling	19.4 (8)	Seed placement
3	Disc harrow and cotton planter	Cultivator and manual dibbling	18.4 (7)	Seed bed preparation and seed placement
4	Rotavator and cotton planter	Cultivator and manual dibbling	11.6 (5)	Seed bed preparation and seed placement
5	Cultivator , plancker and cotton planter	Cultivator and manual dibbling	30.4 (5)	Seed bed preparation, land leveling and seed placement
6	Rotavator, tractor driven interculture hoe and power sprayer	Cultivator, hand weeding and back mounted hand operated knapsack sprayer	56 (1)	Seed bed preparation, interculture & weed management, application of pesticides and nutrients
7	Cultivator, Plancker , cotton planter and tractor driven interculture hoe	Cultivator, manual dibbling and hand weeding	24.8 (13)	Seed bed preparation, land leveling, seed placement and interculture & weed management
Year 2009				
1	Aeroblast sprayer	Back mounted hand operated knapsack sprayer	26 (1)	Application of pesticides and nutrients
2	Power weeder	Hand weeding	3.6 (5)	Interculture and weed management
3	Cotton planter	Manual dibbling	4.8 (4)	Seed placement
4	Rotavator and cotton planter	Cultivator and manual dibbling	4.8 (3)	Seed bed preparation and seed placement
5	Disc harrow andcotton planter	Cultivator and manual dibbling	6 (3)	Seed bed preparation and seed placement
6	Cultivator, plancker and cotton planter	Cultivator and manual dibbling	3.2 (2)	Seed bed preparation, land leveling and seed placement
7	Cultivator, plancker and tractor driven interculture hoe	Cultivator and hand weeding	9.2 (5)	Seed bed preparation, land leveling , interculture and weed management
8	Cultivator, plancker, cotton planter and tractor driven interculture hoe	Cultivator, manual dibbling and hand weeding	2.8 (1)	Seed bed preparation, land leveling , seed placement and interculture and weed management
9	Rotavator, power weeder and aeroblast sprayer	Cultivator ,hand weeding and back mounted hand operated knapsack sprayer	50 (1)	Seed bed preparation, interculture and weed management, application of pesticides and micronutrients

* indicates area of the demonstrated technology while values in the parentheses indicate number of demonstrations for the respective technology

additional return of US$116.5/ha over the respective FP (Table 3). There was a reduction in cultivation cost of US$19.8-29.1 /ha for the tested technologies over the FP. As a result of this, benefit cost ratio (B:C) was improved from 1.42 to 2.00 in case of aeroblast sprayer while for cotton planter and disc harrow, it increased from 1.36 to 1.87 . Technology gaps (782.5-800.4 kg/ha) remained higher than the extension gaps (293.8-378.4 kg/ha) for both of the demonstrated ideas. Being the initial study year, a low adoption index of 20 for aeroblast sprayer and 33.3 per cent for disc harrow and cotton planter was recorded (Table 4).

Year 2006: All the demonstrated plots lead to significant improvement in yield over the respective FP. Demonstration on aeroblast sprayer indicated an increase of 12.3 per cent in SCY over the FP due to uniform applications and timely sprays besides saving of US$20.3/ha as reduction in the cultivation cost. Disc harrow and cotton planter resulted in an increased SCY by 8.6 per cent whereas rotavator and cotton planter resulted in an increased yield by 7.3 per cent over FP. There was an additional return of US$150.5, 118.2 and 108.1/ha over FP for aeroblast sprayer, disc harrow and cotton planter and rotavator and cotton planter, respectively (Table 3).This lead to improved B:C ratio in all the demonstrated technologies over the respective FP. Technology gaps ranged from 244-422 kg/ha while extension gaps varied from 217-358 kg/ha for various demonstrations. Technology index was highest for disc harrow and cotton planter (12.1) followed by rotavator and cotton planter (8.3), while for aeroblast sprayer it was 6.9 (Table 4). Adoption index of 60.0, 50.0 and 83.3 per cent was recorded for aeroblast sprayer, disc harrow and cotton planter and rotavator and cotton planter, respectively.

