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Conservation agriculture in rice and maize based cropping systems for enhancing crop and water productivity: participatory technology demonstration in north-east India

Anup Das[1], G.I. Ramkrushna, B.U. Choudhury, S.V. Ngachan, A.K. Tripathi, R.K. Singh, D.P. Patel[2], J.M.S. Tomar[3], K.P. Mohapatra, Jayanta Layek and G.C. Munda

ICAR Research Complex for NEH, Region, Umiam, Meghalaya; [2]National Institute of Abiotic Stress Management, Baramati, Maharashtra; [3]Central Soil and Water Conservation Research and Training Institute, Dehradun-248 195, Uttarakhand.
[1]E-mail: anup_icar@yahoo.com

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ABSTRACT

Conservation Agriculture (CA) in rice (*Oryza sativa* L.) and maize (*Zea mays* L.) based cropping systems for crop diversification and higher productivity was demonstrated in a participatory mode in 15 farmers' field covering 10 villages across Ri-Bhoi District, Meghalaya during 2010-12. The results indicated significant improvement in cropping intensity, crop and water productivity, employment and income due to adoption of CA approach compared to the Farmers' Practice (FP) of monocropping under conventional tillage. Minimum tillage was followed for *kharif* crops and no-till was practiced for dry season crops. French bean and *rapeseed* was grown after maize and pea and lentil was grown after lowland rice with conserved moisture resulting in doubling of cropping intensity. The productivity enhancement in terms of Rice Equivalent Yield (REY) with rice-pea sequence under CA was 229% compared to FP of rice monocropping. Similarly, maize-French bean under CA recorded 168% higher maize equivalent yield (MEY) compared to monocropping of maize. The maximum enhancement in net return was observed with maize-French bean (465%) followed by rice-pea (360%) under CA over respective FP. Adoption of CA resulted substantial improvement in employment of farmers. Adoption of CA enhanced water use efficiency (WUE) by 12% with maize-rapeseed sequence to as high as 228% under rice-pea sequence. Maximum WUE was achieved with rice-pea system under CA (19.69 kg $ha^{-1}mm^{-1}$) followed by rice-lentil sequence (12.34 kg $ha^{-1}mm^{-1}$) compared to 5.99 kg $ha^{-1}mm^{-1}$ under monocropping of rice and 6.23 kg ha^{-1} mm^{-1} under monocropping of maize under FP. The water productivity of rice- pea (` 9.57 $m^{-3}$ water) and maize-French bean (` 6.59 m^{-3} water) sequences were almost four times higher compared to that under FP of monocropping rice (` 2.66 $m^{-3}$ water) and maize (` 1.80 m^{-3} water). Thus, the study indicated opportunity of CA in north eastern hill region for conserving natural resources and enhancing productivity.

1. INTRODUCTION

Farming in rainfed ecosystem of North-East India is a high risk activity and characterized as complex-diverse-risk prone. Natural resource degradation owing to intensive tillage, residue burning/removal, along the slope cultivation *etc.,* are major concerns for sustainable agriculture in the region (Ghosh *et al*., 2010a). In order to keep production system in different land situations sustainable, CA based on minimum/no-till, residue retention/incorporation and crop diversification is an alternative to develop resilience in agriculture and overcome the imposed constraints of the climate change and high input costs (Aune, 2009). Resource conserving technologies using locally available resources encompasses practices that enhance input-use efficiency and provide immediate, identifiable and demonstrable economic benefits such as reduction in production costs, saving of irrigation water, fuel, labour requirements, and timely establishment of crops resulting in improved yields, soil health and income. Intensive tillage in conventional systems leads to gradual decline in soil organic carbon (SOC) content through accelerated oxidation, with a consequent reduction in the capacity of soil to regulate water and nutrient supplies to plants. Retention of crop residues on soil surface in combination with no-till initiates processes that lead to improved soil quality and overall enhancement of resource-use efficiency (Sangar and Abrol, 2005; Abrol and Sangar, 2006; Ghosh *et al*., 2010b). The increase in water conservation and WUE obtained by no-till system has tremendous effect on yield improvement and production stability in agriculture. Even though, crop residues have high value and a small amount is left after harvesting, a build-up over the years and change in farmer's behaviour towards residue management as a long-term investment on soil quality has been noticed in farmers' field (Ghosh *et al*., 2010b). Moreover, improvement of grain and straw production encourages farmers to leave more residues on their fields and ensure the long-term benefit of no-till system (Grarras *et al*., 2009).

