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Rohit
R B S College, Bichpuri, Agra, Utter Pradesh, India

Jitendra Singh
Assistant Professor, College of Agriculture Science, TMU, Moradabad, Utter Pradesh, India

Robin Kumar
ND University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Correspondence
Rohit
R B S College, Bichpuri, Agra, Utter Pradesh, India

Enhancement of productivity and profitability through resource conserving technologies in Rainfed conditions in Agra

Rohit, Jitendra Singh and Robin Kumar

Abstract
The productivity of crops in Agra district is very low because of hostile climate, low fertility and unfavorable edaphic conditions. To conserve natural resources for enhancing productivity and profitability various technologies during rainy and winter seasons were demonstrated at farmer's field in village Nagla Dulhe Khan during 2011-12 to 2016-17 in Agra, Uttar Pradesh. The technologies demonstrated were as follows: during rainy season: a) Ridge sowing in pearl millet, b) Compartmental bunding in pearl millet, c) Strip cropping of pearl millet and sesame and d) Strip cropping of pearl millet and cluster bean; during winter season: a) Deep tillage in summer, b) Tillage after each effective rainfall, c) Inter cropping of chick pea + mustard and d) Mustard proceeded by green manuring. The experiment was conducted for six years and the result revealed an increase in yield from 28.70 to 94.48% in rainy season and from 25.75 to 54.46% in winter season crops over conventional practices. Monetary benefits over conventional practice ranged from 2023-35619 Rs/ha.

Keywords: Rain fed, pearl millet, mustard, ridge planting, compartmental bunding, strip cropping

Introduction
Agra is located at agro-ecological sub region 4:1(North plain and central high lands including Aravallies). Geographical area of Agra and Aligarh zone is about 22424 sq.km. The main characterstics of the area are that it has hot semi-arid sub tropical with hot and dry summer with scorching heat waves and severe winter with minimum temperature of 0.5 to 0^0C with occasional frost. In summer temperature raises upto 48^0C during May and June. The average annual rainfall is 665 mm, of which 88 percent (589.1mm) received during rainy season, which is not only erratic distributed but also unpredictable. Nearly 88 percent of total rainfall (665mm) is received during monsoon season but water stress conditions are common even in rainy season (Narayan and Biswas, 2012a) [5]. Though the rainfall received is scanty and erratic but high intensity showers received during the monsoon season result into sizable run off and soil loss (Lakaria *et al*., 2010) [4]. During recent past several years have witnessed drought situation in the region. Due to this situation the region is traditionally facing scarcity of water for drinking as well as agricultural purpose. The soil of the district ranges from sandy loam to sandy clay loam. These soils have moderate water retention capacity. The crops experience water stress even in short dry spells during rainy season and the short monsoon season further aggravates the situation, consequently unstable yield and failure of crops are very common (Narayan and Biswas, 2012a) [5]. Under such situation, resource poor farmers are unable to harvest a good crop during the entire year; consequently, a large cultivable area is kept fallow in the region. To overcome these problems various resource conserving technologies *viz*., ridge sowing, compartmental bunding, deep tillage in summer, tillage after each effective rainfall, chickpea-mustard intercropping, pearlmill et-sesame strip cropping, pearlmillet-cluster bean strip cropping and green manuring were demonstrated at farmers field for resource conservation and further increasing the production and returns.

Materials and Methods
Technology demonstrations were conducted during 2011-12 to 2016-17 at farmer's field in village Nagla Dulhe Khan under NICRA project. The climate of village is semi arid and nearly 85 percent of the total precipitation is received during monsoon period (June to September) with long dry spells causing crop failure.

Total rainfall of 696.7, 809.1, 1119.4, 418.8, 550.4 and 983.0 mm was recorded in 2011-12, 2012-13, 2013-14, 2014-15, 2015-16 and 2016-17 respectively. Four technologies during rainy season and four technologies during winter season, were demonstrated in village Nagla Dulhe Khan.

