Conference on Conservation Agriculture for Smallholders in Asia and Africa

7-11 December, 2014

CONFERENCE PROCEEDINGS

Proceedings of the Conference on Conservation Agriculture for Smallholders in Asia and Africa

Published in 2014

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ACI Motors	Herbicides
Alim Industries	VMP, PTOS, PT, Thresher, Maize Sheller
BAU Farm Machinery	Seeder and planter
BARI	Bed planter, Thresher
BRRI	Transplanter prototype, farm machinery
CA Project	VMP, VSTP, Fodder Chopper, Mini Mill
Syngenta	Herbicides
Auto Crop Care	Herbicides, Farm Machinery
Hoque Corporation and Alam Engineering	VMP, USG Applicator

Messages

Message

On the occasion of the Regional Conference on Conservation Agriculture for Smallholders in Asia and Africa, 7-11 December 2014, at Bangladesh Agricultural University, Mymensingh I feel proud that the Bangladesh Agricultural University (BAU) is organizing an international conference on ‘Conservation Agriculture for Smallholders in Asia and Africa’, at the Bangladesh Agricultural University Campus, Mymensingh, Bangladesh during 7-11 December 2014. I gratefully note that some other national and international organizations have extended their good hands in organizing this conference. Those organizations are Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Alim Industries Limited, International Development Enterprises (IDE), Department of Agriculture and Food of Western Australia, Australian Centre for International Agricultural Research (ACIAR), Food and Agricultural Organization of the United Nations (FAO), International Rice Research Institute (IRRI), International Maize and Wheat Improvement Centre (CIMMYT) and Murdoch University, Australia. Around 150 participants from 19 countries of the world are attending this International Conference. My university and I myself are privileged to be the host and part of this conference. Indeed, BAU always encourages such transnational scientific gathering as part of its research and education operations and international functions.

In Bangladesh, BAU is the oldest and premier seat of higher agricultural education and research in the country having more than 50 years of international reputation. BAU focuses on improving the quality and standard of higher agricultural education to produce first-rate agriculturists, agricultural scientists and researchers for shouldering the responsibilities of agricultural development of Bangladesh. The missions of BAU have been to develop the art and science of agriculture for the well being of humanity, and to educate agriculturists to high standards of scientific, managerial and professional competence in harmony with the environment, and to share knowledge and skills with world partners.

Since inception in 1961, BAU has expanded its frontiers in various fields of agriculture such as Veterinary Science, Agriculture, Animal Husbandry, Agricultural Engineering & Technology, Food Engineering, Agricultural Economics & Rural Sociology and Fisheries. BAU always maintain a kind of flexibility to integrate the latest scientific advancement in order to meet the challenges of the new millennium. The university remains open to promote research partnerships and collaborations both within and beyond the university reaching national and international research organizations, industry, government agencies and other universities and scholars from around the world. BAU cooperates with countries in various parts of the world to exchange ideas, conduct research that enables Faculties to carry out work of importance to its international functions. These functions are carried on in collaboration with the researchers of participating universities, research organizations, government agencies and various countries. One such organization is Murdoch University (MU), Western Australia with which BAU has productive partnership since 2011. As a part of such partnership, we are jointly implementing a project titled, Overcoming Agronomic and

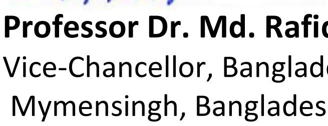
Mechanization Constraints to Development and Adoption of Conservation Agriculture in Diversified Rice-Based Cropping in Bangladesh, funded by ACIAR. The aim of the project is to develop, and accelerate the adoption of Conservation Agriculture for selected soils, crops and cropping systems in Bangladesh, especially in rainfed areas and those with supplementary irrigation, so that agriculture can benefit from cost-saving crop production technologies and sustainable resource management. An interdisciplinary research team comprising teachers from the disciplines of machinery, agronomy, weeds and soil of BAU are carrying out this research under the leadership of Prof. Richard W Bell of Murdoch University. It is very encouraging that the project has substantial progress and by now has achieved very useful findings.

The theme of the present conference is very time demanding and appropriate particularly for Bangladesh as small farms accounted 88% of the total numbers of farm. Nevertheless, these small farms are the major contributor to our agricultural production and economy. Conservation agriculture is now widely practiced in large-scale mono-crop based commercial farming mostly in USA, Canada, Brazil, Australia and Argentina as it provides "win-win" situation for both farmers and the environment. It improves soil qualities, biodiversity, soil moisture conservation and air quality by reducing emission. However, small farmers, especially around Asia, are yet to adopt this beneficial farming principle to arrest their soil and environmental degradation. Most of the farmers of this region still believe that soil tillage is an essential farm operation for crop production, thus, practices aggressive tillage. It is already proven that increased tillage intensity may deteriorate soil qualities and can affect crop yield.

It is proven from our collaborative research findings with Murdoch University (Australia) that adoption of conservation agriculture is feasible to these small farms having mostly rice based cropping pattern. Indeed, it was a big challenge for scientists to practice conservation agriculture in rice based cropping system that practices throughout the South and East Asia. I am very happy to learn that conservation agriculture was successfully adopted in rice based cropping pattern without any influencing the system productivity. Moreover, it reduces the cost of cultivation, seed, water and farm labor and increases crop yield by 10-15% in addition to soil and environmental conservation. Therefore, I believe that the Conservation Agriculture conference would create an opportunity to build up awareness among farmers, agriculture advisors, scientists, policy makers and private sectors to disseminate this beneficial technology in this region.

It is expected that some exciting findings on Conservation Agriculture will be presented in this conference. I hope that a large number of educationists, scientists and researchers from home and abroad attending the conference will discuss and share their latest research findings. This knowledge based discussion will solve the bottlenecks if there is any for adopting conservation agriculture to this region.

I wish the conference a great success.



Professor Dr. Md. Rafiqul Hoque
Vice-Chancellor, Bangladesh Agricultural University
Mymensingh, Bangladesh

Australian High Commission
Bangladesh

Message from Australian High Commissioner to the Regional Conference on Conservation Agriculture for Smallholders in Asia and Africa, Mymensingh, 7-11 December 2014

The Australian Centre for International Agricultural Research – known as ACIAR – operates as part of the Australian Aid Program. Australia's Minister for Foreign Affairs, the Hon Julie Bishop MP, has describe ACIAR as a 'diamond', highlighting its years of work sharing its expertise, technologies, and management methods with developing countries, notably the countries of our region, the Indo-Pacific.

Australia and the countries of South Asia share similar challenges to agricultural productivity growth, including drought and water management, and face many similar food grain and livestock production constraints. Australian expertise therefore has much to offer the region – especially as land and water resources come under increasing pressure from growing population and expanding disposable income.

This is certainly true in the case of Bangladesh, where ACIAR has been working since the mid-1990s. ACIAR has helped improve the productivity of food crops like pulses, wheat and maize, and is also improving farming systems in order to support broader food security – an approach encompassing conservation agriculture, farm mechanisation, saline land management and adaptation to climate change, particularly in rice/ wheat and rice/ maize systems.

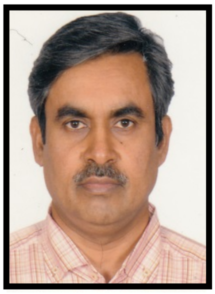
As a long-standing partner for Bangladesh on food security, Australia proudly supports this Regional Conference on Conservation Agriculture for Smallholders in Asia and Africa. ACIAR experts are joined by representatives from Australia's Murdoch and Charles Sturt universities, and from the Western Australia Department of Agriculture and Food. We're grateful for the hospitality and contribution of our friends in the Bangladesh Agricultural University, Mymensingh.

The conference is a timely exercise in sharing what we know about the effects of conservation agriculture on smallholders, identifying the obstacles to its further adoption around the world, and considering how we might engage smallholders, researchers and the private sector in surmounting these obstacles. Joining their colleagues from Bangladesh and other countries, the Australian representatives look forward to sharing Australia's experience in conservation agriculture.

I wish you a very productive meeting. Australia's support for agricultural productivity and food security in Bangladesh is an integral part of our wider development assistance in Bangladesh, valued at over A$90 million this financial year and among the largest country programs Australia runs. It's a reflection of Bangladesh's importance to Australia. Recalling our Foreign Minister's praise for ACIAR, I look forward to showing her its work when she visits Bangladesh.

Greg Wilcock
Australian High Commissioner to Bangladesh

Message



On the event of the Regional Conference on Conservation Agriculture for Smallholders in Asia and Africa, 7-11 December 2014, at Bangladesh Agricultural University, Mymensingh

I am much happy that the Bangladesh Agricultural University (BAU) is organizing an international conference on ‘Conservation Agriculture for Smallholders in Asia and Africa’, at the Syed Nazrul Islam Hall, Bangladesh Agricultural University Campus, Mymensingh, Bangladesh during 7-11 December 2014. We are grateful to the national and international organizations for their active in organizing this conference. They are Bangladesh Agricultural University (BAU), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Alim Industries Limited, International Development Enterprises (IDE), Department of Agriculture and Food of Western Australia, Australian Centre for International Agricultural Research (ACIAR), Food and Agricultural Organization of the United Nations (FAO), International Rice Research Institute (IRRI), International Maize and Wheat Improvement Centre (CIMMYT) and Murdoch University, Australia. Around 150 participants from 19 countries of the world are attending this International Conference.

In Bangladesh, BAU is the oldest and premier seat of higher agricultural education and research in the country having more than 50 years of international reputation. BAU focuses on improving the quality and standard of higher agricultural education to produce first-rate agriculturists, agricultural scientists and researchers for shouldering the responsibilities of agricultural development of Bangladesh. Since inception in 1961, BAU has expanded its frontiers in various fields of agriculture such as Veterinary Science, Agriculture, Animal Husbandry, Agricultural Engineering & Technology, Food Engineering, Agricultural Economics & Rural Sociology and Fisheries. BAU always maintain a kind of flexibility to integrate the latest scientific advancement in order to meet the challenges of the new millennium.

In 1984, Bangladesh Agricultural University established BAU research system (BAURES) for coordination and management of all research projects. BAU research system promotes development of collaboration among different institutions, universities and donor agencies at home and abroad. It encourages formation of research team by the teachers and researchers for formulation of demand led research projects and provide direct assistance in exploring the research funds from the potential donor agencies. It also monitors the research progress and organizes annual research workshop on all projects every year. BAURES has so for completed 1207 research projects and currently implementing 213 projects funded by national and international agencies. Under the research a large number of environmental friendly innovative agricultural technologies was developed and released to the end users (farmers) through proper dissemination policy.

The theme of the present conference is very time demanding and appropriate particularly for Bangladesh as small farms accounted 88% of the total numbers of farm. Nevertheless, these small farms are the major contributor to our agricultural production and economy. It improves soil qualities, biodiversity, soil moisture conservation and air quality by reducing emission. However, small farmers, especially around Asia, are yet to adopt this beneficial farming principle to arrest their soil and environmental degradation. Most of the farmers of this region still believe that soil tillage is an essential farm operation for crop production, thus, practices aggressive tillage. It is already proven that increased tillage intensity may deteriorate soil qualities and can affect crop yield. Therefore, I believe that the Conservation Agriculture conference would create an opportunity to build up awareness among farmers, agriculture advisors, scientists, policy makers and private sectors to disseminate this beneficial technology in this region.
We trust that a large number of educationists, scientists and researchers from home and abroad attending the conference will discuss and share their latest research findings. This knowledge based discussion will contribute significantly in adopting conservation agriculture to this region.

I wish the conference a great success.

Prof. Dr. Lutful Hassan
Director
Bangladesh Agricultural University Research System (BAURES)
and
Chairman, Local Organizing Committee
CASH Conference
Bangladesh Agricultural University
Mymensingh-2202, Bangladesh
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PROGRAM

DAY 1: Sunday (7 December, 2014)

Time	Activities	Location
4:00 - 7:00 p.m.	Registration	Syed Nazrul Islam Conference Hall, Bangladesh Agricultural University (BAU), Mymensingh
7:00 - 9:00 p.m.	Welcome Reception and Dinner	Community Centre, BAU

DAY 2: Monday (8 December, 2014)

Time	Activities	Location
8:30 – 10:00 a.m.	Registration	Syed Nazrul Islam Conference Hall, BAU

Inaugural Session: Syed Nazrul Islam Conference Hall, BAU

Chair	Professor Dr. Lutful Hassan, Chairman, Local Organizing Committee – CASH Conference, and Director, Bangladesh Agricultural University Research System	
Chief Guest	Professor Dr. Md. Rafiqul Hoque, Honorable Vice-Chancellor, Bangladesh Agricultural University, Mymensingh	
Guests of Honor	Dr. Mike Robson, FAO Representative in Bangladesh	
	Dr. Jiban Krishna Biswas, Director General, Bangladesh Rice Research Institute	
	Professor Dr. Mesbauddin Ahmed, Convener, Dean Council, Bangladesh Agricultural University	
	Dr. Md. Rafiqul Islam Mondal, Executive Chairman, Bangladesh Agricultural Research Council and Director General, Bangladesh Agricultural Research Institute	
10:00 – 11:00 a.m.	Welcome address, Overview of the Conference and Background to CA research findings in Bangladesh	Professor Dr. Richard W. Bell, Murdoch University
11:00 – 11:45 a.m.	**Keynote presentation** Overview of the current status of Conservation Agriculture globally and challenges with designing and adapting CA to the circumstances of the smallholders	Professor Dr. Amir Kassam, University of Reading, UK
11:45 – 12:40 p.m.	Speech – Chief Guest, and Guests of Honour	
12:40 – 12:50 p.m.	Concluding Remarks and Vote of Thanks by Session Chair	
1:00 – 2:00 p.m.	Lunch at Community Centre, BAU	

Technical Sessions: Syed Nazrul Islam Conference Hall

Session 1: Chair: Dr. Yuji Niino, Land Management Officer, Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific

2:00-2:40 p.m.	**Keynote paper:** Design and development of - and access to - Conservation Agriculture machinery, implements and tools for smallholders	<u>**Saidi Mkomwa**</u>, Executive Director of the African Conservation Tillage Network (ACT), Hongwen Li, Jack Desbiolles
2:40 - 2:55 p.m.	Evaluation of a mechanical rice transplanter under minimum tillage unpuddled soil conditions	<u>**M.A. Hossen**</u>, M.M. Hossain, M.M. Alam, M.E. Haque, and R.W. Bell
2:55 - 3:10 p.m.	Residue handling capacity of the Versatile Multi-crop Planter for two-wheel tractors	<u>**M.E. Haque**</u>, R.W. Bell, M. Jahiruddin, W. Vance, M.A. Islam, and N. Salahin
3:10 - 3:25 p.m.	Mechanised dry direct seeding of rice: a Cambodian development	S. Pao, N. Pen,J. Desbiolles, <u>**B. Som**</u>, S. Chea, S. Chuong, S. Justice
3:25 - 3:40 p.m.	Optimising the furrow cutting process in rotary strip-tillage	<u>**M.A. Matin**</u>, J.M.A. Desbiolles and J.M. Fielke

3:40 - 4.00 p.m.	Tea/coffee break	
4:00 - 4:15 p.m.	Evaluation of two wheel tractor operated seed drill (Gongli Africa) in Arusha, Tanzania	**W.M. Baitani** and G.L. Mwinama
4:15 - 4:30 p.m.	Furrow openers design can improve seed placement and emergence in strip tillage	**M.A. Hoque**, M.M. Hossain, A.T.M.Z. Uddin, T.J. Krupnik, D.B. Pandit, S. Yasmin and M.K. Gathala
4:30 - 4:45 p.m.	Application of a slack-based DEA model for benchmarking energy inputs use efficiency of selected conservation tillage technology options	S. Aravindakshan, **Frederick J. Rossi**, and T.J. Krupnik
4:45 - 5:00 p.m.	Cost effective small no-till seeder for two wheel tractor in Bangladesh	**Md. Israil Hossain**, J. Esdaile, M.K. Gathala, T.P. Tiwari and Md. Ilias Hossain
5:00 - 5:30 p.m.	Panel discussion	All speakers
Session 2: Chair: Dr. Richard W. Bell, Professor, Murdoch University		
5.30-7.00 pm	Poster discussion - 2-minute presentations at the poster display	Authors of all poster papers
DAY 3: Tuesday (9 December, 2014)		
Session 3: Chair: Professor Dr. Mahfuza Begum, Bangladesh Agricultural University		
8:30 - 9:10 a.m.	**Keynote paper:** Weed management in Conservation Agriculture	**D. Lemerle** and A. Hashem
9:10 - 9:25 a.m.	Crop establishment techniques and weed control strategies for zero-till planted soybean-wheat rotation in India	**Seema Sepat** and A.R. Sharma
9:25 - 9:40 a.m.	Weed control efficacy of herbicides in wheat under strip tillage system	**M.M. Rahman**, T. Zahan, A. Hashem, M. Begum, R.W. Bell and M.E. Haque
9:40 – 9:55 a.m.	Weed control efficacy of herbicides in unpuddled transplanted Aman (summer) rice	**T. Zahan**, M. M. Rahman, A. Hashem, M. Begum, R. W. Bell and M. E. Haque
9:55 – 10:10 a.m.	Weed management in mustard (Brassica napus L.) under minimum tillage and crop residues	**M.M. Hossain**, M. Begum, M.M. Rahman, A. Hashem, R.W. Bell and M.E. Haque
10:10 – 10:30 a.m.	Tea/coffee break **Photo session**	
10:30 – 10:45 a.m.	Row spacing, herbicides and nitrogen effect on crop-weed competition in cereal-broadleaf crop rotation	**A. Hashem**, W. Vance, R. Brennan and R. Bell
10:45 – 11:00 a.m.	Productivity of garlic grown under different tillage conditions and mulches under organic production systems	**M.A. Rahim**, Md.A. Kabir, Md.S. Alam and P.W. Simon
11:00 – 11:15 a.m.	Evaluation of conservation tillage and weed management options on production potential and weed incidences in dry seeded rice	**M.H. Rashid**, J. Timsina, N. Islam, M.K Gathala and J.K Biswas
11:15 –11:30 a.m.	Wheat cultivation under conservation tillage options: a promising, low cost and profitable technology for small holders in Faridpur (Bangladesh)	**M. Elahi Baksh**, F.J Rossi, Md.M. Uddin, Z. Hasan, F. Haque, T.J. Krupnik, A.A. Miah, and T.P.Tiwari
11:30 - 11:45 a.m.	Soil health, weed dynamics and wheat grain yield in different rice-wheat rotations	**Muhammad Farooq**
11:45 a.m. - 12:00 p.m.	Including maize in a rice-wheat cropping system with minimum tillage and crop residue retention	**M. Ataur Rahman**
12:00 - 12:30 p.m.	Panel discussion	All speakers
12:30 - 1:30 p.m.	Lunch at Community Centre, BAU	
Session 4: Chair: Professor Dr. Peter Hobbs, Cornell University		
1:30 - 2:10 p.m.	**Keynote paper:** Soil-water relations and water productivity in smallholder conservation agriculture systems of	**Christian Thierfelder** and Tim Krupnik

	Southern Africa and South Asia	
2:10 - 2:25 p.m.	Soil organic carbon, water stable aggregates and microbial attributes as influenced by conservation agriculture production system (CAPS) in a Fluventic Haplustepts under North Central Plateau Zone of Odisha	K.N. Mishra, A. Mohanty, **Pravat Kumar Roul**, S. Dash, C. Chan-Halbrendt, T. Idol, and A. Pradhan
2:25 - 2:40 p.m.	Effects of minimum tillage practices and crop residue retention on soil properties and crop yields under a rice-based cropping system	**Nazmus Salahin**, M. Jahiruddin, M.R. Islam, R.W. Bell, M.E. Haque and M.K. Alam
2:40 - 2:55 p.m.	Minimum tillage and increased residue retention improves soil physical conditions and wheat root growth in a rice-based cropping system	M.A. Islam, R.W. Bell, C. Johansen, **M. Jahiruddin**, M.E. Haque
2:55 - 3:10 p.m.	Changes in soil organic C, nitrogen and chemical properties under no-till cropping systems on a red oxisol in Cambodia	**Florent Tivet**, S. Boulakia, S. Pheav, V. Leng, R. Kong, L. Séguy
3:10 - 3:25 p.m.	Impact of phosphorus placement methods after three years of different tillage practices on maize productivity and soil properties	**Md. Khairul Alam**, N. Salahin, S. Pathan, R.A. Begum, A.T.M.A.I. Mondol and R.W. Bell
3:25 – 3:40 p.m.	Grain yield and phosphorus accumulation of field grown chickpea to subsoil phosphorus under a dry topsoil in the High Barind Tract	**Enamul Kabir**
3:40 – 4:30 p.m.	Tea/coffee break, Poster viewing and exhibition stall visit	All participants
4:30 – 4:45 p.m.	Effect of tillage type on soil water content and chickpea yields	**Wendy H. Vance**, R.W. Bell, C. Johansen, M.E. Haque, A.M. Musa, A.K.M. Shahidullah and M.N.N. Mia
4:45 – 5:00 p.m.	Tillage and nutrient management in boro rice under rice-mustard-rice cropping system	P.C. Goswami, D. Mahalder, M.K.I. Rony, **M.H. Rashid**
5:00 – 5:30 p.m.	Panel discussion	All speakers
5:30 – 7:00 p.m.	Panel discussion event: enhancing effectiveness of public financing for agriculture	Civil Society Budget Advocacy Group, Uganda
DAY 4: Wednesday (10 December, 2014)		
Session 5: Chair: Dr. Thakur P Tiwari, Country Representative & Cropping Systems Agronomist, CIMMYT-Bangladesh		
8:30 - 9:10 a.m.	**Keynote paper:** Commercialisation, adoption and continuous improvement of Conservation Agriculture-based technologies	**Rafael Fuentes Llanillo,** IAPAR – Instituto Agronômico do Paraná, Londrina, Parana, Brazil.
9:10 - 9:25 a.m.	Adoption and Impact of the Raised Bed Technology in Rajshahi	**M. A. Monayem Miah**, Moniruzzaman, S. Hossain, J.M. Duxbury, J.G. Lauren
9:25 – 9:40 a.m.	Conservation Agriculture packages in the subsistence farming systems of Eastern India	**A.K. Chowdhury**, P.M. Bhattacharya, P.K. Mukherjee, T. Dhar and A. Sinha
9:40 - 9:55 a.m.	Agronomic performance of pigeon pea relay intercropping with maize or sorghum under minimum-tillage of Ghana and Burkina Faso	**H. Omae**, R. N. Issaka, A. Barro, M. M. Buri, S. Simpore, J. Kombiok, J. Ali and F. Nagumo
9:55 - 10:10 a.m.	Adoption of conservation agriculture in South-western Bangladesh	**M. Harunur Rashid**, D. Mahalder, M.K.I. Rony, P.C. Goswami, T. Russell
10:10 - 10:25 a.m.	Strip tillage in maize: farmers' preferences and profit potential in charland of Bangladesh	**D.B. Pandit,** M.A. Arafat, M.E. Haque, M.A. Alam, T.J. Krupnik, T.P. Tiwari and M.K. Gathala
10:25 - 10:45 a.m.	Panel discussion	All speakers
10:45 – 11:00 a.m.	Tea/coffee break	
11:00 a.m. – 12:45 p.m.	**Minimum tillage planting demonstration; experimental field visit (long-term and herbicide trials) at BAU Farm**	**All participants**
12:45 – 1:30 p.m.	Lunch at Community Centre, BAU	

1:30 - 5.00 p.m.	Field visit of Conservation agriculture rotation experiments and on-farm demonstrations at Gouripur	All participants
6:00 – 6:30 p.m.	**Closing session: Syed Nazrul Islam Conference Hall, BAU**	
	Welcome address	Professor Dr. Lutful Hassan, Director, BAURES
	Brief presentation on Smallholders' CA and Conference	Professor Dr. Richard W Bell, Murdoch University, Australia
	Voice from Smallholders CA Stakeholders	Selected farmers, Service Providers, Input Dealers, Researchers, Extensionists, etc
	Speech by Chief Patron	Professor Dr. Md. Rafiqul Hoque, Honorable Vice-Chancellor, Bangladesh Agricultural University, Mymensingh
	Speech by Chief Guest	Principal Motiur Rahman, Honorable Minister, Ministry of Religious Affairs, Government of People's Republic of Bangladesh
6.30-8.00 p.m.	Bangladesh Night, Syed Nazrul Islam Conference Hall, BAU	
8:00 - 9:30 p.m.	Conference Dinner at Community Centre, BAU	
DAY 5: Thursday (11 December, 2014)		
Session 6: Chair: Professor Dr. Richard W Bell, Murdoch University		
8:30 – 8:45 a.m.	Improving soil and crop productivity through resource conservation technologies in drought prone area	**M. Ilias Hossain**, M.E. Haque, M.R.I. Mondal and M.K. Sultan
8:45 – 9:00 a.m.	Wheat requires less amount of applied fertilizers in long term zero tillage	**M.A.Z. Sarker**, M.M. Akhter and A. Hossain
9:00 – 9:15 a.m.	Conservation systems improves soil physical health and resource use efficiency in rice-wheat rotation	**Ahmad Nawaz**, and Muhammad Farooq
9:15 – 9:30 a.m.	Effects of conservation agriculture and nitrogen fertilization on carbon footprint in the wheat-mungbean-rice cropping system	**M.A. Kader**, S. Farhan, M.E. Haque and M. Jahiruddin
9:30 – 9:45 a.m.	The impact of conservation and conventional tillage systems on hydro-physical properties of a Ferric Acrisol	**S.A. Mesele**, B.F. Amegashie, C. Quansah and R.C. Abaidoo
9:45 – 10:00 a.m.	Direct seeded rice (DSR) - sustainable rice production system in East India plateau	A. Kumar, **Abdul Mannan Choudhury**, B. Bellotti, P.S. Cornish
10:00 - 10:20 a.m.	Tea/coffee break	
10:20 - 11:00 a.m.	**Keynote paper:** Policy and institutional arrangements for the promotion of conservation agriculture for small farmers in Asia and Africa. And reflections on the Conference	**Peter Hobbs**, Simon Lugandu and Larry Harrington
11:00 - 11:30 a.m.	Panel discussion	All speakers
11:30 - 12:30 p.m.	Panel discussion with leading CA grass root-level stakeholders: Smallholders CA – what is possible or not possible?	Selected farmers, local service providers, input dealers, retailers, herbicide company, private sector, machinery manufacturers (Facilitator: M.E. Haque)
12:30 - 1:00 p.m.	Concluding remarks from Conference Chair	
1:00 – 2:00 p.m.	Lunch at Community Centre, BAU then scheduled departures	
2:00 – 4:00 p.m.	Round table discussion on mechanisation and commercialisation of CA (Chair: Professor Richard W. Bell)	**Venue: Agriculture Faculty Conference Room, BAU** Invited participants (drawn from research, manufacturing, service providers, and extension)

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Session 6

Policy and institutional framework of conservation agriculture

Inaugural Session

KEYNOTE PAPER

Overview of the current status of Conservation Agriculture globally and challenges with designing and adapting CA to the circumstances of the smallholders

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Background

The global empirical evidence shows that farmer-led transformation of agricultural production systems from tillage-based to Conservation Agriculture (CA) (comprising no or minimum mechanical soil disturbance (i.e. no-tillage), maintenance of soil mulch cover, and crop species diversification) is now a world-wide phenomenon. In recent years the spread of CA has gathered even more momentum as a new paradigm for 'sustainable production intensification', and it is considered to be a climate-smart option.

The updated information on the current status of CA in 2013 globally presented in this paper applies only to arable cropland and is based on several sources: official statistics (e.g. Canada and USA); survey estimates by no-till farmer organizations and agroindustry (e.g. Australia, Brazil, Argentina, Paraguay and Uruguay), by Ministry of Agriculture (e.g. China, Malawi, Zimbabwe), NGOs (e.g. Europe, Russia, Madagascar, Zambia), and well-informed individuals from research and development organizations (e.g. India, Kazakhstan, Ukraine). It has been possible to update the database during 2013 for most countries, except for Africa where much of the information is still from the 2010 database. An overview of adoption of CA in individual countries in 2010/11 is given in Friedrich et al. (2012) and in different regions world-wide in 2013 in Kassam et al. (2014). The latest global state of the art review of CA is given in Jat et al. (2014).

Global spread of CA

The information on the global adoption of CA for arable cropping systems by continent is shown in Table 1. In 2010, CA was practiced globally on about 125 M ha (8.8% of the global arable cropland), across all continents and covering most agro-ecologies, including temperate environments (Friedrich et al., 2012). The updated database for 2013 shows that the global spread of arable CA across all continents is some 157 M ha (11 % of the global arable cropland). However during the 2013 updating of the CA database, it was discovered that the actual spread of CA in 2010 was higher than the reported 125 M ha in Friedrich et al. (2012), more like 145 M ha.

While in 1973/74 the CA system was practiced only on 2.8 M ha worldwide, the area had increased in 1999 to 45 M ha, and by 2003 the area had expanded to 72 M ha. Over the past 10 years CA area has increased at an average rate of some 8 M ha per year, reflecting the increased interest of small and large farmers in switching over to CA. About 50 % of the global CA area is located in the developing regions (Table 1). South America has 42.2 % of the total global area under CA (corresponding to 60.0 % of its arable cropland), United States and Canada has 34.4 % (24.0 % of its arable cropland), Australia and NZ 11.4 % (35.9 %), Asia 6.6 % (3.0 %), Russia and Ukraine 3.4 % (3.3 %), Europe 1.3% (2.8 %), and Africa 0.8 % (0.9 %). Europe and Africa are considered to be the developing continents in terms of CA adoption. Good and long lasting research in these continents has shown positive results for

CA systems, and CA adoption has now begun to make progress as more attention is paid to its promotion by governments and the development community. Arable crop area under CA in Europe has more than doubled since 2010, and indications are that there has been a substantial increase in CA area in Africa in countries such as Zambia, Mozambique, Tanzania, Kenya, Madagascar and Burkina Faso although more recent data is needed to confirm this.

Except in very few countries (USA, Canada, Australia, Brazil, Argentina, Paraguay, Uruguay), CA is not being “mainstreamed” in agricultural development programmes and in only few countries (e.g. Canada, Kazakhstan, China, Zambia) it is backed by government policies and some public institutional support. Thus, globally the total CA arable area is still relatively small compared to areas farmed using soil tillage. However, it is expected that large areas of agricultural land in Asia, Africa and Europe will increasingly switch to CA in the coming decades as is already occurring on large farms in Kazakhstan, on small farms in India, China and Zambia, and larger and smaller farms in Europe.

Challenges

CA represents a fundamental change in production system thinking, and some refer to this as a paradigm change equivalent to the paradigm change from flat earth to round earth. The roots of the origins of CA lie largely in the farming communities, and its initial adoption has been mainly farmer-driven including by smallholders such as those in Paraguay. Research across Asia and Africa has shown that CA does offer many economic, environmental and social benefits for smallholder farmer (Jat et al., 2014). However, evidence across many countries has shown that the rapid adoption and spread of CA requires a change in commitment and behaviour of all concerned stakeholders. For the farmers, a mechanism to experiment, learn and adapt is a prerequisite. For scaling, communication and mutual support is important which can be provided through innovation networks or farmer associations or farmer learning groups such as Farmer Field Schools. Further, the transformation calls for a sustained policy and institutional support role that can provide incentives and required services to farmers to adopt CA practices and improve them over time (Friedrich and Kassam, 2009).

Challenges to designing and adapting CA to the circumstances of the smallholder in Asia and Africa vary across agro-ecologies (including the level of land degradation) and prevailing farming systems, whether in the upland or lowland environment, and whether rainfed or irrigated. Challenges include the need to build farmers’ capacity to change to CA, making affordable equipment and machinery available, and providing short-term financial incentive to switch to CA. Smallholders across Asia and Africa are adopting CA in upland cropping systems, especially in areas that have support programmes in place, offering know-how, participatory learning opportunity, input support and market access (Jat et al., 2014; ACT, 2014). Thus challenges are being selectively addressed for increasing the adoption of CA (Johansen et al., 2012).

In the monsoon regions of Asia, farming systems are dominated by wetland rice grown in paddies with puddled/destructured soils. Transforming such systems into CA systems is a complex technical, economic and social challenge. In Bangladesh and elsewhere in Asia as well as in Africa, several CA approaches for smallholder farmers are showing promise for private sector involvement for commercialization (Johanssen et al., 2012; Haque et al., 2013). For rice-based systems, these approaches include: the direct seeded rice production on permanent no-till permanent ‘narrow’ beds, or direct seeded rice production in no-till levelled paddies, or direct seeded rice in no-till soils with sub-surface micro-irrigation

To accelerate the wide-spread adoption of CA by smallholders in Asia and Africa requires the committed long-term support and involvement of individuals and institutions across the entire spectrum of public (including policy), private (including farmers) and civil sectors. This is increasingly occurring in recent years and is facilitating the generation of locally adapted research knowledge on key challenges such as: the availability and use of CA equipment and machinery; maintenance of soil mulch cover; management of competition for crop residues; effective integrated weed management; and economically and ecologically sustainable cropping systems, including more productive integration of livestock into CA systems (Jat et al., 2014).

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Table 1. Area of arable cropland under CA by continent in 2013 (source: FAO AquaStat: www.fao/ag/ca/6c.html)

Continent	Area (M ha)	Per cent of global total	Per cent of arable land
South America	66.2	42.2	60.0
North America	54.0	34.4	24.0
Australia & NZ	17.9	11.4	35.9
Asia	10.3	6.6	3.0
Russia & Ukraine	5.2	3.3	3.3
Europe	2.1	1.3	2.8
Africa	1.2	0.8	0.9
Global total	**157**	**100**	**11.0**

Session 1

Design and development of CA-based crop establishment and herbicides spraying machinery, implements, tools for smallholders

KEYNOTE PAPER

Design and development of - and access to - Conservation Agriculture machinery, implements and tools for smallholders

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Small holdings form the majority of farms worldwide and produce 80 % of the food in developing countries. The world needs to produce 70 % more food using existing natural resources to feed the projected 9 billion people by 2050. While the world population is expected to increase by 33 % by 2050, it will increase by 115 % in Africa and by 21 % in Asia. Being home of the hungry and with a burgeoning population, Asia and Africa are the regions where food security will be more urgent in the coming years. They will have to supply the larger part of their food requirements, through intensification of production on arable land. The USA experienced devastating Dust Storms in the 1930s because of intensive ploughing. Ukraine has serious soil erosion because of the same reason; China reports dust storms every year because of exposed cultivated land in spring. So, while Asia and Africa have to produce more food, they cannot follow the same way of destroying land and environment. They must use a sustainable intensification with minimum negative social and environmental consequences, that is, Conservation Agriculture (CA).

CA - a farming strategy based on three principles of minimum soil disturbance (or direct seeding), permanent vegetative soil cover and crop rotation - is seen as the alternative to conventional tillage systems, having multiple benefits with regard to productivity and sustainability. The benefits of CA have been widely recognized and various forms of CA systems have been widely adopted in many parts of the world. However, there are some key factors that limit the widespread adoption of CA in Africa and Asia. For instance, the first two core principles of CA call for specialised machinery for seeding on unploughed fields with surface residues, management of cover crops or crop residues, and non-tillage based weed management. Direct seeding and management of soil cover are also the most difficult to implement without access to appropriate farm machinery and in essence are the weakest links in the CA adoption chain. Competing needs for residue from livestock may result in simpler machinery being suitable for the direct seeding task under low and no residue 'partial CA' systems.

In contrast with Asian countries that experienced the Green Revolution, the farm power available per area of agricultural land in Sub-Saharan Africa (SSA) has been stagnating over the past three decades (FAOSTAT 2012), accentuated by the collapse of most government tractor hire schemes, the decline in number of draught animals and the growing shortage (quantity and quality) of human labour. The better mechanised Asia region faces, like Africa, a prominent problem in the unavailability of suitable CA equipment for crop establishment and herbicide spraying to suit small-sized land holder farmers (He et al. 2014).

While the unavailability of appropriate low-cost CA seeders (either imported or locally manufactured) is an immediate obstacle to CA adoption, an additional access pathway to CA seeders may exist in the form of low-cost upgrading of existing conventional seeders to render them suitable for low disturbance direct seeding, especially into low residue environments, as is exemplified in the CA development work by ICARDA in the Middle East (ICARDA, 2012), also duplicated in north Africa.

Functional CA equipment will need to match the available power sources (hand, animal, two wheel and four wheeled tractors); the different soils and crops; terrain and ergonomic needs. A successful CA enterprise will also depend on the role played by the availability and quality of parallel inputs such as herbicides, pesticides, seeds and fertilisers. In addition to the need to perfect the technical performance of the system, innovations to enhance machinery affordability, simplicity and suitability for the local manufacturing industry and repair workshops, and the physical accessibility to proven designs at the local level can greatly contribute to a market pull of CA technology options.

A review of literature on mechanisation of smallholder CA in Africa and Asia conducted for the purpose of the Regional Conference on Conservation Agriculture for Smallholders in Asia and Africa arrived at the following conclusions:

- The need for local manufacturing to have CA seeders continually evolving to address emerging issues and backed up by spares and repair services. This calls for dedicated support to local research and development. The traditional manufacturing of hand and animal traction CA seeders in Brazil (with some 25 no-till planter manufacturers) is now being challenged with affordable and novel seeder solutions by workshops in Africa and manufacturers in China and India. China and Bangladesh are renowned manufacturers of two-wheeled tractor seeders, with new seeder solutions also emerging in South East Asia.
- CA seeders for 2 wheel tractors vary greatly and their ground engaging components may include either passive furrow openers (tine and/or disc blades) or active rotary blade systems producing a full or strip-till direct seeding. A CA seeder of any size can be considered as an association of seeding system single row units, whereby their cumulated individual performance – including their interactions – dictate the seeder overall field performance in practice. Research focussed on the mechanics and performance of single row seeding system units can therefore be applicable across the scale of mechanisation.
- Effective field performance of CA seeders needs to take into account effective management of soil cover (cover crops or crop residues) that seeks to minimise residue disturbance and not block the seeder in operation; nor inhibit precision metering and placement of seeds and fertilisers; while achieving seed covering and furrow firming for firm seed-soil contact, that does not interfere with seedling emergence. He et al. (2014) concludes in their study that there are small to medium size no-till/minimum-till seeders which can promote the extension of CA in Africa and Asia with variable levels of soil disturbance and residue management. However, their development is slow and their uptake limited. They further recommend that: (1) Policy support, including subsidies, is crucial for the rapid development of the seeders, including provision of adequate research projects, funds and establishing proper guiding mechanisms for the implementation of CA; (2) Further improvements can be made on developed CA seeders to suit a wider range of crops and soils in different geographical regions; (3) Development of no-till seeder anti-blocking technology is necessary to ensure good performance and adoption of CA seeders in high residue environments; (4) Universities, research institutions and enterprises should have closer cooperation to design suitable no-till/minimum-till seeders for different cropping areas.

- The contrasting supply models of agricultural mechanization, based on the experiences of some Asian countries where smallholders dominate, as is the case for SSA, are presented by: India (where medium to large scale farmers own medium-size machines and hire out their services to other farmers); China (where specialized enterprises migrate over large areas), and; Bangladesh (where small-scale contractors (who may or may not be farmers) own small machines and hire out their services to farmers). The more socially inclusive and higher mechanisation levels achieved in Bangladesh and other South and South East Asian countries is an outstanding model for smallholders elsewhere.
- While past initiatives of promoting mechanization in SSA generally failed, the situation is changing rapidly, with agriculture becoming more intensive and more commercially-oriented addressing previous pitfalls of lack of demand for mechanization. As a model, the boom in ownership of motorcycles all the way to rural areas in many SSA and South East Asian countries has been accompanied by the parallel development of repair services infrastructure and increased availability of fuel and lubricants that could also support CA marketing systems.
- Appropriate and equitable mechanization (with gender mainstreaming considerations) may be achieved by supporting the promotion of small machines, affordable to farmers and service providers, with a technology adapted to the knowhow of local repair workshops, and suitable for small and fragmented fields encompassing hand, animal traction, small 2-wheel tractors and 4-wheel micro-tractors (typically not powerful enough to conventionally plough but suited to CA). Larger 4-wheel tractors should be considered in areas with larger farm and contract servicing acreages. The demand for mechanization is exacerbated by the shortage of farm labour due to rural–urban migration, higher labour cost, and the ageing farmer population. Reductions in the number of work animals due to epidemics and pasture land pressure calls for motorised mechanisation.
- For smallholder mechanization to succeed, it is essential that all key stakeholders in the machinery supply (manufacturers; importers; distributors and dealers) chain are involved, together with leading farmers in developing and promoting solutions. The private sector must also be making a profit from their businesses. A supply chain of CA product spares and repair services needs to be developed. Support to rural workshops, better trained mechanics, operators and service providers are essential to build the expansion structure of the enterprise.
- Beside the mechanised CA services (direct seeding, herbicide application, combine harvesting and straw/stover spreading) farmers/service providers need to diversify to other services including irrigation water pumping, threshing, shelling and farm transportation to unlock labour bottlenecks and widen service provision revenue streams.
- To develop equipment adapted to local environments, research institutions, NGOs and farmer organisations need to form platforms for joint innovation and adapting the CA concept to specific local situations. The South–South linkages are a valuable platform to share experiences from similar environments. The 2WT newsletter coordinated by Australia-based Jeff Esdaile, the African Conservation Tillage Network (ACT) (www.act-africa.org), and the Conservation Agriculture Alliance for Asia and Pacific (CAAAP) are good examples of information sharing and need to forge stronger ties.
- Extension and training: The early CA adopters face many hurdles, so high-efficiency extension mechanisms and CA expert groups must be funded to provide training and technical support, including free access by farmers to demonstration seeders with technical support. Demonstration of CA seeders must be made under a systems

approach reflecting associated practice changes such as early sowing and reduced seed rate, and maintaining flexibility in the implementation of the CA system, all in the spirit of lowering adoption risks to the small holder farmers. In addition, engaging with policy makers where targeted machinery subsidies can support early stage adoption may be worth consideration based on each country's financial situation.

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Evaluation of a mechanical rice transplanter under minimum tillage unpuddled soil conditions

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Introduction

Labour shortages for rice transplanting across Asia are stimulating interest in mechanical transplanting. While the transplanters have been evaluated in puddled soils, there is little understanding of their efficacy for transplanting into soils following minimum tillage such as zero tillage, strip tillage and raised beds. This study was conducted to evaluate the performance of a mechanical rice transplanter (4 rows walk-behind type daedong rice transplanter, model DP480) under minimum tillage options at Bangladesh Rice Research Institute research farm, Gazipur and on a farmer's field at Kumarkhali, Kushtia, Bangladesh during the irrigated dry season of 2012-13 and the non-irrigated wet season of 2013.

Materials and methods

The bed, strip, zero and conventional tillage treatments were arranged in a randomized complete block (RCB) design with three replications. A Versatile Multi-crop Planter (Haque et al., 2001) was used to prepare the beds and strips during the irrigated dry season whereas the strips and beds were prepared using a conventional rotary tiller powered by a 2-wheel tractor (2WT) and manually during the non-irrigated wet season, respectively. A rotary tiller powered by a 2WT was used for the conventional tillage treatment, consisting of two dry pass, one wet passes and one leveling operation. Seedlings were prepared in plastic trays with 135 gm pre-germinated seeds in each tray. BRRI dhan28 and BRRI dhan49 varieties were used during the irrigated dry and the non-irrigated wet seasons, respectively. Textural classes of Gazipur and Kushtia soils were clay loam and loamy soil, respectively. The benefit-cost ratio (BCR) of each treatment was computed based on total income and production cost of rice under different tillage options. Break-even analysis was also conducted to predict the necessary annual use of the rice transplanter for making a profit.