Year 2007: Among 6 demonstrations on disc harrow and cotton planter, an increased SCY by 5.9 per cent was observed whereas rotavator and cotton planter resulted in statistically increased yield by 9.8 per cent over FP at 11 sites (Table 3). There was an additional return of US$93.3 and 135.3/ha over the FP for disc harrow and cotton planter and rotavator and cotton planter, respectively. As a result of this, benefit cost ratio (B:C) improved from 1.90 to 2.36 in case of disc harrow and cotton planter , while for rotavator and cotton planter , it increased from 1.94 to 2.52 (Table3).Technology gaps ranged from 539.4-703.0 kg/ha while extension gaps varied from 191-211 kg/ha for both of the technologies demonstrated. Technology index was higher for disc harrow and cotton planter (20.1) followed by rotavator and cotton planter (15.4). Lower values for adoption index (66.7 per cent) were recorded for disc harrow and cotton planter as compared to rotavator and cotton planter (83.3per cent), indicating the preference of later among farmers (Table 4).

Year 2008: Single demonstration on aeroblast sprayer revealed an increased SCY by 8.0 per cent while use of cotton planter demonstrated at 8 sites resulted in an increased yield by 6.5 per cent over FP. Disc harrow and cotton planter demonstrations recorded significantly better yield by 7.6 per cent whereas, rotavator and cotton planter resulted in an improved yield by 8.5 per cent.The increase for cultivator, plancker and cotton planter was significantly higher by 7.8 per cent over FP (Table 3). Combined use of rotavator, tractor driven interculture hoe and power sprayer, enhanced yield statistically by 6.2 per cent whereas in case of cultivator, plancker , cotton planter and tractor driven interculture hoe, yield improved by 5.9 per cent. The B:C was improved in all the demonstrations plots over the respective Farmer’s practice .The additional returns over the FP were highest in case of rotavator and cotton planter (US$153.3/ha) with a minimum value (US$107.3/ha) for cultivator,

Table 3. Impact of introduced implements on seed cotton yield and monetary parameters at farmer's fields