Rainy season

1. **Ridge planting** (line spacing 45 cm) was carried out for in-situ moisture conservation in pearl millet and yield obtained was compared with traditional practice (flat sowing).
2. **In compartmental bunding** check basins of 6m x 5m size with bunds of 15cm height was formed for in-situ moisture conservation in pearl millet and yield obtained was compared with traditional practice (No bunding).
3. **Strip cropping of pearl millet + sesame (4:4)** was done to minimize weather risk, increase income and enhance resources use efficiency. Strip cropping yield (pearl millet equivalent) was compared with yield of sole pearl millet.
4. **Strip cropping of pearl millet + cluster bean (4:4)** was done for efficient moisture conservation, increase income and minimize weather risk. Strip cropping yield (pearl millet equivalent) was compared with yield of sole pearl millet.

Winter season

1. **Deep tillage** was carried out for in-situ moisture conservation in mustard. Deep tillage (ploughing with MB plough+2 pass harrow + planking) was done during summer season before sowing of rainy season crops, and the yield obtained was compared with traditional tillage (2 pass harrow + planking).
2. **To conserve rain water, tillage after each effective rainfall** was done in rainy season and mustard was grown in winter season and yield was compared with that under farmers practice (No tillage after rains x).
3. **Inter cropping of chick pea and mustard was done in 5:1 ratios** for better surface cover and efficient soil moisture utilization. Inter cropping yield (chick pea equivalent) was compared with yield of sole chick pea.
4. **The sesbania was grown during rainy season for green Manuring** and it was turned down in the soil by MB plough after 35-40 days of sowing. Mustard was grown during winter season adopting recommended package of practices. Yield was compared with that obtained under farmers practice (fallow-mustard).

Results and discussion

Yield: The results revealed that all resource conservation technologies demonstrated at farmers field were helpful in increasing production and returns over farmer's practice (Table-1). Grain yields of different rainy season crops increased from 28.70 to 94.48 percent and yield of winter season crops increased from 25.75 to 54.46 percent under various resource conservation technologies over farmer's practice. In general, the magnitude of increase in yield of different crops recorded higher during rainy season than winter season crops under various resource conservation technologies, which indicates that there is more necessity for adoption of resource conservation technologies during rainy season than winter season. Various soil and water conservation practices followed under technology demonstrations helped in conserving and retaining higher soil moisture content in soil over farmer's practices that, in turn, resulted in better reproductive growth and higher yield of different crops. Deep tillage, green manuring, INM, strip cropping and inter cropping were found best in conserving rainwater, retaining it for longer duration and ensuring its availability to crop during dry spells over farmer's practice. The findings of present study are in similar with earlier findings of Narayan and Lal (2006) [8], Narayan and Lal (2009) [9], Biswas *et al.* (2012) [1] and Narayan and Biswas (2012b) [6] about green manuring, improved tillage, INM, and inter cropping, respectively.

Table 1: Yield of various crops under different practices from 2011-12 to 2016-17 and their mean

Technology	Crop	Year	Seed yield (kg/ha)		
			Traditional practice	Technology	Percent increase over traditional practice
Ridge sowing	Pearl millet	2011-12	2074	2934	41.46
		2012-13	2216	2723	22.87
		2013-14	1890	2232	18.09
		2014-15	2090	2920	39.71
		2015-16	1008	1320	30.92
		2016-17	1795	2615	45.68
		Mean	**1845**	**2457**	**33.17**
Compartmental bunding	Pearl millet	2011-12	1853	2848	53.69
		2012-13	2325	2685	15.48
		2013-14	1777	2062	16.03
		2014-15	2060	2795	35.67
		2015-16	958	1075	12.21
		2016-17	1690	2260	33.72
		Mean	**1777**	**2287**	**28.70**
Deep tillage in summer	Mustard	2011-12	1583	2232	40.99
		2012-13	1855	2347	26.52
		2013-14	1390	1603	15.32
		2014-15	890	1010	13.48
		2015-16	848	1098	29.48
		2016-17	1775	2202	24.05
		Mean	**1390**	**1748**	**25.75**
Tillage after each effective rainfall	Mustard	2011-12	1590	2303	44.84
		2012-13	1964	2426	23.52
		2013-14	1385	1595	15.16