Results

The un-puddled strip tillage saved about 50-70% for tillage time and fuel consumption. Strip and zero tillage saved 22 and 28%, respectively, of the water required up to transplanting, compared to bed and conventional tillage. In loam and clay loam soil, soil resistance, measured by a hand penetrometer at 5 cm operating depth, during transplanting varied from 3 to 4 N/cm^2 and 15 to 24 N/cm^2 during the irrigated dry season of 2012-13 whereas it was 2 to 12 N/cm^2 and 0 to 9 N/cm^2 respectively during the non-irrigated wet season of 2013.

Overall, strip and zero tillage showed significantly higher field capacity (0.131 to 0.134 ha/hr) followed by conventional and bed tillage (0.115 to 1.21 ha/hr) whereas rice transplanter showed significantly better performance during Aman season in loamy soil conditions (0.140 ha/hr). In clay loam soil, strip tillage showed significantly higher field capacity (0.14 ha/hr) during the irrigated dry season of 2012-13 whereas field capacity of rice transplanter under strip and zero tillage was identical (0.13 ha/hr) during the non-irrigated wet season of 2013. In loam soil, significantly higher field capacity was observed in conventional tillage (0.13 ha/hr) followed by strip and zero tillage (1.2 ha/hr) during the irrigated dry season of 2012-13 whereas zero (0.16 ha/hr) and strip (0.15 ha/hr) tillage showed significantly highest field capacity during the non-irrigated wet season of 2013.

Tillage options also showed significant effects on fuel consumption of rice transplanter operations except on loamy soil during the non-irrigated wet season of 2013. In both loam and sandy loam soil, conventional tillage consumed significantly more fuel during irrigated dry season of 2012-13. In clay loam soil, strip tillage consumed significantly less fuel in both seasons. Averaged over two seasons, bed and conventional tillage consumed significantly more fuel (4.8 to 5.0 litre/ha) followed by strip and zero tillage (4.1 to 4.3 litre/ha). Overall, strip and zero tillage saved about 18 and 14%, respectively, of the fuel required for mechanical transplanting.

Highest percentage of missing hills was observed for bed and zero tillage (11.5 to 13.3%) because of more floating plants, followed by conventional tillage (9.9%). On the other hand, strip tillage resulted in the minimum number of missing hills (7.5%) due to fewer floating and deeply buried plants. In both seasons, minimum tillage resulted in more floating hills whereas buried hills occurred more often in conventional tillage due to differences in soil strength. Picker misses and mechanical damage to plants also varied with tillage treatment, soil condition and seasons. Transplanter slippage significantly reduced the plant to plant spacing during transplanting in conventional tillage from the pre-set spacing compared to minimum tillage in both irrigated dry and non-irrigated wet season soil conditions. Weed infestation and weeding cost increased substantially for un-puddled transplanting during the irrigated dry season.

Averaged over two seasons and two soil types, strip tillage gave significantly higher yield (5.3 t/ha) followed by zero, conventional and bed tillage (5.0 to 5.1 t/ha). On the other hand, Boro season gave more yields over Aman season whereas clay loam soil gave more yield advantages compared to loamy soil. However, zero tillage showed better performance in clay loam soil whereas zero tillage in loamy soil over other tillage options in both Boro and Aman season (Table 1).

Table 1. Grain yield overview of transplanted rice under different tillage systems

Seasons	Soil type	Grain yield (t/ha)				
		BT	ST	ZT	CT	Mean
Boro/12-13	Clay loam	5.5	6.0	6.1	5.8	5.9a
	Loam	5.1	5.4	5.0	5.1	5.2b
Aman/2013	Clay loam	4.6	4.9	5.0	4.8	4.8c
	Loam	4.7	4.7	4.4	4.6	4.6d
Mean		5.0b	5.3a	5.1b	5.1b	
$LSD_{0.05}$	Season(S)=0.13, Soil type(St)=0.13, Tillage=0.18, S×St=0.18 and St×T=0.226					
Level of significance	Season=**, Soil type=**, Tillage=* , S×St=**, S×T=NS, St×T=** and S×St×T=NS					

Note: BT-Bed tillage, ST-Strip tillage, ZT-Zero tillage, CT-Conventional tillage, NS-Not significant, *-significant at 5%, **-significant at 1%, Data followed by different letters differ significantly.

However, strip tillage showed highest BCR (1.60) followed by zero tillage (1.56) compared to bed (1.50) and conventional tillage (1.52). Break-even usage of mechanical rice transplanter was about 6.5 ha/yr irrespective of tillage method.

Conclusions

The mechanical rice transplanter Model DP480 was suitable to operate in both puddled and un-puddled conditions. However, the rice transplanter showed better performance under both strip tillage and zero tillage systems. Rice production under un-puddled strip tillage significantly increased BCR relative to conventional practices. The mechanical transplanter has promise as a means of decreasing labour for rice establishment even under minimum tillage and unpuddled transplanting of rice.

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Residue Handling Capacity of the Versatile Multi-crop Planter for Two-wheel Tractors

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Introduction

Crop residue retention is one of the core principles of conservation agriculture (CA). However, the level of retention and residue handling characteristics depend on household use of residue, crop type, residue type (loose or anchored), freshness (or weathering status), water content in residue, soil type, soil water content in the field, type of implements used to sow the next crop, disease of previous crops, height of residue, etc. Over the last decade, innovations made to a wide range of 2-wheel tractor (2WT) seeding implements now permit reliable seeding into minimally disturbed soil and moderate levels of crop residue. This provides a window of opportunity to develop CA cropping systems for small holder farmers in Asia and Africa, not only in terms of reduced soil disturbance but also with respect to biomass cover and crop rotation. The Versatile Multi-crop Planter (VMP) was designed as multi-functional and multi-crop 2WT-based planter for smallholders with capability for seed and fertilizer application in variable row spacing (Haque et al., 2011) but its capacity for residue handling using single-pass shallow-tillage (SPST), strip tillage (ST), zero tillage (ZT), bed planting (BP), and conventional tillage (CT) has not been systematically tested.

Materials and Methods

Since 2010, a total of seven VMPs were used to establish >4,000 on-farm and on-station trials and demonstration plots into various crop residue types and retention levels in different parts of Bangladesh. The soil moisture levels of the plots, where measured, ranged from 15 to 41 %. Data on tillage type used, residue type and height, and ease of operation were collected from 2,157 on-farm trials and farmers' demonstration plots where each year the VMPs were used to establish many crops (Table 1). The plot size was ranged from 112 to 1333 m^2. On-farm data were collected using structured questionnaires and 12 focus group discussions with farmers and service providers of VMP; on-station data were collected and analysed by Excel.

Results and Discussion

When crop residue accumulates on the rotary shaft and/or the furrow openers this lengthens the sowing operation due to the time required to clear the machine and there are also problems with seed and fertiliser placement which may affect crop establishment. Each tillage type available with the VMP has varying capacity to cope with the volume and height of residue retained from the previous crop.

Strip Tillage (ST): In total 1062 trials were conducted with various residue retention levels. In case of ST with sharp and straight rotary blades that aligned with furrow openers minimal residue accumulation occurred on the rotary shaft or furrow openers if the height of anchored residue was < 60 cm. (equivalent to 5.5 t of rice or wheat residue per ha). If loose and > 40 cm high, rice and wheat residue (up to 4.5 t/ha) accumulated on the rotary shaft and furrow openers especially if the residue was fresh and wet.

Bed Planting (BP): Out of 2,002 trials that retained rice, wheat, and mungbean residue (Table 2), only 16 trials used two tillage passes for forming and/or reshaping beds and planting crops in various levels of retained residue. In case of BP, 20 cm of any type of residue accumulated on furrow openers and needed to be cleaned by an operator quite often. Higher amounts of residue retention and multiple tillage passes enhanced the residue accumulation on the rotary shaft and furrow openers, which was severe if loose and fresh residue was retained in the field.

Zero Tillage (ZT): Residue accumulation on furrow openers was observed if the height of residue was>20 cm; and was more severe with greater amounts of loose residue and tall anchored residue. Higher residue accumulation with furrow openers was observed even with very low retention (<0.4 t/ha) when the retained loose rice or wheat residue was >10 cm long.

Conventional Tillage (CT): Higher residue accumulation on the rotary shaft was observed when the retained anchored residue (Table 2) height was > 30 cm (equivalent to 3.37 t/ha) with 3-4 tillage passes to prepare land. Higher residue accumulation on the rotary shaft was observed even at very minimal retention (<0.4 t/ha) when the retained loose residue (Table 2) was > 30 cm long.

Table 1. Crop-wise residue retention and performance evaluation of VMP under different tillages options for sowing (n=includes the total number of on-farm trials plus farmers' demonstration plots).

Crop species	Tillage type				Total	% of total
	ST (n)	BP (n)	ZT (n)	CT (n)		
Rice	511	64	8	321	904	41.9
Wheat	232	20	-	203	455	21.1
Chickpea	27	13	-	8	48	2.2
Jute	66	24	12	159	261	12.1
Lentil	86	20	8	68	182	8.4
Maize	66	-	-	62	128	5.9
Mungbean	87	20	-	20	127	5.9
Mustard	26	4	-	22	52	2.4
Total:	1101	165	28	863	2157	100

Table 2. Height and weight of retained residue of rice, wheat, and mungbean into which following crops were sown using VMP under various tillage systems.

Crop and height (cm) of retained residue	Residue retained (mean of all (n) determinations)							
	Strip Tillage (ST)		Bed Planting (BP)		Zero Tillage (ZT)		Conven. Tillage (CT)	
	n	t/ha	n	t/ha	n	t/ha	n	t/ha
Rice, >50	27	4.8	27	4.4	27	4.5	27	4.6
Rice, 20- 50	267	3.1	20	3.1	8	2.8	253	3.2
Rice, <20	414	1.5	21	1.5	8	2.5	322	1.5
Wheat,>40	342	2.9	28	2.8	8	2.3	167	2.7
Mungbean,>30	12	2.8	12	2.8	-	-	12	2.8
Total:	1062	-	108	-	51	-	781	

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Mechanised Dry Direct Seeding of Rice: a Cambodian Development

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Introduction

Rice accounts for over 80 % of Cambodia's cropping area with 75 % being rainfed and grown in the monsoon. Cambodia is witnessing a shift away from traditional transplanting to direct seeding of rice using manual broadcasting techniques, due to increasing labour shortage. Seed broadcasting is easy to implement, requiring low labour for fast crop establishment. However, limitations include high seed rate, high losses to predation, often poor and staggered crop establishment and high weed burden. Cambodian agriculture is also undergoing a significant mechanisation shift, with a rapidly increasing adoption of 2 wheel tractors (2WT) used for land preparation and transportation.

Materials and Methods

The concept of a simple drill implement adapted to the expanding 2WT power source was adopted to improve crop establishment quality with direct seeding, anticipating potential benefits as follows:
• Accurate seed placement at optimum depth to maximise field establishment rate
• Row seeding to facilitate mechanical/manual weeding
• Limited or no predation risks or lodging relative to surface established crops
• Time and cost saving when used under zero-tillage to direct sow into unprepared land
• Possibility of establishing rice in stored moisture under rainfed systems
• Opportunity to place fertiliser in the seed row for better nutrient use efficiency
The role of mechanized seeding with accurate seed placement in cultivated soils is critical to minimizing the input cost of quality seeds, and is seen as the first adoption step in Cambodian lowland towards reduced tillage and no-tillage rice crop establishment. Imported drills (e.g. Australian *Rogro* tine & press wheel, *Thai* disc, Chinese rotary till *2BFG-100*) were first evaluated for their suitability to Cambodian conditions. A specific challenge for sowing rice is the ability to maintain a shallow seeding depth (1-2cm) under typically uneven and poorly prepared paddy field conditions, which has clear repercussions on operating depth gauging. The following describes the process of adaptive field research, highlighting a range of limitations on field performance, ergonomics and practicality aspects:
- Any significant drill weight overhang requires substantial front ballast (60-80kg) to improve manoeuvrability. In poorly levelled land conditions as well as during ditch crossing, a heavy 2WT+drill combination, even well balanced, results in highly fluctuating reactions at the handle bar during manoeuvring, increasing operator risk and fatigue.
- A rigid mounting of the drill to a 2WT limits steerability at work unless the drill is lifted out of the ground, which implies higher work burden.
- The need for small modifications to existing 2WT for hitching a new drill implement creates limitations to drill sharing across users
- The need for tools to adjust the drill in the field hinders the use of optimum drill settings by the operator

- A centralised hopper fitted above the handle bars significantly reduces the operator field of vision, impairing the capacity to consistently sow straight and makes refilling more cumbersome for shorter operators.
- Tine openers are prone to seed boot outlet blockage in wet conditions especially with poorly trained or careless operators, while seed outflow can be impaired when seeding in seedbeds dirty with weed residue. Design solutions are a trade-off with seed placement accuracy.
- The power-take-off operated rotary till drill specific to Chinese DF tractors, implies higher adoption and operating costs for mechanised seeding in the Cambodian context, currently dominated by Thai made 2WT, and increases tillage intensity. Effective strip-till modifications are required to make the technology more attractive in a CA context.

Results and Discussion

The following specifications were then finalised for the development of a locally adapted Cambodian seeder solution (see Fig. 1):

Fig. 1: Cambodian RAEM drill

1. 'Trailer-like' pulled and self-contained seeder unit with a simple 'pin and go' hitching process suitable for any 2WT available on-farm.
2. Simple to operate drill, with a base model affordability target at US$500.
3. Seed-only hopper in full view of the operator and with unhindered vision forward, including seed funnelling shallow partitions, and adjustable fluted roller seed metering system.
4. Two side depth-gauging wheels, placed near the row of openers and with spanner-less adjustment for seeding depth and work/transport change-over.
5. Four disc openers set at 20-25cm row spacing with adjustable furrow closers (option for six disc openers set at 15cm row spacing for dry and early wet season rice).
6. Independent and contour following star-wheel ground drive,attached to the drill only, and with on/off clutch positions activated manually from the tractor handle bar

The seeder design solutions, field evaluation and promotion were led by agricultural engineers while manufacturing solutions were optimised by the local workshop. A process of participatory co-learning was applied in fine-tuning performance, manufacturing quality and design specifications. Joint field activities enabled the manufacturer to also assess farmer interest and experience first-hand the field handling issues.The Cambodian drill is 97% made locally with only the metering units imported from China, retails at US$650 and weighs around 110kg. The simplicity of the drill design as a trailed unit is an operator friendly feature helping to facilitate gender mainstreaming of mechanised direct seeding technology, by requiring little or no lifting during a specific field seeding operation. The metering system can also handle a range of seed sizes for dry season rotation crops such as mung bean and maize. The RAEM drill has been tested in cultivated sandy, sandy-loam and clay-loam soils, as well as soft zero-till sandy soils (10-12% of the rice area), with rice establishment being most reliable with good follow-up rainfall and/or with irrigation, achieving similar field establishment rate and grain yield to existing commercial drills. Limitations to date have included poor disc opener penetration in compact soil conditions (resulting in shallow or surface seed placement), soil build up and blockages in excessively sticky soil conditions, and uneven crop establishment in rainfed systems with unreliable follow-up rainfall. A version with tine openers is being evaluated for use in harder soil conditions, a press wheel option for more reliable rice establishment in rainfed systems and a double hopper for combined seed-fertiliser application are being planned. Early signs of adoption interest are being witnessed following a number of field demonstrations to date.

Acknowledgements

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Optimising the furrow cutting process in rotary strip-tillage

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Introduction

Efforts to develop strip-tillage drills for two-wheeled tractors have often used conventional bent rotary blades designed for full disturbance soil tillage. These conventional blades have lengthwise and sidelong sections which cut, carry and throw soil during tilling and help pulverise the soil. However, in strip-tillage the blades result in unwanted soil scattering out of the tilled furrow (leading to a poor furrow backfill[1] which is insufficient to cover seeds) and high power requirement. An improved understanding of the rotary strip-till furrow cutting process would help design blades to produce a desired soil cutting and throwing effect for an improved seedbed and reduce power requirements. This study investigated the furrow cutting process and the outcomes as affected by blade geometry and rotary speed with the aim of optimising into an efficient strip-tilling process.

Materials and Methods

The conventional rotary blades (43 mm wide, 56° bent) were modified to reduce their width to about half (22 mm wide, 22° bent) or straightened (7 mm wide) and were fitted to an experimental rotary tilling unit (detail presented by Matin et al. 2014). Tests in a reconstituted sandy loam soil used 4 blades per furrow set for a cutting width and depth of 50 mm. The progression of soil cutting and throwing at 125–500 rpm rotary speed (forward travel speed of 0.7 m s^{-1}) was recorded using a high speed camera at 1000 frames s^{-1}. The furrow backfill was measured as the percentage of the original soil remained in the tilled furrow. Tilth quality of the backfilled soil was expressed as the ratio of soil breakage (RSB) and measured as the percentage (by weight) of the clods 20 mm or longer. An in-line torque transducer was used to measure the peak and average power requirements.

Results and Discussions

Soil cutting and throwing process

Analysis of the high speed video images revealed that the soil cutting and throwing process varied greatly, depending on the blade geometry. Increasing the rotary speed generally increased the soil scattering and thus reduced the furrow backfill for all the blades.

The conventional blade bent and twisted the soil slice cut in each bite (Fig. 1) and showed the highest soil fracture ability during its entry into the soil and the strongest soil throwing ability from the soil entrainment by its sidelong section. The cut soil was thrown laterally and backward and also carried over (a small proportion) to the front of the rotor. Thus, the blade left the least amount of soil in the furrow as backfill (Fig. 2) required for covering seeds.

In contrast, the half-width blade developed a few soil cracks during its entry into the soil and pushed off the cut soil slices toward the opposite furrow edge whereby some soil was lost out of the furrow. Although there was a minor bending and twisting of the cut soil slice, the blade achieved a soil tilth similar to the conventional blade mainly due to: i) cutting the thinnest soil slice in each bite (Fig. 1) which broke easily, and ii) movement of the cut soil slice

[1] Furrow backfill is the amount of the original soil remained in the tilled furrow after a tillage operation

toward the opposite furrow edge where it was re-cut and broken further into finer clods by the following blade. There was a considerable lateral soil throw during the blade exit out of the furrow from the more open orientation of the sidelong section. However, due to a shorter sidelong section there was virtually no soil lifting or carrying over.

Having no sidelong section, the straight blade produced some effective soil cutting action which created a fine tilth without significant soil throw. Entry of the tip of the blade into the soil created few cracks pushing the cut soil slice toward the opposite edge of the furrow. An important observation was that the laterally-thrown soil was blocked by the following blades and guided inward to the furrow. This blocking helped increase the backfill and improved the soil tilth through a process of cumulative clod fracturing. No soil lifting and minor lateral soil throw was observed during the blade exit out of the furrow. Therefore, the straight blade produced a desirable soil cutting action which involved cutting, re-cutting and re-directing clods, with a minor lateral and backward soil throwing.

Peak and average power requirements
Irrespective of the rotary speed, the peak power was at least twice the average power for all the blades. The straight blade required 17–22% lesser peak power (Fig. 3) and 8–25% lesser average power (Fig. 4) compared to the conventional or half-width blades at 375–500 rpm. This would be due to the low amount of soil throw (as indicated by high amount of backfill, see Fig. 2) by the straight blade even at the high rotary speeds, compared to the other blades.

Generally, the peak and average power requirements increased with the rotary speed (Fig. 3 and 4). However, they remained almost unchanged for the increase of the rotary speed from 250 rpm (40 mm bite) to 375 rpm (27 mm bite) for all the blades indicating the advantage of using a medium rotary speed between 250–375 rpm for an increased effectiveness of the rotary strip-tillage systems. However, this speed may vary depending on the actual field conditions (soil strength, soil moisture, residues, etc.) and would require field investigations.

Extrapolation of the results for a 9 kW two-wheeled tractor-operated six-row seed drill fitted with the conventional and the straight blades shows that the peak engine power requirement at 500 rpm rotary speed would be 13.7 and 11.4 kW, respectively (assuming 82% overall power transmission efficiency as per Beeny and Greig, 1965). This will occasionally overload the engine at 33.3 Hz. The study recommends the use of straight blades and suggests the blades be distributed onto the rotor so that no more than three blades cut the soil at one time.

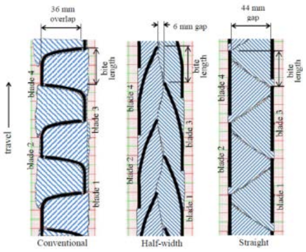

Figure 1. Patterns of soil cutting at 250 rpm

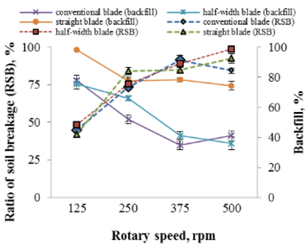

Figure 2. Furrow backfill and soil tilth

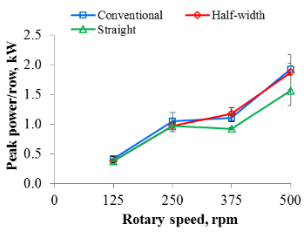

Figure 3. Peak power requirement

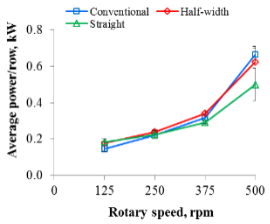

Figure 4. Average power requirement

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Evaluation of Two Wheel Tractor Operated Seed Drill (Gongli Africa) in Arusha, Tanzania

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Introduction

Two wheel tractors (2WTs) have played a very important role in agricultural production in many Asian countries. They have increased cropping intensity, yields and saved costs of ploughing operations in Asian countries including Nepal (Dhakal et al., 2001) and India (Singh, 2002). Two WTs have different uses including haulage, disc ploughing, disc harrowing, mould board ploughing, rotary tillage and direct seeding. With attachments, they can also be used for boom spraying and crop harvesting. In stationary state, 2WTs can be used to run water pumps and maize shellers. In summary, 2WT as a source of farm power can be used to perform different field operations depending on the need and innovations by different stakeholders (Mwinama, 2013).

While the 2WTs have been highly adopted in most Asian countries, the situation is not so for African countries. The reason may be the notion in Africa that the only potential operation for such machines is ploughing. For example, there are increasing numbers of 2WTs in Tanzania most of which are only used for rotary tillage in rice fields (Lyimo, 2011).

The Gongli Africa direct seeder (GADS) is used for direct seeding in conservation agriculture (CA). It was developed as a collaboration among Australia, Kenya and Tanzania under the Farm Power and Conservation Agriculture for Sustainable Intensification (FACASI), Project. GADS can be attached to a 2WT during direct seeding and detached when the 2WT is used for other operations. The main objective of this study was to evaluate the performance of GADS in planting maize in silt soils as compared to manual planting (MP) which in the indigenous method of planting in Tanzania.

Materials and Method

The study was conducted in the VETA area situated in Njiro Arusha district. The total area used for maize placement was four acres of silt soil. This area was divided into 12 small plots from which data for different parameters were averaged. The GADS prototype was operated by a 16 hp Greaves power tiller. In GADS performance evaluation the parameters involved were manpower requirement, work rate, seed placement depths, plant population, cost of operation and operation technical challenges. The GADS performance evaluation was based on Regional Network for Agricultural Machinery (RNAM) procedures of the Economic and Social Commission for Asia and the Pacific (RNAM, 1983). These are the standards adopted by CAMARTEC which has statutory rights to test agricultural machineries and equipment in Tanzania.

Based on the efficiency of its functional parts and comfort in operating the machine, gear 3 low was used. Seed placement was done when the soil was dry. The maize variety was SC-525 which is among the high yielding varieties preferred in Arusha.

Results and Discussion

Comparisons made in the study to evaluate performance of GADS included manpower requirement (man-hours/acre), work rate (acres/hr), seed placement depth (cm), plant population (plants per acre), and cost of operation. With GADS direct seeding average values of manpower requirement, work rate, seeding depth, plant population, and cost of operation were 6.04 man-h/acre, 0.331 acre/h, 4.7 cm, 25,400 plants per acre and 14.19 USD, respectively. In hand planting, the average values of manpower requirement, work rate, seeding depth, plant population, and cost of operation were 16 man-h/acre, 0.0625 acre/h, 7.2 cm, 22,100 plants per acre and 21.21 USD respectively (Table 1). The results clearly show that the use of GADS is preferable as it costs 60-70% of the manual operation in only 20% of the time for manual operation.

Table 1. Performance evaluation results of Gongli Africa direct seeding as compared to manual seed placement

Parameter	Average		
	GADS seed placement	MP seed placement	% (MP/GADS)
Speed of operation (m/s)	0.519	N/A	N/A
Speed of operation (km/h)	1.868	N/A	N/A
Work rate (acre/hr)	0.331	0.0625	18.9
Work rate (ha/hr)	0.134	0.0253	18.9
Fuel consumption (L/hr)	0.696	N/A	N/A
Fuel consumption (L/acre)	2.10	N/A	N/A
Fuel consumption (L/ha)	5.19	N/A	N/A
Theoretical field capacity (acre/hr)	0.415	N/A	N/A
Theoretical field capacity (ha/hr)	0.168	N/A	N/A
Field efficiency (%)	79.7	N/A	N/A
Depth of operation (cm)	4.7	7.2	N/A
Plants population (plants per acre)	25,400	22,100	87
Cost of operation (USD)	14.19	21.21	150

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Furrow Openers Design can Improve Seed Placement and Emergence in Strip Tillage

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Introduction

Strip tillage is a form of minimum tillage used in conservation agriculture (CA) systems. With strip tillage, sowing lines are cultivated while the inter-row space is left undisturbed (Licht and Al-Kaisi, 2005). Appropriate seeding machinery has crucial importance to improve crop performance for CA adopters. The Bangladesh Agricultural Research Institute (BARI) has developed two wheel tractor (2WT) operated seeder modified as strip till seeding mechanism by introducing the soil cutting blades in front of the seeding line, and inclined plate seed metering devices with fertilizing attachment and press wheels behind the seeding line to ensure the furrow is well closed and soil contact with seed is suitable for germination (Hossain et al., 2012). Furrow openers are also a key component to ensure proper seed soil contact as well as maintain proper seed depth. The regular furrow opener supplied with Power Tiller Operated Seeded (PTOS) is shoe type. Shoe-type openers have the disadvantage of a higher rate of soil moisture loss due to greater soil disturbance. The type of furrow opener used varies with soil and operating conditions (Chaudhuri, 2001). Research on performance of different types of furrow opener for 2WT-operated seeder is scarce in Bangladesh. This experiment thus evaluates strip tillage performance for different furrow geometries, and assesses which combination ensures the best seed placement.

Materials and Methods

The experiment was conducted in farmer's fields of Babugang, Barisal and Regional Agricultural Research Station (RARS), BARI, Jamalpur in April 2014. T-inverted furrow openers were designed and fabricated at Farm Machinery and Postharvest Process Engineering division, BARI, Gazipur for 2WT with different rake angles. Maize seed (variety NK40) was sown in 10 × 7.2 m plots with 25 cm anchored rice residue. Line to line distance and seed to seed distance for maize planting were 60 and 20 cm respectively. At least five days before planting, 1 kg active ingredient of glyphosate ha^{-1} was applied in 320–400 L ha^{-1} of water with a three-nozzle flat-fan spray boom. A PTOS fitted with an inclined plate seed metering device and fluted roller fertilizer metering system was used for sowing maize seed in strip tillage with five different geometries of the furrow openers. Treatments (T) were: T_1= Shoe type furrow opener which is generally supplied with Chinese PTOS and usually seed is placed by air drop under full tillage; T_2= Modified shoe type furrow opener which is generally supplied with inclined plate planter designed from Wheat Research Center (WRC), BARI; T_3=T-inverted furrow opener with 55° rake angle; T_4= T-inverted furrow opener with 65° rake angle and T_5= T-inverted furrow opener with 75° rake angle. A randomized complete block design with three replications was used. The PTOS was operated with modified blade design with 15° tip angle and 480 rpm of rotary shaft. 60 cm line-to-line and 20 cm plant-to plant spacing were maintained. Observations of emergence were taken every two days from sowing onwards from a 2 m long strip per plot. Data for mean emergence time (*MET*), emergence rate index (*ERI*), and seedling emergence degree (*PE*) were calculated by using the equations given in Bilbro and Wanjura (1982): where *MET* is mean emergence time (day); *ERI* is emergence rate index, seedlings/day-m; *PE* is percentage of emergence (%); $N_1 \ldots n$ is number of seedlings emerging since the time of previous count; $T_1 \ldots n$ is number of days after the sowing; *Ste* is number of total emerged seedlings per meter and *n* is number of seeds sown per meter. Data were analyzed using CROPSTAT statistical program.

Results and Discussion

All design of T-inverted furrow openers (Table 1) performed better than the existing Chinese or WRC made furrow opener in case of planting maize seed with the inclined plate planter (Fig. 1). Shoe type (T_1) and modified shoe type (T_2) furrow openers were unable to place all the seeds beneath the tilled soil of strip. 53% and 58% of maize seeds were not placed in the furrow but rather bounced onto the soil surface during planting by the shoe type furrow opener both at Barisal and Jamalpur, respectively. Placement of seed into the furrow slot was at least 20% improved by the modified shoe furrow opener even though more than 30% seeds were not covered with soil in both locations. Conversely, there was no significant variation among the T-inverted furrow openers in seeding performance and subsequent seed emergence, indicating their superiority over the shoe-type opener for strip tillage. Further work needs to be conducted to isolate the effect of the inverted-T design from seeding depth by manipulating shank length on all the openers.

Table 1. Pictorial and dimensional outline of different furrow openers

	T_1	T_2	T_3	T_4	T_5
Figure					
Dimensions, (L×H×W) mm	105×178×35	110×210×60	180×350×25	180×350×25	180×350×25

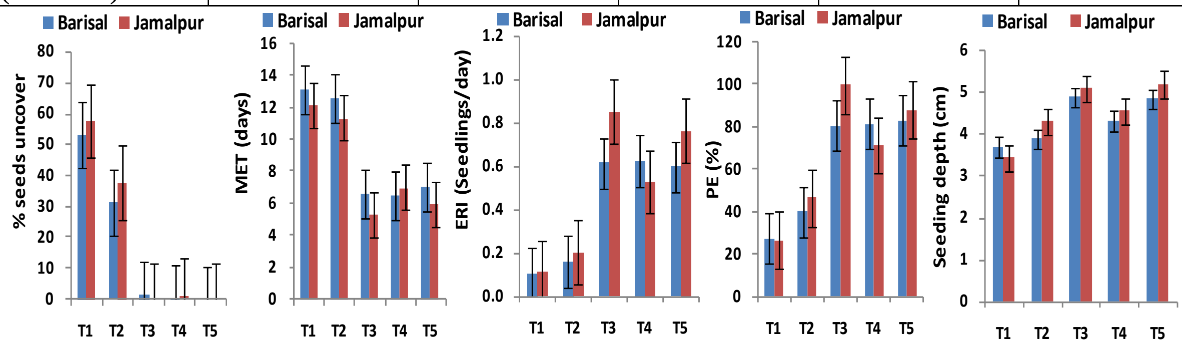

Figure 1. Percentage seeds uncover, mean emergence time (MET), emergence rate index (ERI), seeding emergence degree (PE) and seeding depth for different furrow openers.

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Application of a Slack-based DEA Model for Benchmarking Energy Inputs Use Efficiency of Selected Conservation Tillage Technology Options

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Introduction

The share of energy input costs in agriculture varies widely by crop and region. Energy costs are one of the more rapid growing cost components of rice-wheat systems of Bangladesh (Mottaleb and Mohanty, 2014). The efficient use of energy inputs and resource conserving tillage in rice-wheat systems is increasingly important in terms of both economic productivity and environmental concerns. Alternative technologies that improve the energy inputs use efficiency, productivity, and profitability of rice-wheat farming systems may very well contribute to poverty reduction in Bangladesh. Conservation agriculture (CA) and associated conservation tillage (CT) practices could thus be of potential benefit to myriad farmers seeking alternative practices to enhance profitability through increased energy input efficiency. Since studies on on-farm energy inputs use efficiency in rice-wheat systems are scarce compared to those coming from researcher-controlled, on-station environments, this research analyzes the energy inputs use efficiency of three CT options, plus a control group under traditional tillage (TT), based on data collected from actual farm households and under farmers' own management practices. In addition, a non-parametric *benchmarking* technique is subsequently applied to compute the wasteful quantities of energy inputs.

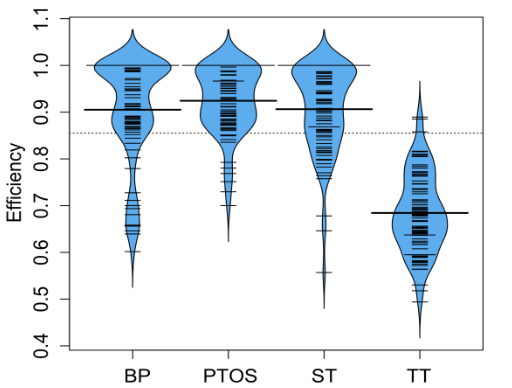
Methodology

Data were collected during 2012 from 328 farm households (HHs) in three districts (Dinajpur, Rajshahi, and Nilphamari) in northwest Bangladesh, as part of the Cereal Systems Initiative for South Asia (CSISA) project. Farm HHs were selected randomly for three CT types (n=82 for each): strip tillage (ST), as an explicit CA practice; bed planting (BP); and power tiller operated seeder (PTOS). In addition, 82 TT farmers (i.e. non-adopters) were also selected as a control group. Although both TT and CT farmers used two-wheel operated tractor, the present study confined CT description to a reduction in frequency of tillage passes in conjunction with the usage of direct seeding equipment. A non-parametric input-oriented *Slack-based* ***Data Envelopment Analysis*** (S-DEA) was employed, using an input-output model (Tone, 2001; Bogetoft and Otto, 2011), to estimate the "*slack*" (wasteful quantities of energy inputs applied) of individual energy inputs (NPK fertilizers, pest control, fossil fuel, irrigation water, labor, and seeds) within the technology options available at the observed level of outputs (grain and straw yield). Data envelopment analysis (DEA) is widely used in agricultural research and the S-DEA is a modification, which is able to deal directly with the input excesses and the output gaps of the farms under evaluation. The underlying technical, institutional, and selected socioeconomic factors determining energy input use efficiency were also analyzed using a Tobit model.

Results

The technical efficiency (TE) estimates presented in the '*bean density*' plots (Figure 1) clearly show higher energy inputs use efficiency of the CT technologies. The *adapted*-Li test (not shown) indicates significant differences between the energy inputs use efficiency of the CT options and TT, rejecting the equality of distributions of adopters and non-adopters across efficiency ranges (Li, 1996). PTOS achieved the highest energy inputs efficiency score (0.92), followed closely by BP and ST (both equal 0.91), whereas TT lags well behind (0.68). The average estimates from the S-DEA suggest opportunities for significant energy input reduction for the CT options, as well as TT. For example, Table 1 presents the possible reduction in energy input use through benchmarking for ST (the representative CA option) and for TT. It is interesting to note that the efficient use of inputs for TT is not on par with those of ST; because of its inherent resource saving principles, wheat farmers employing ST operate at a higher efficiency frontier than TT farmers.

Figure 1. Energy input use efficiencies of RCTs, ST and TT



Perhaps most importantly from the perspective of the farmers, the benchmarking allows on average, a 7.4%, 7.6% , 8.7% and 12.9% decrease in energy input costs in case of BP, PTOS, ST, and TT, respectively (Figures 2 and 3).

Figure 2. Cost of energy inputs before benchmarking

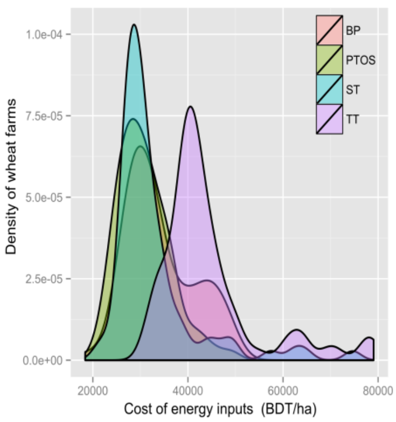


Figure 3. Cost of energy inputs after benchmarking

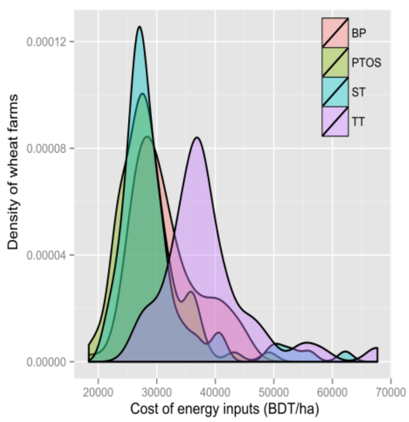


Table 1. Energy input use benchmarking of CA [ST] and TT through technical efficiency improvements

Energy inputs	Unit	ST (n=82)		TT (n=82)	
		Actual use	Eff. use	Actual use	Eff. use
Human labour	psd/ha	57.55 (31.74)	54.97 (29.47)	83.20 (45.40)	71.94 (24.00)
Diesel fuel	litres/ha	44.53 (11.68)	40.06 (9.61)	57.51 (10.04)	48.22 (11.80)
Nitrogen (N)	Kg/ha	111.3 (32.90)	97.75 (24.83)	141.5 (40.90)	124.0 (20.99)
Phosphorous (P_2O5)	Kg/ha	44.66 (20.19)	40.54 (15.85)	78.85 (29.58)	66.23 (14.21)
Potassium (K_2O)	Kg/ha	70.09 (27.33)	60.35 (20.66)	70.09 (30.81)	64.46 (25.15)
Pesticides	Kg/ha	1.88 (1.72)	1.05 (0.91)	2.70 (2.56)	1.38 (1.16)
Irrigation water	M^3/ha	2,493 (988.2)	2,346 (853.0)	3,770 (797.2)	3,627 (609.8)
Seed (wheat)	Kg/ha	128.9 (31.55)	126.4 (22.29)	168.5 (28.79)	161.7 (24.31)

Note: mean values are shown, with standard deviations inside parentheses.

The Tobit results indicate that education, training, experience in CT, and the split application of nitrogen positively affect energy input use efficiency, while the delayed application of fertilizers and the frequency of advice received from input dealers negatively affect energy inputs use and efficiency (Table 2). Private agro-input dealers are sought after more often for advice than extension; they are likely to be biased towards intensive input use and therefore are not a reliable source of information. This study clearly demonstrates the superiority of conservation tillage in terms of input use efficiency; it also highlights the importance of educating farmers regarding efficient input management (in particular for nitrogen) in order to achieve more optimal and profitable cropping systems.

Table 2. Tobit model estimates: determinants of energy input use efficiency

Variable	Estimate	Pr (> t)[1]
Cultivable land owned (ha)	0.00 (0.00)	0.34
Distance to the main road (kms)	0.01 (0.01)	0.45
Distance to the CA hub (kms)	0.00 (0.00)	0.07
Education (years)	0.01*** (0.00)	0.00
Age (years)	0.00 (0.00)	0.74
Frequency of advice received from input dealer (nos.)	-0.03*** (0.00)	0.00
Training (nos.)	0.02** (0.00)	0.00
Experience in CA (nos.)	0.01*** (0.00)	0.00
Access to credit (dummy)	0.00 (0.01)	0.65
Involvement in farming (ordered: 1,2,3)	-0.02* (0.01)	0.03
Household size (nos.)	0.00 (0.00)	0.73
Off-farm income (%)	0.00 (0.00)	0.09
Livestock owned (nos.)	0.00 (0.00)	0.21
Awareness on soil and water conservation (dummy)	-0.01 (0.01)	0.37
Split application of nitrogen (dummy)	0.06*** (0.01)	0.00
Distance to the market (kms)	0.00 (0.00)	0.57
Application of nitrogen before irrigation (dummy)	0.01 (0.01)	0.40
Delay in nitrogen application at crown root stage (dummy)	-0.04** (0.01)	0.01

[1]p-value [Pr (>t)]: probability of obtaining a test statistic < 0.05 denotes the significant effect of the exogenous variable on TE.

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Cost Effective Small No-till Seeder for Two Wheel Tractor in Bangladesh

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Introduction

Conservation agriculture (CA) based two wheel tractor (2WT) operated seeding implements are becoming popular among farmers. About 700,000 2WT are operating in Bangladesh. In Bangladesh, no-till seeder of 2WT was first developed in WRC, BARI with FAO-CIMMYT supported programme (2003-04). This seeder had no press wheel and limitation to bold size seeds sowing. The no-till seeder was improved with ACIAR support with the introduction of lighter weight toolbar frame, press wheel attachment, seed and fertilizer box fixing over the handle bar of a tractor for free flow of seeds to ground (Hossain et al., 2009). This seeder performed better through crop residue but operators were still not satisfied due to the height of seed box which blocked the forward view of the field being seeded. Therefore, a user-friendly, small 2WT no till seeder was developed capable of handling most seeds and managing residue properly.

Materials and methods

Two wheel tractor operated no-till seeder is a pull type seeder and it has been developed in BARI Rajshahi. The major components and specifications are shown in Table 1. All accessories were set up under the handle bar of the tractor. Field performance and adaptive trials were conducted in the farmers' fields by attaching a 12Hp Chinese Dongfeng 2WT in North West drought prone area during 2011-14 for wheat, mungbean, chickpea, maize and rice establishment (Fig.1).

Figure 1. 2WT operated no till seeder

Table 1. Specification of 2WT operated no-till seeder and accessories

S.N.	Items of no-till seeder	Specification	Remarks
1	Power	12-16 Hp, 2WT; one operator	Dongfeng type
2	Hitch plate	120 x 150 mm; Steel plate	Clump and lock pin used
3	Toolbar frame	800 x 1120 mm; 3 bar; 50mm Sq stainless steel	Middle bar position adjustable
4	Seed & fertilizer box	800x330 mm; 22 gauge steel plate	
5	Seed meter mechanism	170 mm, Inclined plate, variable cell size	Plate adjustable 30-60^o position
6	Furrow opener	510x70x10mm"T" type; Steel	Using used car leaf spring
7	Press wheel	250-50 mm; rubber coated	Seeding row adjustable
8	Power transmission	Chain No. 428 with different size sprocket	Power from wheel axel
9	Depth control bar	460 x 10 mm steel bar	
10	Over all dimension	2460x1120x1200 mm weight; 115 kg (without engine)	Turning 1.5 m space

Field performances of the seeder were recorded as per Regional Network of Agricultural Machinery (RNAM) Test Code. Cost was calculated according to the farm machinery utilization method (Hunt, 1995).

Results and Discussion

Field performance of the no-till seeder for wheat, maize, mungbean, chickpea establishment in several farmers' field indicated that crops can be established immediately after rice harvest using residual soil moisture. There was enough ground clearance (45 cm) between soil surface and toolbar frame. Furrow opener layout facilitated crop residue passage without blockage. Row positions can be adjusted sliding the clamp of tynes on the toolbar frame. Effective field capacity of the seeder was 0.12 ha/hr. Seeding with 4 tynes was more appropriate for soft to medium hard soil and 3 tynes for hard soils. The inclined plate seed metering device performed satisfactorily with small to large seeds (Table 2).

The seeder was tested in a wheat-mungbean-rice crop rotation lasting 4 years at Rajshahi where the soil type is dominantly silty clay loam. Rice was seeded directly in unploughed/unpuddled soil. There were no significant yield variations between no-till and conventional method (Table 3). Weed management in no-till rice cultivation is still challenging to convince traditional rice farmers.