Cultivation of *rabi* crops in upland is difficult in the north eastern region due to very less or no rain during November to April and lack of irrigation facilities. Intensive tillage and residue removal results in loss of soil moisture through evaporation and degradation of soil health. Adoption of resource conservation technology like reduced tillage or no-till and residue retention will conserve moisture for cultivation of *rabi* crops like *rapeseed/French bean* in addition to arresting degradation of natural resources and sustaining agricultural productivity. Similarly, in case of lowland, the land remains fallow after harvest of *kharif* rice in Meghalaya/other parts of North Eastern Hills due to excess soil moisture after rice harvest. Under such situation no-till is the only option for cultivating pulses like pea and lentil in rice fallow.

The field experiments conducted at ICAR Research Complex for NEH Region, Umiam, Meghalaya during 2006-12 revealed that productivity of lowland rice under minimum and no-till were about 10% higher compared to conventional tillage. However, the maize productivity under conventional and no-till was statistically similar. The productivity of *rabi* crops like pea, lentil, rapeseed and French bean were about 25% higher in conservation tillage than that under conventional tillage systems (Das *et al.,* 2011). Besides, CA practices enhanced soil health and farmers income due to reduction in cost of cultivation (Ghosh *et al*., 2010b). Keeping the above view in mind, a participatory demonstration was conducted in farmers' field under rice and maize based cropping systems with the objective to assess the influence of CA on crop and water productivity, cropping intensity and income in comparison to the FP.

2. MATERIALS AND METHODS

Participatory field demonstrations on CA in rice and maize based cropping systems were conducted in 15 farmers' field covering 10 villages in Ri-Bhoi district of Meghalaya for enhancing cropping intensity, crop and water productivity and livelihood of farmers. The performance of crops under demonstrations were compared with the FP in term of productivity, income and employment. Soil samples were collected from 0-20 cm depth from all the demonstration sites to determine important chemical parameters. The soil pH was determined in a 1:2.5 soil: water suspension (Jackson, 1973), soil organic carbon determined following Walkley and Black method (1934), available N by alkaline potassium permanganate method (Subbiah and Asija, 1956), available P by Bray's method (Bray and Kurtz, 1945) and available K by ammonium acetate extraction method (Jackson, 1973).

The average amount of annual rainfall received during 2010-12 was 2351 mm, about 79% of which was received during May to September. December to March was the extreme dry period during which crop suffers from water scarcity. The average maximum and minimum temperature were 25.3ºC and 13.7ºC, respectively. The average monthly weather parameter of 2010-11 and 2011-12 are presented in Fig. 1.

The yield of various crops of the respective cropping sequences were converted to rice or maize equivalent yield (REY/MEY) based on the price prevalent in the local market (2012 price). For example, REY of rice-pea sequence was computed by using following formula (De Wit, 1960);

$$\text{REY} = \text{Rice yield} + \frac{\text{Quantity of pea produced (kg)} \times \text{Market price of pea (Rs. kg}^{-1}\text{)}}{\text{Market price of rice (Rs. kg}^{-1}\text{)}}$$

The cropping intensity (CI) was computed using the following formula:

$$\text{CI} = \frac{\text{Gross cultivated area (m}^2\text{)}}{\text{Net cultivated area (m}^2\text{)}} \text{ x } 100$$

Water use efficiency (WUE) was calculated using the formula (Taha and Gulati, 2001);

$$\text{WUE} = \frac{\text{Seed yield or economic yield}}{\text{Crop water requirement (ETc)}}$$

Where, seed yield is grain or economic yield of crops in kg ha^{-1}. Crop water requirement (ETc) (mm) was evaluated by pan evaporation and crop coefficient method (Balasubramanian and Palaniappan, 2007). Crop water requirement (ET) was estimated by multiplying reference