		2014-15	860	1110	29.06
		2015-16	887	1065	20.06
		2016-17	1799	2177	21.01
		Mean	**1408**	**1779**	**26.34**
Strip cropping	PM +Sesame	2011-12	1822	3909	114.54
		2012-13	2085	5725	174.58
		2013-14	1770	2785	57.34
		2014-15	1930	2782	44.14
		2015-16	880	1931	119.43
		2016-17	1630	2552	56.56
		Mean	**1686**	**3279**	**94.48**
Strip cropping	PM + CB	2011-12	1834	3370	83.75
		2012-13	1666	6063	263.92
		2013-14	1680	2623	56.13
		2014-15	1850	2816	52.21
		2015-16	920	1663	80.76
		2016-17	1630	1874	14.96
		Mean	**1597**	**2985**	**86.91**
Inter cropping	CP + Mustard	2011-12	1555	2452	57.68
		2012-13	1599	2511	57.03
		2013-14	1307	2206	68.78
		2014-15	980	1389	41.73
		2015-16	940	1299	38.19
		2016-17	--	--	--
		Mean	**1276**	**1971**	**54.46**
Green manuring	Sesbania - Mustard	2011-12	1496	2206	47.45
		2012-13	1850	2296	24.10
		2013-14	1375	1775	29.09
		2014-15	800	950	18.75
		2015-16	879	1085	23.43
		2016-17	1862	2287	22.82
		Mean	**1377**	**1783**	**29.48**

Economics: Improved technologies were more profitable over conventional practices during rainy season and winter season in every year. Additional net returns of different rainy season crops increased from 2023 to 35619 Rs/ha and winter season crops from 3492 to 35026 Rs/ha under various resource conservation technologies over farmer's practice. Mean results indicated that additional net returns of pearl millet increased to the tune of 8292 and 6491 Rs/ha under ridge sowing and compartmental bunding, respectively over farmers practice. Additional net returns of mustard increased by 13485 Rs/ha under deep tillage and 13389 Rs/ha under tillage after each effective rainfall over traditional practice. Inter cropping of chick pea + mustard registered the higher additional net returns to the tune of 24646 Rs/ha over sole cropping of chick pea. Strip cropping of pearl millet and sesame increased additional net returns to the tune of 13363 Rs/ha over sole cropping of pearl millet. Strip cropping of pearl millet and cluster bean registered the higher additional net returns to the tune of 9193 Rs/ha over sole cropping of pearl millet. Additional net returns of Indian mustard increased by 14639 Rs/ha under INM (green manuring-mustard) over farmer's practice.

Data further indicated the positive effect of technology demonstration over the farmer's practice in registering higher B: C ratio under demonstrations. In general, higher B: Cratio was obtained under improved technologies over conventional practices during rainy and winter season in all the years. Mean results indicated highest increase of 51.56% in B: Cratio under strip cropping of pearl millet followed by 45.02% under inter cropping of chick pea + mustard. An increase of 39.88, 39.75, 22.81, 16.00, 13.33 and 13.16 ratio under improved technologies over farmer's practice was recorded in compartmental bunding, strip cropping of pearl millet and cluster bean, ridge sowing, deep tillage in summer, tillage after each effective rainfall and INM (green manuring-mustard) respectively.

Increase in the pearl millet yield might be the favourable soil conditions created by ridges such as more moisture and nutrient uptake and better root development (Channappa and Ashoka, 1992) [2]. Compartmental bunding increases moisture availability and reduces run off, soil and water nutrient losses which in turn, resulted higher yield and profit. Deep tillage in pearl millet might have helped in recycling of nutrients and conservation of soil moisture for a longer period which helped the crop in dry spell, better moisture availability that, in turn, resulted higher yield and additional net returns over traditional practice *i.e.* shallow tillage (Narayan and Lal, 2009) [9]. The yield of pearl millet under tillage after each effective rainfall might have increased over traditional practice because it improves soil condition by altering the mechanical impedance to root penetration, hydraulic conductivity and holding capacity, which in turn affects plant growth (Dexter *et al*, 1989) [3]. Strip cropping of pearl millet with sesame and cluster bean might have helped in reducing soil erosion and improving soil moisture status through higher canopy cover that might have resulted in higher yield and profit over sole cropping of pearl millet. Similarly, inter cropping of chick pea + mustard increased the productivity and net profits by minimizing the risk of crop failure on account of infestation of wilt and attack of pod borer in sole cropping of chick pea. Green manuring of sesbania during rainy season prior to sowing of mustard minimized soil erosion, increased the higher rain water conservation, reduced infestation of weeds and improved fertility of the soil which in turn increased the crop growth, yield and net returns over traditional practice of fallow-mustard cropping system.