Table 2. Crop establishment by no-till seeder

Parameter	Wheat	Maize	Mungbean	Chickpea
Variety	Prodip	NK 40	BARI Mug-6	BARI Sola 9
Seed rate (kg/ha)	120	20	23	35
Row to row spacing (cm)	20	60	30	40
Average seed to seed distance (cm)	1	20	5	8-10
Number of row per pass	4	2	3	3
Depth of planting (cm)	4	5	4	5
Plant population (m^2)	198	9	34	32
Width of soil opening slits (cm)	2-3	2.5-3	2-3	3
Planting uniformity (%)	85	95	88	94

Table 3. Comparison of yield (t/ha) between no till and conventional planting method

Year	Wheat		Mungbean		Rice		Maize		Chickpea	
	No till	Conv.	No till	Conv.	No till	Conv.	No till	Conv.	No till	Conv.
2011	3.6	3.3	0.9	0.8	3.4	3.5	8.3	8.7	-	-
2012	3.7	3.3	1.0	0.8	3.5	3.7	8.2	8.4	1.8	1.2
2013	3.7	3.4	1.1	0.9	3.63	3.6	8.6	8.7	2.1	1.2
2014	3.9	3.5	1.2	0.9	3.72	4.0	8.8	8.9	1.7	1.1
LSD (0.05)	0.12	0.11	0.11	0.12	0.119	0.11	0.26	0.23	0.23	0.19

Planting cost and break-even point used for no-till seeder was calculated on the basis of fixed cost and variable cost. There were significant cost differences between no-till and conventional practice (Table 4). Break-even point of no till seeder was 4.0 ha.

Table 4. Comparison of cost of planting by no-till and conventional system

Sl No.	Planting system	Cost of planting (Tk./ha)				
		Wheat	Mungbean	Maize	Chickpea	Rice
1	No till seeder	2175	2175	1975	2175	2175
2	Conventional method	5437 **	5437 **	14500 **	5437 **	8675 **

1 US$= Tk.78.0 ** indicates highly significant at 1% level

The 2WT (9Kw) no-till seeder can pull 4 tynes in soft to medium hard soil but 3 tynes in hard soil and it was capable of seeding through heavy rice and wheat residue (1.5 - 2.4 t/ha) without blockages as there are sufficient clearance between toolbar frame and ground surface. The seeder is low cost (US$ 350-400; without power unit), light in weight and local manufacturer can fabricate complete set of no-till seeder within a short period of time. The no-till seeder can be used in other Asian countries where the 2WT is the common farming equipment.

Acknowledgments

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Session 2

POSTERS

Impacts of Conservation Tillage Machinery on Service Provider's Livelihood: A Farm Level Study

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Introduction

Most tillage operations in Bangladesh are done by power tiller to lower cost and decrrease time required for cultivation (Islam, 2000; Miah, 2000; Barton, 2000; Miah et al., 2002; Haque et al., 2008). The traditional tillage method reduces soil organic carbon at double rate and decreases soil fertility (Grace, 2003), has losses of irrigation water and soils (Sayre and Hobbs, 2003), and damages the ecological environment (Grace, 2003). Therefore, the concept of conservation tillage has arisen all over the world which is new in Bangladesh. A power tiller operated seeder (PTOS) is a two wheel tractor operated seed drill, widely used for establishment of various crops. The sowing of seeds and laddering operations are completed simultaneously in a single pass using PTOS in many areas of Bangladesh. Most of the grain seeds like wheat, paddy, maize, jute, pulses, oilseeds etc are sown in line using PTOS. The owners of PTOS are using this device for their own land cultivation and earning cash income through custom hiring to other farmers. The custom hiring of PTOS is highly profitable at farm level (Miah et al. 2010) and many service providers could improve their livelihood through this machine. The socioeconomic impacts of this popular conservation tillage implement have not been done in the country. Therefore, the present study was conducted to explore the socio-economic profile of the PTOS service providers; to find out the usages pattern and problems of PTOS at service providers' level; and to determine the impacts of PTOS on the livelihoods of service providers.

Materials and methods

This study was conducted at four *Upazillas* namely Bochagonj, Fulbari and Dinajpur Sadar under Dinajpur district and Baliakandi under Rajbari district. The reason of this selection was that PTOS is being widely used in Dinajpur and Rajbari districts. A total of 53 service providers taking 47 persons from Rajbari and six persons from Dinajpur district were randomly selected for the study. Data and information were gathered from selected service providers of PTOS through administering household survey using pre-tested interview schedules during July, 2008. The impacts of PTOS on the livelihoods of service providers were assessed through analyzing *'Before'* and *'After'* socio-economic standings of the service providers.

Results and discussion

The study reveals that PTOS has made a tremendous improvement in the livelihoods of its service providers in the study areas. The average land holding has increased by 8.6%. Significant increase was registered in the value of calves (33%), goats (82%) and chickens (27%). The annual household income was significantly increased by 63.4% during post-ownership period. Both the quantity and value of farm equipment and household assets were significantly increased after having PTOS. Again, the number and value of *semi-pacca* building were significantly increased by 42% and 69% respectively during post-ownership period. On the contrary, the numbers of *Katcha-pacca* and *Katcha* houses decreased by 3.7% and 17.1% respectively. The amount of loan received during PTOS ownership period was about 50.5% higher than that of pre-ownership period. The increased income of beneficiaries are mostly spent on farm machinery, nutritious food, clothes, health care, education expenses and making of houses that indicate higher standard of living to some extent, compared to pre PTOS service period. The service providers encountered problems like higher fuel cost, lack of riding facility, non-availability and higher price of spare parts, roller jam, and lack of trained driver.

Due to higher adoption of PTOS, financial support and technical assistance should be made available by the government of Bangladesh for service providers and local manufacturers. Fuel cost may be reduced for small holder farmers. Training on repair and maintenance of PTOS for operators is highly required. Furthermore, research work should be carried out to improve the machine with riding facilities and adding fertilizers application system with existing PTOS that will improve fertilizer uses efficiencies.

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Weed Management in Wheat (*Triticum aestivum* L.) under Minimum Tillage and Crop Residues

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Introduction

Different tillage system can influence the composition of weed species and changing from traditional tillage to conservation (minimum tillage) can lead to shifts in weed flora in agricultural plant communities (Ball and Miller, 1993). The shift from conventional tillage to conservation, can make control weed difficult (Andrew and Kelton, 2011). Many weed species flourish when intense tillage operations are minimized and therefore, minimum tillage has been characterized by greater weed densities than conventional tillage systems (Sosnoskie et al., 2006). With a reduction in tillage, farmers lose weed control offered from seed burial and pre-sowing germination. As a result, producers wishing to adopt minimum tillage are likely to be primarily dependent upon on the extensive use of chemicals applied, such as pre-sowing, pre- emergence and post-emergence. But options for weed control must reduce selection pressure for herbicide resistance as well as provide season-long weed suppression. A cover crop or previous crop residue help in reducing weed infestation through reduced weed emergence. An on-farm experiment was conducted, to examine the performance of tillage practices and residue levels on crop and weeds.

Materials and Methods

The experiment was conducted on farm at the Vangnamari union under Gouripur upazila of Mymensingh district of Bangladesh from 28 November 2013 to 23 February 2014. Wheat cv. *BARI Gom-26*, was sown with 6 tillage and weed control practices *viz*., $\mathbf{W_1}$: Conventional tillage + one weeding (Control); $\mathbf{W_2}$**:** Roundup (RU) + Strip tillage (ST); $\mathbf{W_3}$**:** RU+ ST + Pre-emergence (PE) herbicide (Pendimethalin); $\mathbf{W_4}$**:** RU+ ST + Post-emergence (PO) herbicide (Affinity 50.75 WP); $\mathbf{W_5}$**:** RU+ ST + PE + PO; $\mathbf{W_6}$**:** RU+ ST + weed-free, and 2 levels of crop residue *viz.*, $\mathbf{Cr_1}$**:** Current (20%) residue and $\mathbf{Cr_2}$**:** Increased (50%) residue. The treatments were laid out in randomized complete block design with 4 replications using unit plots of 9 m × 5 m. Weed species and plant densities were recorded randomly from 4 locations of 0.25 m^2 each at 21 days after sowing (DAS), 40 DAS and flowering stages. Weed dry matter assessed by harvesting biomass which was then oven dried at 70^0C for 72 hours. The crop was harvested at maturity from 3 locations of 3 m^2 quadrats and grain yield was recorded. Data were subjected to ANOVA using MSTAT-C and means separated by Duncan's Multiple Range Test.

Results and Discussions

Weed infestation

The experimental plots were infested with 18 weed species belonging to 7 families, of which 15 were annuals and 3 perennials (Table 1). Of these weed species, 6 belonged to Poaceae, 5 to Solanaceae, 2 to each of Asteraceae and polygonaceae and 1 each of the remaining 3 families. The 5 most abundant weeds were *Alternanthera sessilis, Cynodon dactylon, Echinochloa crussgalli, Cyperus rotundus and Eclipta alba.*

Table 1. Weed infestation in the experiment plots at the Vangnamari union under Guoripur upazila of Mymensingh district of Bangladesh in 2013 - 2014 wheat crop (*annual species, ** perennial species)

Species	Family	Density	Species	Family	Density
*Alternanthera sessilis**	Amaranthaceae	**404**	*Cynodon dactylon***	Poaceae	**303**
*Centipeda minima ***	Asteraceae	3	*Parapholis incurva**	Poaceae	2
*Eclipta alba **	Asteraceae	**129**	*Rumex maritimus **	Polygonaceae	1
*Spilanthes acmella**	Campanulaceae	13	*Polygonum coccineum **	Polygonaceae	1
*Cyperus rotundus***	Cyperaceae	**169**	*Physalis minima **	Solanaceae	9
*Echinochloa crusgalli**	Poaceae	**199**	*Solanum torvum **	Solanaceae	17
*E. colonum **	Poaceae	41	*S. carolinense **	Solanaceae	22
*Digitaria sanguinalis **	Poaceae	85	*S. rostrum **	Solanaceae	2
*Eleusine indica **	Poaceae	9	*Nicotiana plumbaginifolia **	Solanaceae	12

Effect of tillage on weed and crop

High weed density in the untreated control (W_1) has resulted in significant reduction (7%) of wheat yield (Table 2). Roundup application at pre-sowing (W_2) did significantly reduced weed density and biomass but this reduction was not high enough to increase grain yield of wheat compared to untreated weedy treatment (W_1). Although application of Roundup plus a pre-emergence with or without a post-emergence application of herbicide significantly reduced weed density and biomass, these treatments did not improve wheat yield compared to Roundup alone.

Table 2. Effect of tillage on density, dry matter and yield of wheat at the Vangnamari union under Guoripur upazila of Mymensingh district of Bangladesh

Tillage and weed control	**Weed density (no. m^{-2})**			**Weed dry matter (gm^{-2})**			**Yield (t ha^{-1})**
	21 DAS	**40 DAS**	**Flowering**	**21 DAS**	**40 DAS**	**Flowering**	
W_1: Conventional tillage + one weeding	**30 a**	**23 a**	**46 a**	**19 a**	**14 a**	**24 a**	3.28 c
W_2: Roundup (RU) + Strip tillage (ST)	21 b	17 b	30 b	18 a	13 a	16 b	3.33 bc
W_3: RU+ ST + Pre-emergence (PE) herbicide	16 c	15 c	24 c	16 b	12 ab	13 c	3.39 b
W_4: RU+ ST + Post-emergence (PO) herbicide	17 c	15 c	25 c	14 c	10 c	13 c	3.40 b
W_5: RU+ ST + PE herbicide + PO herbicide	15 d	13 d	20 d	12 d	8 d	10 d	3.42 b
W_6: RU+ ST + weed free	0 e	0 e	0 e	0 e	0 e	0 e	**3.52 a**
CV (%)	7.28	9.15	6.94	7.25	2.40	6.17	2.21
$LSD_{(0.05)}$	1.22	1.29	1.69	0.98	0.23	0.80	0.08

The highest weed density at 21 DAS (30), 40 DAS (23) and flowering (46) and dry matter 19, 14 and 24 gm^{-2} on that 3 times, respectively and lowest yield (3.2 t ha^{-1}) were found in W_1 while the value for density and dry matter were nil in W_6. However, the lowest density 15, 13 and 19 m^{-2} and dry matter 12, 8 and 10 gm^{-2} were obtained at 21 DAS, 40 DAS and at flowering, respectively, on W_5. W_6 yielded the highest (3.52 t ha^{-1}) while the second highest (3.4 t ha^{-1}) from W_5. The second highest yields were also produced from W_4 and W_3 (Table 2).

Effect of residues on weed and wheat

Figure 1 reveals that, the weed density at 50% residues was reduced by 19 to 30% compared to 20% residues suggesting that higher residues significantly reduced weed emergence. Biomass of weed at 50% residues was also significantly lower than 20% residues further suggesting that high residues not only reduced density of weeds but also reduced weed plant size. The reduction in weed density and biomass due to increased residues has increased wheat yield by about 4%.

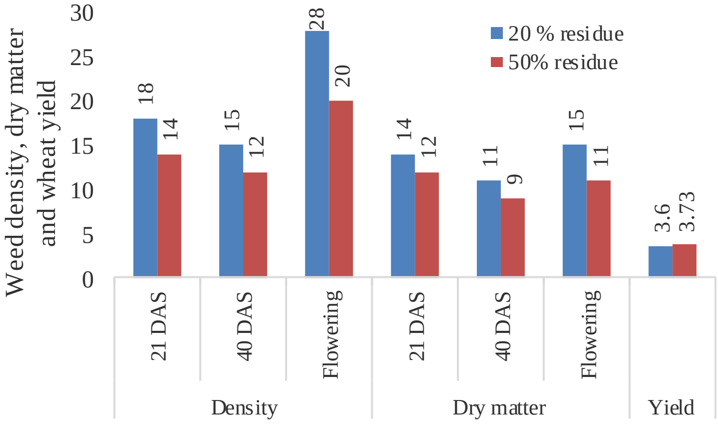

Figure 1. Effect of residues on weed and wheat

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Cowpea an efficient intercrop in banana improves soil health and income under Conservation Agriculture Production System (CAPS)

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Introduction

Vast areas of coastal Odisha in eastern India are inhabited mostly by poor people practicing rainfed agriculture and suffering from resource degradation, soil erosion and run off leading to low productive capacity. Persistent use of conventional farming practices based on extensive tillage combined with *in situ* burning of crop residues have magnified these problems. Intercropping and cover cropping within banana fields, an important fruit crop of the region, may help to address these problems (Yadukumar, 2007). The present study had the objective of finding more efficient intercrops or mulching treatments to improve farmers' income and soil health.

Materials and Methods

A banana field was selected in tropical coastal Odisha during 2012-13. The seven treatments in the inter row space of banana included four intercrops; a polythene mulch; an easily decomposable *Glyricidia maculeata* leaf mulch and a control, i.e. without any intercrop or mulch. The intercrops were leguminous vegetable cowpea and horse gram; non leguminous bottle gourd and sweet potato. There were three replicates of each treatment. The soil of the experimental site was slightly acidic (pH 5.5), medium in organic carbon (6.0 g kg^{-1}) with low available phosphorus (10.5 kg P ha^{-1}) and potassium (93.6 kg K ha^{-1}). All the intercrops were rainfed while banana was drip irrigated after the rainy season. All the crops were raised following standard cultural practices. Minimal tillage and residue incorporation in soil were followed for all the intercrops. The banana plants were recorded for their growth and yield related characters while the soil physical properties and major plant nutrients in the soil were assessed before and after complete cropping sequence. Economic analysis of all the treatments was based on the cost of inputs in the local market and sale price of produce at the farm gate. Banana equivalent yield was calculated by converting yield of intercrops to the yield of banana on the basis of prevailing market prices of the individual crops.

Results and Discussion

Experimental results revealed a highly significant increase in growth characters and yield of banana plant by intercropping with cowpea which is in agreement with the findings of Rao and Reid (1987). In the absence of any weed control measure, which is in line with conservation agriculture, banana yields were not high. Polythene mulch had least weed incidence in the initial stage but could not maintain weed control later on due its low durability. On the other hand sweet potato controlled the weeds very effectively due to its good plant stand; quick growth and high canopy cover (96 %). Soil physical and chemical parameters were influenced to a great extent by the treatments. Though pH and bulk density were not affected, soil organic carbon significantly increased by 25 % from surface decomposition of *Glyricidia* leaf mulch and 18.3 % by intercropped cowpea over the initial status (6 g kg^{-1}) at the end of one cropping cycle. Significant increase in available phosphorus in soil could be observed by 26 % due to improved nutrient cycling through higher crop residue inputs associated with lower nutrient losses under minimum tillage system. Maximum banana yield (34.9 t ha^{-1}) was obtained from polythene mulch but the net return from complete crop cycle was reduced on account of its high cost (US $ 3507). In general, we found that banana intercropped with cowpea could achieve significantly increased banana equivalent yield (40.9 t ha^{-1}) and net return (US $ 3752 $hectare^{-1}$) and therefore would find wide acceptance by the farmers.

Table 1. Effect of various intercrops and other treatments on weed incidence, yield and economics of banana intercrop system

Treatment	Canopy cover (%)	Dry weight of weeds (t ha^{-1})	Banana bunch yield (t ha^{-1})	Total banana equivalent yield (t ha^{-1})	Total cost of cultivation ($ ha^{-1})	Total Net Return ($ ha^{-1})	Benefit:Cost Ratio in the complete system
Banana + Cowpea	84	2.04	34.5	40.9	3179	3752	2.18
Banana + Horse gram	85	2.21	32.5	36.2	2691	3437	2.28
Banana + Bottle gourd	71	2.73	29.0	33.0	2839	2758	1.97
Banana + Sweet potato	96	2.00	30.1	36.0	3103	3006	1.97
Banana + *G.maculeata* leaf	0	2.43	31.7	31.7	2529	2840	2.12
Banana + Polythene mulch	87	3.18	34.9	34.9	3507	2401	1.68
Banana (Control)	0	5.59	22.5	22.5	2141	1679	1.78
SEm(±)		0.21	0.65	0.68			
CD (P = 0.05)		0.66	2.01	2.10			

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Productivity, Profitability and Soil Properties as Influenced by Maize Based Conservation Agriculture Production Systems in Rainfed Uplands of India

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Introduction

Rainfed agriculture accounts for two-thirds of total cropped area and half of the total value of agricultural output in India. Small land holdings, rainfall uncertainty, and few resources constrain productivity. Participatory methods were used to identify conservation agriculture production systems (CAPS) to overcome productivity constraints and improve livelihoods. An investigation was made to evaluate CAPS effects on crop productivity, profitability, and soil properties.

Materials and methods

An on-station experiment was conducted for 3 consecutive years. In the 1st season (June-October) of cropping cycle four treatments were applied in triplicate:

T_1: Conventional tillage with sole maize (*Zea mays*); T_2: Conventional tillage with maize + cowpea (*Vigna unguiculata*); T_3: Minimum tillage with sole maize;T_4: Minimum tillage with maize + cowpea. Improved varieties of maize and cowpea were used.

In the 2nd season (November-January) of cropping cycle, residual effects of four treatments (main plot) and direct effects of cover crop treatments (sub plot) were tested in a split plot design:

NCC: no cover crop (fallow); CC_1: Mustard (*Brassica juncea*) as a cover crop; CC_2: Horsegram (*Macrotyloma uniflorum*) as a cover crop.

Results and discussion

There was no effect of tillage or intercropping on maize yield (Figs. 1 and 2). However, cowpea provided additional yield with intercropping. Minimum tillage resulted in 27% labor savings with the highest profitability of \$403 ha $^{-1}$ yr^{-1} for MT-M+C and the lowest profitability of \$311 ha $^{-1}$ yr $^{-1}$ for CT-M. No significant effect of treatments was noticed on bulk density, organic carbon, pH, and nutrient contents. Conventional tillage had more micro-aggregates (53-125 µ) while minimum tillage had more macro-aggregates (>250 µ) (Fig. 3). More macro-aggregates implied more resistance to dispersion and thereby caused less soil erosion.

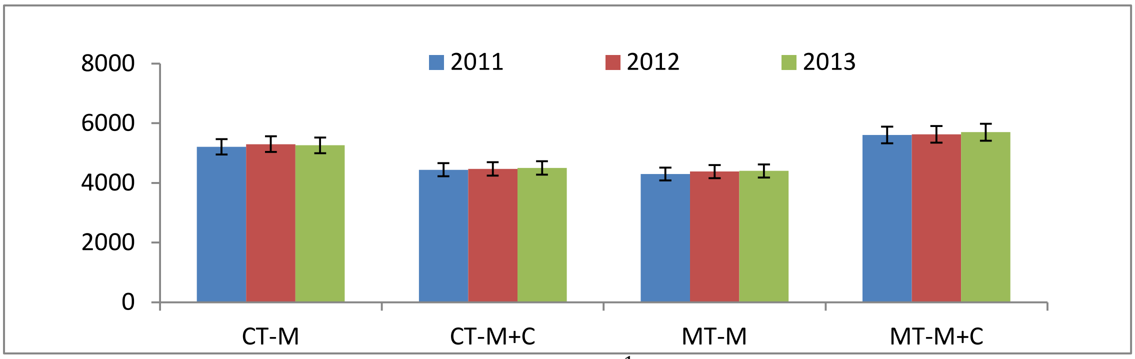

Figure 1. Effect of CAPS on maize yield (kg ha^{-1})

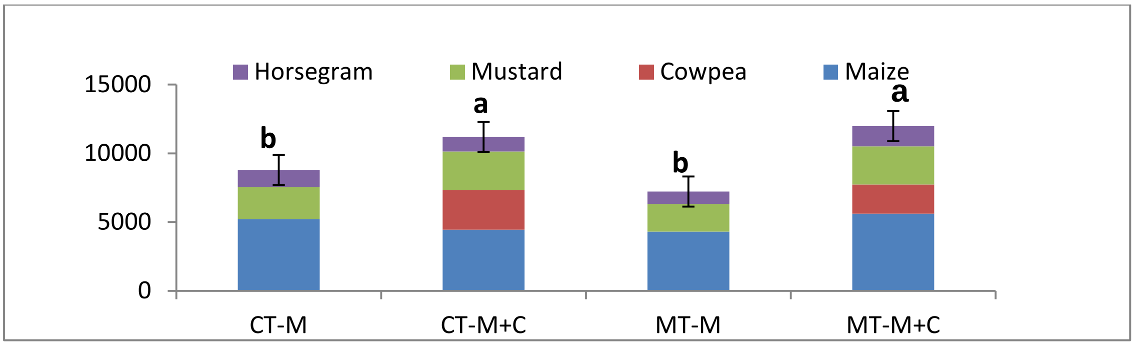

Figure 2. Effect of CAPS on maize equivalent yield (kg ha^{-1})

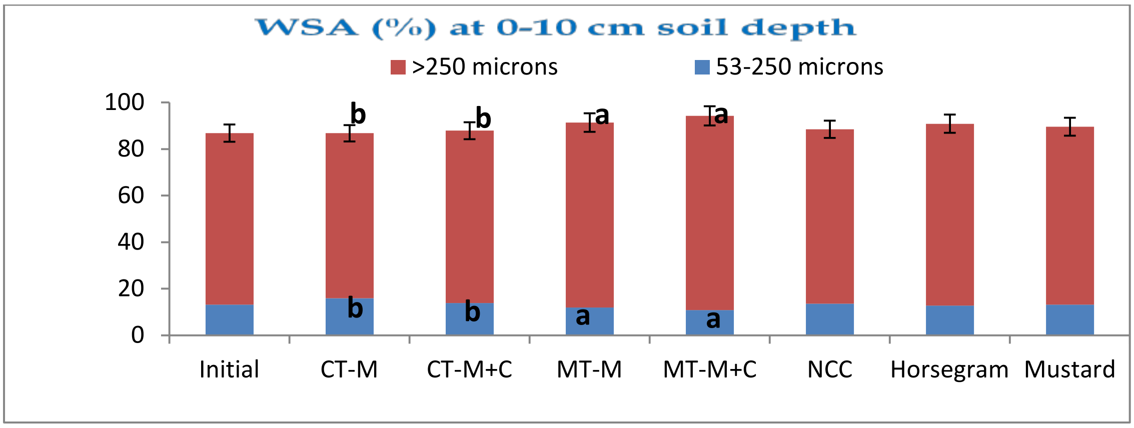

Figure 3. Effect of CAPS on soil water stable aggregates

Conclusion

Minimum tillage with intercropping is most effective in terms of crop productivity, labor saving and profitability.The effect of tillage, intercropping and cover crops on soil physical, chemical and biological status need multiple years of adoption to demonstrate effects.

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Aerobic rice cultivation on adoption of water saving technologies and improving agronomic practices during summer season under conservation agriculture

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Introduction

Increasing physical water scarcity is a main constraint for irrigated rice (*Oryza sativa)* production (Peng et al., 2006). By 2025, the per capita available water resources in Asia are expected to decline by 15–54 percent compared with 1990 (Moya et al., 2001). The supply of water for irrigation is endangered by declining water quality, declining resource availability, increased competition from other users, and increasing costs.

At the farm level, water inputs can be reduced by decreasing the relatively large and unproductive losses from seepage, percolation, and evaporation. Water-saving irrigation technologies such as saturated soil culture and alternate wetting and drying can drastically diminish these losses. In Asia, upland rice is aerobically grown with minimal inputs and it is usually planted as a low yielding subsistence crop in the adverse upland conditions (Lafitte et al., 2002). With predictions suggesting that many Asian countries will have severe water problems by 2025, aerobic rice under conservation agriculture gives hope to farmers who do not have access to enough water to grow flooded lowland rice. A new concept of growing rice using less water is aerobic rice: high-yielding rice grown in non-puddled aerobic soil using supplementary irrigation just like upland crops. Aerobic rice is crop grown in well-drained, non-puddled & non-saturated soils without ponded water (Bouman et al., 2007). Growing rice in conservation agriculture, with the use of external inputs such as supplementary irrigation, fertilizers and aiming at high yields (Bouman et. al., 2007) has been established. Main driving force behind aerobic rice is economic water use. Farmers in Brazil, China, and India are pioneering this system where water is scarce or costly. Preliminary studies in Italian climatic environments have shown promising results when rice was grown under dry land conditions, using sprinkler or flushing irrigation rather than flooding, indicating that rice does not necessary require flooded conditions for high yield and good grain quality (Losavio et.al., 1997; Russo and Nardi, 1996). However, new aerobic rice varieties and specially designed management strategies are needed if this system is going to be successful. Through the adoption of water-saving irrigation technologies, rice land will shift away from being continuously anaerobic to being partly or even completely aerobic.

Materials and Methods

A field experiment on growth and yield of aerobic rice in summer season under various moisture regimes and planting techniques in upland condition was carried out at the Regional Research Station of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur (India) during summer seasons of 2011 and 2012. The station located in a sub-tropical region at 23°N latitude, 89°E longitude and at an elevation of 9.75 m above sea level. The soil of the experimental field is sandy clay loam in texture and the depth of the soil is shallow to medium with total nitrogen (0.072 %), moderate in phosphorus (15.70 kg ha^{-1}) and potassium (193.58 kg ha^{-1}) content. The soil was moderately alkaline in reaction (pH 6.8). Organic carbon content of soil was 0.67 per cent. The bulk density of soil was 1.47 g cc^{-1}. The experiment was laid out in a split plot design and replicated three times. The treatment consist of three irrigation regimes *viz.*, IW/CPE =1, IW/CPE =1.5 and IW/CPE = 2 and four treatments on planting techniques *viz.*, P_1: Sprouted seeds, P_2: Non-sprouted seed, P_3: Soaking seeds overnight (12 hrs), $P_{4:}$ Soaking seeds overnight (12 hrs) followed by shade drying.

Result and Discussion

The results revealed that scheduling of irrigation at IW/CPE = 2 registered significantly maximum growth attributes in *viz.*, plant height (85.98 cm), tiller number (374.17 m^{-2}), leaf area index (3.26), dry matter accumulation (974.97 g m^{-2}), crop growth rate (8.22 g $m^{-2}d^{-1}$) . Root characters *viz.*, root length (24 cm), root volume (12.72 cc $hill^{-1}$) and root weight (121.95 g $hill^{-1}$) also registered maximum when irrigation was scheduled at IW/CPE = 2. The yield attributes panicle length (21.29 cm), filled grains per panicle (84.46) test weight (16.80 g), and also grain yield (4.13 t ha^{-1}) and straw yield (5.84 t ha^{-1}) were significantly higher with scheduling of irrigation at IW/CPE = 2 irrigation regime. Amongst planting technique, sprouted seeds showed maximum growth attributes *viz.*, plant height (85.98 cm), tiller number (376.89 m^{-2}), leaf area index (3.26), dry matter accumulation (1018 g m^{-2}) crop growth rate (8.18 g $m^{-2}d^{-1}$). Root characters *viz.*, root length (24.24 cm), root volume (12.59 g $hill^{-1}$) and root weight (124.05 g $hill^{-1}$) was significantly higher when sprouted seeds were used. The same trend was followed in yield attributes *viz.*, panicle length (21.38 cm), filled grains per panicle (88.11) test weight (17.12 g), grain yield (4.16 t ha^{-2}) (Table 1) and straw yield (5.84 t ha^{-1}. Application of irrigation at IW/CPE ratio of 2.0 along with sprouted seeds recorded significantly maximum water use efficiency (3.84 kg ha^{-1}–mm) than rest of the irrigation regimes. With regard to the production economics in pooled data, highest gross return, net return and consequently highest B:C ratio was obtained in the treatment combination IW/CPE of 2.0 coupled with sprouted seeds (IRs 61000, Rs 2574 and 1.73 respectively). On the basis of results it could be concluded that, scheduling of irrigation at IW/CPE = 2 irrigation regime coupled with sprouted rice seeds soaked for 48 hrs was found suitable as upland aerobic summer rice for maximum growth, yield and monetary benefit. And that saved up to 40% of irrigation requirement for rice cultivation during summer season under aerobic situation.

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Table 1. Effect of moisture regimes and planting techniques on grain yield of rice under aerobic condition in conservation agriculture

Grain Yield (t ha^{-1})			
Treatment	2011	2012	Pooled
Moisture regimes			
I_1	2.93	3.08	3.00
I_2	3.46	3.61	3.54
I_3	4.00	4.26	4.13
SEm($\pm$)	0.06	0.04	0.04
CD at 5%	0.25	0.14	0.12
Planting techniques			
P_1	4.07	4.25	4.16
P_2	3.03	3.24	3.14
P_3	3.30	3.34	3.32
P_4	3.45	3.76	3.60
SEm($\pm$)	0.08	0.08	0.06
CD at 5%	0.23	0.24	0.16

I_1: Irrigation when IW/CPE = 1; I_2: Irrigation when IW/CPE = 1.5; I_3: Irrigation when IW/CPE = 2; P_1: Sprouted seeds; P_2: Non-sprouted dry seeds (control); P_3: Soaking seeds (12hrs); P_4: Soaking seeds overnight (12hrs) followed by shade drying.

Conservation agriculture for smallholders farming on efficient water resources utilization to combat adverse effect of global warming

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Introduction

There is a nexus between conservation agriculture, water resource availability and global warming in relation to smallholders particularly in Asia and Africa. The concept of soil conservation means proper land use, protecting the land from all forms of deterioration, rebuilding eroded soil, conserving moisture, proper drainage and irrigation where needed, building of soil fertility and increasing yield and farm income at the same time. Today, "conservation" means embracing integrated management of all natural resources such as soil, air, water, woodland, pasture, wildlife, in short, of our environment. In broader sense, soil and water conservation means better farming for obtaining yield on sustained basis which has gained prime importance. Hence, appropriate system performance indicators, to assess the sustainability as influenced by tillage methods and soil management, are now established as Conservation Agriculture and that is paramount importance of smallholders in Asia and Africa. Simultaneously, global warming is when the earth heats up (the temperature rises) when greenhouse gases (carbon dioxide, water vapor, nitrous oxide, and methane) trap heat and light from the sun in the earth's atmosphere, which increases the temperature. This hurts many people, animals, and plants. Many cannot take the change, so they die. The greenhouse effect is when the temperature rises because the sun's heat and light is trapped in the earth's atmosphere. The heat and light can get through the atmosphere, but it can't get out. As a result, the temperature rises. Sometimes the temperature can change in a way that helps us. The greenhouse effect makes the earth appropriate for people to live on. Without it, the earth would be freezing, or on the other hand it would be burning hot, that would be freezing at night because the sun would be down. Although the greenhouse effect makes the earth able to have people living on it, if there gets to be too many gases, the earth can get unusually warmer, and many plants, animals, and people will die. They would die because there would be less food (plants like corn, wheat, and other vegetables and fruits). This would happen because the plants would not be able to take the heat. Gradually, people, plants, and animals would all die of hunger. Greenhouse gasses are gasses are in the earth's atmosphere that collects heat and light from the sun. With too many greenhouse gasses in the air, the earth's atmosphere will trap too much heat and the earth will get too hot. As a result people, animals, and plants would die because the heat would be too strong. Global warming is affecting many parts of the world. Global warming makes the sea rise, and when the sea rises, the water covers many low land islands. This is a big problem for many of the plants, animals, and people on islands particularly the smallholders in Asia and Africa becoming worst suffers. The water covers the plants and causes some of them to die. When they die, the animals lose a source of food, along with their habitat. Although animals have a better ability to adapt to what happens than plants do, they may die also. When the plants and animals die, people lose two sources of food, plant food and animal food. Global warming is doing many things to people as well as animals and plants. It is killing algae, but it is also destroying many huge forests. The pollution that causes global warming is linked to acid rain. Acid rain gradually destroys almost everything it touches. Global warming is also causing many more fires that wipe out whole forests.

Adoption of conservation agriculture for smallholders

Acharya and Sharma (1994) reported the beneficial effects of conservation agriculture systems with crop residues or mulching or green manure mulching for improving moisture availability, controlling weeds and regulating soil temperature have been widely investigated in rice-wheat and maize-wheat cropping systems; Sharma and Behara (2006) stated the modern concept of conservation tillage aims at improving resource-use-efficiency with minimum soil disturbance, soil cover through residues and adoption of spatial and temporal crop sequences for achieving higher productivity while protecting natural resources and environment. Lal (1995) observed that long-term and large-scale ecosystem studies are necessary to assess the effectiveness of various conservation tillage systems in reducing pollution of natural waters by sediments, nutrients and pesticides). Gupta *et. al.* (2006) reported that area planted with wheat adopting Zero-till drill has been rapidly increasing where rice-wheat system is now practiced well over two million hectare of arable land. Gajri et al., (1992) stated that zero-tillage was also found feasible in *winter* crops, namely wheat, mustard, linseed and chickpea following *Kharif* crops of maize, green gram or soybean. Conservation tillage with mulching proved beneficial for enhancing water and nutrient use efficiency.

Water Resource

There is also growing recognition that functionally intact and biologically complex freshwater ecosystems provide many economically valuable commodities and services to society (ecosystem services) beyond simply direct water supply. These services include flood control, transportation, recreation, purification of human and industrial wastes, habitat for plants and animals, and production of fish and other foods and marketable goods. These ecosystem benefits are costly and often impossible to replace when aquatic systems are degraded.

Deliberations about water allocation should therefore, always include provisions for maintaining the integrity of freshwater ecosystems, including the need to maintain minimum in-stream flows and to anticipate the impact of hydrologic modifications on downstream environments (Flint et al. 1996). Otherwise, we have few safeguards that will protect the systems that sustain us.

Besides being an integral part of the ecosystem, water is a social and economic good. Demand for water resources of sufficient quantity and quality for human consumption, sanitation, agricultural irrigation, and manufacturing will continue to intensify as populations increase and as global urbanization, industrialization, and commercial development accelerates (Flint and Houser 2001). Water runs like a river through our lives, touching everything from our vigor and the fitness of natural ecosystems around us to farmers' fields and the production of goods we consume. It is critical that efforts intended to be sustainable fully consider the health and operation of aquatic ecosystems and that the environmental value of watersheds be recognized when making economic and social decisions on water allocation and use.

On-farm Water Management

Selection of crop(s) and crop sequence(s) also played an important role for enhancement of water use efficiency through crop cultivation and related agronomic practices. Conservation, distribution and utilization of irrigation water are the basic parameters of on-farm water management. Optimum scheduling of irrigation, suitable method adoption, conjunctive use of rain, surface and ground water for crop cultivation having improved agro-technology adoption and provision of drainage. Application of proper amount of water at proper time increased the water use efficiency and crop yield maximization with given amount of water reducing evaporation and deep percolation. Scheduling of irrigation with limited water availability is a big challenge to the irrigation experts that needs rigorous research.

Conclusion

Research on conservation agriculture lacks systemic investigations with special reference to smallholders. Research on conservation tillage should always be supported by detailed analyses of soil properties, environmental factors and crop characteristics. A system approach is essential for wide adaptation of conservation agriculture, the need of the hours for smallholders those to be adopted successfully in a wide range of soils and environments; they must fit into the overall scheme of the present and the future trends in the farming systems of a region and must meet the rising social and economic aspirations of the farming community. Long-term and large-scale ecosystem studies are necessary to assess the effectiveness of various conservation systems in reducing pollution of natural waters by sediments, nutrients and pesticides.

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Management of weeds through bio-herbicides in soybean

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Introduction

In Indian agriculture, soybean was introduced mainly as a source of protein but it also provides oil. It is grown mostly during the *kharif* season producing high yield as a rainfed crop or low yield as a summer/spring crop. Several factors are responsible for a reduction in yield, weed plays an important role which acts also alternate host of pests having serious effect on soybean crop. Continuous use of heavy dose of chemicals is encouraging resistance development in different pests and endangering the ecosystem. Resistance development among weeds to herbicides is of great concern. The yield loss due to weed in soybean was to the tune of 20-77 percent. Resistance to specific synthetic herbicides is increasing dramatically in the last two decades leading to lowering the land values resulting farmers to run out of the weed controlling chemicals. Now it is imperative to concentrate on research to find out some natural extract from plants having allelopathic effect or bio-herbicide property to control this menace.

Materials and Methods

The experiment was conducted with soybean variety PK-327 in Gangetic new alluvial soil (Inceptisol) with sandy clay loam texture having good irrigation and drainage facility and medium fertility (pH 6.9). The experiment was conducted at the Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Mohanpur, Nadia, West Bengal, India in medium land topography situated at 22˚56' N latitude and 88˚32' E longitude at an altitude of 9.75 m above the mean sea level (MSL) during the pre-*kharif* and *kharif* season of 2011and 12. The experiment studied the potentiality of different botanicals for their bio-herbicidal properties and its effect on the growth and yield of crop. The experiment was laid out in Randomised Block Design having 9 treatments viz T_1-*Bambusa vulgaris* raw leaves extract @ 5%, T_2-*Cucumis sativa* raw leaves extract @ 5%, T_3-*Blumea lacera* raw leaves extract @ 5%, T_4-*Echinochloa colona* raw leaves extract @ 5%, T_5 -*Ageratum conyzoides* raw leaves extract @ 5%, T_6-*Cyperus difformis* raw extract @ 5%, T_{7-} Imazethapyr @1000.0g ha^{-1} at 7 DAS, T_8-Hand weeding at 15 DAS and 30 DAS, T_9-Weedy check. All the botanicals or bio-herbicides were applied as pre-emergence at 2 DAS.

Results and Discussion

The best treatment among the botanicals or bio-herbicides was T_2-*Cucumis sativa* raw leaves extract @ 5% treatment followed by T_5 -*Ageratum conyzoides* raw leaves extract @ 5% and T_1-*Bambusa vulgaris* raw leaves extract @ 5% treatments in terms of minimizing weed density as well as dry weight of weed and maximizing crop yield. The overall best treatment T_8-Hand weeding at 15 DAS and 30 DAS significantly recorded maximum seed yield (2316.67 kg ha^{-1} and 2273.33 kg ha^{-1}) which was significantly different from all other (Table 1) treatments. Next best treatment T_{7-} Imazethapyr @1000 g ha^{-1} at 7 DAS during pre-*kharif* which was statistically at par with all the bio-herbicide treatments during pre-*kharif* season. In *kharif* season, this treatment was significantly at par with T_1-*Bambusa vulgaris* raw leaves extract @ 5% , T_2-*Cucumis sativa* raw leaves extract @ 5% and T_5 -*Ageratum conyzoides* raw leaves extract @ 5% treatments. It was observed that the ability of the botanicals to manage mostly grassy weed flora because of presence of phenol and alike compounds namely rutin and tricin in bamboo, sisymbrifolin in cucumber (Ho et. al, 2008), coumarin in *Ageratum conyzoides* (Tran et. al.2004; Kato et. al, 2001). These allele chemicals are responsible for higher weed control efficiency with lower weed dry weight. Imazethapyr normally inhibited weed flora germination and growth by branched chain amino acid bio synthesis with the help of Acetolactate (ALS) / Actohydroxy acid (AHAS) and block the normal function of enzyme ALS/AHAS/ which is essential in amino acid (protein) synthesis. So botanicals may however, be an alternative promising method for weed management which are safer in nature, less costly than chemical as well as mechanical hand weeding, easily available everywhere with its easy preparation. It was also proved that all the bio-herbicides tested here had no detrimental effect on the soil micro organisms in the long run and ultimately conserve the soil health.

Table 1. Effect of treatments on Seed yield, Weed Index (%) and Increase of seed yield over control (%)

Treatments	**Seed yield(kg/ha)**		**Weed index**		**%increase of seed yield over control**	
	Pre-*kharif*	***Kharif***	**Pre-*kharif***	***Kharif***	**Pre-*kharif***	***Kharif***
T_1	1700.00	1626.67	26.63	25.12	33.85	48.31
T_2	1800.00	1723.33	22.31	20.7	41.73	57.06
T_3	1616.67	1500.00	30.21	30.97	27.32	36.73
T_4	1640.00	1466.67	29.21	32.48	29.13	33.72
T_5	1746.67	1617.33	24.6	25.58	37.56	47.4
T_6	1596.67	1533.33	31.07	29.45	25.74	26.64
T_7	1900.00	1883.33	17.99	13.34	49.61	62.53
T_8	2316.67	2273.33	-	-	82.44	88.96
T_9	1270.00	1096.67	52.65	49.51	-	-
SEm (±)	124.91	109.21				
CD (P=0.05)	374.42	327.36				

T_1: *Bambusa vulgaris* raw leaves extract @ 5% at 2DAS, T_2: *Cucumis sativa* raw leaves extract @ 5% at 2DAS T_3: *Blumea lacera* raw leaves extract @ 5% at 2DAS, T_4: *Echinochloa colona* raw leaves extract @ 5% at 2DAS, T_5: *Ageratum conyzoides* raw leaves extract @ 5% at 2DAS, T_6: *Cyperus difformis* raw leaves extract @ 5% at 2DAS, T_7: Imazethapyr 10 %SL@ 1000.0g ha^{-1}, T_8: Hand weeding (15 DAS and 30 DAS), T_9: Weedy check.

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Optimization of seedling density as influenced by seed rate for mechanical transplanting

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Introduction

Mechanization of rice cultivation, including transplanting, is spreading in Bangladesh in order to reduce the cost of production, the need for labour and to increase productivity of rice cultivation. Quality seedlings are a key factor for the success of mechanical rice transplanting. Seeding density in the seedling tray has considerable influence on seedling quality, and hence on plant establishment and the percentage of missing hills in the field after transplanting. There are combined effects of seedling adjustment options of the rice transplanter and seedling density on number of plants per hills and percentage of missing hills. Rice grain size and shape in terms of length, breadth and length-breath ratio differs among rice varieties. Based on size and shape, rice grain can be classified as bold, medium and slender, long and extra long (Belsnio, 1992). This study, conducted during the irrigated dry season of 2013-14, aimed to identify the optimum seed rate for quality seedlings production to minimize the percentage of missing hills. In addition, suitable seedling adjustment option of the rice transplanter for different seedling densities were identified to maintain optimum numbers of seedlings per stock (plants/hill) by the rotary picker of the transplanter.