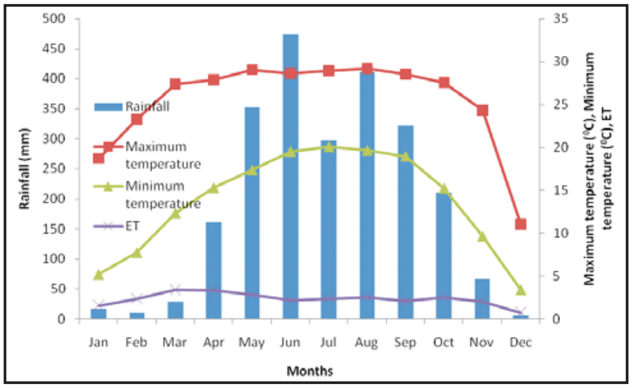

Fig. 1. Average monthly weather parameter of Umiam during 2010-12

evapotranspiration (ETo) obtained from pan evaporation data with crop coefficient (Kc) value. Crop growing period was divided into four stages. Kc values for different crops were referred from FAO-56. The sum of the ET values of all the four growth stages of crops, gives the total water requirement (ETc) during crop growth.

WUE can also be computed by using rainfall and yield data (Morgan, 2003).

$$\text{WUE} = \frac{\text{Yield (kg ha}^{-1})}{\text{Rainfall received (mm)}}$$

Water productivity (WP) was computed using following formula (Hashmi *et al*., 2012).

$$\text{WP} = \frac{\text{Total production of system (kg)}}{\text{Water used (m}^{3})}$$

The benefit: cost ratio (B:C ratio) was computed by dividing gross return with cost of cultivation.

Surveys were conducted to select farmers from different villages of Ri-Bhoi district (864 to 998 m above msl) for implementing the programme. Selections of interested farmers were done, sensitization meetings were conducted where farmers, village headman, secretaries as well as scientists of the working group were present. The objectives, goal and importance of demonstration programme were highlighted during the meetings. Practical demonstration was also organized on use of furrow opener, sprayer, mulching, seed treatment, *etc.* Leaflet in local language (*Khasi*) was prepared and distributed to the farmers for their easy understanding and technology dissemination. As a part of small scale mechanization for enhancing efficiency of labour and drudgery reduction, tools and implements like manual furrow opener, sprayer, 1HP *tulu* pump, *etc.* were provided to the farmers. For higher productivity and income, farmers were provided with seeds of high yielding varieties of rice (cv. 'Shahsarang-1'), maize (cv. 'DA 61 A'), pea (cv. 'Prakash' and 'Vikash'), lentil (cv. 'DPL-15'), French bean (cv. 'Naga local'), *etc.* Necessary technical backstopping on nutrient, weed, insect and disease management was also provided.

Altogether 15 farmers were selected for demonstration of CA in rice and maize based cropping systems (Table 1). The soils of the demonstration sites were acidic in reaction (5.07 to 5.86), mostly high in available N, K and organic carbon (SOC) and low to medium in P (Table 1).

Technology Demonstrated

Rice based cropping system

Minimum tillage (one or two ploughing followed by leveling) was practiced for rice cultivation. Crop and weed residues available in the field were incorporated into the soil for rice and retained on surface as mulch for second crop (pea/lentil). About 25 days old rice seedlings were

Table: 1
Demonstration sites, villages covered and fertility status of the demonstration sites

Demonstration sites	Village name	Latitude (N)	Longitude (E)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Soil pH	SOC (%)
1	Bhoirymbong	-	-	213.3	30.9	5.86	2.51
2	Umeit	25.709722	91.951111	213.3	26.7	5.6	2.13
3	Umeit	25.692778	92.074722	238.3	30.2	5.6	2.12
4	Mawlein Mawkhan	25.698333	91.896111	225.8	33.7	5.66	2.15
5	Mawbri	25.724167	92.040000	213.3	31.6	5.7	2.50
6	Mawlein Mawkhan	25.714444	91.906389	213.3	33.0	5.62	2.19
7	Nongthymmai	25.688333	92.067778	188.2	28.8	5.09	2.04
8	Mawnohsyrum	25.68	92.083056	200.7	35.8	5.4	2.14
9	Umeit	25.708611	91.951667	225.8	29.5	5.19	2.13
10	Mawlein Mawkhan	25.705278	91.885278	200.7	35.1	5.59	2.17
11	Thadnongiaw	25.738056	92.063889	263.4	26.7	5.07	1.91
12	Mawbri	25.726667	92.048889	213.3	33.0	5.8	2.54
13	Mawlein Mawkhan	25.714444	91.906389	213.3	34.4	5.67	2.22
14	Mawlasnai	-	-	263.4	40.9	5.86	2.51
15	Lumsohlang	-	-	210.6	29.8	5.56	2.33