Sr. No.	Improved Technology (IT)/ Implement used	Seed cotton yield (kg / ha)		Increase (US$/ha) over FP (%)	COC (US$/ha)		Reduction in COC (US$/ha)	Gross returns (US$/ha)		Net returns (US$/ha)		Additional returns over FP (US$/ha)	B:C ratio	
		IT	FP		IT	FP		IT	FP	IT	FP		IT	FP
Year 2005														
1.	Aeroblast sprayer	2717.5*	2339.1	16.1	296.6	316.5	19.8	889.4	765.5	592.7	449.0	143.7	2.00	1.42
2.	Disc harrow and cotton planter	2693.9*	2426.8	11.0	307.7	336.7	29.1	881.6	794.2	574.0	457.5	116.5	1.87	1.36
Year 2006														
1	Aeroblast sprayer	3256.0*	2898.0	12.3	301.0	321.4	20.3	1184.0	1053.8	883.0	732.5	150.5	2.93	2.28
2	Disc harrow and cotton planter	3078.0*	2836.0	8.6	320.4	350.7	30.2	1119.3	1031.3	798.9	680.6	118.2	2.49	1.94
3	Rotavator andcotton planter	3210.0*	2993.0	7.3	315.5	344.7	29.2	1167.3	1088.4	851.8	743.7	108.1	2.70	2.16
Year 2007														
1	Disc harrow and cotton planter	2797.0	2640.3	5.9	333.2	363.7	30.6	1118.8	1056.1	785.6	692.4	93.3	2.36	1.90
2	Rotavator andcotton planter	2960.6*	2697.5	9.8	336.6	366.7	30.1	1184.2	1079.0	847.7	712.3	135.3	2.52	1.94
Year 2008														
1	Aeroblast sprayer	2580.0	2389.0	8.0	327.6	350.1	22.5	1313.5	1216.2	985.8	866.1	119.7	3.01	2.47
2	Cotton planter	2828.1	2654.8	6.5	335.6	362.7	27.1	1439.7	1351.5	1104.1	988.8	115.3	3.29	2.73
3.	Disc harrow and cotton planter	2844.6*	2644.4	7.6	334.5	364.8	30.3	1448.1	1346.2	1113.7	981.4	132.2	3.33	2.69
4	Rotavator and cotton planter	3048.0	2809.8	8.5	337.5	369.5	32.0	1551.7	1430.4	1214.2	1060.9	153.3	3.60	2.87
5	Cultivator , plancker and cotton planter	3007.8*	2789.2	7.8	342.3	368.1	25.8	1531.2	1419.9	1188.9	1051.8	137.1	3.47	2.86
6	Rotavator, tractor driven interculture hoe and power sprayer	2760.0*	2598.0	6.2	346.6	375.0	28.4	1405.1	1322.6	1058.5	947.6	110.9	3.05	2.53
7	Cultivator, Plancker, cotton planter and tractor driven interculture hoe	2751.8	2598.1	5.9	368.5	397.6	29.1	1400.9	1322.7	1032.4	925.1	107.3	2.80	2.33
Year 2009														
1	Aeroblast sprayer	2758.0*	2566.0	7.4	363.6	386.7	23.1	1504.4	1399.6	1140.8	1012.9	127.9	3.14	2.62
2	Power weeder	2588.2*	2417.0	7.0	360.5	394.8	34.3	1411.7	1318.4	1051.3	923.6	127.7	2.92	2.34
3	Cotton planter	2814.2	2570.5	9.4	367.7	395.9	28.2	1535.0	1402.1	1167.3	1006.2	161.1	3.17	2.54
4	Rotavator and cotton planter	2648.6	2500.0	5.9	355.6	383.4	27.9	1444.7	1363.6	1089.1	980.2	108.9	3.06	2.56
5	Disc harrow and cotton planter	2668.6	2482.0	7.5	365.7	397.6	31.8	1455.6	1353.8	1089.9	956.2	133.6	2.98	2.41
6	Cultivator, plancker and cotton planter	2663.0	2502.0	6.4	369.1	394.3	25.2	1452.5	1364.7	1083.5	970.5	113.0	2.94	2.46
7	Cultivator, plancker and tractor operated interculture hoe	2630.4	2509.8	4.8	363.9	393.7	29.9	1434.8	1369.0	1070.9	975.2	95.7	2.94	2.48
8	Cultivator, plancker, cotton planter and tractor operated interculture hoe	2580.0	2350.0	9.7	369.5	401.0	31.5	1407.3	1281.8	1037.8	880.8	157.0	2.81	2.20
9	Rotavator, power weeder and aeroblast sprayer	2647.0*	2439.0	8.5	366.7	396.2	29.4	1443.8	1330.4	1077.1	934.2	142.9	2.94	2.36

Local market rates for seed cotton were US$ 32.7, 36.4, 40.0, 50.9 and 54.5/q for years of 2005,2006,2007,2008 and 2009, respectively.
{**IT**: Improved Technology whereas **FP**: Farmer's practice}, **COC:** cost of cultivation; **B:C** ratio: benefit cost ratio
* indicates that means under IT are statistically better than the respective mean for FP

plancker, cotton planter and tractor driven interculture hoe. Technology gaps ranged from 452-920kg/ha while extension gaps varied from 153.7-238.2 kg/ha for various kinds of the demonstrations (Table 4).Technology index was highest for aeroblast sprayer (26.3) and lowest for rotavator and cotton planter (12.9).However, adoption index ranged from 66.7-100 per cent for different technologies demonstrated with highest value for cotton planter thereby indicative of enhanced acceptability over the previous years.

Year 2009: Aeroblast sprayer significantly increased SCY by 7.4 per cent over the FP. Demonstrations on cotton planter and rotavator, increased SCY by 5.9 per cent over the conventional method besides saving in production cost by US$27.9/ha (Table 3). Power weeder also resulted in significant enhancement in yield by 7.0 per cent. While cotton planter resulted in an increased yield by 9.4 per cent, increase for cultivator, plancker and cotton planter was 6.4 per cent. Disc harrow and cotton

Table 4. Yield gaps in *Bt* cotton as affected by mechanization factors at farmer's fields