Materials and Methods

Rice varieties BR3 (L/B ratio=2.77), BRRI dhan28 (L/B ratio=3.87), BRRI dhan29 (L/B ratio=3.62) and BRRI dhan50 (L/B ratio=1.85) were selected as bold, medium and slender and extra long grain types, respectively. Daedong DP 480 model rice transplanter was used to test the number of plants per hill and percentage of missing hills for identifying the optimum density of seedlings of different varieties under different seed rate. Germination percentage was 90, 86, 89 and 87% for BR3, BRRI dhan28, BRRI dhan29 and BRRI dhan50, respectively. Seed rates were 100, 120, 130, 140, 150 and 160 gram of seeds/tray. Stroke area of the rotary picker (area of cut) under 9 seedling adjustment options of the rice transplanter was measured to find out the number of effective strokes per tray and number of trays required per hectare. Width of cut during stroke of the rotary picker under each of the 9 seedling adjustment options was 1.2 cm whereas depth of cut per stroke of the picker started from 1.12 cm for option 1 with the increments of 0.8 cm with successive options. As seedling adjustment options changed from 1 to 9, the number of strokes per tray decreased from 1200 to 656 and the number of trays per hectare for transplanting increased from 185 to 339.

Results

Percentages of the seedlings emerged from the sown seeds decreased from 61 -70% to 54 - 59% with increasing seed rate irrespective of the variety. Seedlings height ranged from 197 mm for BRRI dhan50 to 179 cm for BR3. Averaged across the four varieties, plant height increased from 178 mm with 100 grams of seeds/tray to 186 mm for 130 grams of seeds/tray and decreased from 185 mm with 140 grams of seeds/tray to 182 mm for 160 grams of seeds/tray. Highest seedling strength (0.04 gram/cm) was observed for BR3 and lowest (0.02 g/cm) for BRRI dhan50. Interaction of variety and seed rate also showed significant effect on seedling strength. With increased seed rate, seedling strength decreased.

Average number of plants per stock of the rotary picker of the rice transplanter increased and percentage of missing hills decreased with increasing both seed rate and seedling adjustment options of the rice transplanter irrespective of variety (Table 1). In case of bold grain paddy, seedlings per stroke and percentage of missing hills for the seed rate of 130, 140 and 150 g of seeds/tray varied from 3.2-5.4 to 3.5-6.4 and 14-4 to 13-3 respectively for 5 to 8 seedlings adjustment options of the rice transplanter which is almost same. Seedlings per stroke and percentage of missing hills of medium and slender grain paddy (BRRI dhan28 and BRRI dhan29) for the seed rate of 140, 150 and 160 g of seeds/tray was found to be almost the same (2.7-6.8 to 3.0-6.8 and 12-3 to 12-1 respectively), for 5 to 7 seedlings adjustment options of the rice transplanter. However, there was minimum difference of seedlings per stroke and percentage of missing hills among 120, 130 and 140 gram of seeds/tray (2.5-6.8 to 2.5-8.6 and 12-2 to 11-1 respectively) for the options of 3-7 for extra long and slender paddy (BRRI dhan50).

Table 1. Seedlings per stroke and percentage of missing hills as affected by seed rate and seedling adjustment options of the rice transplanter

Seeds/tray	Seedlings/stroke and % of missing hills for 1 to 9 seedling adjustment options of the transplanter							
	BR3		BRRI dhan28		BRRI dhan29		BRRI dhan50	
	Seedlings /stroke	% of missing hills	Seedlings /stroke	% of missing hills	Seedlings /stroke	% of missing hills	Seedlings /stroke	% of missing hills
100 g	2.5-4.6	27-14	2.0-4.5	25-12	2.15-4.5	24-10	2.4-5.5	18-8
120 g	2.6-5.1	22-10	2.5-5.1	21-9	2.5-6.5	20-8	2.5-6.8	12-2
130 g	3.2-5.4	14-4	2.5-6.0	13-3	2.5-6.7	15-5	2.4-7.5	13-2
140 g	3.3-5.9	13-4	2.7-6.8	12-3	2.8-6.9	12-2	2.5-8.6	11-1
150 g	3.5-6.4	13-3	2.8-7.7	13-2	3.0-7.5	12-1	2.5-8.5	11-3
160 g	2.9-5.3	14-5	3.0-6.8	12-4	3.0-6.8	12-1	3.0-9.9	11-1

Conclusion

Based on missing hills and number of seedling per hills under different seedling adjustment options, 130g of seed/tray for bold grain, 140 g/tray for medium and slender grain and 120 g/tray for extra long and slender paddy were suitable for the studied transplanter.

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Conservation Agriculture-the light house to sail for sustainable agricultural growth in Bangladesh

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Introduction

Agriculture value addition (annual % growth) in Bangladesh was last measured at 3.11 of 6.32 of total growth in 2012 (World Bank 2012). The rural economy constitutes a significant component of the national GDP, with agriculture accounting for 21% and the non-farm sector, which is also driven primarily by agriculture, for another 33% (World Bank 2011). The sustainability of the growth of agriculture sector is a daunting task with loosing 1% of arable land per year (Mahbub, 2003) and continuous degradation of soil fertility (Karim et el 2000). Because of limited knowledge on conservation agriculture (CA) among the people the issue of land degradations is avoided. This paper includes an initiative to provide basic knowledge on CA to build awareness among the people. Progress of CA, Global and Indo-Gangetic-Plain are mentioned to compare the current status of Bangladesh along with the organizations involved. Possible constraints are depicted along with recommendations for adoption of CA in Bangladesh.

Materials and methods

Conservation agriculture can be defined by a statement given by the Food and Agricultural Organization of the United Nations) as "a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment" (FAO 2007). Advantages of CA for the farmer are less machinery cost, 70% fuel saving, 50% labour saving, 20-50 % input saving, less drudgery, stable yields, food security= better livelihood/income (FAO 2011)**.**

Results and Discussions

The global agricultural production systems based on CA comprising minimum mechanical soil disturbance, organic mulch cover, and crop species diversification, is now practiced globally on about 117 M ha in all continents and all agricultural ecologies, including in the various temperate environments. (Kassam et al., 2010). In Indo-Gangetic-Plains in 2005 about 1.9 million ha were reported under no-tillage in this region (Rolf et al.,). By 2006-07, the area under zero-till was escalated at around 3 million hectares (RWC) was possible due to availability reasonably priced high quality implements from the private sector and technical support from extension service and external fund support (Harrington and Hobbs, 2009). In Bangladesh research and development work on conservation tillage was started in the name of Resource Conserving Technology (RCT). Power tiller operated seeders were imported from China in 2003-04, 10 ha area was brought under zero-till drill (Roy et al., 2004). Australian Centre for International Agriculture (ACIAR) is pioneer in promoting CA and they are funding different organizations. International Development Enterprise (iDE) has been implementing projects supported by ACIAR. CIMMYT developed CA equipment Versatile Multiple-Crop Planter (VMP) is useful for strip tillage, minimum tillage, bed formation and conventional tillage (Islam et al., 2010). **Sustainable and Resilient Farming Systems Intensification (SRFSI)** for South-Asia, an ACIAR project, focuses on CA partnering with national research and development institutions, NGOs and INGOs, CG Institutes, Australian universities and CSIRO (BSS, 2014). CSISA Mechanization and Irrigation Project aims to unlock agricultural productivity in southern Bangladesh also based on conservation agriculture (Krupnik 2013). Cereal Systems Intensification in South Asia (CSISA) a BMGF and USAID funded project implemented jointly by IRRI and CIMMYT also worked on CA in central and northern Bangladesh (Ali MA et al., 2011).

The major reasons depicted for poor adaption of CA in Bangladesh:

1. Limited knowledge on CA: Inadequate knowledge on CA among the framers, extension agencies, scientists, policy makers and general mass.
2. Technical constraints*:* Quality drill, training facility and spare parts are not available, suitable herbicides and knowledge of application is limited among farmers.
3. Extension constraints: Department of Agriculture Extension (DAE) responsible for technology transfer to farmers has no work in the name of CA.
4. Lack of government polices: There are no legislation or policy in the name of CA to save the soil from degradation.
5. Financial constrain: To sustain current agriculture growth a huge amount of money is required to initiate project on CA but it is absent in the government or donor budget.
6. Attitude of the general mass: Due to knowledge gap the attitude about CA remains wrong that "Good tilth good crop".

Recommendations to overcome constrains of adoption of conservation Agriculture:

1. Awareness building: Awareness on CA be build up involving farmers, researchers, extension agencies, civil societies, professionals, media etc.
2. Government Policy: There should be Govt. policy on CA, in this respect the concern ministries should create posts with particular assignment on CA.
3. Education and training on CA: Curricula on CA should be introduced in the universities and the institutes engaged to provide education/training on agriculture.
4. Incorporation of CA in National Agriculture Research and Extension System NARES: DAE staffs should be trained on specific CA technology packages and should be in the hand to transfer to the farmers based country on research findings.
5. Legislation: There should be legislation for CA, to prevent activities by human or use of machines harmful for soil properties.
6. Availability of equipment and herbicides: Suitable CA equipment for seeding/planting crops, herbicides and service providers should be made available to the farmer.
7. Support from the international donor: More donors should come forward for the expansion of CA in Bangladesh to sustain the growth of agriculture production.

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Performance Evaluation of Compressor and Lever Operated Type Sprayers for Weed Control

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Introduction

In Bangladesh most of the farmer use manual weed control practices like hand hoe. However, virtually weed-free conditions are now possible using the range of herbicides available. Herbicides are particularly useful for inter-row weeding especially when it is difficult to hoe in the planted row without damaging the crop. So herbicides spraying can be the most suitable approach for farmers because it is less time consuming and less laborious way for weed control. It is the most effective way also because it destroys not only weed foliage but also roots, rhizomes, stems and the apical shoots. Even in conservation agriculture (CA) system weed control is the main factor which can be effectively controlled by spraying herbicide with sprayer before planting. This is why performance evaluation of sprayers is now important to control weeds.

Materials and methods

The research was conducted to evaluate the performance of two sprayers named compressor type sprayer (CTP) and lever operated sprayer (LOP). The sprayers were tested at three different pressures and three different water-chemical ratios. The sprayers were calibrated at the Farm Power and Machinery laboratory, Bangladesh Agricultural University. The pressures were 2.5 kg/cm^2, 2 kg/cm^2 and 1.5 kg/cm^2 and the water-chemical ratios were 1 L: 15 ml, 1 L: 20 ml and 1 L: 30 ml. The average walking speeds were 2.37 km/hr and 2.43km/hr for CTP and LOP over 50 m, respectively. The nozzle of the CTP was single while the nozzle of the LOP was double. Data was taken from 3 days after application of herbicide and continued up to 7 days.

Results and discussions

At 7 day maximum weed death occurred in both compressor and lever operated type sprayers (Fig. 1 and Fig. 2). A comparison between CTP and LOP was drawn on the basis of percent green weed after seven days.

Figure 1. Experimental plot after 7 days for CTP at pressure 2 kg/cm^2 and water chemical ratio 1 L:20 ml

Figure 2. Experimental plot after 7 days for LOP at pressure 2 kg/cm^2 and water chemical ratio 1 L:20 ml

For 2.5 kg/cm^2 pressure and water-chemical ratio 1 L: 20 ml, the percent green weeds was apparently same for both CTP and LOP (Table 1). But the CTP was cost effective for weed control. The operational cost was 1367 Taka/ha and 3831 Taka/ha for CTP and LOP, respectively. The field efficiency was about 88 percent for both sprayers. Therefore it can be concluded that a CTP with a pressure gauge might be used rather than LOP for weed control.

Table 1. Effect of variable pressures for weed control by compressor and lever operated type sprayer

Pressure (1.5-8) kg/cm^2	water chemical ratio (L : ml)	No. of green weeds before applicat ion	No. of green weeds after 3 days of applicat-ion	No. of weeds after 5 days of applicat -ion	No. of weeds after 7 days of applicat -ion	% green weeds foliage after 7 days.	% average green weeds foliage
Compressor type sprayer							
1.5	1:20	1276	1230	452	12	0.94	1.14
		1406	1383	542	18	1.29	
		1356	1303	365	16	1.18	
2	1:20	1440	1412	548	13	0.9	1.19
		1483	1456	564	17	1.17	
		1390	1367	436	21	1.5	
2.5	1:20	1354	1309	423	4	0.30	0.28
		1389	1333	375	0	0	
		1467	1412	512	8	0.54	
Lever operated sprayer							
1.5	1:20	1223	1131	357	19	1.55	1.21
		1236	1203	332	14	1.13	
		1353	1108	304	13	0.96	
2	1:20	1340	1219	442	21	1.66	1.09
		1463	1396	244	15	1.03	
		1490	1377	353	9	0.6	
2.5	1:20	1334	1209	320	3	0.23	0.36
		1289	1183	272	4	0.31	
		1427	1212	232	8	0.54	

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Performance of Maize Hybrid under Conventional and Strip-Tillage Systems inThree Districts of Bangladesh

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Introduction

Rice-maize cropping system has expanded in Bangladesh due to the demand for maize in poultry and aquaculture and also human consumption (Timsina et al., 2010). Approximately 0.83 million ha was occupied by maize in 2012 (AIS, Krishi Dairy, 2013). However, average farm yield of maize is much lower than attainable yields and such large yield gaps suggest substantial scope for improvement. Hence, germplasm and management constraints need to be overcome to ensure that maize is profitable, resource-efficient, and grows in a manner that ensures food security and livelihoods. Since maize is a relatively new crop in Bangladesh, better agronomic management practices, and better genotypes are under development. Tillage options are required; however, there is also lack of information on genotype x tillage interaction in Bangladesh. The objective of this study was to assess the performance of maize hybrids under conventional and strip tillage across different environment in Bangladesh.

Materials and Methods

The experiment was conducted in 18 farmers' fields of two upazila in each district in Comilla (23°28'N), Rangpur (25°42'N) and Rajshahi (24°22'N) under the agro ecological zone of Middle Meghna River Floodplain, Active Tista Floodplain, Tista Meander Floodplain, and Active Ganges Floodplain, respectively (FRG2012).

The experiment was conducted in a split-split plot design with 50 m^2 the smallest plot size and with 3-replicates in each Upzilla. Tillage options viz. strip tillage (ST) and conventional tillage (CT) were considered as main plots and six maize hybrids viz. BHM-9 (BARI hybrid), Sunshine (Syngenta hybrid), Pinacle (Monsanto), 900M Gold (Monsanto), 981 (Monsanto), and Pacific 984 (BRAC hybrid) as sub-plots. Strip tillage (ST) was done by single pass, making strips by maintaining 60 cm row spacing with 6 cm depth for seed sowing and immediately covering the seed with soil and simultaneously applying basal fertilizer by 2-wheel power tiller operated seeder. Conventional tillage (CT) was formed by 3 full tillage passes by 2-wheel power tiller, followed by a single planking, and then manual seeding by dibbling. The spacing was 60 cm between rows and 20 cm between plants in each row.

In all treatment plots were fertilized as recommended based on site specific nutrient management and cultural practices carried out properly when necessary. At crop maturity all yield contributing characteristics and grain yield were estimated from each plot in sampling area of 10.08 m^2. Data were analysed using the mix-model procedure of the Statistical Analysis System (SAS institute, 2001) and means effects were separated by Turkey's test.

Results and Discussions

The interactions between tillage options and maize hybrids, and among sites and hybrids were non-significant for all characters except 1000-grain weight. Plant height and cob length were significantly higher in CT that in ST but other parameters, grains per cob, 1000-grain weightand cob girth were similar between CT and ST. The1000-grain weight of Pinnacle was highest followed by 900M Gold, 981 and BHM-9, respectively, and statistically identical with Pacific 984 and Sunshine. The lowest 1000-grain weight was for BHM-9 which was significantly lower than other hybrids except 981. The longer cobs were formed in 900M Gold followed by Pacific 984.

For crop yield and partial economics the sites (upazila) and replications (farmer) were highly significant effects (p=.001). The site x hybrids interactions were significant for grain yield, gross return and net income (p=0.06). The interaction indicated that the maize hybrids performed differently in different sites. Tillage was unable to show any significant effects on yield parameters. The cost of production was higher in CT than ST but it was reverse for net income. BHM-9 and produced the highest stover yield among hybrids followed by 900M Gold, Sunshine, 981, Pinnacle and Pacific 984, respectively. It was due to more plant height in the hybrid. Grain yield was the highest for 900M Gold, Sunshine and 981(9.29-9.55 t ha^{-1}). BHM-9 and Pacific produced lowest grain yield among the hybrids. The highest biomass was found in Sunshine, BHM-9 and 900M Gold (19.9-19.4 t ha^{-1}) and lowest in Pacific 984 and Pinnacle with the remaining hybrids produced intermediate biomass.

As with grain yield, gross return and net income were highest for 900M Gold, Sunshine and 981. These higher returns were due to higher grain yield. However, there was no effect of tillage type on net income differences among maize cultivars.

Table 1. Crop yields and partial economics under different tillage options at different locations during 2012-13 in Bangladesh

Hybrids	Yield (t ha^{-1})			HI	BDT (1 BDT = 0.0129241 USD)ha^{-1}		
	Stover	Grain	Biomass		Production cost	Gross return	Net income
981	9.61bc	9.29ab	18.9abc	0.49a	106569	185905ab	79336ab
900MGold	9.78abc	9.55a	19.3ab	0.4a	106827	191363a	84536a
BHM9	10.3a	8.93c	19.3ab	0.46b	106167	179717c	73550c
Pacific984	9.31c	8.94c	18.3c	0.49a	106158	179505c	73348c
Pinnacle	9.56bc	9.09bc	18.7c	0.49a	106371	182238bc	75867bc
Sunshine	10.1ab	9.32ab	19.4a	0.48ab	106591	187123ab	80532ab
Tillage							
CT	9.93	9.23	19.2	0.48	110740A	185256	74516B
ST	9.63	9.14	18.8	0.49	102155B	183362	81207A
ANOVA	Probability						
Site	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Rep	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tillage	0.107	0.281	0.064	0.372	0.001	0.257	0.001
Hybrid	0.019	0.002	0.009	0.014	0.981	0.002	0.007
Site x Hybrid	0.127	0.021	0.075	0.195	0.999	0.031	0.068
Tillage x hybrid	0.862	0.619	0.737	0.883	0.999	0.654	0.718

These results suggest that 900M Gold is better grain yielding hybrid of maize among the tested six hybrids but no significance differences with 981 or Sunshine under the both tillage system in three districts and ST was more profitable than CT. However, there was no indication that cultivar performance varied with strip tillage compared to the conventional tillage under which prior selection has been conducted.

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Weed Incidences and Crop Performance of Zero Tilled Dry Seeded Rice under Different Weed Management Options

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Introduction

Conventional transplanting for rice production is achieved by intense tillage under ponded water conditions which requires more time, labor, energy and more water availability. In recent years, there has been shifting from TPR to DSR cultivation in several countries of Southeast Asia due to increase labor cost and reduced profit margin. Since hand weeding is become expensive due to shortage of labour and higher costs, use of herbicides can be a better cost effective alternative to control weeds. Keeping this in view, the present field investigation was carried out to test the response of weed management techniques in dry DSR under zero tillage system.

Materials and Methods

The trial comprising fourteen combinations of weed management for DSR under zero tillage was conducted in BRRI Rajshahi during wet season of 2011 and 2012. The weed management options were 1. Panida (Pandimethalin; pre-emergence herbicide), 2. Panida + Hammer (Carfentrazone-ethyl post emergence herbicide); 3. Panida+Sunrise (Ethoxysulfuron; post-emergence herbicide), 4. Panida +1 Hand weeding (HW), 5. Topstar (Oxydiargyl; pre-emergence herbicide), 6. Topstar + Hammer 7. Topstar +Sunrise, 8. Topstar +1 HW, 9. Hammer 10. Hammer + 1 HW, 11. Sunrise 12. Sunrise + 1 HW, 13. Weed free (3 Hand weeding) and 14. Weedy. Post-emergence-Nominee Gold (Bispyribac Na^+) was used instead of Sunrise during 2nd year. The sowing of seeds was done directly by power tiller operated seeder (PTOS) with slightly opening the untilled soil.. Glyphosate was applied in untilled soil before sowing of seeds. Total weed data were counted in dry matter basis at 28 and 56 DAS. Data were analyzed using Crop Stat (version 7.2).

Results and discussion

Total weed dry matter of weeds at 28 and 56 days after seeding were significantly affected by weed management options (Table 1). The weed dry biomass of weeds either 28 DAS and 56 DAS was found higher in weedy check compared to the treatments. The treatments comprised of post emergence either alone or with pre-emergence proved to be comparatively superior in decreasing dry weight at 28 DAS . The biomass at 56 DAS was the lowest in weed free and nominee gold +1HW treatments, respectively during 2011 and 2012. Among the herbicide applied plots, the highest weed dry biomass at 56 DAS was observed in Panida treatment. Next to panida treatment, the lower crop weed competition was observed in Topstar indicated that pre-emergence caused less suppression on weeds intensity which was supported by Chauhan et al. (2006). The crop weed competition was found better in the following order as weed free> any post –emergence herbicide + 1HW>any pre-emergence + 1HW>any pre-emergence + any post emergence>any post emergence>any pre emergence.

The weed management packages had significance influence on grain yield and the higher yield was found in weed free and that was the lower in weedy treatment across the years. It also found that Weed free, Topstar + 1HW and Hammer + 1HW treatments produced statistically similar grain yield during first year. The pre or post emergence herbicide alone or in combination of pre and post emergence did not produce remarkable yield in first year compared to 1 HW plus one pre or post emergence herbicide. The grain yield of rice in 2nd year was comparable among weed free, any pre or post-emergence+1HW and the combinations of pre + post-emergence. Although the gross return was higher but the gross margin was comparatively lower in weed free treatment. Next to weed free, higher gross return was found in the treatments receiving pre or post-emergence + 1 HW. In contrast, without manual weeding treatments had more gross return. Increasing labor cost of manual weeding treatments caused lower gross return which was supported by Sanjay et al. (2008).

Table 1. Effect of weed management options on weeds dry matter, grain yield, gross return and gross margin in DS Aman rice under zero tillage system, 2011 and 2012

Treatments	Weed dry wt. (g m^{-2}) at 28 DAS		Weed dry wt. (g m^{-2}) at 56 DAS		Grain yield (t ha^{-1})		Gross return (Tk. ha^{-1})		Gross margin (Tk. ha^{-1})	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Panida	13.2	9.9	39.6	46.5	3.28	2.90	53710	51318	28117	24567
Panida+Hammer	4.43	5.23	23.6	27.6	3.33	5.00	58210	85286	30274	56050
Panida+SR/NG	5.91	2.91	26.3	37.3	3.53	4.50	51700	77168	23732	47917
Panida+1HW	9.41	3.04	12.3	16.5	3.74	3.93	57780	68811	23937	31560
Topstar	9.35	6.25	37.8	29.9	3.56	3.06	54880	53116	30423	27500
Topstar+Hammer	5.40	6.44	18.5	16.1	3.52	4.12	46900	73265	20199	45280
Topstar+SR/NG	4.30	5.25	21.4	14.0	3.08	4.63	66390	80128	39318	51756
Topstar+1HW	8.60	3.63	16.0	23.1	4.17	4.18	68300	73493	35551	37335
Hammer	6.02	6.81	33.8	36.8	2.81	4.33	57800	75434	33657	50133
Hammer+1HW	5.30	7.43	14.6	17.5	4.05	5.09	48150	87665	15664	51770
Sunrice/N. Gold	5.11	1.88	28.9	14.0	2.87	4.63	61530	80823	37321	55472
SR/NG+1HW	5.50	4.59	18.2	12.2	3.82	4.70	63350	82074	30707	46023
Weed free	12.3	9.91	11.5	9.5	4.64	5.24	76010	89543	35292	44592
Weedy	19.1	13.8	107	89.0	2.08	2.49	36060	44650	13217	20699
LSD(0.05)	6.33	4.58	25.8	35.6	0.67	1.17	13078	19044	13051	19008

Conclusion

In conclusion, the crop weed competition was lower in weed free followed by any post-emergence + 1HW. Grain yield and gross return was remained higher in weed free treatment in both the years but gross margin was comparatively lower due to increase weeding cost. One hand weeding + any pre or post emergence herbicide performed well in regards to yield and also the gross margin and gross return.

Acknowledgements

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Productivity of Lentil as Influenced by Different T. Aman Rice Varieties in High Barind Tract

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Abstract

Lentil (Lens culinaris) production by using residual soil moisture after harvest of short duration T. Aman rice is increasing in High Barind Tract. An experiment on lentil (BARI Masur-7) was conducted to evaluate the suitable T. Aman rice variety for lentil production using residual soil moisture. The treatments were i.e., T_1: Swarna-lentil, T_2: BINA dhan7-lentil, T_3: BRRI dhan33-lentil, T_4: BRRI dhan39-lentil, T_5: BRRI dhan49-lentil and T_6: BRRI dhan57-lentil. The maximum number of pods plant^{-1}, seeds pods^{-1}, thousand seed weight, seed and stover yield was obtained from treatment T_2 (BINA dhan-7 - lentil) and the minimum was from treatment T_1 (Swarna-lentil). So, sowing of lentil seed at just after harvest of BINA dhan7 rice and BRRI Dhan 33 T. Aman rice varieties were optimum for maximizing the yield of lentil in High Barind Tract soil.

Introduction

In the High Barind Tract (HBT), a vast area of land remains fallow after harvesting of T. Aman rice. The area and production of lentil (*Lens culinaris)* has increased in this region. Lentil is a deep rooted crop and a low amount of moisture is required. Normally the farmer has less chance to cultivate lentil after harvesting of long duration T. Aman rice varieties Swarna. BINA Dhan7, BRRI-Dhan39 and BRRI Dhan49 are short duration rice varieties. These high yielding T. Aman rice varieties may be suitable for getting higher yields from both rice and lentil crops using present soil moisture. The HBT, specifically north-western part of Rajshahi division, is different from other parts of the country due to its undulating topography and compact, low fertile soils. A crop production system with high yield targets cannot be sustainable unless balanced nutrient inputs are supplied to soil against nutrient removal by crops (Bhuiyan and Panaullah, 1991). Therefore, the present study will be under taken to find out the suitable T. Aman rice variety for lentil production using residual soil moisture.

Materials and Method

An experiment on lentil was conducted at farmer's field of FSRD site Kadamshahar, Godagari, Rajshahi (AEZ 26) during *Rabi* season 2012-13 & 2013-14 to evaluate the suitable T. Aman rice variety for lentil production using residual soil moisture for maximizing the yield. The experimental design had six treatments; laid out in a randomized complete block design with eight dispersed replications. The treatments were; T_1: Swarna-lentil, T_2: BINA dhan-7-lentil, T_3: BRRI dhan33-lentil, T_4: BRRI dhan39-lentil, T_5: BRRI dhan49-lentil and T_6: BRRI dhan57-lentil. Lentil variety (BARI Masur-7) was used in this study. The land was fertilized with 24-18-20 N-P-K kg ha^{-1} (FRG, 2005) in the form of urea, triple super phosphate and muriate of potash, respectively. Seeds of lentil were sown in line maintaining a spacing of 30 cm × 5 cm on 5-24 November 2012 and 10-30 November 2013. Lentil was harvested on 15-30 February 2013 and 16-30 February 2014. Data was collected on yield and yield components from 10 randomly selected plants per plot. The data were analyzed statistically and the mean differences were calculated by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Yield of T. Aman rice and lentil responded significantly differences among the treatments. Average of two years results revealed that the maximum grain yield of T. Aman rice (4.73 tha^{-1}) was recorded from T_2 followed by T_3 and T_4 but minimum yield (3.50 t ha^{-1}) from T_1 (Table 1). However, for lentil, average of two years results show the maximum seed yield (1.68 t ha^{-1}) was for T_2 and T_3 (1.61 t ha^{-1}) and lowest yield (0.78 t ha^{-1}) in late sowing treatment (T_1) (Table 1). The cost-benefit analysis of average 2012-13 & 2013-14 results showed that T_2 produced the maximum gross margin of Taka (Tk.) 150730 ha^{-1} and the lowest Tk. 64260 ha^{-1} from T_1 (Table 1). This variation occurred due to the variation of yield. Treatment T2 was found economically profitable and viable among treatments for the cultivation of T. Aman rice and lentil in the High Barind Tract soil.

Conclusion

From two years results, it may be concluded that sowing of lentil seed just after harvest of T. Aman rice (BINA Dhan 7 and BRRI Dhan 33) was optimum for maximizing the yield of lentil production in High Barind Tract soil as maximum soil moisture prevails in the plot than other treatments.

Table 1. Yield and economic return of different T. Aman rice varieties and lentil at FSRD site, Kadamshahar, Godagari, Rajshahi (Average of 2012-13 & 2013-14)

Treatments	Rice yield (t ha^{-1})		Lentil seed yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
	Grain	Straw				
T_1	3.50 d	4.98 c	0.78 f	122230	57970	64260
T_2	4.73 a	5.96 a	1.68 a	208700	57970	150730
T_3	4.33 ab	5.50 ab	1.62 b	196140	57970	138170
T_4	4.18 bc	5.35 ab	1.57 c	190490	57970	132520
T_5	4.05 bc	5.20 bc	1.42 d	176800	57970	118830
T_6	3.96 c	5.10 bc	1.15 e	156880	57970	98910
CV (%)	5.36	9.74	4.50	-	-	-

Price (Tk kg^{-1}): Urea 20, TSP 22, MP 15, Gypsum 6, Zinc sulphate 130, Boric acid 130, Rice seed 40, Lentil seed 100, Lentil – 70, Rice- 18 & Rice straw-1

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Soil Moisture Conservation as Influenced by Mulching and Tillage and its Effect on Potato Yield in High Barind Tract

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Introduction

Availability of soil moisture is the most limiting factor for growing winter crop in High Barind Tract (North Western part) of Bangladesh. Potato *(Solanum tuberosum)* is an important vegetables crop, cultivated in *Rabi* (winter season) season in Bangladesh. The High Barind Tract (HBT) is a drought-prone area characterized by grey terrace soil, low organic matter, low rainfall, high temperature and low soil pH (<6). In the case of dry land farming, the use of mulch is beneficial to conserve soil moisture, reduce soil temperature, minimize evaporation loss and enhance root growth (Allamaras et al. 1977; Gupta and Gupta, 1986). On the other hand moisture conservation may be determined by tillage type in rainfed cultivation. It is recognized that minimum tillage improves soil water conservation. Since, most of the lands in the HBT of Bangladesh remain fallow in winter season due to shortage of water, a combination of different mulching materials and tillage options will be the best soil moisture conservation techniques for potato production. Considering scarcity of water, the present experiment was undertaken to find out the suitable tillage methods and mulch application to conserve residual soil moisture for the better growth and yield of potato during *Rabi* season in the HBT of Bangladesh.

Materials and Methods

A field trial was conducted at the OFRD site Kadamshahar, Godagari, Rajshahi during *Rabi* seasons of 2012-13 and 2013-14.The initial soil in the experimental field contained a pH value 5.7, 0.89 % organic matter, 0.07 % total nitrogen, available P, S, B and Zn were 12.4, 14.7, 0.16 and 0.85 mg/kg soil, respectively. The treatments comprised two different tillage options viz., reduced tillage (one ploughing followed by laddering) and conventional tillage (4 ploughings followed by laddering) and three different mulch materials viz., rice straw cover on the soil surface @ 3 t ha^{-1}, rice straw cover on the soil surface @ 5 t ha^{-1} and no mulch. The trial was laid out in split plot design with six dispersed replications. Tillage treatments were placed in the main plots and mulch treatments in the sub-plots. Potato variety Cardinal was used in the study. The potato seeds were sown on 24-26 November 2012 and 25-30 November 2013 with the line sowing (40 cm x 20 cm). A fertilizer dose of 100-25-100-15-10 kg N–P-K-S-Mg/ha was applied in the field. Soil moisture regimes of the experimental plots were recorded at a depth of 0-15 cm at 15-day intervals. Only a single irrigation was applied during 30-35 days after planting for establishment of the crop. The crop was harvested on 23-26 February 2013 and 26-28 February 2014. The data were analyzed statistically and the mean differences were adjudged by Duncan's Multiple Range Test and student t-test (Gomez and Gomez, 1984).

Results and Discussion

Soil moisture regime: Average over two years the soil water in the reduced tillage plots with 5 t of straw mulch ha^{-1} decreased at slowest rates followed by reduced tilled plots with 3 t of straw mulch ha^{-1} (Table 1). On the other hand, conventional tilled plots with no mulch decreased at highest rates.

Combined effect of tillage options and mulching: The highest tuber yield (25 t ha^{-1}) and net return was recorded from the combination of reduced tillage coupled with 5 t straw mulch ha^{-1}. The reason for higher yield in reduced tillage and 5 t ha^{-1}straw mulch might be due to decreased soil temperature and more efficient conservation of water which favoured growth and development of the crops during the growing period. The lowest yield was recorded in no- mulch irrespective of tillage options. Mondal et al. (2003) also reported that straw mulch was more effective than soil mulch in mustard. Reduced tillage (one ploughing) coupled with straw mulch at the rate of 5 t ha^{-1} might be a good option for better soil moisture conservation, higher economic benefit and yield of potato in High Barind Tract of Bangladesh.

Table 1. Changes in soil moisture (%) of potato field as influenced by tillage and mulch at different days after sowing (Average of two years)

Tillage and straw	Days after sowing (DAS)						
(t ha^{-1})	0	15	30	45	60	75	90
Reduced + 5	39.0	37.7	36.1	38.6	33.6	32.2	30.7
Reduced + 3	38.0	35.0	33.3	36.5	31.5	27.3	26.3
Reduced + 0	33.7	32.1	30.2	32.5	28.8	24.6	23.5
Conventional + 5	38.9	36.9	35.2	36.9	32.1	31.8	29.7
Conventional + 3	35.8	34.5	32.3	33.4	29.3	27.5	25.7
Conventional + 0	34.5	31.9	30.6	31.5	27.3	24.4	23.1

Table 2. Yield and yield contributing character, cost and return analysis of potato as influenced by tillage options and mulch at Kadamshahar, Godagari, Rajshahi (Average of two years)

Tillage and straw (t ha^{-1})	No. of tuber $plant^{-1}$	Tuber weight $plant^{-1}$ (g)	Tuber yield (t ha^{-1})	Net return (Tk ha^{-1})	BCR
Reduced + 5	10.4a	634a	25.0a	139000	2.25
Reduced + 3	9.88ab	595ab	23.5ab	126800	2.17
Reduced + 0	6.66c	500bc	20.8bc	104200	2.01
Conventional + 5	8.53b	566b	21.8b	116100	2.13
Conventional + 3	7.43bc	447c	21.0bc	104500	1.99
Conventional + 0	6.20c	448c	19.3c	95200	1.97
CV (%)	8.1	7.6	6.1	-	-

* Means followed by different letters were significantly different at 5% level by DMRT

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An Introduction of a Change Hypothesis to Promote Small-scale Farmer-friendly 2WTs Innovation in Conservation Agriculture, Bangladesh

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Introduction

In Bangladesh, the emergent agricultural technology known as conservation agriculture (CA) may be hampered as local small-scale farmers (SSFs) have no provision in national agricultural policy and governance. In this paper, the main question is how in the name of the elite-driven agriculture governance and policy (EDAGP), national and international agricultural reforms have affected SSFs in Bangladesh and how CA through agricultural technology innovation will overcome the barriers created by the EDAGP. Based on this premise, emphasis will be placed onto a. identifying the impacts of important national and international agricultural reforms on Bangladeshi SSFs; b. categorizing the obstacles that CA encounters in the new technology adoption process; and c. proposals to solve the above-mentioned obstacles through the proposed 'Change Model for Pro-poor National Agricultural Policy'. To achieve this research aims the relevant research questions are: is the change model worthwhile for empowering the SSFs, and; more importantly, what factors will compel the elite groups to partake in Pro-poor national agricultural policy (PPNAP)? Thus the paper aims to provide an insight into the EDAGP in Bangladesh, to provide an understanding of the effectiveness of the institutional interventions and identify the obstructions created by this approach. The key contribution of this paper is to help policy makers understand the obstacles and potentialities of promoting a PPNAP. In fact, two related facts are important to identify the research gaps: what type of strategic alliances among diverse national and international stakeholders will compel the rich farmers and elite groups to accept a small-scale farmer friendly agriculture policy? And, what strategic and institutional changes will ensure small-scale farmer's friendly gradual reforms within related agricultural institutions, and farmers' group?

This paper primarily draws on the literature on food security and agricultural governance of Bangladesh as well as conservational farming project reports of ACIAR projects in Bangladesh and from working papers of national and international agricultural organizations on small-scale farming.

Results and Discussion

The process of changing policy is not easy. Establishing a change hypothesis becomes difficult when throughout the change process it becomes evident that not only inadequate laws but also inefficient law enforcing institutes are also responsible for SSFs marginalization (Lewis and Hossain 2008). The change hypothesis has designed a change model through a power analysis that tries to make a strategic alliance between the vertical (across local, national and global levels) and horizontal levels (among local stakeholders) so that not only the visible forms of obstacles but also the invisible (mindsets of SSFs) as well as the hidden forms of obstacles become minimized (Gaventa 2006). In the case study the suggested change process is cumulative and sequential. Especially, when the rich farmers and elite groups are the promoted groups of any existing policy, there is less chance that without any strong strategic alliance among diverse national and international stakeholders a new agricultural policy adoption will be possible.

Conclusions

This paper aims to provide an insight into the EDAGP in Bangladesh, to provide an understanding of the effectiveness of the institutional interventions and identify the obstructions created by this approach. Hence, this project will endeavor to postulate a change hypothesis. The key contribution of this project is to help policy makers understand the obstacles and potentialities of promoting a PPNAP. From the paper it is evident that the SSFs get promoted when improved agriculture governance with developed new technologies and an effective targeting strategy from the national and international level act together.

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Conservation agriculture increases land and water productivity of a rice-wheat-mung system on the High Ganges River Flood Plain of Bangladesh

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Introduction

Cropping systems on the High Ganges River Flood Plain of Bangladesh are highly diverse, but usually include puddled transplanted rice (PTR) during the rainy season (aman rice). However, establishment costs of PTR are high due to intensive tillage and the high labour requirement for transplanting. Furthermore, puddling for rice damages soil structure and impairs the performance of non-rice crops in the rotation. Also, groundwater levels are declining due to intensive pumping during the dry season. Therefore, we established an experiment to evaluate the effects of reduced tillage and aman residue retention on land and irrigation water productivity of a rice-wheat-mung cropping system.

Materials and methods

The experiment evaluated 3 tillage/establishment method (TE) treatments in main plots (9 m x 22 m) – TE1: PTR followed by conventional tillage and sowing of wheat or mungbean in a single pass using a power tiller operated seeder (PTOS); TE2, dry seeded rice (DSR) followed by wheat and mungbean, with all 3 crops established with the PTOS; TE3: DSR followed by wheat and mungbean with all crops established with the PTOS but using strip tillage. There were two levels of aman rice straw retention in sub plots – none (removed at ground level), or retention of 40 cm high standing straw, and 3 replicates. The site was on a clay loam soil at BARI, Jessore. Safe alternate wetting and drying (AWD) water management was used for all rice crops, based on soil tension of 15 kPa at 15 cm soil depth. Rice equivalent yield of wheat and mungbean was calculated based on their prices relative to that of rice. Data were analysed by ANOVA using a split plot design.

Results and discussion

Yield of the second and third wheat crops was significantly higher (by 12-14%) when grown in rotation with DSR compared with PTR (data not presented). Aman straw retention significantly increased yield of the second mungbean crop (by 6%) and the second and third wheat crops (by 10%). DSR and PTR had similar yield each year. However, irrigation input to DSR was ~55% of that to PTR.

Total system rice equivalent yield was not affected by TE treatment in the first 2 years (Fig. 1A), however, the systems with DSR (TE2,3) reduced total irrigation input by about 600 mm (35%) compared with the system with PTR (TE1) (Fig. 2A). Rice residue retention significantly increased system yield (by 0.5 t ha^{-1} or 3%), compared with residue removal in the second year, and when averaged over the first 2 years (Fig. 1B). Rice residue retention significantly reduced system irrigation input in the second year, by 50 mm or 4% (Fig. 2B). Irrigation water productivity (WP_I) was highest in the systems with DSR (TE2,3), with no difference between conventional and strip tillage after 2 years (Fig. 3A). Rice residue retention also gave a small but significant increase in WP_I (Fig. 3B).

The similar yields of PTR and DSR were consistent with the findings of Sudhir-Yadav et al. (2011) who also compared DSR and PTR on a clay loam soil with safe AWD water management. Yield of wheat declined after only one year of puddling on this soil which had not previously been puddled. Along similar lines, other studies show that on soils with a history of puddling, yields of wheat start to improve after 2-4 years of replacement of PTR with DSR (e.g. Gathala et al. 2011).

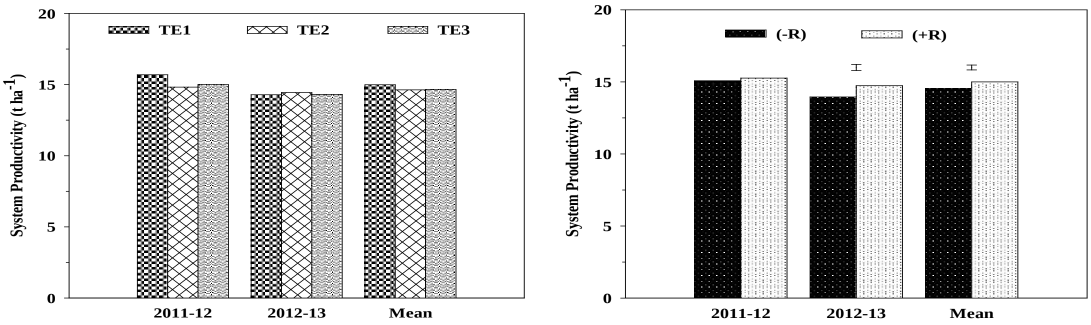

Figure 1. (A) System productivity (rice equivalent yield) of tillage/ establishment treatments (TE- see materials and methods), and (B) residue treatments, in the first 2 years.

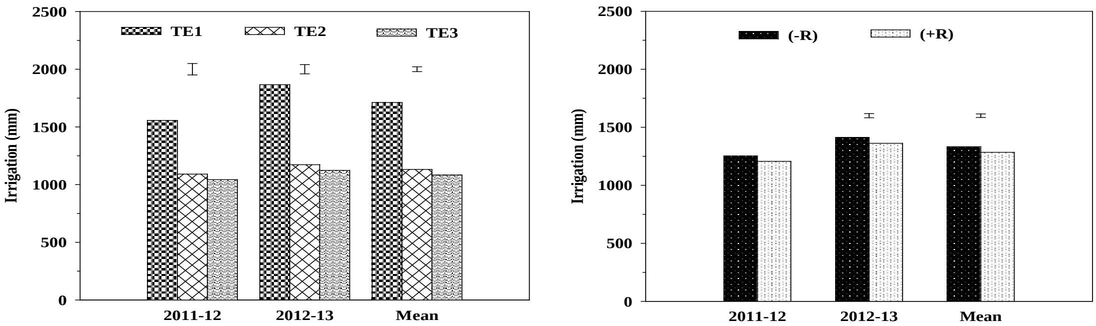

Figure 2. (A) System irrigation input of TE, and (B) residue treatments, in the first 2 years.

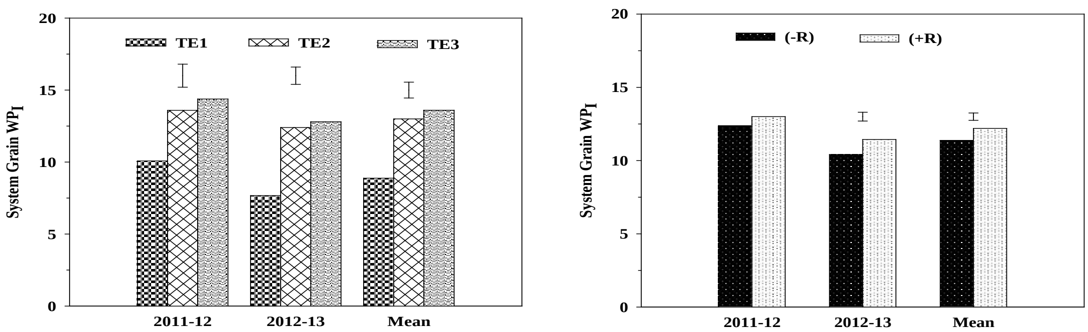

Figure 3. (A) System irrigation water productivity of TE, and (B) residue treatments, in the first 2 years.