transplanted at a spacing of 20 cm x 20 cm with one or two seedlings hill^{-1} during first week of July. A fertilizer dose of 60 kg N (130 kg urea ha^{-1}), 45 kg P_2O_5 (280 kg SSP ha^{-1}), 30 kg K_2O (50 kg MOP ha^{-1}) and FYM 5 t ha^{-1} was applied to meet the crop nutrient requirement. Two mechanical weeding was done by a cono-weeder at 30 days after transplanting (DAT) and 50 DAT for managing weeds. Rice was harvested at maturity leaving 30 cm standing stubbles in the field. To control weeds, glyphosate @ 3 ml liter^{-1}water was sprayed at about 10 days before sowing of pea/lentil. Narrow furrows in between two rice rows were opened with the help of furrow opener, manure (FYM 5 t ha^{-1}) and fertilizer [(20 kg N (43 kg urea ha^{-1}), 45 kg P_2O_5 (280 kg SSP ha^{-1}), 30 kg K_2O (50 kg MOP ha^{-1})] placed, seeding performed and covered with the soil. Other operations like weeding, irrigation, pest management *etc.,* performed as and when required. In case of excess water, adequate drainage facilities were provided by opening narrow drainage channel around the field at adequate intervals preferably at physiological maturity of rice (10 days before harvest).

Maize based cropping system

Minimum tillage was advocated in maize similar to rice and residues were incorporated in to the soil along with ploughing. A fertilizer dose of 60 kg N (130 kg urea ha^{-1}), 45 kg P_2O_5 (280 kg SSP ha^{-1}), 30 kg K_2O (50 kg MOP ha^{-1}) and FYM 5 t ha^{-1} was applied to meet the crop nutrient requirement. Maize was sown during second fortnight of May at a spacing of 50 cm x 25 cm. Weeding and pest management were performed as and when required. Maize was harvested at maturity by keeping the maize stalk standing in the field. *Ambrosia artemisiifolia* or *Eupatorium adhenophorum* (locally available weed in plenty) biomass was applied as mulch @ 10 t ha^{-1} in between standing stalk of maize. Systemic herbicide glyphosate @ 3 ml litre^{-1} water was applied to kill the weeds at about 10 days before sowing of French bean (mid-August) or *rapeseed* (end of September). Thereafter, standing maize stalks were cut and placed on the surface on the top of the *Ambrosia* or *Eupatorium* mulch thus, forming a 'double mulch' *i.e.,* a layer of weed biomass and a layer of maize stalk. For sowing French bean or rapeseed, the mulch materials were pushed aside towards the row of maize forming an open space in between two maize rows. Sowing performed in between two rows of maize following same techniques as that of pea/lentil after rice. Before sowing of French bean/rapeseed, 50 kg N (108 kg urea ha^{-1}), 45 kg P_2O_5 (280 kg SSP ha^{-1}), 30 kg K_2O (50 kg MOP ha^{-1}) and FYM 5 t ha^{-1} was applied in furrow.

Farmers' practice

Rice under FP was cultivated with conventional tillage (3 ploughing and leveling) and a fine seed bed was prepared. Random transplanting was practiced and 4-5 seedlings hill^{-1} of 30-35 days old seedlings were transplanted. Local long duration cultivars such as '*Mendri', 'Manipuri', etc.* were grown under FP. Minimal quantity of fertilizer (DAP) and/or FYM (5 t ha^{-1}) was applied. After rice harvest, no *rabi* crop was grown as land generally remains fallow under FP.

For cultivating maize, repeated tillage was performed to get a fine tilth as practiced by the farmers in the region. The crop and weed residues were collected and burnt in the field as per local practice. In valley land, farmers cultivate low yielding local varieties and broadcasting is followed. Whereas, in slopping lands, *bun* (raised bed of 0.75 m width x 4-5 m length) cultivation is practiced. Only FYM was applied (10 t ha^{-1}). After maize harvest no *rabi* crop was grown as land generally remains fallow under FP.