Sr. No.	Improved Technology (IT)/ Implement used	Potential yield (kg/ha)	Techn-ology gap	Exten-sion gap	Techn-ology index	Adoption score of farmers	Maxi-mum score	Adoption index (%)
Year 2005								
1.	Aeroblast sprayer	3500	782.5	378.4	22.4	1	5	20.0
2.	Disc harrow andcotton planter	3500	800.4	293.8	22.9	2	6	33.3
Year 2006								
1	Aeroblast sprayer	3500	244.0	358.0	6.9	3	5	60.0
2	Disc harrow and cotton planter	3500	422.0	242.0	12.1	3	6	50.0
3	Rotavator and cotton planter	3500	290.0	217.0	8.3	5	6	83.3
Year 2007								
1	Disc harrow and cotton planter	3500	703.0	191.0	20.1	4	6	66.7
2	Rotavator and cotton planter	3500	539.4	211.0	15.4	5	6	83.3
Year 2008								
1	Aeroblast sprayer	3500	920.0	191.0	26.3	4	5	80.0
2	Cotton planter	3500	671.9	173.3	19.2	6	6	100.0
3.	Disc harrow and cotton planter	3500	655.4	200.2	18.7	4	6	66.7
4	Rotavator and cotton planter	3500	452.0	238.2	12.9	5	6	83.3
5	Cultivator, plancker and cotton planter	3500	492.2	218.6	14.1	5	7	71.4
6	Rotavator, plancker, tractor driven interculture hoe and power sprayer	3500	740.0	162.0	21.1	5	7	71.4
7	Cultivator, Plancker, cotton planter and tractor driven interculture hoe	3500	748.2	153.7	21.4	6	8	75.0
Year 2009								
1	Aeroblast sprayer	3500	742.0	192.0	21.2	4	5	80.0
2	Power weeder	3500	911.8	171.2	26.1	3	5	60.0
3.	Cotton planter	3500	685.8	243.7	19.6	6	6	100.0
4	Rotavator and cotton planter	3500	851.4	148.6	24.3	4	5	80.0
5	Disc harrow and cotton planter	3500	831.4	186.6	23.8	4	6	66.7
6	Cultivator, plancker and cotton planter	3500	837.0	161.0	23.9	5	7	71.4
7	Cultivator, plancker and tractor operated interculture hoe	3500	869.6	120.6	24.9	5	7	71.4
8	Cultivator, plancker, cotton planter and tractor operated interculture hoe	3500	920.0	230.0	26.3	6	8	75.0
9	Rotavator, power weeder and aeroblast sprayer	3500	853.0	208.0	24.4	5	7	71.4

planter recorded 7.5 per cent increase in yield over the FP. Use of cultivator, plancker and tractor operated interculture hoe improved yield by 4.8 per cent . Combined use of cultivator, plancker, cotton planter and tractor operated interculture hoe enhanced yield by 9.7 per cent whereas in case of rotavator, power weeder and aeroblast sprayer, yield improved statistically by 8.5 per cent (Table 3).The B:C was improved in all the demonstrations plots over the respective FP. The additional returns over the FP were highest in case of cotton planter (US$161.1/ha) with a minimum value for cultivator, plancker and tractor driven interculture hoe (US$95.7/ha). Technology gaps ranged from 685.8-920.0kg/ha while extension gaps varied from 148.6-243.7 kg/ ha for various kinds of demonstrations. Technology index ranged from 19.6-26.3 for evaluated technologies. Adoption index range varied from 60-100 per cent for technologies demonstrated with minimum values for power weeder (Table 4).

Effect of mechanization practices on seed cotton yield : The data in Table 4 indicated an increasing acceptability for most of the introduced implements over the years. Range of increase in SCY among various demonstrations was 11.0-16.1, 7.3-12.3, 5.9-9.8, 5.9-8.5, and 4.8-9.7per cent for 2005, 2006, 2007, 2008 and 2009, respectively. The overall decline in yield after 2006 could be attributed to the epidemic of mealybug, *Phenacoccus solenopsis*. However, the attack of this bug was managed with a package of integrated IPM practices developed and demonstrated to cotton farmers. Apart from benefits in SCY, saving in terms of labor and time in accomplishing field operations as observed by the cotton growers have been recorded as direct feedback and are considerable (Table 5).The saving as experienced by farmers matched fairly with the calculated values for implements as evident from Table 3. thereby indicating strong validity of the recorded observations. These findings are well supported by Khobragade *et al.,* (2010) who revealed that improved machines consumed less energy as compared to its traditional counterpart. Similarly, Jansirani (2011) has also reported positive impact of technology demonstrations in improving the cotton productivity and reducing the cost of cultivation. Our findings are in accordance with Kapadiya *et al.,* (2012) who reported an increase of 4.6 per cent in SCY and 3.1per cent reduction in cultivation cost besides increased net returns by 9.9 per cent following improved technologies over the FP. The adoption of new mechanical practices in FLD's has revealed similar findings (Table 3). These results are in line with the results of Kumar *et al.,* (2005) has also found FLD's to be the most feasible way by which improved technology can be demonstrated at the Farmer's fields besides identification of yield gaps between FP and demonstrations.