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Study on inundation periods of land for mechanical transplanting under minimum tillage unpuddled transplanting

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Introduction

In Bangladesh and other countries in Asia, manual transplanting of rice into puddled soil is conventional practice but relies on access to cheap readily-available labour. Besides being costly and time consuming, puddling results in degradation of soil (Chauhan et al., 2012). The use of continuous puddling results in the formation of a hard pan with a consequent increase in bulk density and lowering of hydraulic conductivity below the plow layer (Singh et al., 2009). To overcome labour and water shortages, mechanical transplanting of rice under minimum tillage is of considerable interest but little is known of the optimal inundation for soils before transplanting. In this study both farmers' participatory and research station-based experiments evaluated the performance of a mechanical rice transplanter at Bangladesh Rice Research Institute research farm, Gazipur and on farmers' fields at Kushtia and Rangpur, Bangladesh under minimum tillage options and varied inundation periods.

Materials and Methods

The Versatile Multi-crop Planter and a rotary tiller both powered by a two-wheel tractor prepared the strip and conventional plots, respectively. Two dry and one wet pass followed by one leveling operation produced conventional puddling of soil. Seedlings of cv. BRRI dhan28 were raised at 130 gram of pre-germinated seeds in each tray. Textural classes at Gazipur, Kushtia and Rangpur were clay loam, loamy and sandy loam soil, respectively. Soil resistance during transplanting was measured by a hand penetrometer at 5 cm operating depth. Tillage treatments in a split plot design with three replications were strip tillage (ST), zero tillage (ZT) and conventional tillage (CT) and the inundation periods as sub-plots before transplanting were 12, 18 and 24 hrs. The 4 row walk-behind type Daedong rice transplanter, model DP480 was used to transplant into the strip, zero and conventional tillage plots.

Results

Average tillage time for ST and CT was 11.0 and 24.8 hr/ha. Un-puddled ST saved 56% of tillage time and fuel consumption compared to CT. Conventional tillage demonstrated significantly higher soil resistance (22.4 N/cm^2) in clay loam soil whereas ZT and ST (in the furrow of the strip) demonstrated higher soil resistance (16.8 and 14.6 N/cm^2 respectively) in sandy loam soil at 0-5 cm operating depth. Soil resistance varied among the soils in the order sandy loam > loam > clay loam soil. In clay loam soil, highest field capacity (area coverage per unit time) of the transplanter was observed for ST and ZT (0.128- 0.127 ha/hr). In loamy soil¸ CT showed higher field capacity. In clay loam and loamy soil, field capacity of the rice transplanter decreased with increased of inundation periods. By contrast, in sandy loam soil higher field capacity of the rice transplanter was observed for 18 hrs inundation period. In sandy loam soil, ST and ZT saved about 20% fuel consumption over CT. Inundation period showed insignificant effect on fuel consumption in all cases.

Tillage showed significant effect on volume of water required for transplanting. Strip and ZT saved 10-20%, 15-30% and 20-30% of the water required to prepare soils for transplanting of rice in clay loam, loam and sandy loam soil, respectively compared to CT. On the contrary, inundation periods before transplanting had no significant effect on volume of water required in three types of soil.

Tillage treatment did not affect the percentage of missing hills in clay loam and sandy loam soil conditions. In loam soil, however, lowest percentage of missing hills was observed for ST. Zero tillage provided more missing hills because of more floating plants followed by CT. On the other hand, ST provided minimum missing hills. There were fewer missing hills with 24 hrs inundation with each tillage treatment. There have no inundation effect on weed infestation. Zero and ST showed significantly height weed infestation compared to CT.

Strip tillage gave significantly higher yield in loam and sandy loam soil (Table 1). There was no significant difference in yield between ZT and CT in sandy loam soil. Inundation period showed significant effect on yield in three types of soil. In sandy loam soil, 18 hrs for ST and 24 hrs for ZT and CT gave highest yields. However, averaged across three soil types, ST with 18 hrs inundation period showed higher BCR 1.54 followed by 1.51 and 1.45 for CT and ZT, respectively, with 24 hrs inundation period.

Table 1. Grain yield at 14 % moisture content (t/ha) as affected by tillage treatment and inundation period (IP) in three soil types.

	Clay loam soil				Loam soil				Sandy loam soil			
	IP_{12}	IP_{18}	IP_{24}	Mean	IP_{12}	IP_{18}	IP_{24}	Mean	IP_{12}	IP_{18}	IP_{24}	Mean
ST	4.7	5.1	5.3	5.0	4.7	5.5	5.4	5.2 a	6.0 cd	7.0 a	6.3 bc	6.4 a
ZT	5.2	5.2	5.6	5.3	4.3	4.5	4.8	4.5 c	5.2 f	5.8 de	6.5 ab	5.8 b
CT	4.8	5.4	5.7	5.3	4.7	4.8	5.3	4.9 b	5.5 ef	5.8 ef	6.3 bc	5.8 b
Mean	4.9 b	5.2 ab	5.5 a	-	4.6 b	5.0 a	5.2 a	-	5.6 c	6.1 b	6.4 a	-
$LSD_{0.05}$	T= NS, IP=0.40 and T × IP = NS				T= 0.22, IP =0.23 and T × IP = NS				T= 0.24, IP =0.25 and T × IP = 0.4240			

Note: ST=Strip tillage, ZT=Zero tillage, CT=Conventional tillage, NS-Not significant, *-significant at 5%, **-significant at 1%, Data followed by different letters differ significantly.

Conclusions

Rice transplanter operation and rice production under minimum tillage was satisfactory irrespective of soil especially under ST. Averaged across three soil types, 18 hrs inundation for ST and 24 hrs inundation for ZT and CT showed more benefit for rice production.

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Development of the riding-type rice transplanter for unpuddled transplanting

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Introduction

Transplanters have been developed for rice seedling planting into puddled soils to alleviate labour shortages and reduce costs of rice establishment (Adhikari et al., 2006). Although tillage for rice establishment is significantly mechanized in Bangladesh, 16-18 % of total production costs are due to tillage and land leveling (BRRI, 2013). Development of a rice transplanter suitable for unpuddled transplanting under minimum tillage conditions could further minimize the land preparation cost which will be of interest to small-holder farmers. No significant work to date has been conducted in Bangladesh to develop a rice transplanter for minimum tillage unpuddled soil conditions. The following development study was conducted to modify and evaluate a riding-type, 6-row mechanical rice transplanter for unpuddled soil conditions.

Materials and Methods

A strip tillage mechanism was attached in front of and in line with the rotary picker for transplanting rice seedlings (Fig. 1). Fabrication was conducted according to a design made at the FMPHT Division, BRRI. Engine power available at a 3600 rpm was conveyed to the strip tillage rotary shaft with the arrangement of a belt-pulley, worm gearing, shaft-universal joint, involutes spline shaft and bevel gear resulting in a 450 rpm rotary blade speed. A lever-operated tensioning pulley was included into the belt drive to engage and disengage the power to the strip tillage shaft. A B-section V belt (38^0 groove angle) was used based on design power and rpm of the engine shaft pulley. A straight-face worm gear was designed to reduce main shaft speed to 450 rpm from a secondary shaft speed of 2250 rpm considering transmitted power 1.75 kW. The tine was designed to produce a 2 cm deep ×2 cm wide strip (Fig. 1). The modified rice transplanter was evaluated for transplanting seedlings in moisture-saturated and unpuddled soils produced under minimum tillage.

Results

The values of specific draft (Barger et al., 1978) varied from 1.4 to 2 N/cm^2 of furrow cross section area for sandy soils, 2 to 5 N/cm^2 for sandy or silt loam soil and 4 N/cm^2 for clay loam soils and declined with increased soil moisture content up to 11.7%. A 2.6 N/cm^2 force was thus assumed for torque calculation considering a soil specific draft of 4 N/cm^2 and 35% reduction for saturated condition. It was calculated that about 1.0 kW power is required to cut strips simultaneously across the width of the rice transplanter in operation. A double-groove pulley of 12.5cm diameter was attached to the engine shaft to replace the single-groove pulley and to share the engine power for strip tillage by transmission to the secondary shaft attached below the engine shaft. Centre-to-centre distance of the engine shaft and the secondary shaft is 33.0 cm. A pulley (20 cm diameter) was attached to the secondary shaft to reduce the engine rpm from 3600 to 2250. Diameter of the secondary shaft was critically designed to be 2.3 cm considering the combined twisting and bending moments. Input shaft of the worm gear was coupled with the secondary shaft because of equal speed of the worm and the secondary shaft. Tangential load acting on the gear was calculated as 1088 N and design tangential load was calculated as 2007 N. The design load was more than the tangential load acting on the gear (1088 N). The design is also safe from the stand point of dynamic, static and wear load because of more loads compared to the tangential load. Design diameter of the worm shaft was 14.05 mm (taken 20 mm) considering resultant bending moment and equivalent twisting moment on the worm shaft.

Figure 1. Rice transplanter developed for unpuddled transplanting

Bevel gears were used to connect the 90 degree intersecting shafts to transmit main shaft power to the rotary shaft of the strip tillage tine. Equal bevel gear having equal teeth and equal pitch angle connected two shafts whose axes intersected at a right angle. Because of same teeth, pitch angle for pinion and gear is same of 45 degree. An involutes spline shaft was used in the developed transplanter in between bevel gear and main shaft with hub to slide along the shaft. Total length of the shaft is 23.3 cm along with 17.5 cm spline shaft and hub. Transmitted torque of the spline shaft is same as the main shaft torque because of same rpm. Torque of the main shaft is 37.15 N-m based on transmitted load 1.75 Kw. The developed transplanter was tested in the FMPHD soil bin. During test, average strip size was 2.0 x 2.10 cm. Seedlings were placed uniformly in the strip without damage.

Conclusion

A commercial riding-type mechanical rice transplanter was modified to operate under minimum tillage unpuddled transplanting with the capability of making strips concurrently with rice transplanting, in a one pass operation following basic land preparation without puddling. The developed transplanter performed well in preliminary tests by making strips and by satisfactory seedling placement in unpuddled soil.

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Effect of different green manures on rice productivity and soil conservation

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Introduction

Green manure (GM) is a kind of organic fertilizer grown chiefly to supply nitrogen (N) to the main crop in a cropping system. It can also draw up other nutrients from deeper soil layers and enrich the surface soils. From the economic point of view, green manuring with locally available resources offers an opportunity since the chemical fertilizers are increasing in cost. Islam et al. (2014) reported that in-situ application of green manure produced higher rice yield. Pre-rice green manuring with *Sesbania* greatly contributes to improving soil fertility and organic matter build up of the soils in Rice-Rice or other important cropping patterns. Besides *Sesbania*, mungbean and blackgram can also be used as GM crops. The present research assessed the effect of different green manures on the growth and yield of rice cv. BINA dhan7 to determine a suitable combination of GM and N fertilizer for rice.

Materials and Methods

The experiment was conducted at Bangladesh Agricultural University, Mymensingh during the monsoon season of 2013 to study the effect of different GM on the growth and yield of rice. Five GM treatments were: Fallow (No GM), GM with *Sesbania aculeata*, *Sesbania rostrata*, blackgram (*Vigna radiata*) and mungbean (*Vigna mungo*). After chopping GM at 50 days, short duration rice BINA dhan7 was planted with nine treatment combinations: T_1 (No GM + 100% recommended dose of N), T_2 (*Sesbania aculeata* + 75%N), T_3 (*Sesbania aculeata* + 50%N), T_4 (*Sesbania rostrata* + 75%N), T_5 (*Sesbania rostrata* + 50%N), T_6 (*Vigna radiata* + 75%N), T_7 (*Vigna radiata* + 50%N), T_8 (*Vigna mungo* + 75%N) and T_9 (*Vigna mungo* + 50%N). The experiment was laid out in a randomized complete block design with three replications. The crop was harvested at maturity and the yield attributes, grain and straw yields were recorded. The residual effect of GM was also evaluated on the succeeding wheat crop. Effects on physico-chemical properties of soil due to GM were also assessed (data not shown).

Results and Discussion

Panicle length and filled grains panicle^{-1} of BINA dhan7 responded positively to application of *Sesbania* when applied with 75% N (Table 1). Grain yield and straw yield, N uptake in grain and straw also had significant positive response with the application of *Sesbania aculeata* and *Vigna radiata* when applied with 75% N (Table 1 & 2). The positive response of GM might be due to the release of N. The release of nutrient from GM is relatively slow so it acts like a continuous supply of nutrient throughout the crop growth period with benefits over fertilizer N application. Application of fertilizer N dissolves quickly and N becomes available instantly and thus a greater part of it is lost from the system through volatilization, denitrification, leaching loss. Only 35% of the added N from fertilizer is used by the plant and the rest is lost; which determines the efficiency of combined application of GM and chemical fertilizers. The results presented from the experiment also show that GM can compensate 25% reduction of recommended fertilizer N dose but not 50%.

Conclusion

Green manuring with leguminous crops is a widely used practice in rice cropping systems in Bangladesh and has potential for reducing use of fertilizer-N application besides improving soil fertility. Research panicle length, filled grains per panicle, grain and straw yield and N uptake were higher in the plots treated with GM in combination with 75% recommended N fertilizer. Among the GM crops *Sesbania aculeata* performed better. Therefore, *Sesbania aculeata* with 75% of recommended N fertilizer application could be recommended for BINA dhan7 production in aman season in Bangladesh.

Table 1. Effects of different green manures with different levels of nitrogen on yield components and yields of rice cv. BINA dhan7

Treatments	Plant height (cm)	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Grains panicle^{-1} (No.)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	88	12	23.7	87	4253bc	4542
T_2	88	12	24.6	96	5483a	5160
T_3	86	12	24.5	100	4221bc	4456
T_4	85	11	24.2	96	4293bc	4992
T_5	84	12	23.6	82	4624b	5482
T_6	88	12	23.7	89	5408a	5358
T_7	86	11	23.3	86	4531bc	5080
T_8	88	13	24.1	82	4125c	4628
T_9	81	11	21.9	81	4306bc	4788
P value	0.15	0.33	0.21	0.10	<0.001	0.29

Means in a column having common letters do not differ significantly at P<0.05.

Table 2. Effects of different green manures with different levels of nitrogen on N uptake by rice

Treatments	N uptake (kg/ha)		
	Grain	Straw	Total
T_1	55c	25	80cd
T_2	65ab	32	98ab
T_3	53c	25	78d
T_4	52c	32	84bcd
T_5	59bc	35	93abc
T_6	70a	31	101a
T_7	58bc	27	85bcd
T_8	51c	26	77d
T_9	51c	27	78d
P value	<0.001	0.402	<0.001

Means in a column having common letters do not differ significantly at P<0.05.

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Practices of Conservation Agricultural Technologies in Diverse Cropping Systems in Bangladesh

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Introduction

In order to feed the increasing population of Bangladesh, priority was given to produce more food in terms of grain through intensification of land usage. As a result, the immediate objective of more grain production have been achieved and grain (especially rice) production has increased manifold. For a shorter period, Bangladesh has attained self sufficiency in food (rice) production. On the contrary, over extraction of soil nutrients was followed in this food production strategy which includes introduction of various HYVs and hybrids, and using higher doses of chemical fertilizer and pesticides. In addition, the increased use and increased price of agricultural inputs (fertilizer, pesticides, irrigation, etc.) resulted in much higher production cost day by day. The scenario is that though the grain production has been increased many times, the farmers who produced crops became marginalized. In this context, conservation agriculture (CA) is becoming increasingly important in overcoming the problems of declining agricultural productivity both in developing and developed world. Conservation agriculture offers a powerful option for meeting future food demands and contributing in sustainability of agriculture and rural development. Farmers (CA adopters) and other stakeholders who are new or are at the initial stages of converting to CA require tangible evidence on the benefits and impacts of CA. It is necessary to know whether CA significantly increases productivity and food security for their families or not. It is also a crucial question to the CA adopters whether CA helps them to save production costs and generate income or not. Based on the above discussion, the main objective of this paper is to investigate the present status of CA practiced by the farmers in Bangladesh. The specific objectives are as follows:

i) To investigate the present status of CA in respect to knowledge, tillage operation, weed control, and usage of various crop rotations in different parts of Bangladesh.
ii) To identify the constraints and opportunities to adoption of CA in diversified rice-based cropping systems
iii) To suggest some policy guidelines for popularizing CA in Bangladesh.

Materials and Methods

A multistage sample technique was applied to gather the required data and information. Firstly, four districts (Thakugaon, Rajshahi, Rajbari and Mymensingh) were selected considering different soil types and cropping systems. Secondly, the households were selected through FGD considering the adoption level of CA such as cultivation by minimum tillage, retention of crop residues and crop rotations. Thirdly, the households were categorized by cropping systems, mostly rice based (rice-pulses or rice-oilseed) cropping systems. Both the former CA research sites and new research sites were included in the sample for a better understanding of CA techniques used. Thus, a total of 458 farms were selected followed by a field reconnaissance and key informants interviews with different stakeholders for baseline survey.

Results and Discussion

The respective costs for four tillage types by season are presented in Table 1. Methods of weed control and crop rotation practices by households are presented in Table 2 and Table 3, respectively.

Table 1. Cost of Tillage Operations by Season

Types of tillage	Rabi		Kharif I		Kharif II	
	No. of tillage	Cost in BDT/hectare	No. of tillage	Cost in BDT/hectare	No. of tillage	Cost in BDT/hectare
Draft Power	3.04	4258	3.55	3829	3.13	2994
Power tiller	1.55	1186	1.75	1373	1.80	1415
Tractor	1.38	1070	1.67	1317	1.89	1672
Seeder machine	1.70	1371	1.86	1210	1.83	1223

*1 US$= 78 BDT.

Table 2. Methods of Weed Control Operation by the Respondent Households

Crop	By traditional practices		By CA practices	
	No. of HH	% of HH	No. of HH	% of HH
Rice	374	81.7	131	28.6
Wheat	183	40.0	12	2.6
Jute	162	35.4	12	2.6
Pulses	46	10.0	7	1.5
Oilseeds	19	4.2	10	2.2
Vegetables	145	31.7	47	10.3

Table 3. Crop Rotation Practices by the Respondent Households

Area	Crop Rotation (Yes)		Crop Rotation (No)	
	No. of HH	% of HH	No. of HH	% of HH
Mymensingh	65	55.1	53	44.9
Rajbari	63	39.4	97	60.6
Rajshahi	52	43.3	68	56.7
Thakurgaon	0	-	60	100
Total	180	39.3	278	60.7

The perceived constraints of CA technologies reported by the farm households are: low production at minimum tillage (47.7%), growing of more weeds (47.4%), lower level of animal feed (36.3%), lower level of cooking fuel (35.2%), and bothering job (29.9%). On the other hand, the reported opportunities to adopt CA technologies are: low cost of labour for seeding, weeding and harvesting (43.3 %), increased soil fertility through crop rotation (30.8 %), herbicides can be used to control weeds (14.4%), and crop residues can be handled easily to procure animal feed (8.7 %).

Conclusion

On the basis of the findings, promotion of knowledge on the benefits of CA technologies should be ensured through training by Department of Agricultural Extension and local NGOs. In addition, government should come forward to provide agricultural machineries through local workshops at reasonable price. Finally, research on crop rotations and cropping patterns for harvesting the benefits of CA technologies is also suggested.

Effect of Application Timings of Pre Emergence Herbicides on Weed Efficacy and Crop Phytotoxicity in Dry Seeded Rice

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Introduction

Due to the decreasing availability of labor and water, farmers in many Asian countries are shifting from puddled transplanted rice to dry seeded rice (DSR) (Pandey and Velasco 2005). DSR can be established directly in the field with no prior tillage (zero tillage) or following dry tillage (reduced tillage). Dry-seeding readily enables mechanization of rice crop establishment using seeder powered by a 2-wheel tractor, or using 4-wheel tractor mounted seed drills, with low labor requirement. Dry seeding also reduces irrigation water requirement through elimination of puddling. However, weeds are major constraints to its success when grown under non-ponded conditions (Chauhan and Opeña, 2012). Pre-emergence herbicides are considered to be the best tool to manage weeds in DSR. Several pre-emergence herbicides are now available in the market, but selection of right herbicide is very important to suppress weeds from the existing weed seed bank, in an economical way. In addition, environmental conditions, such as soil water content at the time of application, can influence both herbicide efficacy and crop phytotoxicity by altering herbicide absorption, translocation, or metabolism (Chauhan and Johnson, 2011). So, herbicide application timing and soil moisture condition are very important to reduce both the crop phytoxicity and to increase the herbicide efficacy on weeds. Therefore, the aim of our study was to determine the effect of time of application of soil-applied herbicide on rice plant establishment, weed growth and crop yield in dry-seeded rice.

Materials and methods

There were three times of herbicide application [before sowing (BS), after sowing but before irrigation (ASBI), after sowing and irrigation (ASI)] and four methods of weed control (weed-free, partial-weedy, oxadiargyl 80 g active ingredient (ai) ha^{-1}, pendimethalin 1000 g ai ha^{-1}), in a split plot design. In the partial-weedy treatment, only one hand weeding was performed at 40 DAS. Rice plant density (no. m^{-2}) was determined at 14 DAS. The crop was sown into dry tilled soil using a seed-drill with a fluted roller seed-metering device and a power tiller linked to a 2-wheel tractor. Weed density was determined at 20 DAS, and weed density and biomass were determined at 40 DAS, separated into grasses, broad leaves and sedges. At harvest, panicle density (no. m^{-2}) was determined at 4 randomly selected locations in each plot. Rice grain yield was determined from an area of 6.6 m^2. Grain yield was converted to t ha^{-1} at 14% moisture content. Data were analyzed using ANOVA and the means were separated using least significant differences (LSD) at the 5% level of significance using Crop Stat 7.2.

Results and Discussion

Rice plant stand was highly affected by application time, weed control method and their interaction (Fig.1). Rice plant density was decreased with pendimethalin at all application times, by 43 (BS), 19 (ASBI) and 12% (ASI) compared with the non treated plots (188 to 195 rice plants m^{-2}). In contrast, oxadiargyl did not affect plant density, regardless of application time. Application of pendimethalin to dry soil before irrigation had more phytotoxicity than when applied after irrigation. At 20 DAS, there was a significant interaction between herbicide timing and weed control method on density of grass and broad leaf weeds, but not sedges (Fig. 2). Pendimethalin was very effective against grasses regardless of application time, reducing the grass population to zero when applied BS or ASBI, and reducing it to 92% of the grass weed density when applied ASI, compared with the non-treated plots. Oxadiargyl was also effective against grasses when applied ASBI and ASI. But the performance of oxadiargyl was very poor when applied BS and reduced the grass density by only 38 %. At 40 DAS, the interactions between application time and weed control method on total weed density and total weed biomass were significant (Fig. 3). This was largely due to the fact that application of pendimethalin before sowing had a significant effect on weed density and weed biomass, while oxadiargyl did not. There was consistently better herbicide performance with application after sowing and irrigation. Yields with oxidiargyl and pendimethalin were similar, with maximum yield (4.0 t ha^{-1}) with application after sowing and irrigation, 1 t ha^{-1} lower than yield of the weed-free treatment. Herbicide application after sowing and irrigation increased yield by 2.1 t ha^{-1} compared with the weedy treatment (1.9 t ha^{-1}). The study suggests that to increase herbicide efficacy on weeds and reduce phytotoxicity to dry seeded rice, both oxadiargyl and pendimethalin should be applied after sowing and irrigation. In addition, our study also suggests, preplant application of pendimethalin may not be feasible, and this may reduce some mechanization options (e.g., spray with a tractor before irrigation/wet conditions).

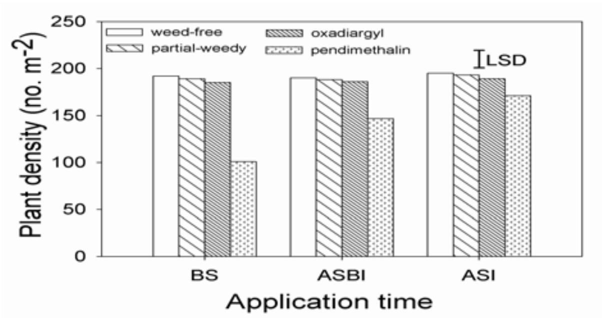

Figure 1. Effect of application time and weed control method on rice plant density at 14 DAS.

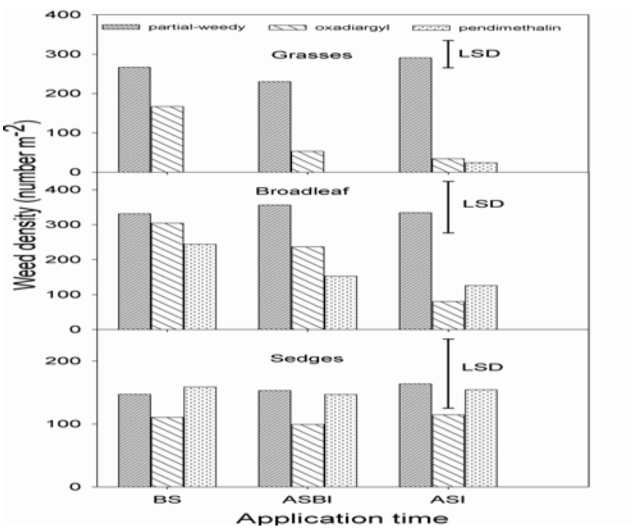

Figure 2. Effect of application time and weed control method on weed density (number m $^{-2}$) of grasses, broad leaf weeds and sedges at 20 DAS.

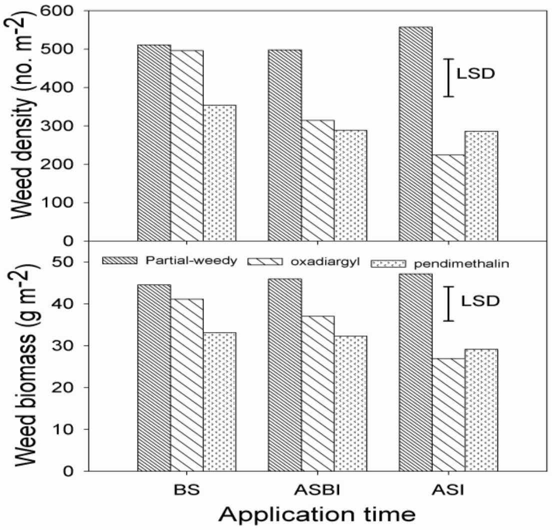

Figure 3. Effect of application time and weed control method on weed density (number m $^{-2}$) and biomass (g m^{-2}) at 40 DAS.

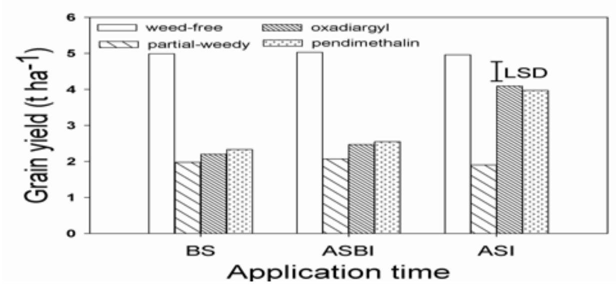

Figure 4. Effect of application time and weed control method on grain yield (t ha $^{-1}$).

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Computational Modelling and Finite Element Analysis of Strip Tillage Components for Fabrication Purposes

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Introduction

New agricultural implements are being developed at an accelerating pace to meet the growing needs of farmers who practice conservation agriculture (CA). In Bangladesh, most CA technologies are modifications of available materials and devices, retooled to meet the immediate needs of individual farmers in the field. While such innovations can be effective, their applicability for scaling-up is limited due to development within a range of constraints intended for prototyping. This approach fails to consider the stress capabilities of component materials, the impact on draft capacity of the engine, or manufacturing and commercial viability; all are crucial for bringing an agricultural implement to market. By using computational modelling software, multiple iterations of existing field innovations can be virtually tested, saving time and money otherwise spent for field-testing. This method of structural analysis, called finite element analysis (FEA) can determine modes of failure including where loads can exceed maximum yield stresses. Designs can also be geared to meet manufacturing and distribution specifications such as fabrication time, material selection, and weight constraints.

Materials and methods

We analysed inverted-T style furrow openers, which use two tubes for seed and fertilizer delivery and a reinforced front edge, for CA based direct seeding of crops in Bangladesh (Krupnik et al., 2013). Our work builds on designs developed by M.A. Hoque through CIMMYT supported research at BARI and the Bangladesh Agricultural University (BAU). Dassault Systemes Solidworks® Premium (2014, Vélizy-Villacoublay, France) was used for the three-dimensional modelling and stress-testing of the furrow opener.

Inverted-T furrow openers are intended for operation in conjunction with the CA practice of strip tillage. In worst-case scenarios, the opener might be used by itself in a zero-till fashion (requiring the use of additional press wheels). The shear forces that would be imparted on the opener were based on the yield strength of soils with limited to excessive soil cohesion, from 20 to 640 kPa (Hawkins and Hudson, 1992). Material cost predictions were based on plain carbon steel of 574 USD/t (Management Engineering & Production Services, 2014). Labour cost analyses were based on reported best practices of Bangladeshi labour at 0.81 USD/h, and Chinese labour at 4.00 USD/h.

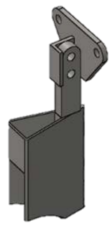
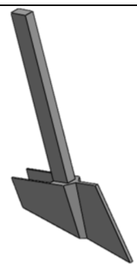
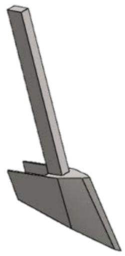
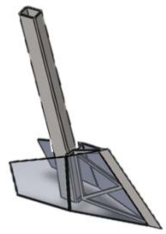
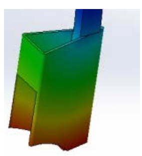
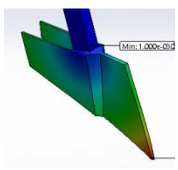
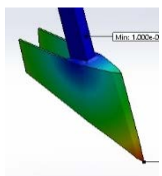
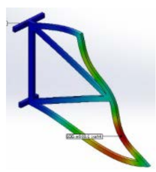
Four virtual designs were tested: Shoe Style-Current (SS-C) furrow opener included on the power tiller operated seeders (PTOS) that are manufactured in China, and which can be converted for strip tillage, Furrow Opener-Prototype 1 (FO-P1), which is one of the versions currently under field testing, an alternate Furrow Opener-Manufactured 1 (FO-M1) which would be caste and uses the least amount of labour, and Furrow Opener-Manufactured 2 (FO-M2), which moves the strength into an internal truss design to minimize weight and costs. Stress analysis of FO-M2 was conducted only on the internal truss, to ensure it had enough strength to handle the design forces. Each inverted-T simulation had an applied pressure on the leading edge of 637,000 N/m^2, the equivalent of a high resistance soil with a resistance of

640kPa. All used plain carbon steel as the material with a yield strength of 2.20594e+8 N/m^2, and tensile strength of 3.99826e+8 N/m2.

Results and Discussion

All designs were capable of withstanding the applied design force of 640kPa. They also had a factor of safety more than two, i.e. they could withstand at least double the applied design forces. FEA of the designs show FO-M2 had the best balance of cost, weight, and strength out of all the designs (Table 1). Displacement visualizations show fatigue would be systematic in all designs except FO-M2, where it would be isolated to the forward members of the truss. FO-M2 uses 61.6% of the steel in FO-P1, and 46.9% of the steel in FO-M1, while sustaining the structural capacity requirements. Based on this, it is possible to utilize a truss similar to FO-M2 to reduce weight and costs while retaining the required strength. Further analysis and field testing is required to determine how different materials will impact the performance of the FO-M2 design.

Table 1. Stress analysis applied to four potential inverted-T furrow opener configurations. Von Mises stress is the amount of load subjected to a member. If the imparted stress is higher than the yield strength of the material, FEA would indicate structural failure. Displacement is a measure of deflection, based on distributed loads and material properties, allowing for predictions of systematic stress. The blue and red colors indicate the lowest displacement to highest displacement, respectively.

Image of 3D Model (Not to Scale)				
Name:	SS-C	FO-P1	FO-M1	FO-M2
Mass (kg):	0.57185	1.30227	1.64549	0.77187
Primary Machining Method:	Welding, Cutting	Welding, Grinding	Casting	Welding, Pressing
Predicted Material Cost per Single Opener (USD):	$0.33	$0.75	$1.10 at 500 units	$0.44
Predicted Hours of Labour per Unit (h):	0.82	1.78	NA	0.95
Predicted Labour Cost per Unit (USD):	$0.66[a], $3.28[b]	$1.44[a], $7.12[b]	NA	$0.77[a], $3.80[b]
Predicted Sum per Unit (USD):	$0.99[a], $3.61[b]	$3.22[a], $7.87[b]	$1.10	$1.21[a], $4.24[b]
Von Mises Stress Min N/m^2: *Max N/m^2:*	79.212 5.99159e+7	9.33157e-19 1.10291e+7	8.01343e-18 1.69544e+7	72.4005 1.04183e+8
Max Displacement mm:	0.0965558	0.0074994	0.00858932	0.0283803
Displacement Visualization: (Highly exaggerated to emphasize how stresses are transferred through each design)				

[a]Bangladeshi Labour [b]Chinese Labour

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Fodder Chopper for Livestock Producers: A Case Study of Commercialization of Machinery for Smallholders in Bangladesh

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Introduction

Farmers in Bangladesh are very interested to produce more milk products and beef to meet rising consumer demand. Small and medium livestock farmers have between 10 and 30 cows or beef cattle. A major constraint to the expansion of dairy holdings and beef production in Bangladesh is the scarcity of quality fodder, especially during the dry winter season (Haque et al., 2008). Straw from paddy rice is the main source of fodder for livestock in Bangladesh, but has being abundant and low quality (Haque et al., 2008). Napier grass, fodder maize, para, jambo grass, triticale and lathyrus are all grown as higher quality fresh fodder supplements to rice straw. These fodders are normally fed to cattle in the form of whole fresh or dried stems and leaves, and commonly 15 to 20 per cent of the material is refused and wasted. To reduce wastage, some farmers are trying to chop straw and other fodders by hand for their cattle but this is slow, laborious and costly. To overcome the problem, the Power Straw and Fodder Chopper (PSFC) was developed in 2006 and commercialized. This short paper describes the PSFC, its uses, initial experiences with its promotion and marketing by the Pilot Program on Increasing the Availability of Quality Fodder for Dairy Production in Bangladesh (PPIAQFDP) funded by DANIDA.

Materials and methods

The PSFC was fabricated with locally available materials and can be powered a 4 hp diesel engine or single phase electric motor. The main functional parts of the PSFC were: the toolbar frame, cutter blades, safety cover, power transmission pulley, feeding rollers and feeding tray (Figure 1). As far as possible, it was fabricated using locally available materials including M.S. angle, solid bar, M.S. sheet, cutter blades, ball bearings, and feeding tray. Performance evaluation of the PSFC has been done through various laboratory tests and on- farm monitoring. Several rounds of improvements were made based on feedback from farmers, operators and manufacturers. Data were also collected to determine the labour requirement and costs of chopping various straws and fodder types by the conventional methods and using the PSFC. From the beginning, Modern Engineering Workshop (MEW) was engaged to fabricate the first prototype of the PSFC with the condition that once the prototype was shown to be successful MEW would produce and market it commercially. It was also agreed that the project would initially support MEW with demonstration. The PPIAQFDP supported MEW in demonstrations and other promotional activities with the PSFC in several districts where the PPIAQFDP was working. To create demand, PPIAQFDP

Figure 1. Power Straw and Fodder Chopper (PSFC) being demonstrated.

procured 6 PSFC and demonstrated them in the project working districts its use in 2006 through the network of the Department of Livestock Services (DLS). Since 2008, the ACIAR funded projects (LWR LWR-2005-001 and LWR-2010-080) has been provided technical support to MEW for improvement and commercialization of PSFC.

Results and Discussions

The PSFC could chop 480 kg of rice or wheat straw per hour and 1150 kg of fresh napier or maize fodder plants per hour into pieces 4 to 6 cm long. The operational cost of the chopper was Tk 105 (US$ 1.35) per hour. Tk 840 (US$ 10.77) was required to chop the same amount of straw or fresh fodder manually by hand. Depending on farmer's buying capacity, MEW has released new models (Table 1). The MEW demonstrated the chopper through project support, attending various agricultural fair, etc. Until April 2014, MEW was able to sell 610 units of various models with a pricing range of Tk. 24,000-55,000 (Table 1). To create demand initially, the project provided 50% of the purchase cost as a promotional price to 12 small dairy farmers in six districts of Bangladesh. At the beginning, MEW tried to involve local level agricultural machinery marketing dealers to sell the chopper. However, until 2010, demand was not sufficient to attract dealers to sell MEW choppers through their network. Project-led various promotional efforts with MEW e.g., operation, repair and maintenance training; demonstrating the PSFC at local agricultural fairs; PSFC demonstration during cattle farmers' training programs at Bangladesh Livestock Research Institute (BLRI) and Department of Livestock Services (DLS); awareness raising; etc were the major interventions to boost-up commercial sale of PSFC in Bangladesh. Since 2011, ten local dealers (one each in Thakurgaon, Dinajpur, Rangpur, Satkhira, and Bogra districts; and five in Nilphamari district) have been sold about 40% of MEW choppers; the rest were sold by MEW directly to the dairy farmers based on information support from BLRI, DLS, etc. There is no simple, shortcut approach to commercialize small-scale agricultural machineries in the smallholder community (Haque et. al., 2013), however, a multi-dimensional approach e.g., initial price support; demand creation and technical support by project staffs, stakeholder institutions (BLRI and DLS) helped to commercialize the PSFC.

Table 1. Capacity, price and number of unit sold of fodder chopper upto end of April, 2014.

Model	Capacity (kg/hr)	Unit price (Tk)[1]	Unit sold	Comments
PSFC	480	47,500**	80	Original model developed by senior author
Fixed 86	350	24,000*	120	Modified version by MEW without safety cover
01Spring	350	26,000*	300	Modified version by MEW without safety cover
011Mobile	450	35,500*	50	Modified version by MEW without safety cover
014MC	600	55,000***	60	Modified version by MEW with safety cover
	Total:		610	

*=without power engine; **=with 4 hp diesel engine; ***= with 3 hp single phase electric motor. Cost of 4 hp diesel engine Tk. 12,000; and 4 hp electric motor Tk. 10,000 per set. [1]Tk. 78=US$ 1.00.

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Soil organic carbon sequestration and soil fertility improvement under systems of rice intensification (SRI) technique

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Introduction

Rice production in India has increased during the last 60 years by nearly 425 per cent or 4.3 times from 20.58 million tonnes in 1950 to nearly 87.5 million tonnes during the year 2009-10. There is considerable increase in productivity of rice in India during the recent past. The productivity of rice which was 668 kg ha^{-1}in 1950-51 has reached to 2,066 kg ha^{-1} during 2001-02. The increase in productivity of rice is about 209 per cent and this increase is due to introduction of high yielding rice varieties responsive to high dose of fertilizers coupled with improved package of practices evolved by Agricultural Scientists of various regions.

Among the micronutrients, zinc is the most limiting nutrient whose deficiency is a wide spread nutritional disorder of wetland rice. Widespread occurrence of zinc deficiency has been reported from many parts of the world where high yielding, fertilizer responsive varieties of rice (*Oryza sativa L.)* are being grown intensively under low land puddled soil conditions (Ponnamperuma 1977. Zinc is one of the essential micronutrient elements most commonly deficient in flooded rice soils and has Zinc deficiency in rice appears right from seedling stage in nursery and three weeks after transplanting in transplanted plots. Rice being the crop having high water requirement, there is a need to search for alternate methods to reduce water requirement of rice without reduction in the yield. Systems of rice intensification (SRI) seems to be a promising technique to overcome the storage of water in irrigated rice. Therefore, the present investigation was undertaken to study the integrated approach of nutrient management under SRI technique using less water with the following objectives

1. to increase the soil organic carbon contents in soil and hence soil fertility using less water
2. to increase yield and uptake of nutrients

Materials and methods

Field experiments were conducted during the year 2008-09 and 2009-10 at the "Model Demonstration Farm", Water Management Research Station, Ranaghat, district of Nadia, West Bengal, India (23°11'N latitude and 88°33'E longitude), with an altitude of 7.00 m above the mean sea level. The soil of the experimental field is typically of Gangetic new alluvial (aeric endoaquept) having medium water holding capacity and moderate fertility status. The experiment was laid out in randomised block design (RBD) with 8 treatments each replicated thrice. Recommended doses of 120 kg N, 60 kg P_2O_5 , 60 kg K_2O and Zn at 5 ha^{-1} were applied. Nitrogen to be applied which was divided into ¼, ½ and ¼ parts. At basal $1/4^{th}$ of N along with full amount of P_2O_5 and K_2O were applied. First top dressing of ½ N was at 21 days after transplanting (DAT) and second ¼ N was made at 42 DAT. FYM applied two week before the final land preparation. 18 and 22 day old rice seedlings (*cv. IET-4786*) were transplanted with a spacing 25cm × 25cm with single seedling per hill. Periodic soil and plant samples were collected and analysed following suitable analytical methods.

Results and Discussions

The results reveal the mean amount of organic carbon content in soil has been found to be increased being highest (1.14%) in the treatment T_6 where FYM at 10 t ha^{-1} along with recommended NPK and Zn at 5 kg ha^{-1} were applied togetherly. The highest mean available N (298.80 kg ha-1) , P_2O_5 (202.56 kg ha^{-1}) and K_2O (273.78 kg ha^{-1}) were recorded in the treatment T_6 where FYM at 10 t ha^{-1}, recommended NPK and Zn at 5 kg ha^{-1} was applied togetherly. The highest extractable Zn content was recorded in the treatment T_7 where recommended NPK, FYM at 10 t ha^{-1} and Zn at 10 kg ha^{-1} were applied togetherly. Such increase in the DTPA-extractable Zn content in soil due to combined applications of recommended doses of NPK, FYM at 10 t ha^{-1} and Zn at 10 kg ha^{-1} as $ZnSO_4$ might be due to the acidification of rhizosphere resulting in release of H^+ from the roots to balance excess intake of cations over anions and H^+ generated in the oxidation of Fe^{+2} by root released O_2 (Naik and Das, 2008). The yield of rice during both the years have been found to be significantly varied with treatments, being mean highest yield of grain (66.80 q ha^{-1}) was recorded in the treatment T_6 where integrated approach was made *i.e.* recommended levels of NPK, FYM at 10 t ha^{-1} and Zn at 5 kg ha^{-1} were applied togetherly. The results further reveal that about 97 and 98 per cent of the variability towards contributing grain yield of rice were recorded from effective and abortive tillers, and panicle length, grains per panicle and test weight respectively. The highest uptake of N (66.28 kg ha^{-1})) and K (23.38 kg ha^{-1}) by grain was recorded in the treatment T_6 where recommended NPK, FYM at 10 t ha^{-1} and Zn at 5 kg ha^{-1} were applied togetherly. The overall results suggest that the approach of integrated nutrient management (INM) *i.e.* the application of NPK (120:60:60 kg ha^{-1}) and organic matter 10 t ha^{-1} along with Zn at 5 kg ha^{-1} have been proved best management practice for rice cultivation during *rabi* season under systems of rice intensification (SRI) with respect to maintain optimum soil organic carbon and soil fertility with the simultaneous increase in yield of rice.