3. RESULTS AND DISCUSSION

The enhancement in productivity of rice under demonstration ranged from 10.6 to 35.5% compared to rice grown under FP (Table 2). Similarly, the productivity of maize under demonstration enhanced from 17.9 to 51.3% as compared to maize grown under FP. Intercropping of maize with groundnut and soybean were also practiced by some farmers which gave higher return to the farmers.

The average rice and maize productivity under demonstration was 31% and 33% higher than their respective FP (Table 3 & 4). Cultivation of high yielding rice (cv. 'Shahsarang 1') and maize (cv. 'DA 61-A') varieties along with improved CA based cultivation practices resulted such yield enhancement in rice and maize. Adoption of CA practice like reduced/no-till and *in-situ* residue management facilitated conservation of soil moisture in the field and improved succeeding rapeseed/pea/lentil and French bean yield substantially. The land which used to remain fallow earlier after maize (upland) due to moisture scarcity and after rice (lowland) due to excess moisture and unfavorable soil condition, was brought under cultivation and very good productivity was achieved. On an average mulching with maize stalk and no-till resulted 10% enhancement in soil moisture compared to conventional tillage and residue removal. The *in-situ* residue management and conservation tillage in the field also increased WUE, improved soil health, reduced cost of cultivation and enhanced yield of both maize-French bean/*rapeseed* and rice-pea/lentil system and gave higher income to farmers (Table 3 & 4). The highest net return (based on 2012 price) was recorded with rice-pea sequence

Table: 2
Production of various crops under demonstration and farmers' practice

Demonstration sites	Season	Crop	Area (m^2)	Production (kg)		
				Demonstration	Farmers' practice	% increase
Rice based cropping systems						
1	*kharif*	Rice	1500	660	570	15.8
	rabi	Pea	1000	495	-	-
	rabi	Lentil	320	25.6	-	-
2	*kharif*	Rice	900	418	378	10.6
	rabi	Pea	700	315	-	-
3	*kharif*	Rice	1300	572	455	25.7
4	*kharif*	Rice	1200	515	438	17.6
	rabi	Pea	900	398	-	-
	rabi	Lentil	300	21.5	-	-
5	*kharif*	Rice	1800	716	539	32.8
6	*kharif*	Rice	700	298	238	25.2
	rabi	Pea	600	308	-	-
7	*kharif*	Rice	1100	458	338	35.5
	rabi	Pea	800	425	-	-
	rabi	Lentil	300	27.3	-	-
8	*kharif*	Rice	1600	634	498	27.3
Maize based cropping systems						
9	*kharif*	Maize	1800	515	396	30.1
	Pre-*rabi*	French bean	1000	538	-	-
	kharif	Soybean	500	110	-	-
10	*kharif*	Maize	2000	525	385	36.4
	kharif	Groundnut	250	78	-	-
	kharif	Soybean	250	50	-	-
	Pre-*rabi*	French bean	1000	459	-	-
	rabi	Rapeseed	250	15	-	-
11	*kharif*	Maize	500	122	95	28.4
12	*kharif*	Maize	1200	270	229	17.9
	kharif	Groundnut	310	88	-	-
	Pre-*rabi*	French bean	800	424	-	-
13	*kharif*	Maize	1600	392	309	26.9
	kharif	Groundnut	220	69	-	-
	Pre-*rabi*	French bean	1000	724	548	24.3
14	*kharif*	Maize	600	180	119	51.3
	Pre-*rabi*	French bean	500	310	288	7.1
15	*kharif*	Maize	400	118	88	34.1

Table: 3
Production, employment and income from rice based cropping systems

Crops	Area (m^2)	Production (kg)	Employment (Man days)	Cost involvement (₹)	Gross return (₹)	Net return (₹)
Conservation agriculture in rice-pea/lentil system						
Rice	2000	852	20	5000	12780	7780
Pea (after rice)	1000	484	13	2850	9680	6830
Lentil (after rice)	1000	81	11	1800	3240	1440
Total	2000	—	44	9650	25700	16050
Farmers' practice (control)						
Rice	2000	652	20	4500	9780	5280