Table 2: Additional net returns and B: C ratio under various crops in different practices from 2011-12 to 2016-17 and their mean

Technology	Crop	Year	B:C ratio		
			Additional net returns under technology over traditional practice(Rs/ha)	Traditional practice	Technology
Ridge sowing	Pearl millet	2011-12	8922	2.16	2.82
		2012-13	4791	2.12	2.47
		2013-14	3966	2.29	2.39
		2014-15	11845	2.63	3.21
		2015-16	5324	1.12	1.45
		2016-17	14905	2.06	2.87
		Mean	**8292**	**2.06**	**2.53**
Compartmental bunding	Pearl millet	2011-12	10349	1.94	2.73
		2012-13	3052	2.36	2.44
		2013-14	3173	2.15	2.21
		2014-15	10227	2.59	3.07
		2015-16	2023	1.06	1.18
		2016-17	10122	1.94	2.48
		Mean	**6491**	**2.00**	**2.35**
Deep tillage in summer	Mustard	2011-12	25764	5.21	6.63
		2012-13	17639	5.50	6.31
		2013-14	6061	3.72	3.81
		2014-15	3492	2.53	2.61
		2015-16	10144	2.33	2.70
		2016-17	17812	4.72	5.80
		Mean	**13485**	**4.00**	**4.64**
Tillage after each effective rainfall	Mustard	2011-12	28423	5.23	6.79
		2012-13	15445	5.84	6.14
		2013-14	6099	3.70	3.82
		2014-15	9594	2.34	2.74
		2015-16	6399	2.44	2.60
		2016-17	14374	4.77	5.44
		Mean	**13389**	**4.05**	**4.58**
Strip cropping	PM + Sesame	2011-12	15320	2.09	3.28
		2012-13	30590	1.99	4.37
		2013-14	4755	2.19	2.54
		2014-15	2865	2.42	2.54
		2015-16	12420	0.98	1.84
		2016-17	14231	1.89	2.87
		Mean	**13363**	**1.92**	**2.90**
Strip cropping	PM+CB	2011-12	5891	2.10	2.84
		2012-13	35619	1.58	3.70
		2013-14	3573	2.07	2.24
		2014-15	3435	1.00	1.34
		2015-16	3047	1.03	1.23
		2016-17	3595	1.89	2.14
		Mean	**9193**	**1.61**	**2.24**
Inter cropping	CP + Mustard	2011-12	23730	5.50	7.38
		2012-13	35026	4.93	7.39
		2013-14	31387	3.56	5.99
		2014-15	14350	2.24	3.14
		2015-16	18734	2.91	3.82
		2016-17	--	--	--
		Mean	**24645**	**3.82**	**5.54**
Green manuring	Sesbania-Mustard	2011-12	31013	4.92	6.26
		2012-13	15214	5.47	5.86
		2013-14	12830	3.68	4.17
		2014-15	3939	2.27	2.34
		2015-16	8236	2.41	2.67
		2016-17	16603	4.94	5.50
		Mean	**14639**	**3.94**	**4.46**

Conclusion

Resource conserving technologies were demonstrated at farmer's field in village Nagla Dulhe Khan during 2011-12 to 2016-17 in Agra, during rainy and winter seasons. Results revealed an increase in yield ranging from 28.70 to 94.48% in rainy season crops and 25.75 to 54.46% in winter season crops as compared to conventional practices. Monetary benefits over conventional practices ranged from 2023-35619 Rs/ha. Results of demonstration of resource conserving technologies at farmer's field clearly indicated that improved technologies were helpful over farmer's practices in increasing yield and additional net returns. Study suggested that the productivity and profitability could be enhanced considerably at farmer's field by adopting suitable resource

conserving technologies during various seasons in Agra district.

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