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Pea as Relay Crop in between Monsoon rice and Summer rice: a Resource Conservation Technology

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Abstract

Bangladesh is one of the most populous and poverty affected country in the world. The soil condition is poor in nutrients and water content. However, growing of legumes helps in improving the soil condition and pea (*Pisum sativum*) as a food legume has a great role in human food, animal feed and sustainable agriculture. Whereas, after harvesting of monsoon rice, it is difficult to timely sowing of pea as a sole crop due to late harvest of rice/excess soil moisture/ soil moisture goes down before rice harvest under high to medium high lands. In this circumstances, relay cropping of pea as green pod for vegetable and fodder production in the standing monsoon rice field, 15-20 days before rice harvest has a great opportunity. This ensures timely sowing and best use of residual soil moisture and also low cost technology. But for better adaptation and successful crop production within the window of two rice, it needs selection of suitable variety along with production techniques. Pea has been tested as relay crop with rice at on- station as well as on-farm in three locations during rabi season of 2011-2013. It was found that, a variety, Natore local produced the highest green pod yield (4.8 t -5.3 t/ha) and fodder yield (8.4 t- 8.5 t/ ha) with maximum gross margin was TK.145809-152836/ha **(**US$ 1870-1960/ha), and BCR (4.04- 4.65). Hence, if peas can be inserted in between monsoon and summer rice as vegetable and fodder (cash crop) a large area of lands may bring under pea cultivation. It also enhance pea production as green pod & fodder, farmer's income, and human & animal nutrition, create job opportunity for green pod picking which all together will increase the livelihood of small farmers and to ensure soil health improvement for sustainable production system.

Comparison of greenhouse gas emission characteristics between rice cropping and fallow season in a temperate paddy soil

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Introduction

There were numerous studies done about the greenhouse gas (GHG) emission characteristics in rice paddy soils. However, such studies were done only during rice cultivation period and mainly focused on the individual GHG emission impact without the overall quantification of the total global warming potential (GWP). In particular, mono-rice paddy soils like in Korea and Japan are flooded for less than 100 days during cropping season, and aerobically managed under dried soil condition over 200 days a year. Therefore, it is necessary to simultaneously investigate their individual contributions during rice cropping and fallow season.

Materials and methods

In order to quantify the impact of flooded rice cultivation and dried fallow seasons on total GWP in mono-rice cultivation system, two fertilization systems (NPK, and NPK+Cover crop) were installed in a typical rice paddy soil, and the emission patterns of CH_4, CO_2, and N_2O were monitored for two consecutive years. In NPK+Cover crop treatment, a seed mixture of barley and hairy vetch were broadcasted with 75% and 25% of each recommendation (barley 140 kg ha^{-1}, and vetch 90 kg ha^{-1}) after rice harvesting in 2010 and 2011, respectively. In the early June, 2011 and 2012, around 36 Mg ha^{-1} of the fresh above-ground biomass was harvested, and the chopped biomass was mixed mechanically in the surface soil one week before rice transplanting. The recommendation rates of chemical fertilizers (N-P_2O_5-K_2O = 90-45-57 Kg ha^{-1}) were applied in two treatments. Transparent glass chambers which have surface area 62 cm x 62 cm and height 112 cm were placed permanently on the flooded soil to monitor CH_4 and N_2O emission rates during rice cultivation. In addition, acrylic column chambers (D. 20 cm and H. 20 cm) were placed inner soil surface between rice plants for evaluating CO_2 emission rates during rice cultivation and three gases emission patterns during the fallow seasons.

Results and Discussion

The contribution of seasonal GWP scales to the annual GWP value was big different between the fallow season and the rice cultivation season (Fig. 1.). In the NPK treatment, total GWP value was 14.2-16.0 Mg ha^{-1}. Around 51-60% of total GWP was affected by the seasonal GWP value during the fallow season. However, cover crop cultivation during the fallow season and biomass addition as a green manure for the rice cultivation significantly increased total GWP value to 60.5-60.7 Mg ha^{-1} in the NPK+Cover crop treatment, mainly due to CH_4 and CO_2 emission increase during rice cultivation. Different with that in the NPK treatment, about 79-81% of total GWP value were affected by the seasonal GWP value during rice cultivation. Carbon dioxide was the most influential GHG in increasing the growth scale of the total GWP during the dried fallow season, but CH_4 most strongly influenced the total GWP scale during the rice cropping season irrespective with the soil management condition. The contribution of CH_4 to the annual GWP value was significantly increased by cover cropping and its biomass addition from 25-30% in NPK to 58-60% of NPK+Cover crop.

In conclusion, the impact of greenhouse gas emission during the dried fallow season covered around 20-60% of total GWP scale, and then we need to develop soil management strategy to decrease GHG emission during the fallow season in mono rice paddy soil.

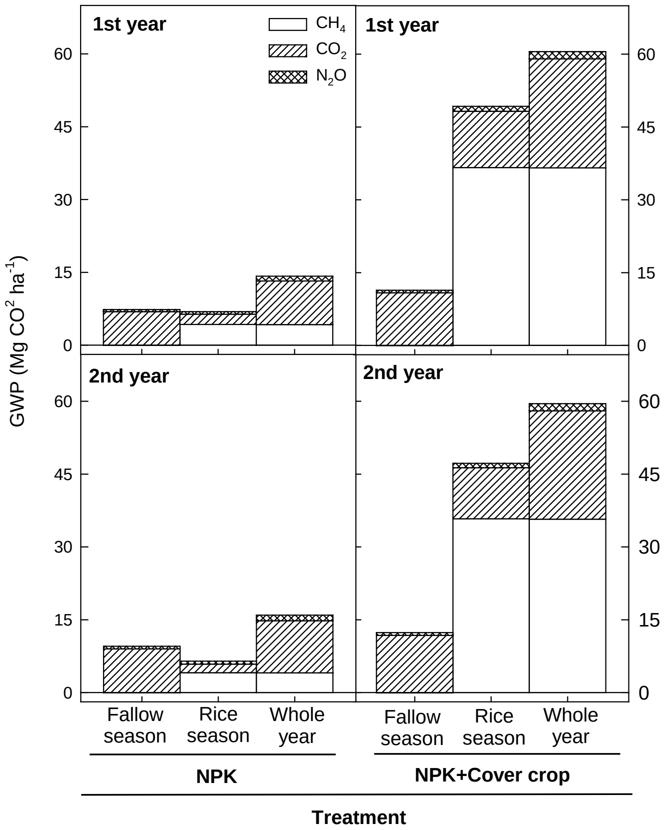

Figure 1. Contribution of major greenhouse gas emissions to total global warming potential (GWP) during the dried fallow season and rice cropping season in a mono-rice paddy soil.

Effect of Different Tillage Options on Soil Moisture Conservation in Chickpea and Lentil Field under Rainfed Conditions

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Introduction

Rainfed agriculture in the High Barind Tract (HBT) of north-west Bangladesh is constrained by drought due to erratic and low rainfall from October-April. There is only a short period after harvest of rice during which surface soil moisture is conducive for sowing of cool-dry season (*Rabi)* crops. Tillage practice plays a vital role in conservation of residual soil moisture in rainfed cultivation. For greater root density and better plant performance minimum tillage is being advocated. However, information on sowing time and tillage options for chickpea and lentil cultivation using residual soil moisture after harvest of T. Aman rice in High Barind Tract is inadequate. Therefore, the present study was carried out to evaluate the effect of tillage practices for chickpea and lentil using residual soil moisture after harvest of T. Aman rice.

Materials and Method

An experiment on chickpea and lentil was conducted on a farmer's field, Kadamshahar, Godagari, Rajshahi, during *Rabi* season 2013-14 to evaluate the effect of tillage practices on chickpea and lentil using residual soil moisture after harvest of T.Aman rice. The chickpea variety (BARI Chola 9) and lentil variety (BARI Masur-6) were used in this study. The soil texture of trial plots belongs clay loam to sandy clay loam. The experiment was designed with six treatments laid out in a randomized complete block design with six dispersed replications. The treatments were i.e., T_1: One conventional tillage, T_2: Two conventional tillage, T_3: Three conventional tillage, T_4: One power tiller operated tillage, T_5: Two power tiller operated tillage and T_6: PTOS. The land was fertilized with 24-18-20 N-P-K kg ha^{-1} (FRG, 2005), respectively. Seeds of chickpea and lentil viz. T_1, $T_{2,}$ $T_{3,}$ $T_{4,}$ T_5 were broadcast while T_6 (PTOS) was sown on 10-15 November 2013. Soil moisture regimes of the experimental plots were recorded at a depth of 0-15cm at 15 days intervals. Observations were made on yield components from 10 randomly selected plants per plot. The data were analyzed statistically and the mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

The maximum number of plants m^{-2}pods $plant^{-1}$, seeds $pods^{-1}$, thousand seed weight and grain yield were generally found in $T_{6\ \mathrm{and}}$ T_5 for both chickpea and lentil (Table 1). Soil water(%) was decreased with the increasing of days after sowing (DAS) both lentil and chickpea field. Maximum soil water (%) was found 30.0 to 32.2 in minimum tillage options. So, just after harvest of T.aman rice with minimum tillage for lentil and chickpea production might be a good options for better soil water content.

After harvest of T.Aman rice, chickpea and lentil could be grown with PTOS (T_6) for maximizing yield of chickpea and lentil production in High Barind Tract to available soil moisture.

Table 1. Yield and yield component of chickpea as influenced by different tillage practices after harvest of T.aman rice *Rabi* season 2013-14

Treatment	Plant height (cm)	No. of plant m^{-2}	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000- seed weight (g)	Stover yield (t ha^{-1})	Seed yield (t ha^{-1})
T_1	38.8d	30.0e	38.5c	1.06e	14.0d	1.31e	2.44c
T_2	41.4cd	33.0cd	42.3bc	1.26cd	15.1c	1.40c	2.59abc
T_3	43.9bc	34.5c	43.8ab	1.35c	16.6b	1.46b	2.62abc
T_4	40.8cd	30.8d	40.7bc	1.15de	14.7c	1.36d	2.52bc
T_5	44.9ab	37.0b	45.9ab	1.58b	17.8a	1.51a	2.68ab
T_6	47.9a	39.5a	48.0a	1.75a	18.3a	1.54a	2.76a

Table 2. Yield and yield component of lentil as influenced by different tillage practices after harvest of T.Aman rice during *Rabi* season 2013-14

Treatment	Plant height (cm)	No. of plant m^{-2}	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000- seed weight (g)	Stover yield (t ha^{-1})	Seed yield (t ha^{-1})
T_1	33.6d	125.1d	76.6c	1.00b	13.9d	1.39c	1.03c
T_2	36.3c	132.6bc	86.1b	1.33ab	14.8c	1.53abc	1.05bc
T_3	38.8b	137.5ab	89.1b	1.50ab	15.8b	1.59abc	1.11b
T_4	35.0cd	129.1cd	80.6c	1.33ab	13.9d	1.43bc	1.04c
T_5	40.8b	141.0a	93.5a	1.66a	16.3b	1.68ab	1.21a
T_6	43.5a	143.6a	95.8a	1.83a	17.0a	1.74a	1.24a

Table 3. Changes in soil water (% gravimetric) of chickpea field as influenced by various treatments at differenttillage practices during 2013-14

Treatment	Days after sowing (DAS)						
	0	15	30	45	60	75	90
T_1	32.3	29.8	26.8	25.1	22.5	20.1	19.8
T_2	31.8	29.1	26.0	24.8	21.8	20.0	19.1
T_3	30.0	28.8	25.8	24.1	20.9	19.5	19.0
T_4	32.6	30.0	25.2	23.2	21.1	20.0	19.0
T_5	31.9	28.9	24.8	23.0	20.9	19.8	18.2
T_6	31.7	28.9	24.5	22.0	20.0	19.8	18.5

Table 4. Changes in soil water (% gravimetric) of lentil field as influenced by various treatments at different tillage practices during 2013-14

Treatment	Days after sowing (DAS)						
	0	15	30	45	60	75	90
T_1	31.5	28.5	26.5	24.2	21.5	19.8	18.2
T_2	31.0	28.0	25.8	23.6	20.2	19.5	18.1
T_3	30.0	26.0	24.4	21.2	19.1	18.8	18.0
T_4	31.5	27.4	25.7	22.2	20.2	19.8	18.5
T_5	32.1	26.9	24.6	21.7	19.7	18.9	18.1
T_6	32.2	26.1	25.5	21.2	19.2	18.0	17.8

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Pulses De-husking Mill for Smallholders: A Case Study of Commercialization of Machinery for Small Entrepreneurs in Bangladesh

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Introduction

Pulse crops such as lentil, mungbean, blackgram and lathyrus are important in the traditional diet of Bangladesh. However, the production of pulses has been declining over the last two decades. The bulk of the pulse grains are consumed as *dal* and therefore need to be de-husked. Currently farm households de-husk pulses by locally-fabricated rudimentary devices, known as *jata* or *daki*, resulting in a high percentage of crushed (~35% dust), broken or split grain (>90%). Such *dal* receives a lower price than properly milled de-husked full grain. Thus, farmers sell unhusked pulses grain in the local market and ultimately that goes to a large mill for de-husking. The large pulse de-husking mills are mostly located in the bigger cities of Rajshahi and Dhaka division of Bangladesh which are remote from small pulse growers. There is a significant price gap between unhusked pulses at the farm gate and de-husked *dal* at the final point of sale. On the other hand, mechanized de-husking mills where farmers can de-husk pulses and produce quality dal for family consumption or to sell at higher price are not commonly available in small towns. The lack of mills to de-husk small quantities of pulses (~5 kg) has also discouraged farmers from growing pulses. These factors are contributing to decline in pulse production by small and marginal farmers. To overcome the problem, the pulse de-husking mill (Mini Mill) was developed in 2009 and commercialized in Bangladesh. The present paper is a case study of a development and commercialisation process for mechanisation of farm operations for smallholders in Bangladesh. In this short paper we describe the Mini Mill, its uses, initial experiences with its promotion and marketing.

Materials and methods

With the ACIAR Project LWR/2005/001funding support the Mini Mill was fabricated with locally available materials and can be powered an 8 hp diesel engine or electric motor. The main functional parts of the Mini Mill were: the wooden platform, power transmission pulley, feeding chamber, sieve, collecting tray, safety cover, ball bearings, etc. Performance evaluation of the Mini Mill was completed through laboratory tests and on- farm monitoring. A few cycles of improvements were made based on feedback from farmers, operators and manufacturers. Data were also collected to determine the costs of de-husking, efficiency, recovery, and number of runs required for full polish *dal*. From the beginning, Masuda Engineering Workshop (MEW) was engaged to fabricate the first prototype of the Mini Mill with the condition that once the prototypewas shown to be successful MEW would produce and market it commercially. It was also agreed that the project would initially support MEW with demonstrations and other promotional activities in several districts. To create demand, the Project procured 5 Mini Mills and demonstrated with 50% price support to the service providers in the project working districts in 2010 through the network of the project partnering organizations (Bangladesh Agricultural Research Institute [BARI], Rangpur and Dinajpur Rural Services [RDRS], ICARDA, CIMMYT). Since 2012, the ACIAR funded project LWR-2010-080 has provided technical support to MEW for improvement and commercialization of the Mini Mill.

Results and Discussion

As in large scale mills, the Mini Mill for pulses uses an abrasive roller to polish seed. It removes 99% of the seed coat of whole de-husked lentil, and >70% in the case of mungbean and blackgram grains. The recovery rate of the de-husked grain was 85% of the original un-husked. Full polishing of the pulses requires about four runs through the mill (as is the case with large mills). Ex-factory price of the Mini Mill was Tk. 22,000 (US$300) per unit. Attachment of additional tools at the cost of Taka 16,000 allows for de-husking of chickpea, lathyrus, pigeon pea, and making wheat and maize flour. Since 2010, a total of 25units of the Mini Mill have been commercially manufactured and marketed by MEW. Since the setup of the initial four Mini Mills in February 2011 to the end of May 2012, a total of 77.5 t of lentil, mung bean and black gram have been de-husked providing service to 1,676 pulse growing farmers in these areas. The maximum de-husking was accomplished in Rangpur (60 t, mostly black gram), followed by Magura (11 t, mostly lentil), Faridpur (5 t, mostly lentil), and Madaripur (2 t, mostly lentil). The maximum number of farmers (757) served using the Mini Mill was in Magura, followed by Rangpur (429), Faridpur (346), and Madaripur (145). The Mini Mill Service Providers have been charging Taka 5 per kg of pulses in Faridpur, Magura and Madaripur districts, but only Tk. 3-4 per kg in Kurigram. Other than Kurigram, the pulses farmers have brought small quantity of pulses (mostly 5 - 25 kg each) for de-husking. In Kurigram, in addition to small pulse farmers, small pulse marketing businessmen have emerged to buy un-husked pulses from local markets of that area and use the Mini Mill for processing and sale to the larger markets at upazila or district level market. The Mini Mill owners have not reported major difficulties yet with operation and maintenance of the mill and no design and manufacturing defects were identified. The demand for Mini Mills in the pulse-growing farmers' community has been increasing to enhance consumption by farmers of their own pulses even a small quantities (e.g. 5 kg). Alternatively, pulse farmers can de-husk their own grain and sell directly to local markets for higher profit.

At the beginning, MEW tried to involve local agricultural machinery dealers to sell the Mini Mill. However, demand was not sufficient to attract dealers to sell Mini Mill through their network. Project-led promotional efforts with MEW e.g., operation, repair and maintenance training; demonstrating the Mini Mill at local agricultural fairs; project -led video display, distribution of leaflets, demonstration during farmers' training programs at BARI and RDRS; awareness raising; etc were the major interventions to commercialize sales of the Mini Mill in Bangladesh. All of the Mini Millswere sold by MEW directly to the small rice and wheat mill owners of the pulses growing areas, based on information support from existing Mini Mill owners (who purchased mills with 50% price support), BARI and RDRS, etc. There is no simple, shortcut approach to commercialize small-scale agricultural machinery in the smallholder community (Haque et al., 2013), however, a multi-dimensional approach e.g., initial price support; demand creationand technical support by project staff and stakeholder institutions (BARI, RDRS, ICARDA, CIMMYT) helped to commercialize the Mini Mill. Further interventions may yet be needed to accelerate and disperse sales more widely in target pulse growing areas.

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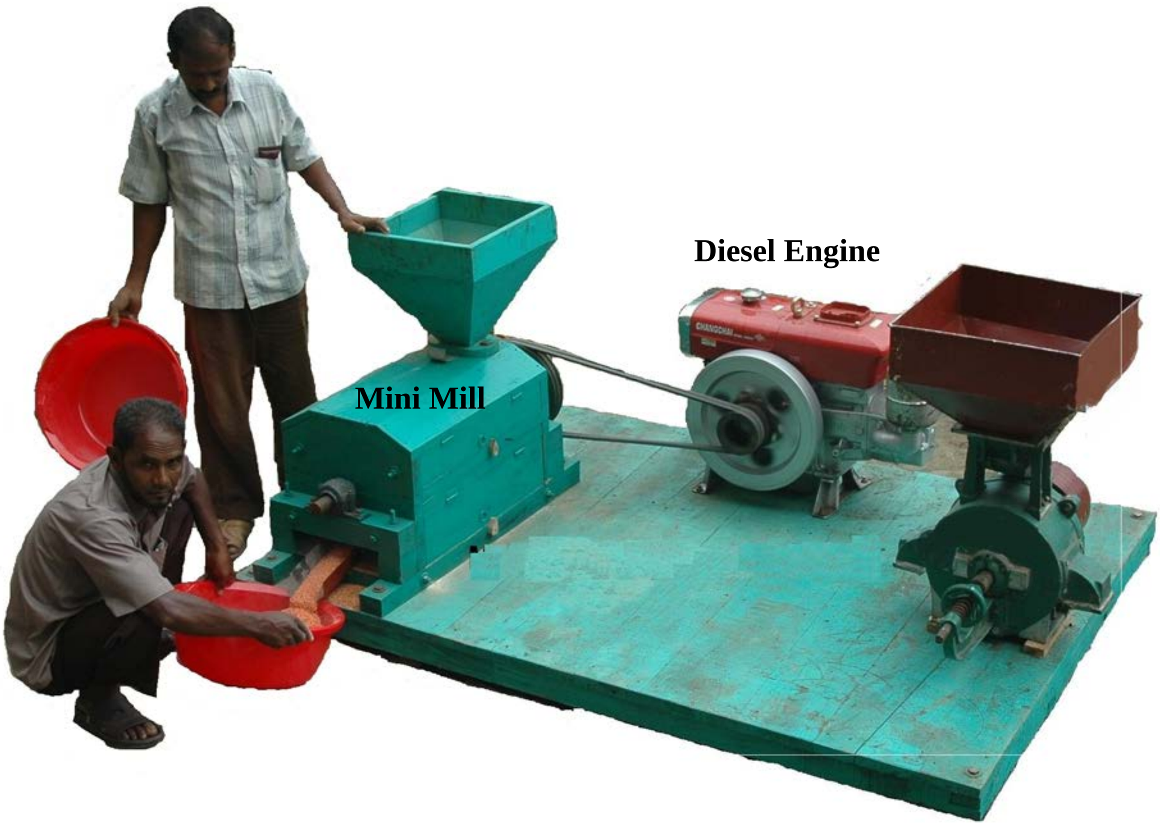

Figure 1. Pulses de-husking mill (Mini Mill) being demonstrated.

Sustainable Livelihood Outcome through Water Resource Management: A Case Study on Household Character in North West Region in Bangladesh

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Introduction

Water resource management has become a key element for improved livelihood globally (Rockström, Lannerstad and Falkenmark 2007). Also, household's demographic and socio-economic character impacts sustainable livelihood for smallholder. Bangladesh is an agrarian country where agriculture contributes 23.5 percent national GDP and offers 60 percent of rural employment (BBS 2012). The present study covered the North West (NW) region of Bangladesh that represented as a major source of national food production. Livelihood and economy in NW region is heavily depending on natural resources where 75 percent of the land is used for agriculture (BBS 2012). Moreover, 59 percent of the cultivable land is under irrigation and nearly 75 percent of irrigation water comes from groundwater in NW (Banglapedia 2003). Moreover, this area is frequently affected by flood and drought which sometimes adversely affect livelihood. Understanding livelihood impacts of water resources is challenging because many aspects of spatial setting, household character, and broad economic drivers affect livelihoods. There is no investigation that features evaluation of how spatially heterogeneous natural resources including water access as well as household character influence livelihood outcomes like income and nutrition in Bangladesh.

Materials and methods

Present study included detail household character with spatial information characterizing natural resource determinants of districts where those households were located. Present study used 2010 Bangladesh Household Income and Expenditure Survey (HIES) dataset and different secondary sources. It further aggregated geographic information as per each district in NW. It was then categorized into five capitals as physical, financial, human, social and natural for analysis and interpretation. Study examined two separate sets of statistical (multiple linear regression) tests for both nutrition and income to see influences of those on livelihood outcomes in NW of Bangladesh.

Results and Discussions

Overall the nutrition and income model had moderate explanatory power with an *R*-square value of 0.26 and 0.29 for calorie consumption and income respectively. Different forms of capitals were statistically significant for two of those models and it varied regionally across NW. The key finding was proportion of the area under severe drought in each districts was impacted calorie consumption negatively. On the other hand proportion of zilla area where household is located inundated by major flood was impacted on income positively. However, households reporting exposure to flood in the survey year was impacted negatively on average yearly income in a short run. On the other hand, regionally impact of severe drought and major flood differed across the North West region of Bangladesh (Figure 1).

Present study showed socio-economic development through industrialization that created wage income was major contributors to both household income and nutritional well-being.

Also, natural resource management constrain, like drought might impact ground water access which may not sustain in future. It is important to incorporate actual geographical coordinates for each household including their detail characters and merge with more natural resource accumulation at different administrative level in North West region of Bangladesh.

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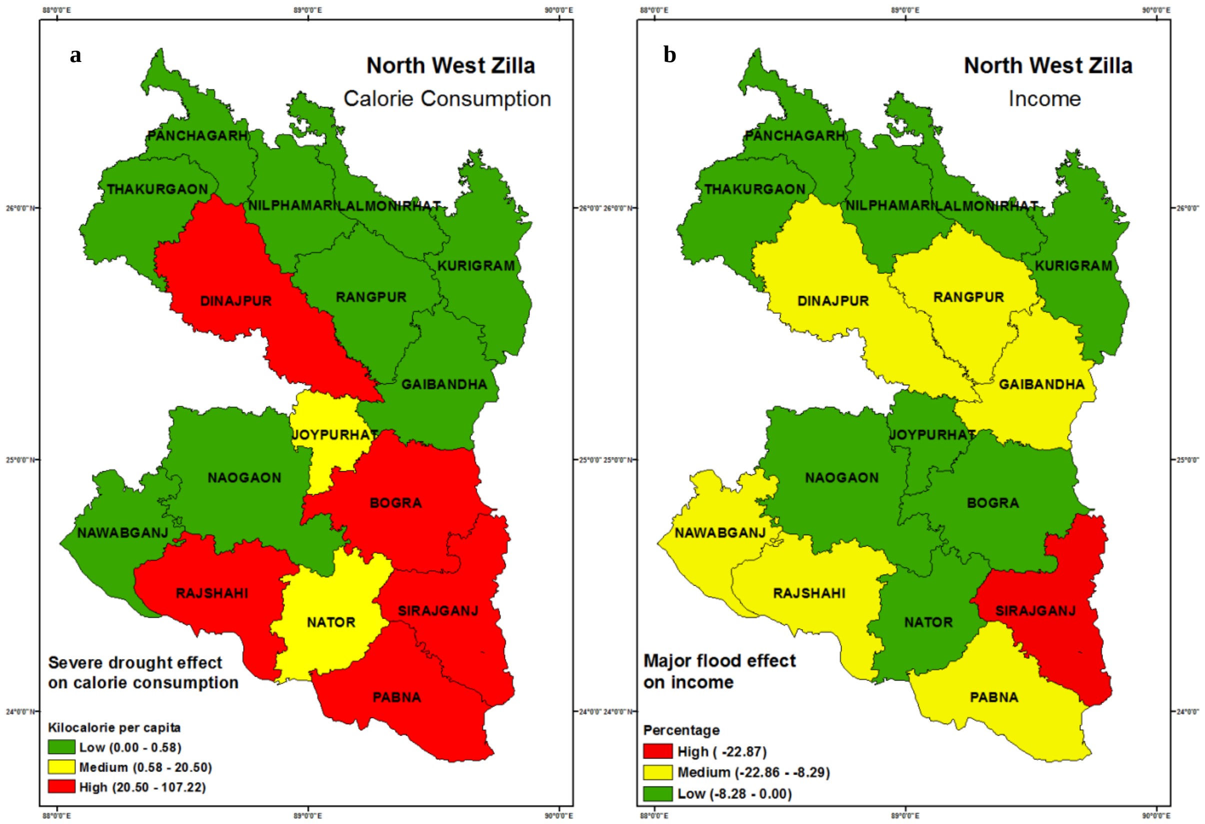

Figure 1. Regional impact of severe drought on calorie consumption (a) and regional impact of major flood on yearly income (b) in North West regions Bangladesh.

Strengthening Conservation Agriculture in Cambodia

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Introduction

In Cambodia, after the restoration of peace, spontaneous migration from the central plains to the peripheral areas changed drastically the development of the Western and Northern provinces. The area of annual upland crops (i.e., soybean, maize, cassava) soared from 120,000 ha in 2000 to about 800,000 ha in 2013. However, in combination with the harsh climate, and high rate of soil organic carbon (SOC) mineralization, mechanized farming exacerbated the problem of soil degradation. Maintaining productive capacity of the soil is a crucial element for long-term improvement of livelihoods. In 2004, the Cambodian Ministry of Agriculture and Forestry (MAFF) has hosted a research and development program led by the General Directorate of Agriculture (GDA), the CIRAD, and since 2009 through a partnership with the North Carolina A&T. The program is directed at local smallholders and based on conservation agriculture (CA) and diversified direct seeding mulch-based cropping (DMC) systems. The activities took place in Kampong Chamand Battambang provinces.

Methods and Results - A Holistic Approach based on Diagnostic, Design, Assessment, Training and Extension (DATE)

DATE is a multi-scale, multi-stakeholder participatory approach, integrating scientific and tacit knowledge. The approach combines *de novo* innovation through expert-based prototyping, keeping the range of possible options wide open, and a *step-by-step* design, favouring adaptation and learning processes. DATE is built on four main components: a diagnosis and three loops of cropping system design. The diagnosis provides a multi-scale analysis of the agricultural systems. On this basis, a large range of cropping system are designed and tested at different scales, with three successive learning loops (Husson et al., forthcoming).

1st loop - Experimental Units for diversified DMC systems

DMC systems are based on a large diversity of cover/relay crops in association, succession and rotationwith the main staple and cash crops (Séguy et al., 2006; Boulakia et al., 2012). The aim is to diversify and increase the biomass input allowing a continuous C flux above and below ground, increasing soil organic C accumulation, improving hydraulic properties, nutrients cycling, soil fauna and microbial functional diversity. Experimental units were established for a total of 21ha integrating three main components: (i) engineering of DMC systems, (ii) thematic studies for in-depth analysis of biophysical processes, and (iii) preservation of a large diversity of cover/relay crops (28 species, 40 cultivars) and staple crops (i.e., soybean, mungbean, rice-bean, cow pea, rice) to diversify the cropping systems and to anticipate market changes.

2nd and 3rd loops - On-farm assessment and network of pre-extension

The second loop takes place in farmers' fields where the most promising systems are tested by farmers in interaction with agronomists and researchers. In addition, machinery for small-scale farming is also assessed with equipment that fit different farms' conditions (i.e., hand jab seeder, planters for power tiller and tractor). Precious information on practicability and management principles are developed. Feed-back from the smallholders is recorded throughout the process, so that every constraint can be taken into account during the experimental phase (Chabierski et al., 2012).The third loop takes place through a network of pre-extension where the changes in technical and economic performances are assessed in real conditions and the constraints to adoption are reviewed, to identify and test measures to facilitate the dissemination process. The integration of these three loops into a holistic innovation approach feeds the overall learning-by-doing process. In RattanakMundol (Battambang) and Dambae (Kampong Cham) districts, these networks cover a total of 9 villages and involved 250 households on ~400 ha in 2013.

Discussion

After a first period based on the generation of innovative cropping systems, technologies, assessment and preservation of a large diversity of species and cultivars, developing knowledge and know-how, there is a need for increased collective learning, participation amongst the main actors, integration of the different components of the farming systems, and developing a participatory land use planningcombining development needs and preservation of rural environment (Bourgoin et al., 2012). Thus, there is a need to develop an iterative and integrative approach that unites engineering, research, extension, training, and higher education.To go through this process, the General Directorate of Agriculture has established in 2013 the Conservation Agriculture Service Center (CASC) aiming at developing engineering, training, research activities, and promoting CA through partnerships. The center will benefit of the regional initiatives carried-out by the Conservation Agriculture Network in South East-Asia (CANSEA, http://cansea.org.vn/).

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Influence of conservation tillage on livelihood improvement in the deltaic eco-system of Sundarban, India

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Introduction

Growing a second crop following winter rice in typically clay-loam saline soil of Sundarban is essential for improving people's livelihood that is impaired mostly by root-zone stress as well as rise in soil temperature ($\geq 1^{0}$C). Information on root-zone environment and its impact on crop growth and productions, especially under saline eco-system, are limited. Hence, this study was planned to examine the effect of conservation tillage on modification of root-zone environment and its influence on growth and productivity of some selected winter crops in saline eco-system of Sundarban.

Methods

Lentil (*Lens esculenta*), gram (*Cicer arietinum*) and mustard (*Brassica campestris*) were sown in the harvested wet-season rice fields adopting conservation tillage practices, viz. conventional (CT), strip (ST) and zero (ZT), along with mulches e.g. paddy straw (M_1) and transparent polyethylene (M_2); while a treatment was kept without mulch (M_o) as control. Treatments were replicated thrice in 3^3–factorial design. Daily weather data was collected from meteorological observatory of the research station. Standard methods were used to measure and estimate moisture and salinity of soil collected from four profile depths. Soil temperature at 0.15 m depth and biometric observations were recorded *in situ*, periodically. Crop yields were recorded at harvest. Moisture conservation efficiency (MCE) was calculated after Dastane and Joshi (1961). Moisture use efficiency (MUE) and Moisture use index (MUI) were calculated following Chakraborty (2000).

Results

Results reveal that conservation tillage reduced evapotranspiration rate from1.65 to1.35 mm d^{-1} irrespective of crops and cropping years (Fig-1). It not only helped in lowering soil salinity, in general, from 2.32 to 0.58 d Sm^{-1}, but also modified soil temperature which varied with nature of mulch. Addition of poly-mulch (M_2) increased temperature by 1.7 $^{\circ}$C, whereas straw mulch (M_1) decreased it by 0.7 $^{\circ}$C (Fig. 1). Such reductions were most pronounce under ZT or ST in association with paddy-straw mulch, which helped in reducing stress and thereby developing the root-zone environments, conducive for growth and yield of crops irrespective of the years (Table 1). This, however, was associated with moisture conservation efficiency (MCE) of tillage and mulch. Further, significantly higher MCE (Table1) under both minimum tillage (ST or ZT) and mulch, in general, indicates its effectiveness in conserving profile moisture. This was more conspicuous during wet-year when crops, in general, produced relatively higher grain yield; but, considerable reduction in yield was more pronounce due to prevalence of prolong dry spell. However, 1.43-1.09 and 2.34-2.10 times higher MUE, irrespective of mulches, in wet and dry years respectively (Table 1) over control (M_0) indicates such tillage practices conserve soil moisture better even under drought and adverse climatic condition. Conversely, MUI, in general, was relatively higher in dry year both with minimum tillage and mulch and best performance was recorded under M_1. Among the crops, MUI of lentil was highest, which was Rs.99.94 and Rs.156.97 ha^{-1} mm^{-1} in wet and dry years respectively, followed by gram and mustard. Hence, lentil may be successfully incorporated in this mono-cropped area adopting ST or ZT together with paddy-straw mulch following wet-season rice, which will indeed substantially help in improving livelihood vis-à-vis quality of life of people of the delta.

Table 1. Grain Yield, Moisture Use Efficiency (MUE), Moisture Conservation Efficiency(MCE) and Moisture Use Index (MUI) of the winter crops grown with tillage and mulch

Treatments	**Grain Yield, kg ha^{-1}**		**MUE, Kg ha^{-1}mm^{-1}**		**MCE, %**		**MUI, Rs ha^{-1}mm^{-1}**	
	Y_w	Y_d	Y_w	Y_d	Y_w	Y_d	Y_w	Y_d
Crops:								
Lentil	982	779	5.26	6.01	80.59	66.03	99.9	157
Gram	744	671	6.97	4.88	80.87	67.09	87.1	88.5
Mustard	584	29	1.65	0.21	76.65	55.77	47.9	4.8
LSD (p= 0.05)	-	-	0.73	0.92	1.31	1.39	10.9	20.8
Tillage:								
Conventional	841	484	4.32	3.47	75.82	60.65	77.2	81.7
Strip	762	487	5.16	3.61	82.80	62.82	83.1	84.5
Zero	541	568	3.38	4.02	80.09	65.51	57.7	84.0
LSD (p= 0.05)	-	-	0.19	0.31	2.17	NS	6.2	1.4
Mulch:								
No mulch	596	291	3.76	2.04	74.82	55.31	60.1	46.8
Paddy straw	943	648	5.39	4.78	82.40	65.42	94.8	102
Polythelene	633	540	4.06	4.28	82.90	68.15	68.5	101
LSD (p= 0.05)	-	-	0.57	0.82	2.23	1.83	6.6	8.6

Note: Y, indicates cropping year and subscripts w and d indicate wet and dry seasons respectively.

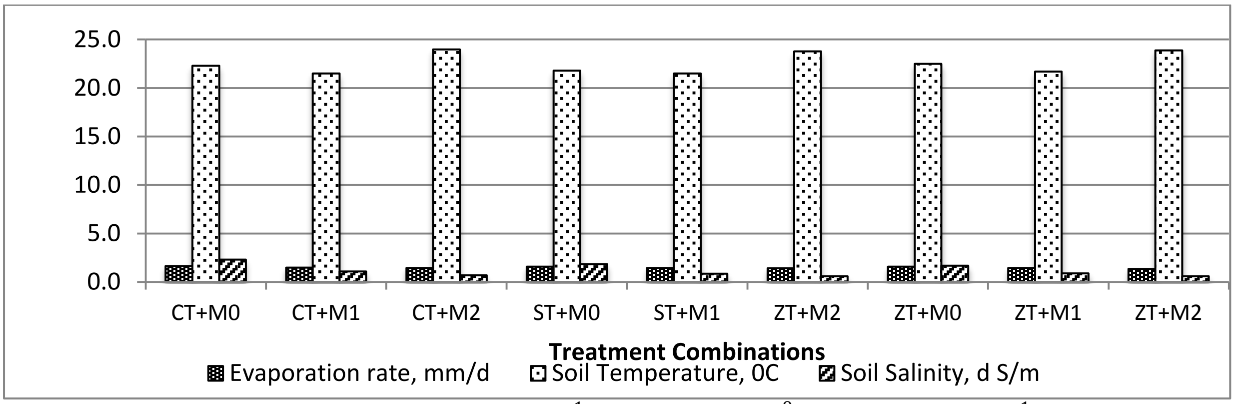

Figure 1. Rate of evapotranspiration (mm d^{-1}), temperature (^{0}C) salinity (dS m^{-1}) of soil as influenced by conservation farming

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Session 3

Weed Management: Suitable weed management options (chemical, mechanical, crop rotation and biological)

KEYNOTE PAPER

Weed Management in Conservation Agriculture

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Weeds have a major impact on global agriculture and food security through reduced production and high costs of control. Conservation agriculture (CA) with stubble retention and no-till is very important for improving soil condition by increasing organic matter, microbial content, reducing power cost and increasing water use efficiency. Tillage and stubble burning are replaced by herbicides for weed control in CA, leading to increased selection pressure for herbicide resistance. World-wide 238 species (138 dicots and 100 monocots) have evolved resistance to 22 of the 25 known herbicide mode of action and to 155 different herbicides in 83 crops in 65 countries (Heap 2014). New knowledge is urgently required to ensure durable and safe herbicide use, develop cost-effective non-chemical (cultural and physical) options and integrate these with herbicide use. In this paper we discuss the challenges and opportunities for managing weeds in CA to reduce threats of resistance, and ultimately decrease weed control costs for farmers.

Challenges

Herbicides are simple and cost-effective and it is not until farmers 'hit the wall' with resistance that they consider cultural and physical control options, even when the considerable benefits of integrated weed management are widely promoted. Resistance to glyphosate is rapidly spreading due to overuse in CA systems and the rapid adoption of glyphosate-resistant crops. This is of considerable concern given the lack of new modes of action entering the market place to replace herbicides as resistance spreads. Adoption of CA changes weed infestations and control options (e.g. Derksen et al. 1993 Feldman et al. 1996; Torresen et al. 2003; Staricka et al. 1990), leading to increasing dominance of difficult-to–control species, especially biennial, perennial, wind-dispersed and herbicide-resistant species; staggered patterns of weed emergence; decreased crop emergence, early vigour and competitiveness; concentration of weed seeds on or near the soil surface; and reduced herbicide efficacy of soil applied herbicides. Complex interactions of weed species with climatic and soil interactions cause variable and unpredictable weed responses to CA.

Opportunities

One of the most cost-effective ways to reduce the spread of resistant weeds is to maintain diverse rotations enabling different control tactics to reduce weed seedbanks and seedbank replenishment. Many cultural control options were used prior to the development of selective herbicides, and are still used in some areas where herbicides are unavailable. Techniques include (e.g. Radosevich et al. 1997; Upadhyaya and Blackshaw 2007), crop competition, preventing the spread of weeds between fields by machinery or livestock, rotating crops and pastures, delaying sowing, strategic tillage, thermal weeding (flaming) and tactical burning, grazing by livestock in the pasture phase, using living mulches, and intercropping and cover crops. Crop competition is an important low-cost tactic for weed management (e.g. Lemerle et al. 2001; Mohler 2001) and can be manipulated by agronomy to favour the crop growth and suppress weeds by choice of vigorous crop species and cultivar, elevated seeding rate, narrow row spacing, large seed size and quality, shallow seeding depth, careful and safe herbicide use, strategic fertiliser timing and placement, crop row orientation, green/brown manuring, immature seed head trimming, inter-row weed control, hand weeding, rouging, and correct use of pesticides for disease and pest control. Breeding for crop traits linked to competitive ability, including early vigour, shading ability and allelopathy also needs to be considered. Recent advances in thermal weed control have seen the development of infrared and microwave weeders. Making silage or cutting hay of very weedy crop for animal forage can be an effective option for certain weed species (Blackshaw and Rode 1991) by removing weeds prior to seed set to avoid seedbank replenishment. Weed contamination of grain or forage can spread weeds to new sites and must be avoided. Retention of stubble can minimise weed emergence and reduce moisture loss. The roles of infrequent strategic stubble burning and tillage are currently being reconsidered by farmers for use within the cropping rotation. Deep burial of *Lolium rigidum* using a mouldboard plough is an effective control tactic in some soils (Douglas and Peltzer 2004). Innovations such as the Harrington Seed Destructor[R], a machine that pulverises weed seed at harvest shows potential. New crops with resistance to glyphosate, glufosinate and other existing herbicide modes of action are under development. New uses for existing chemistry and greater use of residual herbicides are also being examined. The efficacy of herbicides can be improved when combined with increased competitive ability in crops. New strategies, such as the use of site-specific weed management, integration of bio-control, and utilising the benefits of biodiversity for weed seed predation, also offer potential future options.

Conclusions

Weeds will continue to evolve to changing cropping systems and farmers will adapt their management strategies accordingly. The future performance of herbicides is expected to decline with the spread of resistance and with climate change. At early stages of CA adoption, farmers should adopt and continue cost-effective cultural tactics including crop competition with herbicide options. Research is required to provide information on the percentage efficacy of new control tactics on the important weed species impacting on crop productivity. Farmers require knowledge and understanding to assess the technological and socio-economic feasibility of new control options. Adoption of new technologies is most likely when they are practical, cost-effective, adaptable, and fit within the small land holding farming system.

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Crop Establishment Techniques and Weed Control Strategies for Zero-till Planted Soybean-Wheat Rotation in India

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Introduction

Soybean [*Glycine max* (L.) Merrill] has emerged as one of the major rainy season cash crops in central India. Recently, in India, conservation agriculture adoption in rice-wheat cropping system is increasing especially in Indo-Gangetic Plains (IGP). Wheat productivity can be enhanced 10-25% with the adoption of zero tillage but little is known about conservation agriculture (CA) practices for soybean-wheat rotation. Weed management is very crucial in CA. In IGP, application of pre-emergence (PE) herbicides followed by hand weeding (HW) is the most prevalent practice. The recent hike in labour prices has made farming uneconomical, and most of the farmers in this region are marginal and resource poor. A substitute of HW is required in which weed growth at later stages can be checked. For this mixture of PE and post emergence (POE) herbicides could be used. Further, in CA, retention of crop residue will reduce initial growth of weed. Keeping this in view, a new conservation approach of weed management i.e. straw mulch + POE was tested. A four year field experiment was conducted to assess the effects of different tillage and weed management practices on system productivity and weed control efficiency in soybean-wheat cropping system of India.

Materials and methods

The field experiment was conducted during 2010-11 to 2013-14 at the research farm of Indian Agricultural Research Institute, New Delhi. The treatments (16) comprised of combinations of 4 tillage and crop establishment techniques (conventional tillage – raised bed (CT-B); conventional tillage – flat bed (CT-F); zero tillage – raised bed (ZT-B) and zero tillage – flat bed (ZT-F) in main plots and 4 weed control strategies viz., no herbicide in both crop; IWM (pendimethalin 0.75 kg/ha PE+ HW 30 DAS in soybean and isoproturon 1.0 kg/ha POE + HW in wheat); sequential application of herbicides (SHA)(pendimethalin 0.75 kg/ha PE+ imazethapyr 0.075 kg/ha POE 30 DAS in soybean and mesosulfuron + iodosulfuron 0.40 kg/ha POE 30 DAS in wheat) and conservation approach of weed management (CAWM) (wheat straw mulch+ imazethapyr 0.075 kg/ha POE 20 DAS in soybean and soybean mulch+ isoproturon. 1 kg/ha POE in wheat) in subplots, allocated randomly in a split plot design and replicated thrice. Soybean (cv PS 9072) was sown in rows at 30 cm apart so as to get two row on each bed (70 cm centre to centre spacing), while three rows of wheat (cv HD 2895) were accommodated on the respective beds. Soybean was sown during first week of July and manually harvested about 10 cm above the ground level during first week of November. Wheat was sown in third week of November and harvested in third week of April across the years. System productivity of the system was worked out by adding wheat yield in to wheat equivalent yield for respective years. Here, wheat equivalent yield (WEY) of system was calculated by using the following formula: WEY = (yield of soybean (t/ha) x price of soybean (INR/t))/ price of wheat (INR/t).