Table: 4

Production, employment and income from maize based cropping systems

Season	Crops	Area allotted (m^2)	Production (kg)	Employment (Man days)	Cost involvement (₹)	Gross return (₹)	Net return (₹)
Conservation agriculture in maize-French bean system							
kharif	Maize	2000	528	15	3000	7920	4920
rabi	French bean	2000	1060	15	6500	21200	14700
Total		2000		38	9500	29120	19620
Conservation agriculture in maize-rapeseed system							
kharif	Maize	2000	528	15	3000	7920	4920
rabi	Rapeseed	2000	120	7	2000	3600	1600
Total		2000	-	22	5000	11520	6520
Farmers' practice							
kharif	Maize	2000	398	12	2500	5970	3470

Table: 5

Rice equivalent yield, water use efficiency and water productivity of rice based cropping systems

Farming practice	Rice equivalent yield ($kg\ 2000\ m^{-2}$)	WUE ($kg\ ha^{-1}mm^{-1}$) based on		Water productivity	
		ETc	Rainfall	$kg\ m^{-3}$ water	Rs. m^{-3} water
Conservation Agriculture					
Rice-pea	2143	19.69	1.28	0.64	9.57
Rice-lentil	1284	12.34	0.73	0.34	5.62
Farmers' practice					
Rice-fallow	652	5.99	0.36	0.18	2.66

(₹ 21,440 from 2000 m^2 area) followed by rice-lentil sequence (₹ 10,660 from the same area). Beneficial effect of mulching on soil moisture conservation and subsequent higher productivity of *rabi* crops has been also reported by Sharma *et al*. (2013).

Similarly, CA practice in maize based systems enhanced productivity, employment and income substantially (Table 4). The net return recorded with maize-French bean, maize-rapeseed and maize monocropping was Rs.19620, Rs. 6520 and Rs. 3470, respectively, from 2000 m^2 area. Substantial enhancement in system productivity due to inclusion of French bean in cropping system has been also reported by Das *et al*. (2013).

The REY recorded with rice-pea sequence was 2143 kg from 2000 m^2 area, whereas, the REY with rice-lentil sequence was 1284 kg from the same area compared to 652 kg under FP (Table 5). Thus, REY enhancement was 229 % and 97% with rice-pea and rice - lentil compared to monocropping of rice, respectively. Such high increase in REY under rice-pea/lentil sequences were due to comparatively higher price of lentil and higher green pod yield of pea. Similar enhancement in REY due to inclusion of pea/lentil in rice fallow has been reported by Das *et al.* (2013). The WUE and WP also enhanced substantially under rice-pea/lentil system compared to FP of monocropping rice (Table 5).

Maize - French bean sequence recorded highest MEY (1413 kg) followed by maize-*rapeseed* sequence (768 kg) in compared to maize monocropping (528 kg). Thus, maize-French bean by 168% whereas, maize-*rapeseed* sequence enhanced MEY by 45% (Table 6). The maximum WUE and WP were recorded with maize-French bean (11.58 kg $ha^{-1}mm^{-1}$ and 0.32 kg m^{-3} water, respectively) followed by maize- *rapeseed* sequence (6.98 kg $ha^{-1}mm^{-1}$ and 0.23 kg m^{-3} water) compared to monocropping of maize (6.23 kg ha^{-1} mm^{-1} and 0.16 kg m^{-3} water) (Table 6).

Equivalent Yield, Net Return, Employment and Water Productivity

The production from various components were converted to REY/MEY considering the local market price for comparing the productivity, income, employment, water use efficiency, benefit cost : ratio *etc.* (Table 7). The employment enhancement in demonstration ranged from 83% under maize-rapeseed to as high as 150% under maize French bean compared to FP. However, maximum

Table: 6

Maize equivalent yield, water use efficiency and water productivity of maize based cropping systems

Farming practice	Maize equivalent yield (kg 2000 m^{-2})	WUE (kg ha^{-1} mm^{-1}) based on		Water productivity	
		ETc	Rainfall	kgm^{-3} water	$Rs.m^{-3}$ water
Conservation agriculture					
Maize-French bean	1413	11.58	0.64	0.32	6.59
Maize-rapeseed	768	6.98	0.47	0.23	3.50
Farmers' practice					
Maize-fallow	528	6.23	0.32	0.16	1.80

Table: 7

Summary of equivalent yield, net return, employment, B:C ratio and water productivity under various technologies vs. farmers' practice