Effect of mechanization practices on economic analysis : The effectiveness of any production system especially in agriculture is based on its economics as economic analysis is the primary consideration to determine which treatment delivered highest net returns. The comparative profitability of cotton crop has been studied by estimating the benefit cost ratio (B:C) and the results have been found promising. Highest net and additional returns were recorded in Improved techniques over Farmer's practice, which in turn lead to better B:C ratio showing higher profitability over FP. Considerable improvement in the B:C ratio for most the introduced implements has been observed. Though, additional returns over the FP were variable (US$93.3-161.1/ha) over the years but it clearly indicated a *win win* situation by adopting new mechanical technology. Singh *et al.,* (2013) also reported that cotton growers are keen to improve profit margins by adopting such practices while maintaining yield. The study further revealed that the fluctuation in yield is the major cause for the fluctuation in the output.

Effect of mechanization practices on adoption indices : From the initial year range of 20.0-33.3 per cent, adoption index increased in the range of 60-100 per cent during 2009 indicating clear acceptability of the introduced implements among the cotton growers of three districts in the Punjab state. Further, the technology gaps were higher compared to respective adoption gaps except for the year 2006 which could be due to the lack of awareness about the improved mechanized technologies. This has to be highlighted to educate the farmers more about improved practices. In the present studies, it ranged from 4.8-16.1 per cent besides a reduction in cost of cultivation by US$19.8-34.3, over the years as well as range of implements evaluated. These results are in line with Wasnik *et al.,* (2011) who reported an increased SCY by16.8per cent with adoption of technology compared to FP besides reduction in pesticide sprays and reduced production cost.

The adoption index in the final year studies clearly indicated that aeroblast sprayer, cotton planter and rotavator have become most popular among farmers. The farmers feedback for low value of adoption index (60%) in case of power weeder was its high initial cost besides more expenditure on petrol required to run it over the other diesel operated implements. Diesel prices are highly subsidized in India because of primarily agrarian based economy as compared to petrol and this has affected the farmer's choice for a particular implement. At present, there is 100 per cent adoption of cotton planter in north India because it has associated advantages such as uniform seed distribution, sowing at proper depth and coverage of more area per unit time. Singh *et al.,* (2012a) has also reported considerable energy saving by use of cotton planter in Haryana. Similar findings have also been reported by Singh *et al.,* (2012b) in cotton

Table 5. Impact analysis of most accepted implements in terms of specific advantages

Sr. No.	Name ofthe Implement	Saving of man h/ha	Saving in terms of money (US$/ha)	Specific views of farmers
1	Aeroblast sprayer	10-15/spray	9.1-13.6/spray	Timely spray Uniform spray Coverage of more area/time Improved SCY
2	Cotton planter	50	21.8-27.3	Timely sowing Uniform and optimum stand Coverage of more area/time Improved SCY
3	Rotavator	10-15tractor h	36.4-45.5	Saving of diesel Coverage of more area/time Enhanced seed cotton yield
4	Power sprayer	5-8/spray	6.8-9.1/spray	Uniform spray Coverage of more area/time Improved SCY
5	Tractor drivenInter culture hoe	62-100/hoeing	22.7-31.8	Coverage of more area/time Better weed control Improved soil aeration Improved SCY
6	Plancker	15	13.6	Moisture conservation Better germination/emergence and less seedling mortality Better water flow efficiency Improved SCY
7	Power weeder	65	18.2-27.3	Coverage of more area/time Better weed control Improved soil aeration Improved SCY

agro ecosystems of Punjab. Suresh *et al.,* (2013) has also stressed for making the newer technology affordable and accessible to large number of cultivators so as to attain high growth with stability. This is important in view of the dominance of the small scale production system and weak institutional mechanisms like credit delivery in India.