Afterwards, system productivity was pooled across four years and analysis of variance was performed to draw some logical conclusions. Here, weed control efficiency (WEC) of the herbicides is calculated by using following formula:

WEC = [{Weed density (number/m^2) in control plot – weed density (number/m^2) in treated plot} X 100]/ Weed density (number/m^2) in control plot.

A three factor analysis of variance (ANOVA) was carried out to test the significance of treatments. Critical difference (CD at P=0.05) was used to determine whether means differed significantly or not. Microsoft excel (Microsoft Corporation, USA) was used for statistical analysis of data.

Results and Discussions

System productivity and net returns

There was no significant ($P\leq 0.05$) influence of tillage on system productivity of soybean-wheat over the years. But, net returns were increased by adoption of zero tillage (Table 1). This is mainly due to saving in diesel costs. Averaged over four years, the system productivity of the system was varied from 2.69 to 4.74 t/ha. Raised bed planting gave 9.91% higher system productivity over flat bed. System productivity and net returns were significantly influenced by weed control strategies (Table 1). The highest system productivity was found with integrated weed management (IWM) followed by sequential application of herbicides (SHM), which remained at par with conservation approach of weed management (CAWM). Contrary, highest net returns was found in SHM compared to IWM, which may be due to increased prices of labor involved in hand weeding. Weedy check gave lowest yield and net returns.

Weed dry weight and weed control efficiency

Weed dry weight, weed control efficiency and % yield increase over control were significantly influenced ($P\leq 0.05$) by tillage and crop establishment techniques in soybean (Table 1). Zero tillage gave more weed dry weight than conventional tillage. Hence, weed control efficiency and weed index was found higher in conventional tillage. This is mainly due to mechanical knock down of weeds in conventional tillage practices. The % yield increase over control was higher in zero tillage, mainly due to better growth of soybean. Raised bed was superior over flat bed in terms of weed dry weight, weed control efficiency and weed index. Weed control strategies significantly influenced weed dry weight and weed control efficiency (Table 1). Integrated weed management (IWM), sequential application of herbicides (SHM) and conservation approach of weed management (CAWM) was found at par in terms of weed dry weight in soybean (g/m^2) at 60 DAS. The highest weed control efficiency and % yield increase over control was found in IWM over the rest of treatment. The apparent visible control of weeds could be a possible reason that instead of higher cost of hand weeding, this practice is still popular amongst farmers. The CAWM was found at par with SHM with respect to % yield increase over control. This is mainly due to retention of straw at soil surface, which improved soil health (Sepat et al., 2013). This could be a potential strategy to control weed in future. The highest weed index was found in CAWM, which indicate that still there is a scope to control weeds in long run.

Conclusion

From present investigation it can be concluded that zero-tillage with either raised bed or flat bed is suitable for the soybean-wheat rotation in the Central Plateau of India. Application of pendimethalin 0.75 kg/ha PE+ HW at 30 DAS in soybean and isoproturon 1.0 kg/ha POE + HW in wheat can be substituted by sequential application of herbicides viz., pendimethalin 0.75 kg/ha PE+ imazethapyr 0.075 kg/ha POE 30 DAS in soybean and mesosulfuron +

iodosulfuron 0.40 kg/ha POE 30 DAS in wheat. Conservation approach of weed management that is straw mulch followed by post emergence herbicide application can be a better alternative in long term.

Table 1. Effect of tillage, crop establishment techniques and weed management on system productivity and weed indices (mean over four years)

	System productivity (t/ha)	Net returns (x 10^3 INR*/ha)	Weed dry weight in soybean (g/m^2) 60 DAS	Weed control efficiency (%)	Weed Index	% Yield increase over control
Tillage						
Conventional	4.02	76.7	65	64.6	21.9	29.5
Zero	4.21	84.2	78	60.1	13.3	32.6
LSD(P=0.05)	NS	6.4	8.0	1.94	NS	NS
Crop establishment technique						
Raised bed	4.31	75.3	76	61.0	18.1	29.3
Flat bed	3.92	85.6	67	63.8	17.0	32.8
LSD(P=0.05)	0.30	6.4	8.0	1.94	NS	NS
Weed control strategies						
IWM	4.74	92.8	28	85.1	19.3	50.0
SHA	4.55	96.1	32	83.3	24.7	39.0
CAWM	4.48	88.9	36	81.1	26.4	35.2
Weedy check	2.69	44.11	190.0	-	-	-
LSD(P=0.05)	0.16	3.89	8.0	1.24	7.89	12.44

*1 INR=60 US $

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Weed Control Efficacy of Herbicides in Wheat under Strip Tillage System

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Introduction

Rice-wheat–mungbean cropping system has been established as a profitable and highly accepted cropping pattern mostly under rainfed system in Bangladesh to improve water- and nutrient-use efficiency and sustain crop productivity (Naresh et al., 2013). Conventional full tillage (3-4 passes) is done for sowing of wheat but considering the environmental and economic advantages, strip tillage (single pass) is becoming popular now-a-days (Norberg, 2010). Wheat gives better yield performance and economic return under strip tillage than conventional full tillage (Hossain et al., 2004; Siddique, 2004; Hossain et al., 2014), but weed is the major barrier to crop production in the strip tillage system. Weeding is generally done by manual or mechanical means but the recent increased cost and decreased availability of labour forced farmers to rely on herbicide as the best option for weed control. Although herbicides help to control weed effectively at lower cost, repeated use of herbicides with same mode of action may lead to herbicide resistance in weeds. Therefore, it is important to select herbicides with different modes of action to control weed successfully by avoiding development of herbicide resistance in weeds. This study evaluated the weed control efficacy of some selected herbicides in wheat field under strip tillage system for identifying herbicides with different modes of action.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from Nov 2013 to Mar 2014 which included eighteen treatments (Table 1) in a randomized complete block design with three replications. Pre-plant application of Glyphosate was applied @ 3.75 L ha^{-1} on 16 Nov 2013. Seed of BARI Gom-26 was sown @ 120 kg ha^{-1} on 23 November 2013 with a Versatile Multi-crop Planter (VMP) and the fertilizer was applied at recommended rates with VMP during seeding. Weed population and biomass were collected from randomly selected three locations of 0.25 m^2 each at 30 and 50 days after sowing (DAS). The crop was harvested on 19 Mar 2013 and the grain yield was recorded. The collected data were statistically analyzed using standard protocol.

Results and Discussion

At 25 DAS, no weed was found with T_5 and T_7 but the lowest amount was observed with T_{15}, T_3, T_9, T_{11} and T_{18}. The lowest weed biomass at 50 DAS was found with T_3 followed by T_7, T_{13} and T_{15} (Fig. 1a). Thus the highest weed control efficiency (WCE) was found with T_5 and T_7 at 25 DAS while the highest WCE at 50 DAS was found with T_{15}, T_3 and T_{13} (Fig. 1b). The highest grain yield was obtained with T_7 and consequently the yield increase over control (YOC%) was also the highest with T_7 followed by T_8, T_{15}, T_3 and T_9 (Fig. 1c and 1d). The study revealed that Pendimethalin or pretilachlor could be used for pre-emergence application followed by ethoxysulfuron and/or any of the post-emergence herbicides such as carfentrazone-ethyl, carfentrazone-ethyl + isoproteuron or 2,4-D for effective weed control. However, use of herbicides with different mode of action within the same crop can delay the evolution of herbicide resistance in weeds.

Table 1. Treatments used in the trial [‘fb’ stands for ‘followed by’, ‘HW’ stands for ‘hand weeding’]

T_1 = No weeding	T_{10} = Pretilachlor fb carfentrazone-ethyl
T_2 = Weed free (4 hand weeding)	T_{11} = Pendimethalin fb pyrazosulfuron-ethyl fb 2,4-D
T_3=Pendimethalin fb pendimethalin	T_{12} = Pretilachlor fb pyrazosulfuron-ethyl fb 2,4-D
T_4 = Pretilachlor fb pretilachlor	T_{13} = Pendimethalin fb 2,4-D
T_5=Pendimethalin fb ethoxysulfuron	T_{14}= Pretilachlor fb 2,4-D
T_6=Pyrazosulfuron ethyl fb ethoxysulfuron	T_{15}=Pendimethalin fb (carfentrazone-ethyl + isoproteuron)
T_7=Pendimethalin fb ethoxysulfuron fb carfentrazone-ethyl	T_{16}= Pretilachlor fb (carfentrazone-ethyl+ isoproteuron)
T_8=Pretilachlor fb ethoxysulfuron fb carfentrazone-ethyl	T_{17}=Triasulfuron fb (carfentrazone-ethyl+ isoproteuron)
T_9 = Pendimethalin fb carfentrazone-ethyl	T_{18} = Triasulfuron fb 2,4-D

(a) (b) (c) (d)

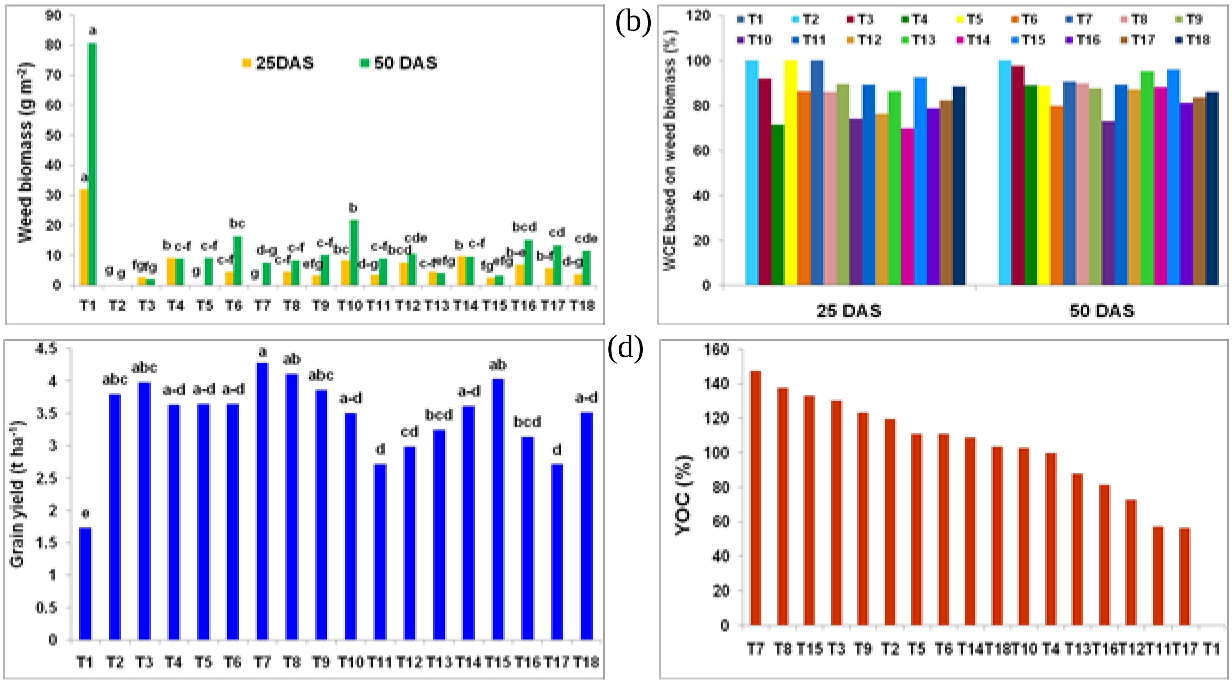

Figure 1. Effect of different herbicide treatments on (a) weed biomass, (b) percent weed control efficacy on weed biomass at 50 DAS, (c) grain yield and (d) percent yield increase over control during 2013-14 [Treatments are mentioned in Table 1]

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Weed Control Efficacy of Herbicides in Unpuddled Transplanted A*man* (Summer) Rice

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Introduction

Rice is generally grown by seedling transplanting on puddle land to facilitate easy crop establishment and weed control. Very recently, seedling transplanting is done in unpuddled land just after strip tillage (a form of conservation tillage that clears crop residues in a narrow zone of soil and loosen subsoil layers prior to planting, Mitchell et al., 2009) followed by irrigation. The unpuddled transplanted rice gives yield similar to that of puddle transplanted rice (Haque, 2009; Saharawat et al., 2009). The weed pressure during crop establishment is low in the puddle transplanted system, but weed is the major barrier in strip till unpuddled transplanted rice. The manual or mechanical weeding is no longer feasible because of scarcity of labourers and increased labour costs. This labour situation has forced the farmers to rely on herbicides as the best option for weed control. The continuous use of the same herbicide aids the development of herbicide resistance in weeds which make weed control difficult. Herbicide resistance can be managed by rotation of herbicides with alternate modes of action. Therefore, it is essential to study the efficacy of a number of herbicides with different modes of action for controlling weeds in unpuddled transplanted rice. The present study was aimed to evaluate the weed control efficacy of herbicides with different modes of action for sustainable weed management for unpuddled transplanted rice under the strip tillage system.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from June to November, 2013. The trial comprised eighteen weed control treatments shown in Table 1. The experiment was laid out in a randomized complete block design with three replications. Seven days before transplanting of rice seedling, pre-plant glyphosate was applied @ 75 mL/10 L water. Strip tillage was done with a Versatile Multi-crop Planter (VMP) and then the land was inundated to 3-5 cm standing water for 48 hours. Twenty five days old rice seedlings of variety BINA dhan7 were transplanted on 22 July 2013 and the fertilizers were applied as per recommended practice. The crop was harvested at maturity on 04 November 2013. Data on weed, grain yield and relevant attributes were recorded. Weed samples were taken from randomly selected three locations of 0.25 m^2 each at 35 and 50 days after transplanting (DAT). Data were subjected to ‘ANOVA’ and means were compared by DMRT using MSTATC.

Results and Discussions

Herbicide treatments exhibited significant effects on weed biomass at 35 and 50 DAT (Fig. 1a). At 35 DAT, pyrazosulfuron ethyl fb orthosulfamuron fb 2,4-D (T_{16}) treated plots produced the lowest weed biomass and highest (100%) weed control efficiency (WCE) compared to the weedy control plot (Fig. 1b). Lower weed biomass also observed in T_4, T_8, T_{11}, T_{12}, T_{14}, T_{15}, T_{17} and T_{18}. But at 50 DAT, the highest weed control efficiency (85%) was obtained from Butachlor fb Orthosulfamuron fb 2,4-D (T_{17}) followed by T_4, T_5, T_7, T_{10}, T_{11}, T_{12}, T_{13}, T_{15}, T_{16}, T_{17} and T_{18}. The highest grain yield and percent yield increase over control (YOC%) was obtained from T_{16} followed by T_{15}, T_2, T_3, T_5, T_4 and T_{17} (Fig 1c and 1d).

Therefore, pre-emergence application of pyrazosulfuron ethyl or pendimethalin or butachlor followed by orthosulfamuron followed by either (butachlor+ propanil) or 2,4-D can be used for effective weed control in unpuddled transplanted aman rice. However, repeated application of the herbicides having same mode of action should be avoided within the same crop to delay the evolution of herbicide resistance in weeds.

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Table 1. Treatments used in the trial ['fb' stands for 'followed by', 'HW' stands for 'hand weeding']

T_1 = No weeding	T_{10}= Pretilachlor fb (aceta+bensul)
T_2 = Weed free	T_{11}=Pendimethalin fb orthosulfamuron (orthosulfa) fb (butachlor+ propanil) (buta+propa)
T_3 = Pendimethalin fb HW	T_{12}=Pyrazo ethyl fb orthosulfa fb (buta+ propa)
T_4 = Pyrazosulfuron Ethyl (Pyrazo ethyl) fb HW	T_{13} = Butachlor fb orthosulfa fb (buta+ propa)
T_5 = Butachlor fb HW	T_{14}= Pretilachlor fb orthosulfa fb (buta+ propa)
T_6 = Pretilachlor fb HW	T_{15} = Pendimethalin fb orthosulfa fb 2,4-D
T_7=Pendimethalin fb (acetachlor+bensulfuron methyl) (aceta+bensul)	T_{16} = Pyrazo ethyl fb orthosulfa fb 2,4-D
T_8=Pyrazo ethyl fb (aceta+bensul)	T_{17} = Butachlor fb orthosulfa fb 2,4-D
T_9=Butachlor fb (aceta+ bensul)	T_{18} = Pretilachlor fb orthosulfa fb 2,4-D

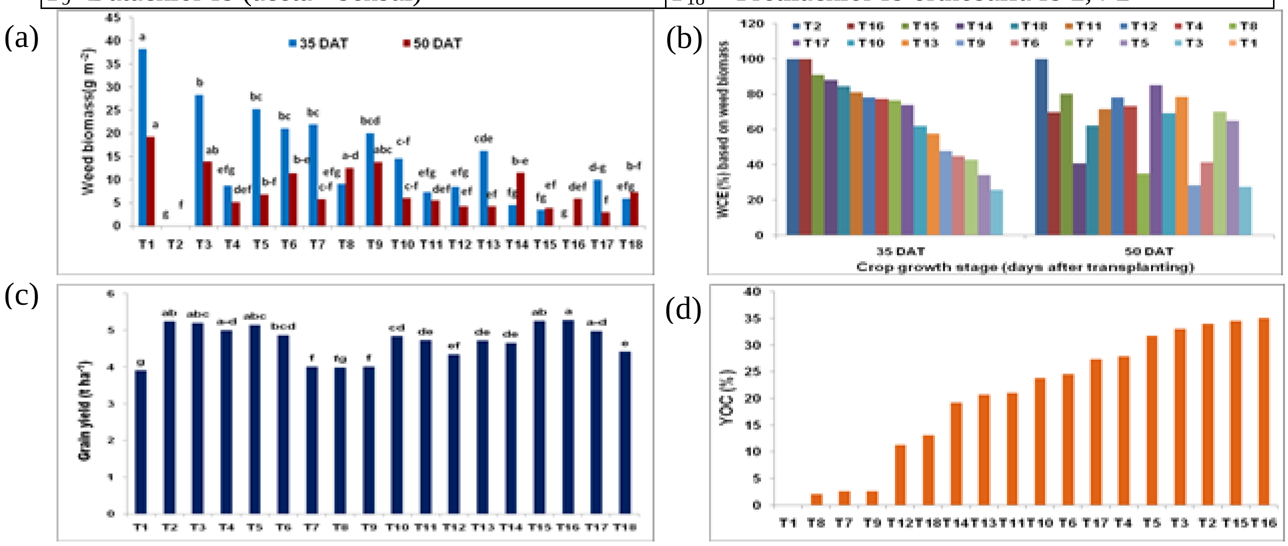

Figure 1. Effect of herbicides on (a) weed biomass at 35 and 50 DAT, (b) WCE (c) grain yield and (d) YOC of unpuddled transplanted *aman* rice in 2013 [Treatments are mentioned in Table 1].

Weed Management in Mustard (*Brassica napus* L.) under Minimum Tillage and Crop Residues

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Introduction

Weed management is critical to obtaining profitable yields in minimum tillage system. Innovative weed control strategies including chemical methods will continue to be an essential component in the development of sustainable conservation agriculture (CA) practices (Andrew and Kelton, 2011). Weed management in minimum tillage relied on extensive use of herbicides. This may leads to the development of resistance in weeds. Crop residue can decrease density and dry weight of perennial weeds by 35 and 75%, respectively, and of annual weeds around 80% compared to no residue (Fisk et al., 2001). Wheat (*Triticum aestivum* L.) residue can reduce weed seedling emergence in corn by 45% (Crutchfield et al., 1986) and weed biomass in sorghum (*Sorghum bicolor* L.) by 60% (Wicks et al., 1994). These results suggest that, residue retention can be a promising method providing a sustainable approach for suppressing weeds in conservation tillage. Therefore, a study was undertaken to examine, weeds management and yield performance of mustard under minimum tillage and different levels of residue retention.

Materials and Methods

An on-farm research was conducted at the Vangnamari union under Gouripur upazila of Mymensingh district of Bangladesh during 13 November 2013 to 4 February 2014. In this experiment a mustard CV. *BARI sharisha-14*, was sown with 6 tillage and weed control practices *viz*., $\mathbf{W_1}$: Conventional tillage + one weeding (Control); $\mathbf{W_2}$**:** Roundup (RU) + Strip tillage (ST); $\mathbf{W_3}$**:** RU+ ST + Pre-emergence (PE) herbicide (Pendimethalin); $\mathbf{W_4}$**:** RU+ ST + Post-emergence (PO) herbicide (Oxadiazon); $\mathbf{W_5}$**:** RU+ ST + PE + PO; $\mathbf{W_6}$**:** RU+ ST + weed-free, and 2 levels of crop residue *viz.*, $\mathbf{Cr_1}$**:** Current residue (20%) and $\mathbf{Cr_2}$**:** Increased residue (50%). The design was randomized complete block design with 4 replications consisting 48 (6×2×4) plots of 9 m × 5 m each. Weed samples were taken randomly from four locations of 0.25 m^2 at 35 days after sowing (DAS). Weed populations were counted species wise and then oven dried at 70^0C for 72 hours. The crop was harvested from three locations of 3 m^2 areas and grain yield was recorded. Data were subjected to analysis of variance using MSTAT-C and means were separated by Duncan's Multiple Range Test.

Results and Discussions

Weed infestation

The experimental plots were infested with 24 weed species belonging to 13 families, of which 18 were annuals and 6 perennials (Table 1). Of these weed species, 6 belonged to Poaceae 3 to Cyperaceae, 2 to each of Amaranthaceae, Asteraceae, Brassicaceae, Fabaceae and each one of rest of the 7 families.

Tillage and weed control effect on weed and crop

The highest weed density (40 m^{-2}) and dry matter (29 g m^{-2}) was found in control (W_1) while both were nil in strip tilled (ST) weed free plots (W_6). However, the lowest weed density (12 m^{-2}) and dry matter (6 gm^{-2}) was recorded in ST followed by RU, PE and PO (W_5) (Fig. 1). W_1 yielded the lowest (0.58 tha^{-1}) and the highest (0.95 tha^{-1}) was recorded from W_6 while the second highest (0.90 tha^{-1}) from W_5 (Figure 2). The highest BCR (2.29) was calculated from W_5 in contrast to W_6 (2.13) (Fig. 2).

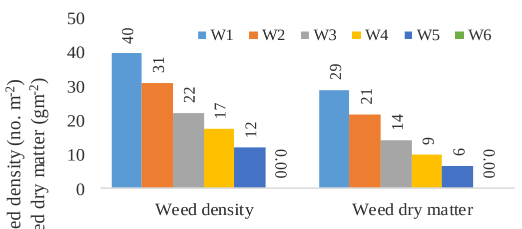

Fig.1. Tillage and weed control effect on weed density and weed dry matter

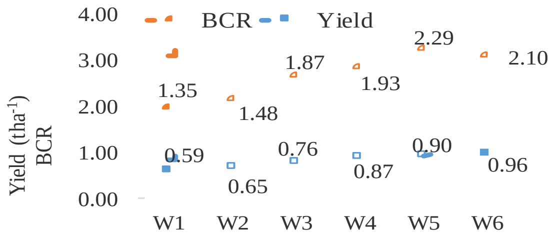

Fig.2. Tillage and weed control effect on Yield and BCR

Effect of crop residue on weed and mustard

Figure 3 shows that, at low crop residues, weed density and weed dry matter were high but crop yield was low. In contrast, weed density and weed dry matter was low and crop yield was high at high crop residue. These results suggest that, increased residue might have reduced weed emergence and increased crop yield by 52%.

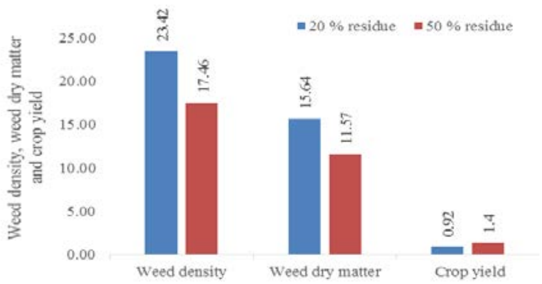

Fig. 3. Effect of crop residue on weed and mustard

Table 1: Weed infestation in the experiment plots (*annual species, ** perennial species)

Species	Family	Density	Species	Family	Density
Alternanthera sessilis *	Amaranthaceae	**300**	*Vicia sativa* *	Fabaceae	8
A. philoxeroides *	Amaranthaceae	26	*Desmodium triflorum* **	Fabaceae	2
Centipeda minima **	Asteraceae	14	*Marsilea quadrifolia**	Marsiliaceae	15
Eclipta alba *	Asteraceae	**198**	*Jussiaea decurrens* *	Onagraceae	10
*Heliotropium indicum**	Boraginaceae	16	*Echinochloa crusgalli* *	Poaceae	**99**
Brassica kaber *	Brassicaceae	14	*E. colonum* *	Poaceae	29
Raphanus raphanistrum *	Brassicaceae	6	*Digitaria sanguinalis* *	Poaceae	5
*Spilanthes acmella**	Campanulaceae	14	*Cynodon dactylon* **	Poaceae	9
Chenopodium album *	Chenopodiaceae	10	*Leersia hexandra* **	Poaceae	4
Cyperus rotundus **	Cyperaceae	4	*Panicum repens* **	Poaceae	6
Cyperus difformis *	Cyperaceae	2	*Polygonum coccineum* *	Polygonaceae	**46**
Fimbristylis miliaceae *	Cyperaceae	20	*Lindernia procumbens* *	Scrophulariaceae	**38**

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Row Spacing, Herbicides and Nitrogen Effect on Crop-Weed Competition in Cereal-Broadleaf Crop Rotation

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Introduction

Proximity factors such as row spacing change the spatial distribution of crop plants and alters the intensity of crop-weed competition (Fischer and Miles 1973). Narrow row spacing is likely to facilitate crop plants with greater competitive ability than weeds, compared to wide row spacing (Hashem et al. 1998). In dry land conservation agriculture (CA), wide rows may ensure some temporal and spatial water availability at critical crop growth stages to ensure profitable yields. However, good weed management becomes critical to the success of wide row systems, as failure to control water-using weeds defeats the purpose of wide row cropping where water conservation is the focus. Management of nitrogen (N) also greatly affects the growth of weeds. While weeds may have easy access to applied N if top-dressed on the soil surface at sowing time, strategic N application technique may maximise the access of crop plants to N compared to weed plants such as annual ryegrass. This study was undertaken to examine the interaction of N rate (and N application technique) and weed control options under normal and wide row spacing in a wheat –lupin–canola rotation in CA.

Materials and Methods

To complement research and development on CA in Bangladesh, a three-year rotation trial (wheat (*Triticum aestivum* L.)– lupin (*Lupinus angustifolius* L.) –canola (*Brassica napus* L.)) was conducted at Cunderdin [117.14E, 31.39S], Western Australia to examine the effect of crop row spacing, herbicides and applied N on crops and weeds. N was applied in wheat and canola but not in lupin.

Treatments

Rotations: Both wheat and lupin crops were grown in separate plots in 2012. Wheat plots of 2012 were rotated to lupin in 2013 while lupin plots of 2012 were rotated to wheat in the 2013 season. Roundup Ready® (RR) canola crop was grown in the 2014 season in all wheat and lupin plots of 2013.

Row spacing, herbicide and nitrogen (N): Crops were sown at 22 cm and 44 cm row space in each growing season (May to November). Triflur X® (trifluralin 480 g/L) at 2 L/ha and Sakura® (pyroxasulfone 850 g/kg) at 118 g/ha were applied to wheat crop. Gesatop Granules® (simazine 900 g/ha) at 1 kg/ha and Outlook® (dimethenamid-P 720 g/L) at 1 L/ha were applied in lupin crop. Roundup Ready® (glyphosate 690 g/L) was applied at 900 g/ha in 2014 RR Canola at 2- and 5-leaf stages. Double super (17.5% P) at 50 kg/ha was applied in all crops. Wheat and canola crops received three nitrogen treatments viz., N_{25} (25 kg N/ha), N_{50} (50 kg N/ha) (N drilled in front of tynes as urea (46% N), and Flexi N_{50} (50 kg N/ha as Flexi N (urea-ammonium nitrate (32%N)) solution placed at 7 cm depth for wheat and 4.5 cm for canola). The trials were conducted in a randomised complete block design with four replications using a unit plot of 20 m by 2 m under minimum tillage systems.

Data analysis

Data were subjected to ANOVA by Genstat 15th Edition. Means were separated by LSD.

Results and Discussion

The main weed species was annual ryegrass (*Lolium rigidum*) with 610 plants/m^2 in 2012 growing season, 80 plants/m^2 in 2013, and 480 plants/m^2 in 2014. Increases in row spacing from 22 cm to 44 cm reduced wheat yield by 29% in 2013 season while row spacing did not influence lupin grain yield in either season, suggesting that unlike wheat plant, lupin plant growth is more plastic to produce vegetative growth and yield. Sakura® was more effective on weeds in wheat than trifluralin while Outlook® was more effective than simazine in lupin, leading to increases in grain yield of wheat and lupin in both seasons. The extent of wheat grain yield increase due to Sakura® was greater in 44 cm than 22 cm. Flexi N_{50} had higher initial weed plants than N_{25} or N_{50}, indicating a possible stimulation of annual ryegrass emergence by Flexi N. The weed plant number was lower in 22 cm row space than 44 cm under flexi N.

Table 1. Effect of row spacing (RS), herbicide (H) and nitrogen (N) on the weed control and grain yield in wheat in 2012 and 2013 seasons and effect of RS and H on weed control and grain yield in lupin in 2012 and 2013 at Cunderdin, Western Australia. Wheat crop was not harvested in 2012. ns = Not significant; "-" indicates N was not applied in lupin crop.

Treatment	Weed control in wheat crop (p-values)		Wheat yield in 2013 (p-values)	Weed control in lupin (p-values)		Lupin yield (p-values)	
	2012	2013		2012	2013	2012	2013
RS	ns	ns	<0.001	ns	<0.001	ns	ns
H	0.003	0.01	<0.001	<.001	ns	<0.001	0.01
N	ns	0.06	ns	-	-	-	-
RS*H	ns	0.03	ns	0.03	ns	ns	ns
RS*N	0.01	ns	ns	-	-	-	-
H*N	0.03	ns	ns	-	-	-	-
RS*H*N	0.04	0.05	ns	-	-	-	-

Complex three-way interactions occurred for weed control in wheat crop in both seasons. No interaction between herbicides and row spacing on weed control was found in lupin in either season, suggesting that lateral vegetative growth of lupins effectively suppressed weeds in wide row lupin. No significant effect of N on wheat was found in 2013 season, probably due to a possible N saturation resulted from residual N of 2012 lupin crop. In summary, herbicides reduced weeds and increased grain yield in wheat and lupin crops. Close rows (22 cm) reduced weeds and increased grain yield in wheat crop but not in lupin. So, small holders in CA should practise chemical and cultural weed control options to optimise cereal yield.

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Productivity of garlic grown under different tillage conditions and mulches under organic production systems

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Introduction

The poor yield of garlic may be due to the lack of inadequate soil and water management practices with reference to soil water shortage in the soil profile. However, a considerable amount of fallow land can be brought under garlic cultivation through utilization of residual soil moisture as well as application of reduced supplemental irrigation. Unfortunately little work has been done in Bangladesh to test the feasibility of garlic production by conserving soil moisture through the management of tillage and mulch practice. From the previous experiment it was found that both tillage as well as mulches exerted profound effects on yield and yield contributing characters. Nevertheless, the present investigation was carried out to observe the combined effect of mulches and tillage on garlic.

Materials and Methods

Expt 1. Effects of tillage and different thickness of water hyacinth mulch on the growth, yield and storage quality of garlic: This experiment was conducted at the USDA Allium field laboratory of BAU during 2006-2007 with objectives i) to compare the production of garlic between with and without tillage (zero tillage) conditions and ii) to determine the appropriate amount of mulch materials for soil conservation under zero tillage conditions. The treatments were: Factor A: i) Conventional tillage ii) Zero tillage; Factor B: Different thickness of water hyacinth mulch viz. i) 6 cm, ii) 8 cm, iii) 10 cm, iv) 12 cm and v) No mulch (control). The experiment was set in Randomized Complete Block Design with three replications. The results were analyzed following the MSTAT package program.

Expt 2. Productivity of garlic grown under different tillage conditions and mulches in presence of organic manure: This experiment was also conducted at the USDA Allium field laboratory of BAU during 2006-2007 with objectives: i) to compare the production of garlic under different tillage conditions; and ii) to identify the best mulches for garlic production. The experiment consisted of Factor A: Tillage; i) Conventional or normal tillage (4 ploughings followed by laddering); ii) Puddling (2 ploughings followed by irrigation) and ii) Zero tillage (without land preparation in the wet soil)- Factor B: Mulches (3) viz. i) Rice straw; ii) Water hyacinth (Eichorina and iii) Sotty leaf (Curcuma amada) mulch. Design, analysis and other practices same as Expt. 1.

Results and Discussion

A series of experiments were conducted in the field laboratory of USDA-Alliums' project, Bangladesh Agricultural University, Mymensingh during rabi seasons of 2006-2009 with the main objective of determining the effect of manure, tillage and mulch on the growth, yield and quality of garlic.

In 2006-2007 growing season, the treatment combination of zero tillage with the 10cm thickness of mulch produced the highest yield (9.92 t/ha). Moreover, zero tillage conditions showed the highest storage quality because it possessed the lowest values in case of weight loss (8.45%), insect infested bulbs (6.67%) as well as percent rotten bulbs (2.44%) even after

150 days of storage. In contrast, conventional tillage with no mulch, and conventional tillage with 6 cm mulch were found to have lower storage quality compared to the other treatment combinations. Zero tillage garlic showed remarkable variation. However, differences were not significant between rice straw and water hyacinth mulch. It was also noticed that both the tillage conditions as well as mulches exerted profound effects on the yield and yield contributing parameters. Puddling and zero tillage garlic resulted higher yield compared to the conventional tillage.

In 2007-2008 growing season, a comparison of the developed package of production technology for two registered varieties of garlic (BAU Garlic-1; BAU Garlic-2) with BARI recommended technology under dry land (conventional cultivation method) and wetland (zero tillage method) conditions made at BAU, Mymensingh during the growing season 2007-08. The results demonstrated that the growth of plants, development of bulb and yield were significantly better in the newly developed technology than the BARI recommended technology both under dry and wetland conditions. The garlic variety BAU Garlic-1 with the developed technology yielded 21.40 t/ha under the dry land condition, and 14.20 t/ha under the wetland conditions. Whereas, the garlic variety BAU Garlic-2 with the developed technology yielded 17.91 t/ha under the dry land condition, and 12.10 t/ha under the wetland condition.

Rice straw mulch showed better performance than the control or sotty (*Curcuma amada*) leaf. The rice straw conserved more moisture in the soil compared to other mulch practices namely water hyacinth or sotty leaf. The reason for higher yield in the rice straw mulch might be due to decreased soil temperature and diurnal temperature fluctuation too, and more efficient conservation of water, which favoured growth of the crop. High soil temperature suppressed the rate of root elongation and decreased root density in the surface layer of unmulched bare soil. The increased root density enhanced better uptake of water and nutrients and ultimately increased plant height and yield of garlic. Furthermore, rice straw mulch prevented the weeds and ultimately plants grew without any competition. These results are in agreement with the experiences of Halim (2000) and Aliuddin (1986).

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Evaluation of Conservation Tillage and Weed Management Options on Production Potential and Weed Incidences in Dry Seeded Rice

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Introduction

The challenge of crop production is to produce more food at less cost and to improve water, labor and land productivity. Direct seeded rice (DSR) is a resource conservation technology that satisfies these requirements and is conducive to mechanization. The recent development of post-emergence herbicides provides an opportunity to develop CA associated with dry DSR. Hence DSR and adoption of conservation tillage based practices together with mechanical seeder for crop establishment can be evolved as sustainable technology with low cost in this region.

Materials and methods

The experiment was carried out at the BRRI Regional station, Rajshahi in the wet season of 2010 and 2011. The main plot treatments were Zero tillage (ZT), Strip tillage (ST), Minimum tillage using PTOS (MT), Permanent bed (PB), Fresh bed (FB) and Conventional tillage (CT). Except conventional tillage, other treatments were termed as conservation tillage. The subplot treatments were Weed free (W_1); Post emergence herbicide + 1 hand weeding (W_2), Pre-emergence herbicide + Post-emergence herbicide (W_3), Post emergence herbicide (W_4) and Weedy control (W_5). Pandimethalin (Panida) and bispyribac Na^+ (Nominee Gold), respectively were used for pre- and post-emergence weed control. The soil was low in OM (1.35%), very low in available N (0.07%) and low in P, K, S and Zn. Except in CT, rice was established in dry direct seeding with pre application of glyphosate. The rice variety was BRRI dhan49. In case of ZT, little slits were made in the untilled soil by hook like tool and then the seeds were sown on manually followed by covering the soil. Strip and minimum tillage as well as seed sowing were done in untilled soil through one pass with PTOS machine. Bed was prepared by bed planter in untilled soil as well as seed dropping was occurred simultaneously. Data were analyzed using Crop Stat (version 7.2) program.

Results and Discussion

In 2010, the main effect of tillage did not affect dry matter of broadleaf weeds but it did little influence in 2011 (Table 1). The maximum broadleaf biomass was recorded in MT and ZT in 2011 while CT obtained the lowest biomass. Sedge biomass was higher in FB which was statistically comparable with other conservation tillage treatments during both the years. In 2010 and 2011, the maximum grass biomass was found in ST which was statistically similar to other conservation tillage treatments. It was found that the dry matter of all categories of weeds were top ranked in W_5 which was statistically differed with rest of the treatments in each year. The weed intensity was the same between W_3 and W_4 during both the years indicated that the post-emergence (Bispyribac Na^+) alone or combination with pre-emergence had similar result. Mahajan et al. (2009) also cited that Bispyribac Na^+ was very effective against most of the weeds in DSR.

The grain yield of rice was little affected by the tillage options across the years (Table 1). The CT and MT, respectively recorded the highest and the lowest grain yield in both the years where identical effect had been remained among CT, ZT, PB and FB in first year and among CT, ST, PB and FB in the succeeding year. Irrespective of tillage treatments, the superior grain yield of rice was found in W_1closely followed by W_2 across the years while the significantly lower grain yield was recorded in W_5.Among herbicide applied treatments, grain yield was significantly superior in W_2 over W_3. Although the gross return remained higher in CT a superior gross margin was recorded in PB followed by FB in both the years. Irrespective of tillage options, higher gross return was found in W_1 closely followed by W_2 in both the years. In contrast, the W_2 obtained the higher gross margin over the years.

Table 1: Weeds dry matter, grain yield, gross return and gross margin as affected by tillage and weed

Treat-ments	Weed dry matter at 2nd hand weeding						Grain yield ($t\ ha^{-1}$)		Gross return ($Tk.\ ha^{-1}$)		Gross Margin ($Tk.\ ha^{-1}$)	
	Broadleaf ($g\ m^{-2}$)		Sedge($g\ m^{-2}$)		Grass($g\ m^{-2}$)							
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Tillage												
ZT	6.3	6.3	9.6	5.3	26.6	16.0	3.95	3.93	75480	79664	38785	42143
ST	5.2	4.8	9.7	5.2	20.3	12.3	3.89	4.05	74344	81979	39904	47057
MT	6.4	5.7	16.4	9.0	28.1	15.9	3.73	3.71	70026	75215	35340	40027
PB	4.6	4.9	13.7	7.6	17.5	16.9	4.22	4.33	80370	87381	45406	51913
FB	4.5	4.4	18.9	9.8	24.7	16.4	4.21	4.18	80327	84179	45515	48854
CT	4.2	3.7	7.4	8.1	8.6	6.8	4.28	4.37	81540	87850	41624	46768
LSD 0.05	ns	1.73	10.4	3.3	18.3	7.10	0.37	0.39	3039	7110	3098	7279
Weed management options												
W1	1.22	0.86	2.55	1.73	6.94	5.62	4.65	4.82	88571	96453	44862	51197
W2	1.68	1.16	2.51	2.31	4.91	2.76	4.59	4.76	87144	94902	49452	56366
W3	2.91	2.64	5.73	3.71	10.27	5.01	4.25	4.20	80598	85300	45143	494440
W4	3.28	3.23	7.56	6.08	12.33	8.46	3.85	3.90	74830	79173	42443	46471
W5	16.93	16.97	44.91	23.65	70.60	48.38	2.90	2.78	53926	57730	23579	27156
LSD 0.05	1.53	2.10	9.45	3.32	16.18	4.80	0.31	0.34	3110	6379	3052	6315

In summary, CT obtained lower weeds biomass over the conservation tillage treatments, but weed biomass was similar among the weed-free and herbicide applied treatments. The grain yield and gross return were comparable among CT, PB and FB. The Bispyric Na^+ +1 HW (W_2) treatment showed identical effect with weed free (W_1) in relation to grain yield and gross return. On the other hand W_2 gained higher gross margin over CT in both the years. Grain yield, gross return and gross margin were significantly superior in W_2 over W_3 indicated that post-emergence herbicide supplemented with one hand weeding is necessary for DSR under conservation tillage system.

Acknowledgements

The authors acknowledge the financial and technical support provided by the ACIAR, IRRI, CIMMYT and Bangladesh Agricultural Research Council (BARC).

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Wheat cultivation under conservation tillage options: a promising, low cost and profitable technology for small holders in Faridpur (Bangladesh)

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Introduction

Increasing scarcity of resources (labour, water, and energy) and cost of production are major challenges for the sustainability of wheat production in Bangladesh. Considering these challenges, efforts are being made to develop improved cultivation practices with high yield potential that reduce farmers' production costs. Smallholders in Bangladesh cultivate wheat by conventional tillage, which is both intensive and costly, involving several passes by 2 wheel tractor (2WT) and plankings to create the seedbed. Intensive tillage not only increases cost of production, but it also delays the turnaround period after rice cultivation, often delaying wheat planting such that a yield loss of around 32 kg/ha are incurred for each day's delay after November (Pathak et al. 2003; Rawson 2011). Conservation tillage options are thought to: facilitate optimal sowing time by reducing turnaround time; improve crop productivity while potentially conserving soil moisture and structure; and reducing land preparation costs (resulting in a higher profitability). Thus, CIMMYT projects in Bangladesh have been demonstrating wheat cultivation under conservation tillage technologies such as bed planting (BP) and strip tillage (ST) with recommended fertilizer management at different parts of Bangladesh, including Faridpur. These tillage implements are attached to the2WT, which is ubiquitous in Bangladesh. Acceptance of any technology by farmers is dependent upon its availability, its economic profitability, and its agronomic viability; as such, this study was conducted to: (1) estimate the profitability of wheat cultivation with respect to tillage options, and (2) make recommendations on the basis of economic performance.