Cropping sequence	Area (m^2)	Rice/maize equivalent yield (kg)	Net return (Rs)	Employment (Man days)	WUE (kg ha^{-1} mm^{-1})	Water productivity (kg m^{-3} water)	B:C ratio
Rice based cropping systems							
Rice-pea	2000	2143 (229)*	21440 (306)	46 (130)	19.69 (228)	0.64 (255)	5.78
Rice-lentil	2000	1284 (97)	10660 (102)	42 (110)	12.34 (106)	0.34 (89)	2.24
Rice - fallow (Farmers' practice)	2000	652	5280	20	5.99	0.18	2.17
Maize based cropping systems							
Maize-French bean	2000	1413 (168)	19620 (465)	30 (150)	11.58 (86)	0.32 (100)	3.88
Maize-rapeseed	2000	768 (45)	6520 (88)	22 (83)	6.98 (12)	0.23 (44)	2.30
Maize - fallow (Farmers' practice)	2000	528	3470	12	6.23	0.16	2.39

*Figure in the parenthesis indicates percent enhancement over farmers' practice.

employment generation was from rice-pea (230 man days ha^{-1}) followed by rice-lentil sequence compared to only about 100 man days in rice monocrooping. The highest WUE was observed with rice-pea (19.69 kg $ha^{-1}mm^{-1}$) under CA practice followed by rice-lentil (12.34 kg $ha^{-1}mm^{-1}$) and maize-French bean (11.58 kg $ha^{-1}mm^{-1}$) sequence (Table 7). Similarly, there was substantial enhancement in WP under various rice/maize based systems under demonstration compared to farmers' practice.

Feedback and Impact Analysis

Through the FPARP-II project, for the first time in North Eastern region of India, the technologies for CA based practices were demonstrated in farmers field. The reduction in tillage resulted saving of labour, conserved soil moisture and improved soil health. Farmers were able to cultivate a second crop of *French bean*/*rapeseed* with conserved moisture after maize and pea/lentil/rapeseed after rice harvest. Otherwise, farmers used to keep their land fallow during *rabi* season due to moisture scarcity in upland and some time due to excess moisture in lowland. The farmers' income and employment enhanced substantially due to this intervention. More and more farmers are now coming forward for adopting no-till technology for French bean and *rapeseed* cultivation after maize and pea and lentil in lowland rice fallow. The significant aspect of the programme was the active involvement and participation of the local peoples including women at all the stages. The community participation was ensured through involvement of local *Dorbar Shnong* (village panchayat) besides direct interaction and visits to individual farmers.

Two farmers Mr. E. Dohling and Mr. M. Lamare from Umeit village, Ri-Bhoi District, Meghalaya developed an innovative bamboo made furrow opener of their own which is easy to operate and made with locally available bamboo saving almost 1000 rupees for procuring an iron made furrow opener indicating the innovations and involvement of the farmers in the programme.

Mr. Benantios Rymbai is a farmer from Thadnongiaw village; Meghalaya adopted for demonstration of CA practice in maize based cropping system. His total production of maize increased from 229 kg (earlier practice) to 270 kg (under demonstration) from 1200 m^2 field area. Beside he obtained an additional production of 88 kg groundnut and 424 kg French bean (green pod) from the same area. Similarly, his net income enhanced from Rs. 3,435 under earlier practice to Rs. 9,420 with the adoption of maize-French bean/groundnut system under CA. He is now cultivating vegetables such as pea, cabbage, beans, *etc.* Thus, livelihood of his family improved substantially. More and more farmers are now looking for technical supports for adoption of CA practice in maize and rice based cropping systems in Ri-Bhoi District, Meghalaya.

4. CONCLUSIONS

Adoption of CA practices like reduced/no-till and *in-situ* residue management facilitated conservation of soil moisture and improved succeeding rapeseed/French bean/pea/lentil yield substantially. About 2000-2500 kg ha^{-1} of maize, 500-550 kg ha^{-1} of *rapeseed* seed yields were obtained following CA practice. Similarly, 3000 to 3500 kg ha^{-1} rice and about 5000 kg ha^{-1} vegetable pea were harvested under rice based system. The WP also enhanced substantially due to rice-pea (0.64 kg m^{-3} water) sequence compared to rice monocropping (0.18 kg m^{-3}). The rice productivity in successive years increased due to fixation of nitrogen by leguminous crop (pea/lentil), addition of organic matter owing to better residue management and improvement in physico-chemical and biological parameters of the soils. Therefore, the practice of no-till pea/lentil/French bean /*rapeseed* cultivation in rice and maize fallow is a viable resource conserving technology for the NEH region for increasing cropping intensity, water productivity, employment, and higher income of farmers.