It can be concluded from the studies that agricultural extension that functions through a participatory approach has a great potential to play in facilitating a national, long range agricultural mechanization developmental plan. There are several government policies that affect the way in which mechanization inputs are made available to farmers and this shall determine the effectiveness of the thrust areas. In the present studies, efforts made by government to improvise the existing technology will definitely help to improve the economy of cotton growers. We can surely realize a successful cotton mechanization plan if we view agricultural inputs within broader agricultural production systems and try to tackle challenges arising within and between systems through a short and long term development plan while following agricultural development strategy for upliftment of cotton production and productivity in India .

REFERENCES

Chand, R. and Raju, S. S. 2009. Instability in Indian agriculture during different phases of technology and policy. *Ind J Agric Econ* **64 :** 187–207.

Clarke, L. J. 2000. Strategies for Agricultural Mechanization Development: *The Roles of the Private Sector and the Government. Agricultural Support Systems Division.*FAO Publication, Rome, Italy.

Jansirani, R. 2011. Extent of adoption of production technologies in *Bt* cotton by growers in Kovilpatti block of Tamilnadu. *J. Cotton Res. Dev.* **25 :** 296-97.

Kapadiya, H. J., Butani, A. , Khanpara, M. D. and Nariya J. N. 2012. Farmers participation in front line demonstrations for *Bt* cotton in Saurashtra region of Gujrat. *J. Cotton Res. Dev.* **26 :** 137-41.

Khobragade, H. M., Kamble, A. K. and Thakare, S. H. 2010. Mechanization of cotton crop production in India. *Int J Agric Engg* **3 :** 331-35.

Kranthi, K. R. 2012. *Bt Cotton,Questions and Answers,*Published by Secretary Central Institute for Cotton Research, Nagpur. Indian Society for Cotton Improvement (ISCI), Mumbai Pp.1-71

Kumar, A. B., Jayaprakash, T. C., Gowda, D. and Karabhantanal, S. 2005. Evaluation of front line demonstration trials on cotton in Haveri district of Karnataka. *Karnataka J. Agric. Sci.* **18 :** 647-49.

Singh, Kulvir, Harmandeep Singh, Gumber, R. K., and Rathore, Pankaj 2011. Performance of cotton genotypes under different planting dates in south western Punjab. *J. Cotton Res. Dev.* **25 :** 210-13.

Singh, Kuldeep, Mukesh, S., Bansal, N. K. and Sandeep, Kumar 2012a. Role of cotton planter in enhancing the productivity in the scenario of climate change. Silver jubilee International Symposium *on "Global Cotton Production Technologies vis-a-vis Climate Change".* Organised by Cotton Research and Development Association at CCSHAU, Hisar, 10-12 Oct., 201 pp. 91.

Singh, Kulvir, Singh, Harmandeep, Singh, Kuldeep, Rathore, Pankaj and Gumber, R. K. 2012b. Ascertaining the damage to water soaked *Bt* cotton seed sown by seed drill. Silver jubilee International Symposium on *"Global Cotton Production Technologies vis-a-vis*

Climate Change". Organised by Cotton Research and Development Association at CCSHAU, Hisar, 10-12 Oct,2012.Pp:40

Singh, Kulvir, Singh, Harmandeep, Singh, Kuldeep and Rathore, Pankaj 2013. Effect of transplanting and seedling age on growth, yield attributes and seed cotton yield of *Bt* cotton (*Gossypium hirsutum*). *Ind J Agric Sci.* **83 :** 508-13.

Suresh, A., Ramasundaram, P., Samuel, J. Y. and Wankhade, S. 2013. Impact of technology and policy on growth and instability of agricultural production: The case of cotton in India. *Ind. J. Agric. Sci.* **83 :** 939–48

Wasnik, S. M., Raju, A. R., Palve, S. M., Parwate, P. P. 2011. Cotton frontline demonstrations: an approach for sustainable and profitable cotton production .World Cotton Research Conference on *"Technologies for Prosperity"*, abstract no.143 https://www.icac.org/meetings/wcrc/wcrc5/Pdf_File/ pp 169.pdf

---

Received for publication : July 31, 2014
Accepted for publication : January 9, 2015