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REFERENCES

Abrol, I.P. and Sangar, S. 2006. Sustaining Indian agriculture conservation agriculture the way forward. *Curr. Sci.*, 91(8):1020-1025.

Aune, J.B. 2009. Conservation, Organic and Conventional Agriculture Compared- Impacts on food production and the environment. Abstracts of 4th world congress on conservation agriculture, 243 p.

Balasubramanian, P. and Palaniappan, S.P. 2007. Principles of Agronomy, Agrobios India, pp. 268-270.

Bray, R.H. and Kurtz, 2.T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Sci.*, 59: 39-45.

Das, Anup., Patel, D.P., Munda, G.C., Ghosh, P.K., Ngachan, S.V., Choudhury, B.U., G.I. Ramkrushna., R, Saha., Rajkhowa, D.J., Panwar, A.S., Kumar, Rajesh., Kumar Manoj and Buragohain, Juri. 2011. Conservation agriculture in rice and maize based cropping systems: package and practices for NEH Region. Research Bulletin No. 75. ICAR Research Complex for NEH Region, Umiam, Meghalaya, 36 p.

Das, Anup., Patel, D.P., Ramkrushna, G.I., Munda, G.C., Ngachan, S.V., Buragohain, J., Kumar, M and Naropongla. 2013. Crop diversification, crop and energy productivity under raised and sunken beds: results from a seven-year study in a high rainfall organic production system. *Biol. Agric. Hort.*, 30(2): 73-87.

De Wit, C.T. 1960. On competition. Verslag Land-bouwkundige Onderzoekingen. Wageningen, 66: 18.

Ghosh, P.K., Das Anup, Saha, R. and Tomar, J.M.S. 2010a. Improving mustard yield through *in-situ* soil moisture conservation and conservation tillage in foot hills of Meghalaya. *Ind. J. Soil Cons.*, 38(3): 184-187.

Ghosh, P.K., Das, Anup, Saha, R., Kharkarang, E., Tripathi, A. K., Munda G.C. and Ngachan S.V. 2010b. Conservation agriculture towards achieving food security in North East India. *Curr. Sci.,* 99(7): 915-921.

Grarras, O.E., Brahli, A.E. and Mourid, M.E. 2009. No-till system applied to Northern African rainfed agriculture: Case of Morocco. Lead Paper presented in 4th World Congress on Conservation Agriculture at New Delhi, India, 4-7 February, 2009.

Hashim, M.A.A., Siam, N., Al-Dosari, A., Asl-Gaddi, K.A., Patil, V.C., Toal E.H.M., Rangaswamy, M. and Samdani, M.S. 2012. Determination of water requirement and crop water productivity of crops grown in the Makkah Region of Saudi Arabia. *Aust. J. Basic App. Sci.*, 6(9): 196-206.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India, New Delhi.

Morgan, J.M. 2003. Making the most of available water in wheat production. NSW Agriculture, agnote. http://www.dpi.nsw.gov.au, accessed on 9th February, 2014.

Sangar, S. and Abrol, I.P. 2005. Conservation agriculture for transition to sustainable agriculture. *Curr. Sci.*, 88: 686-687.

Sharma, NK., Ghosh, B.N., Khola, O.P.S. and Dubey, R.K. 2013. Residue and tillage management for soil moisture conservation in post maize harvesting period under rainfed conditions of north-west Himalayas. *Ind. J. Soil Cons.*, 41(3): 287-292.

Subbiah, B.V. and G.L. Asija. 1956. A rapid procedure for the determination of available nitrogen in soils. *Curr. Sci.*, 25: 259-260.

Taha, M. and Gulati, J.M.L. 2001. Influence of irrigation on yield and moisture utilization of groundnut (*Arachis hypogea* L.). *Indian J. Agron.*, 46(3): 523-527.

Walkley, A. and Black, J.A. 1934. Estimation of soil organic carbon by chromic acid titration method. *Soil Sci.,* 17: 29-38.