Methodology

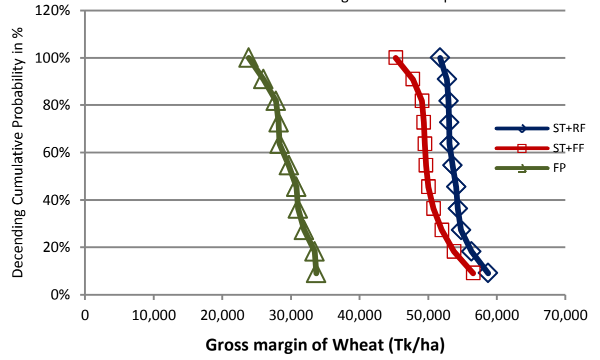
Description of Experiment: To analyze crop productivity and production costs under conservation tillage, demonstrations involving BP and ST with fertilizer management were conducted at different upazilas in greater Faridpur during the cool-dry (Rabi) season 2013-14. A randomized complete block design was followed with 16 and 11 replications for BP and ST, respectively. Tillage machines were operated by local service providers (LSPs) who added the BP/ST implements to their existing 2WT for ploughing /seeding purposes. Two separate demonstrations were conducted (one with BP and another with ST) on different farmers' plots. The treatments were: (T_1) BP/ST+RF (recommended fertilizer), (T_2) BP/ST+FF (farmer's fertilizer), and (T_3) conventional tillage + FF. Seed was sown between the 3rd week of November and the 1st week of December 2013, irrespective of location. For T_3, farmers used their own wheat cultivation practices, while they used project recommended packages (including seeds, fertilizers, etc.) for T_1. New varieties like BARI Gom 25, 26, 27, 28 were supplied to the farmers.

Economic Analysis: For economic analysis, all the data were collected from field demonstrations conducted at Faridpur; contemporary market prices of inputs and outputs were used to estimate the cost and returns. Total variable costs (TVC) included labor and production inputs (e.g. tillage, planting, seed, fertilizer, pesticide, irrigation, harvesting, threshing). The cost of labor used for different operations was based on person-days/ha considering 8 hr/day. Gross returns (GR) included the total value of the main crop and any by-products. Gross Margin (GM) was calculated by deducting TVC from GR. The benefit-cost (BC) ratio was calculated by dividing gross return by TVC. All the cost and returns are presented on a per hectare basis. Cumulative probability curves of GM were estimated to compare the relative scenario of profitability of the tillage options.

Results and Discussion

For adopting both BP and ST options, all operational costs except fertilizer and herbicide use were less for T_1 than the other treatments (farmers traditionally use less fertilizers compared to recommended doses, and they seldom use herbicides). Among all costs, land preparation/seeding cost was remarkably lower for both BP and ST, followed by irrigation cost (Table 1). Cost of seed and labor were also reduced (by 19% and 18%, respectively) as compared to the farmers' practice (T_3), since farmers broadcast more wheat seed than the recommended rate for machine line-sowing (120 kg/ha). Although the total variable cost was approximately 16% less with farmers' fertilizers dose (Table 1), the yield of wheat was increased by 26% for BP and 28% for ST. Simultaneously, gross returns and gross margin were also increased by using tillage machines (76-88% increase GM for BP, and 76-91% increase for ST), which is the noteworthy impact of adopting conservation tillage machinery.

Fig. 1 Cumulative probability curve on Gross margin of wheat yield under ST with fert management at Faridpur



Note: ST= Strip till, RF= Recommended fertilizer, FF= Farmers fertilizer and FP= Farmers' practice

Figure 1 shows the cumulative probability curves for GM: there are clear differences between the ST and farmer's practice (FP) (BP not shown). Both of the conservation tillage options (i.e. ST and BP) performed well, but performed even better with recommended fertilizer doses-resulting in more economic benefits than obtained under the FF (Table 1, Figure1). This study clearly demonstrates the potential for farmers to save on production costs while increasing yield and revenue by adopting BP or ST as preferred tillage options for establishment of wheat. Hence, by adopting these technologies where they are available, farmers can save their scarce resources and earn increased profits. One must note, however, that limited machinery supply in the market constrains the wider adoption of these valuable technologies; this fact therefore needs to be accorded more attention to foster the adoption of tillage technologies for the cultivation of Rabi crops such as wheat.

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Table 1. Percent changes in cost and returns (BDT/ha) for adoption of conservation tillage over farmers practice at Faridpur, 2014

Cost/returns (BDT/ha)	Bed planting option			Strip Till option			% change in comparison to FP			
	BP+RF	BP+FF	FP	ST+RF	ST+FF	FP	BP+RF	BP+FF	ST+RF	ST+FF
Land preparation cost	5,187	5,187	8,669	4,446	4,446	8,273	-40	-40	-46	-46
Seed cost	4,392	4,392	5,328	4,392	4,392	5,400	-18	-18	-19	-19
Fertilizer cost	11,467	8,138	7,989	11,321	7,273	7,171	44	2	58	1
Labour cost	2,709	2,709	3,294	3,910	3,910	4,470	-18	-18	-13	-13
Irrigation cost	9,611	9,611	11,754	8,758	8,758	12,171	-18	-18	-28	-28
Herbicide cost	209	209	209	3,335	3,335	1,816	0	0	84	84
Harvest& carrying cost	14,550	13,742	14,882	13,079	13,094	13,710	-2	-8	-5	-4
Total variable Cost	48,125	43,988	52,125	49,241	45,208	53,010	-8	-16	-7	-15
Yield (t/ha)	4.594	4.261	3.646	4.820	4.438	3.757	26	17	28	18
Gross Return	100,873	93,556	80,219	105,66	97,369	82,610	26	17	28	18
Gross Margin	52,748	49,568	28,094	56,455	52,161	29,600	88	76	91	76
BCR	2.10	2.13	1.54	2.15	2.15	1.56	36	38	38	38

Note: BP= Bed Planting, ST= Strip till, FP=Farmers' practice, RF=Recommended fertilizer dose, FF= Farmers' fertilizer dose

Soil Health, Weed Dynamics and Wheat Grain Yield in Different Rice-Wheat Rotations

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Introduction

The rice-wheat rotation is the predominant cropping system in the Indo-Gangetic Plain (IGP) of South Asia. However, this system is being threatened by declining water availability, increasing labor costs and environmental concerns (Farooq et al., 2011). Developing strategies for the sustainability of the rice-wheat cropping system is imperative to ensure food security for the future generations. Adoption of resource conservation technologies, like aerobic rice culture and zero tilled (ZT) wheat planting, offer a pragmatic option to address many of the key constraints. However, information on soil health and weed dynamics in ZT-wheat following aerobic rice in the region is lacking. This study was conducted to monitor the soil health, weed dynamics and wheat grain yield in different tillage-based rice-wheat rotations.

Materials and Methods

This study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (31.25°N, 73.06°E and 183 masl), Pakistan during three consecutive years 2008-09 to 2010-11. The experiment was laid out in randomized complete block design with four replications. After the harvest of flooded or aerobic rice, soil was sampled from a depth of 0-5 cm. Total soil porosity was estimated following Vomocil (1965) and root penetration resistance was measured according to Bradford (1986). Wheat was sown during the second week of November and was harvested during the last week of April. In ZT, wheat was directly drilled into the rice stubbles with zero tillage drill. In deep tillage, the field was ploughed with chisel plough followed by two cultivations with cultivator and two plankings. In conventional tillage (CT), after rice harvesting field was ploughed with chisel plough followed by two cultivations with cultivator and two plankings. Data on total weed density were recorded 30 days after sowing from two places in each plot. Weeds were removed from the whole field by hoeing. Data collected were statistically analysed by analysis of variance followed by a mean separation by least significant difference.

Results and Discussion

Root penetration resistance was higher after flooded rice, irrespective of seeding method in flooded culture, than aerobic rice; however there was tendency of decreased root penetration resistance over time after aerobic rice (Table 1). Total soil porosity was higher after the harvest of aerobic rice than the flooded rice, seeded by any method, during all experimental years. Nonetheless, soil porosity tended to increase in fields vacated by aerobic rice over time (Table 1). Total weed density was higher in wheat planted after aerobic rice than the crop planted after flooded rice; however, that was more in ZT-wheat than CT-wheat during all three experimental years. A decreasing trend in weed density, over time, was noted in ZT-wheat planted after aerobic rice (Table 2). During year 1, maximum wheat grain yield was recorded from aerobic rice–CT wheat followed by flooded rice–CT wheat and aerobic rice–ZT wheat. However during the 2nd and 3rd years of experimentation, wheat grain yield was more when planted, by CT or ZT, after aerobic rice than the crop planted after flooded rice (Table 2). Nonetheless, after flooded rice, grain yield was higher in CT-wheat than ZT-wheat

(Table 2). Soil physical properties were better after aerobic rice than flooded rice during all experimental years (Table 1) as a puddling-induced hard pan, formed during seedbed preparation for flooded rice, was not present in aerobic rice culture (Farooq and Nawaz, 2014). Puddling disturbed the soil health, which influenced the germination, growth and yield of post-rice wheat (Table 2). As seed of several weeds are damaged during flooding in rice, less weed infestation was noted in wheat planted after flooded rice (Table 2). Wheat grain yield tended to increase in ZT-wheat planted after aerobic rice over time (Table 2). Zero tilled-wheat after aerobic rice seems a pragmatic option for the sustainability of rice-wheat cropping systems in the IGP.

Table 1. Influence of different rice production systems on soil physical properties

Treatments	Root penetration resistance (kPa)			Total soil porosity (%)		
	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11
Direct seeded aerobic rice	874 b	863 b	858 b	52 a	54 a	57 a
Direct seeded flooded rice	906 a	905 a	897 a	46 b	43 b	42 b
Transplanted flooded rice	919 a	917 a	921 a	44 b	42 b	41 b
LSD (P = 0.05)	25.3	29.7	27.3	3.1	5.5	4.6

Table 2. Wheat grain yield and total density of associated weed in different rotations

Treatments	Total weed density (m^{-2})			Grain yield ($t\ ha^{-1}$)		
	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11
Aerobic rice – ZT wheat	125 a	137 a	114 a	4.11 b	4.56 a	4.78 a
Aerobic rice – CT wheat	107 b	113 b	103 b	4.61 a	4.57 a	4.64 a
Flooded rice – ZT wheat	98 c	101 c	95 c	3.56 c	3.79 c	3.87 c
Flooded rice– CT wheat	86 d	80 d	84 d	4.23 b	4.41 b	4.34 b
LSD (P = 0.05)	7.3	9.4	8.4	0.35	0.41	0.27

ZT= Zero tillage; CT= Conventional tillage

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Including Maize in a Rice-Wheat Cropping System with Minimum Tillage and Crop Residue Retention

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Introduction

More demand for food and livestock feed coupled with scarcity of arable land resulted in intensified cereal cropping in Bangladesh. Inclusion of maize in the rice-wheat cropping system facilitates further intensification. But the triple cereal system may cause soil nutrient exhaustion that needs to be addressed through conservation agricultural (CA) practices. The CA has the potential to improve and sustain system productivity (Wall et al. 2010). CA ensures minimum soil disturbance while keeping crop residue in the field improves soil quality. It also minimizes production constraints like water stress, weed infestation and favored production factors like retention of residual moisture, root growth and N use efficiency (Rahman et al. 2005). However, most of the CA works reported on either single or double cropping systems and intervention of CA in a triple cereal system is scarce. Thus the experiment aimed at evaluating CA practices in improving productivity of a wheat-maize-rice cropping system.

Materials and Methods

The field trial was done at the research farm of Bangladesh Agricultural Research Institute, Gazipur (lat 24° N, long 90°3´E, 8 m elev.) starting with a wheat crop in 2010-11. The experiment was laid out in a randomized complete block design with three replications of four CA treatments imposed on the component crops under wheat-maize-rice cropping system. The four treatments were: T_1 = Conventional practices; T_2 = Conservation practices (wheat sown in post rice harvest field with standing straw using PTOS (Power tiller operated seeder) followed by no-till maize and then puddled transplanted rice (PTR)); T_3 = Bed planting (wheat was sown by power tiller operated bed planter followed by no-till maize then PTR); T_4 = Conservation practice in Bed (same as T_3 with standing residue retention of rice and wheat). The crop varieties used were BARI GOM 26, BARI hybrid Maize 7 and BINA Dhan 7 for wheat, maize and rice, respectively. The recommended rates of fertilizers for wheat ($N_{120}P_{30}K_{50}\ S_{20}B_1$), maize ($N_{200}P_{50}K_{80}\ S_{40}Zn_5B_2$) rice ($N_{80}P_{25}K_{50}S_{20}$) were applied in all the plots. The wheat crop was irrigated thrice (crown root initiation, booting and grain filling stages), two irrigations were applied in maize (post sowing and after germination) to ensure germination and stand establishment and rice was rain-fed. After harvest, the grains were dried and grain moisture was measured to converted grain yields to t ha^{-1} at 12% moisture content for wheat and maize, and 14% moisture for rice. Soil samples were collected after each cycle of cropping and analyzed following standard methods to estimate organic matter (OM) and available nutrient contents.

Results and Discussion

CA practices of double zero tillage with standing crop residue retention (T_2 and T_4) influences soil hydraulic properties resulting in higher soil moisture between irrigation events in wheat. Excessive water was well-drained from the plots under CA causing favorable moisture regimes in maize field during early monsoon. Thus by altering the soil moisture regimes, CA contributed to stand establishment resulting in higher number of spikes/m^2 of wheat and the cobs/m^2 of maize. Sharma and Acharya (2000) and Erenstein (2002) reported the beneficial effect of crop residue on wheat yield. In the present study, CA practices either on beds or on flat land (T_2 and T_4) were equally effective in improving grain yield of wheat and maize for the last 3 years (Table 1). The residual effect of CA imposed on wheat and maize crop had no effect on rice yield until the second year but then became significant in the third year.

Soil OM did not decline due to triple cropping of cereals for 3 years but improved under CA compared to initial soil and conventional practices (Fig. 1). Total N, available K and S content slightly declined in conventional practices relative to the initial soil. On the contrary, under CA the intensive wheat-maize-rice cropping did not cause nutrient decline but most of the nutrients including N, P, S and B increased under CA. The study demonstrated that inclusion of maize between wheat and rice with conservation practices has the potential to improve productivity.

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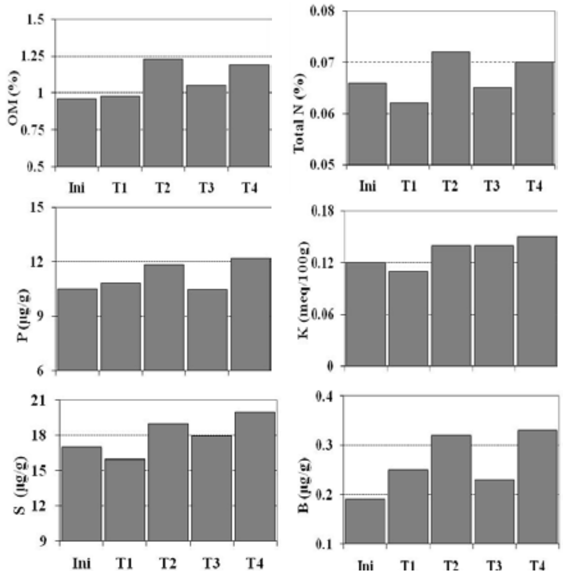

Fig. 1. Effect of CA on available nutrient content in soil after 3 years of wheat-maize-rice cropping in relation to initial soil (Ini= Initial soil)

Table 1. Grain yield (t ha^{-1}) of component crops under CA practices from 2010-2011 to 2013-14. See Materials and methods for description of treatments.

Treat-ment	Wheat				Maize			Rice		
	2010-11	2011-12	2012-13	2013-14	2011	2012	2013	2011	2012	2013
T_1	3.15	3.51	3.83	3.92	5.78	4.74	6.84	4.28	4.48	4.80
T_2	4.35	4.38	5.85	5.18	6.76	7.15	8.05	4.35	4.65	5.12
T_3	4.22	4.04	4.54	4.38	6.02	5.67	6.65	4.02	4.32	4.67
T_4	4.48	4.55	5.56	5.05	6.60	6.86	7.88	4.24	4.84	5.15
$LSD_{0.05}$	0.38	0.35	0.47	0.41	0.55	0.61	0.70	NS	NS	0.43

Session 4

Soil and water management, and agronomy for smallholder

KEYNOTE PAPER

Soil-water relations and water productivity in smallholder conservation agriculture systems of Southern Africa and South Asia

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Introduction

Smallholder, resource-poor farmers around the world are faced with dwindling agricultural resources. The challenges of increasing soil degradation, rainfall variability, physical and/or economic scarcity of irrigation, and the negative effects of climate change necessitate that smallholders adapt traditional farming systems to increase production efficiency, profitability, and resilience (Thierfelder et al. 2014). A proposed solution to these problems is conservation agriculture (CA), which involves minimum soil disturbance, crop residue retention, and rotation. Combining these practices may comprise an important part of the solution to improving rainfed crop productivity in predominantly maize-based systems of southern Africa. In southern Asia, by contrast, most cropping systems are rice-based, commonly incorporating upland crops and irrigation. But despite irrigation availability, energy costs for pumping are increasing, making water a progressively more costly resource. These changes increase the need to better manage CA to improve soil-water relations to boost yield and water productivity (WP). This study summarizes the benefits and constraints of CA on soil-water relations and WP in rainfed and irrigated systems in southern Africa and southern Asia and identifies strategies to adapt to climate variability and change.

Materials and Methods

The results from CA long-term trials, carried out from 2004-2014 in Zimbabwe and Zambia were used in the southern African study (Thierfelder and Wall, 2009). Soil moisture was measured using capacitance probes and infiltration was captured using a mini-rainfall simulator. Other soil quality indicators (earthworm population, aggregate stability, soil carbon) were routinely measured. All indicators were analysed and their impact on the productivity of CA systems summarized. For the South Asia study, a systematic literature review of studies focussing on CA, soil water relations, and WP was used. Common for these studies were a minimum requirement on data quality standards, and that CA was compared to conventional management. The studies were systematically analysed and summarized to examine each systems' impact on WP in irrigated and rainfed environments.

Results and Discussion

The results from on-station and on-farm trials in rainfed systems of southern Africa, dominated by manual and animal traction seeding, showed that maize-based CA treatments maintained higher rates of infiltration (14-42 mm h^{-1}) as compared to conventionally ploughed control treatments without residue retention. This contributed to increased soil moisture and buffered against seasonal drought and dry-spells. Longer-term improvements in soil structure and carbon, as well as increased biological activity, resulted from the combined use of CA principles. This in turn increases the likelihood of greater yields with reduced risk of crop failure. A regional assessment of eight different CA systems across a range of agro-ecologies in southern Africa showed that in 80% of cases there was a positive yield response to CA. The challenge for smallholder farmers in Africa is to implement all three CA principles at once, as farmers face many constraints affecting the ability to retain residues, practice rotations, apply adequate amounts of fertilizers and effectively control weeds (Wall et al., 2013).

When considered in the context of rice-wheat crop rotations, which are for example common in much of South Asia, CA can modify and reduce the influence of several biophysical factors that negatively influence crop WP (Figure 1). In both rainfed and irrigated environments, CA can help improve soil water relations and WP by reducing unproductive evaporative losses. In fully and partially irrigated systems, CA and dry direct seeding save water by reducing unnecessary flooding for soil puddling in rice. Irrigation volume and frequency in unflooded, non-rice crops can also be reduced, although researchers rarely design experiments to explicitly address this important point. Where tillage is avoided and residues retained following monsoon rice, farmers can also benefit by 'banking' residual soil moisture for the subsequent crop. The principles of how CA changes WP emerging from our systematic analysis allow the development of generalized hypotheses for later field-testing. However, because many farmers may not adopt the all three CA practices simultaneously, as is the case in southern Africa, further research is needed to disentangle which principles most influence soil-water relations and WP in different cropping sequences and environments. This will also help defining pathways for sustainable intensification for smallholder farmers in the future.

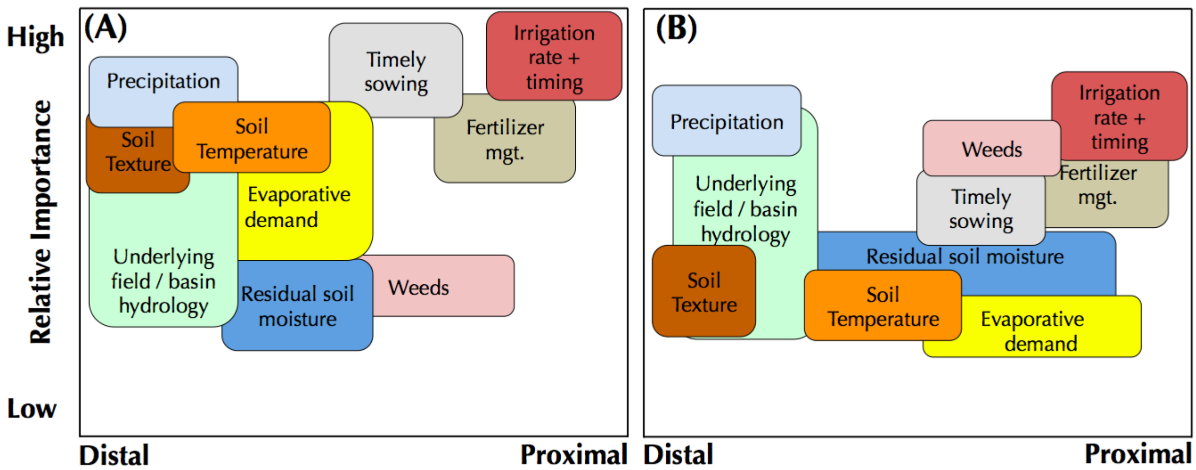

Figure 1. Theoretical representation of the relative and conceptual importance (high vs. low, on the ordinate axis) and proximal (easy for farmers to manage or change) and distal (difficult for farmers manage or change) placement of key biophysical and management factors affecting WP in a generalized rainfed rice – irrigated wheat cropping pattern in S. Asia on the abscissa. Panel A shows the generalized relation of these factors under conventional tillage, while panel B depicts them under CA based crop management. The sizes of boxes indicate significance and responsiveness of each factor to conversion from conventional to CA management. Overlap indicates mechanistic relations between the factors. For example, Panel A shows residual soil moisture under conventional management, which is of low importance because pre-seeding tillage causes evaporative losses. It is also restricted to the distal side of the *x*-axis, because it is more difficult for farmers to manage than when compared to CA, where mulching and reduced tillage moves this factor to the proximal of the *x*-axis, indicating that farmers can more easily manage and conserve soil moisture. The importance of residual soil moisture in boosting WP is also relatively higher under CA than with conventional practices.

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Soil organic carbon, water stable aggregates and microbial attributes as influenced by conservation agriculture production system (CAPS) in a *Fluventic Haplustepts* under North Central Plateau zone of Odisha

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Introduction

Conservation agricultural production system (CAPS) with minimum tillage, legume intercrop and a succeeding cover crop was established in 2011 at Regional Research and Technology Transfer Station, Kendujhar, located under Eastern Peninsular Plateau in Odisha state of India. The objective was to assess its impact on soil organic carbon, water stable aggregates and microbial attributes after two years.

Materials and methods

The soils of the experimental site (20^0 50’ 55.38” N, 85^0 34’ 30.61” E and 499 m above the MSL) developed from colluvial-alluvial deposits belong to *Fluventic Haplustepts*. The climate is hot and sub humid with mean annual rainfall of 1473 mm. The treatments with conventional (CT) and minimum (MT) tillage with maize sole (M) and maize cowpea intercrop (M+C) as main plots during wet season and no cover crop (NCC), horse gram (H) and mustard (T) as sub-plots during dry season were replicated thrice. Soil samples (0-10 cm) collected initially (2011) and after two cropping cycles (2013) were analyzed for soil organic carbon, water stable aggregates, microbial population, microbial biomass carbon (Vance et al.,1987) and statistically complied by F-test (Gomez and Gomez, 1984).

Results and Discussion

Minimum tillage increased (Table 1) the water stable macro-aggregates (+12.7%) with concomitant decrease in water stable micro-aggregates (-23.8%) over the conventional tillage system. This might be attributed to the elevation of soil organic carbon (+20.0%) due to greater residue inputs from crops in the surface soils associated with reduced biological oxidation in less disturbed soils, hence increased microbial activity (Mikha et al., 2004) and lower aggregate turnover rates. Moderation of the soil temperature and moisture due to accumulation of soil organic matter in the soil surfaceunder minimum tillage systems enhanced the population of bacteria (+10.8%), actinomycetes (+8.8%) and MBC (+8.1%)as compared to conventional tillage (Balota et al., 2004). The inclusion of cover crops (horsegram and mustard) also enhanced the soil organic carbon (+6.8%), actinomycetes (+6.4%) and microbial biomass carbon (+5.8%) over no cover crop. Considerable buildup of soil organic matter due to residue incorporation from crops and its protection under minimum tillage contributed significantly in improving the status of macro-aggregates (r = 0.72**), bacteria (r = 0.66**), actinomycetes (r = 0.72**) and MBC (r = 0.96**).Minimum tillage with maize cowpea intercrop and the follow up horsegram cover crop appeared to be the suitable CAPS for this undulating hilly tract for restoration of soil quality in the long run.

Table 1. Effect of tillage and cropping systems on water stable aggregates, soil organic carbon and microbial attributes

Treatments	WSA % >250µm	WSA % 53-250µm	SOC g kg^{-1}	Bacteria $x10^6$cfu g^{-1}	Actinomycetes $x10^6$cfu g^{-1}	MBC µg of C g^{-1}
Initial	73.7	13.1	6.62	12.34	20.85	120.7
Main plot						
CT-M	69.9	15.9	6.12	13.19	21.40	112.9
CT-M+C	74.0	13.9	6.80	14.32	22.53	129.5
MT-M	78.5	11.9	7.58	15.02	23.19	157.0
MT-M+C	83.7	10.8	7.93	15.44	24.61	172.3
LSD (0.05)	4.00	1.00	0.60	0.82	1.17	7.21
Sub plot						
NCC	74.9	13.6	6.81	14.28	22.35	130.3
H	78.2	12.7	7.54	14.78	23.77	155.5
T	76.5	13.1	6.98	14.43	22.68	142.9
LSD(0.05)	NS	NS	0.33	NS	0.94	7.02
Interaction	NS	NS	NS	NS	NS	NS

CT: Conventional tillage, MT: Minimum tillage, M: Maize, C: Cowpea, NCC: No cover crop, H: Horsegram, T: Mustard, WSA: Water stable aggregates, SOC: Soil organic carbon, MBC: Microbial biomass carbon

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Effects of Minimum Tillage Practices and Crop Residue Retention on Soil Properties and Crop Yields under a Rice-based Cropping System

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Introduction

Average cropping intensity is 191% in Bangladesh but cropping patterns are mainly rice-based (BBS, 2012). Depletion of soil organic matter as well as other plant nutrients is one of the most serious threats to the sustainability of agriculture in Bangladesh (Rijpma and Jahiruddin, 2004). Hence, conservation agriculture (CA) practices such as minimal soil disturbance, crop residue retention with suitable crop rotations could be a good option for Bangladesh. However, the effects of CA practices in intensive rice-based rotations on soil properties along with crop yields have not been adequately assessed in Bangladesh. The present study was undertaken to determine the effects of minimum tillage practices and crop residue retention on soil properties and crop yields under a rice-based cropping system.

Materials and Methods

The experimental site is located at Baliakandi upazilla, Rajbari district, in a sub-tropical, wet and humid climate, characterized by distinct wet and dry seasons on the Low Ganges River Floodplain. The soils are calcareous type with sandy loam to loamy texture. The four tillage practices- zero tillage (ZT), strip tillage (ST), bed planting (BP) and conventional tillage (CT) were allocated to the main plots and two levels of crop residue retention of rice and legume residue i) low (20%), comparable to farmer’s retention practices and ii) high (50%) were allocated to the sub-plots in a split-plot design with four replications in a rice-lentil-jute cropping sequence. Soil samples were collected at the initiation of the experiment as well as at the end of each cropping cycle in rice-lentil-jute cropping sequence from 0-5, 5-10 and 10-15 cm and analyzed by standard methods for soil physico-chemical properties. Rice equivalent yield (REY) of lentil and jute crops was computed as the yield of lentil and jute crop divided by current market price of rice and multiplied by market price of lentil and jute crop. The software package MSTATC was followed for statistical analysis.

Results and Discussion

The highest available P was in ZT followed by ST, CT and the lowest result was in BP practice whereas the highest available Zn was found in ST followed by BP, ZT and CT practices. All other nutrients remained unchanged (data not shown). Retention of increased amounts of previous crop residues (>6.0 t ha^{-1} $year^{-1}$) significantly increased SOC and other plant nutrients after 1-crop cycle under the rice–lentil-jute cropping sequence (data not shown).

Soil bulk density and soil penetration resistance followed the sequence, ZT>ST>BP>CT, while increased crop residue retention significantly decreased soil penetration resistance at 0-5 and 5-10 cm after the 4^{th} crop harvest. Soil moisture content was inversely related to soil bulk density and penetration resistance after 4^{th} crop harvest due to different tillage and residue management (Table 1).

In the first cropping year, the highest rice and lentil grain yield was attained in CT and the lowest in ZT. However in the second year, the highest grain yield of rice and lentil was attained in ST and BP. Lowest rice and lentil yields were obtained in CT (Table 2). The fibre yields of jute followed the sequence: ST>ZT>CT>BP in both years. Higher crop residue retention increased rice and jute yield in the second year but the opposite results were found with lentil in the second year. Rice equivalent yield was significantly higher in ST compared to other tillage practices whereas higher residue retention increased REY in the second cropping year. Strip tillage with higher residue retention are showing promising results after 4 crops in terms of soil properties and crop yield in the intensive rice-lentil-jute crop sequence.

Table 1. Effects of tillage practices and crop residue retention levels on soil bulk density, penetration resistance and soil water content after the harvest of the 4th crop

Treatments	Bulk density (g cm^{-3})			Penetration resistance (N/cm^2)			Soil water content (%)		
	0-5 cm	5-10 cm	10-15 cm	0-5 cm	5-10 cm	10-15 cm	0-5 cm	5-10 cm	10-15 cm
Tillage practices									
ZT	1.54 a	1.56 a	1.57 a	87 a	179 a	249	33.4 b	32.9 b	32.0
ST	1.51 ab	1.52 ab	1.54 ab	67 b	158 a	230	33.7 b	33.0 b	32.7
BP	1.49 b	1.51 b	1.52 b	86 a	118 b	224	33.4 b	33.3 ab	33.1
CT	1.48 b	1.50 b	1.53 ab	58 b	116 b	206	35.5 a	34.2 a	34.0
P	*	*	*	*	*	NS	*	**	NS
Previous crop residue retention levels									
Low	1.51	1.53	1.55	80	152	237	33.8	32.9	32.8
High	1.49	1.51	1.53	69	134	218	34.2	33.7	33.1
P	NS	NS	NS	**	**	NS	NS	*	NS

Table 2. Effects of tillage practices and crop residue retention levels on crop yields (t ha^{-1})

Treatments	Rice grain 2012	Lentil seed 2012-13	Jute fibre 2013	Rice grain 2013	Lentil seed 2013-14	Jute fibre 2014	REY 1st year	REY 2nd year
Tillage practices								
ZT	2.66 b	1.40 b	4.61 a	5.81 bc	1.45 bc	4.62ab	21.8	22.5b
ST	3.24ab	1.76ab	4.69 a	6.71 a	1.65 ab	4.87 a	24.7	24.8 a
BP	2.88 b	1.51 b	2.98 c	6.28ab	1.93 a	3.39 b	18.8	22.5 b
CT	3.70 a	1.98 a	3.54 b	5.38 c	1.19 c	3.52 b	23.7	18.5 c
P	*	*	*	*	**	*	Ns	**
Previous crop residue retention levels								
20%	-	1.70	4.08	5.82	1.62	3.85	22.8	21.6
50%	-	1.63	3.83	6.27	1.49	4.35	21.7	22.5
P	-	ns	ns	**	*	*	Ns	*

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Minimum tillage and increased residue retention improves soil physical conditions and wheat root growth in a rice-based cropping system

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Introduction

Wheat (*Triticum aestivum* L.) is grown in rice-based cropping systems of the eastern Indo-Gangetic Plain in soils subjected to repeated tillage to prepare puddled soil for preceding monsoon rice (*Oryza sativa* L.). Such soils commonly have a hard plough-pan layer (10-15 cm depth) which limits root growth and yield of wheat (Mohanty et al., 2006). Conservation agriculture offers the potential for improved soil physical properties and increased root growth and yield of wheat (Aggarwal et al., 2006). However, it is unclear whether such changes will occur in intensive rice-based cropping sequences and the dependence of improvement on crop residue retention. A field experiment assessed changes in soil physical properties after 7 consecutive crops in relation to minimum tillage and crop residue retention levels.

Materials and methods

The study was conducted at Digram village in Rajshahi, Bangladesh (24°31 N, 88°22 E) in the drought-prone ancient alluvial plain (High Barind Tract) during 2010-13. Only data of 2012-13 are presented here. Wheat was the first crop grown, followed by mungbean (*Vigna radiata* L.) and rice. The sequence was repeated and ended with a 3rd wheat crop (crop number 7 in the sequence). Main plots consisted of strip tillage (ST), bed planting (BP) and conventional tillage (CT) while high residue (HR) and low residue (LR) levels were retained on sub-plots. Each treatment was replicated four times. Volumetric soil water contents (SW) were measured with a capacitance sensor and penetration resistance (PR) with a hand penetrometer. In this study, SW and PR values for conventional tillage were compared with the average of in-the-strip and between-the-strip values; and on top of the bed. Root volume (RV) was recorded by water displacement and root length by the grid intercept method. When the F-test was significant (GenStat 15th ed.), treatment means were separated by least significant difference (lsd, $P \leq 0.05$).

Results and Discussion

Regardless of tillage method and residue management, PR and SW increased with soil depth which may reflect the existence of a plough pan (Fig. 1a and 1b). At 0-5 cm and 5-10 cm soil depth, the lowest PR value was obtained in the BP-system and the greatest PR obtained with CT treatment. High residue decreased the penetration resistance and increased the SW level.

Regardless of treatments, wheat root volume and RLD decreased with increasing soil depth (Fig. 2a), which might be related to increasing PR (Fig. 1b). In the surface layers (0-10 cm soil depth), significantly greater root volume and root length density were found in beds than other tillage treatments. High residue also enhanced the root growth in the surface layer of soil (Fig. 2). At 10-20 cm depth, the root growth followed the order: BP > ST > CT. Below 20 cm soil depth, treatment variation in RV and RLD disappeared.

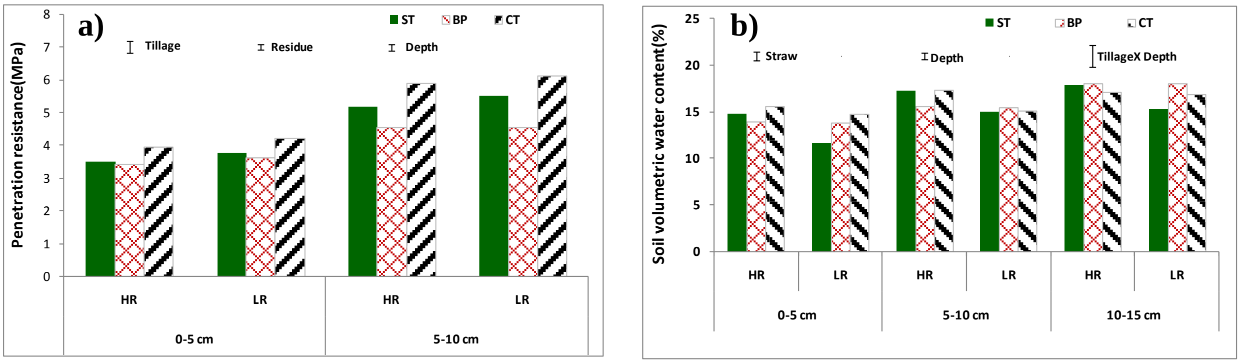

Figure 1. The mean of a) PR and b) SW with increasing depth under different tillage and residue treatments. Floating bars represent lsd for significant treatment differences.

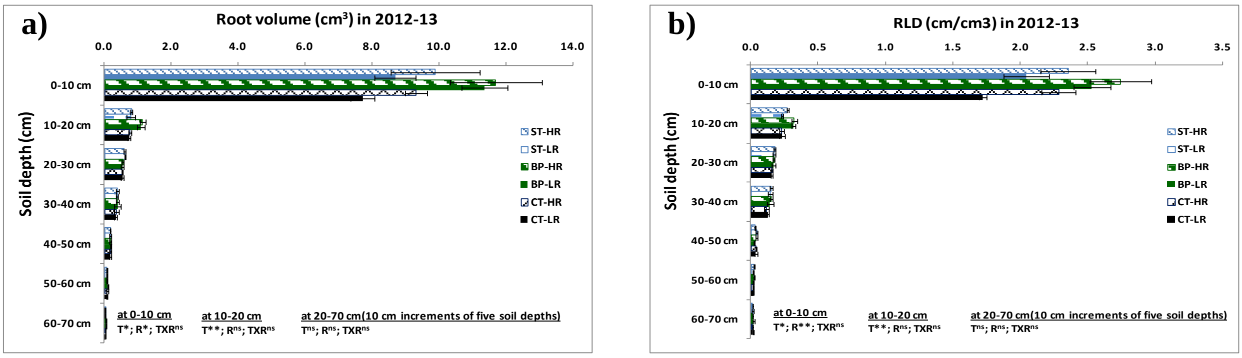

Figure 2. The mean of a) root volume (cm^3) and b) root length density (cm/cm^3) under different tillage and residue treatments. Error bars indicate ± 1 standard error.

Conclusions

Initial bed forming followed by minimum tillage planting for six consecutive crops decreased soil impedance to root growth of wheat. Strip tillage for 7 consecutive crops also increased root growth of wheat at 10-20 cm depth. High residue retention for six consecutive crops increased SW and decreased mechanical impedance which led to increased root growth of wheat. None of the tillage or residue retention treatments affected root growth or soil properties below 20 cm after 7 consecutive crops. In an intensive (3 crops/year) rice-based cropping system, the beneficial effects of CA on physical properties of the surface soil and on root growth have developed relatively quickly.

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Changes in soil organic C, nitrogen and chemical properties under no-till cropping systems on a Red Oxisol in Cambodia

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Introduction

In Cambodia, small scale subsistence farming has quickly shifted to commercial farming based on annual cash crop production (i.e., soybean, corn, and cassava). Conventional plough-based practices adopted by the farmers growing two cycles per year have induced progressive depletion of the soil fertility even on the deep and well-drained Red Oxisol of Kampong Cham province. Coupling with climate change impacts and higher production costs, it has jeopardized the agronomic and economic performances of the family farm. Since 2004, diversified no-till (NT) cropping systems were developed and assessed in terms of technical practicability, agronomic performance, and economic profitability (Boulakia et al. 2012). In Cambodia, there is still a paucity of information on the effects of NT systems on soil organic carbon (SOC) short- to medium-term dynamics. This research was carried-out to assess the changes in SOC, N, and chemical attributes under contrasted cropping systems (till and no-till × cropping sequence: main crop + cover/relay crops), and the capacity of medium-term NT systems to increase SOC stock.

Materials and Methods

The experiment was set up in 2004 in Chamcarleu district (Kampong Cham province). The climate of the region is characterized by a 7-month tropical wet season and a 5-month long dry season, with annual rainfall of ~1500 mm. Soil is classified as a red clayey Oxisol (718 g clay kg^{-1}, 272 g silt kg^{-1} in 0-30 cm depth). The cropping systems studied, implemented on 12 × 58.5 m plots, were: (i) farmer's practices consisting of two crops per year, early wet season sesame followed by soybean, managed under conventional plough-based tillage – **CT;** (ii) **NT1** - soybean managed under no-till with *Stylosanthes guianensis* and sorghum used as relay crops and broadcast at a rate of 4 kg ha^{-1} and 15 kg ha^{-1}, respectively; and (iii) **NT2** - two years rotational sequence between soybean and maize with *S. guianensis* and sorghum used as relay crops after soybean, and stylo associated with maize at the sowing time. Six bulk soil samples for five depths (0-5, 5-10, 10-20, 20-40, and 40-60 cm) were collected in November 2011. Soil bulk density (ρ_b) for each layer was measured by the core method. The SOC and N stocks were estimated to 0.6-m depth by the dry combustion method, and computed on an equivalent soil mass-depth basis.

Results and Discussion

Concentrations of SOC and N exhibited different patterns of distribution amongst tillage treatments (Fig. 1). Soil OC concentration under NT was stratified within the top 20 cm layer, while a uniform concentration was observed under CT due to the mixing effect of ploughing. Among tillage treatments, the soil under NT2 was significantly ($P<0.05$) enriched in SOC and contained 6.4 and 2.1 g kg^{-1} more SOC than that under CT in the 0-5 and 5-10 cm depths, respectively. In addition, higher SOC concentration ($P<0.05$) was reported in NT2 soil when compared with NT1 soil in 0-20 cm depth (Fig. 1). Expectedly, SOC concentration was positively correlated with N concentration ($R^2 = 0.96$, $P < 0.0001$) across all soil depths. However, higher C:N ratio values were found under NT1 and NT2 in 0-5 cm depth, emphasizing a higher content of labile moieties. Soil pH, Ca^{2+} and CEC significantly increased in NT2 soil in 0-20 cm depth (data not shown). The soils under NT1 and NT2 in 0-5 cm depth contained 2.07 and 3.37 Mg ha^{-1} more SOC and 0.15 and 0.25 Mg ha^{-1} more N than that under CT after 7 years. However, averaged across soil depths, SOC stock in 0-60 cm depth were lower in NT1 soil (58.2 Mg C ha^{-1}) than that recorded under CT (60.5) and NT2 (63.1). Monoculture of soybean and use of *S. guianensis* every year as a relay/cover crop may explain this result. *S. guianensis* performs well on this Red Oxisol. Its root system is highly active even in the dry season, adding labile C in the subsoil that may enhance the activity of the microbial communities and thus decrease SOC through a priming effect on decomposition (Fontaine et al., 2007). By contrast, the biomass-C input of the two-year rotational sequence between soybean and maize exhibits more balanced amounts of N and hemicellulose when compared with NT1. Thus differences in biomass-C inputs (i.e., quantity and quality) may explain this result. The combination of expert-based prototyping of NT cropping systems and in-depth analysis of biophysical processes are essential to optimize the use of cover/relay crops, enhance ecosystem services, and advance farm sustainability.

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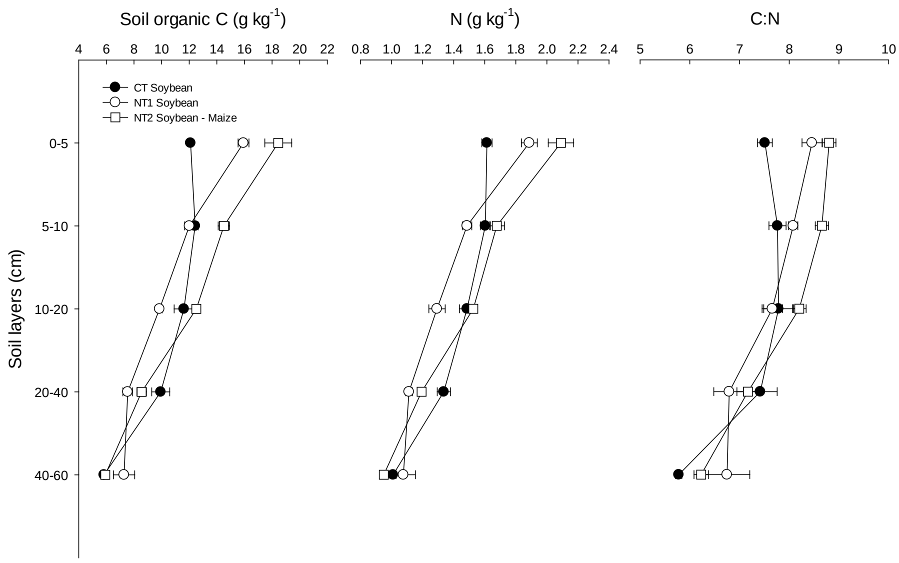

Figure 1. Soil organic carbon (SOC), total nitrogen (N) and C:N ratio (mean ± Std. error, n=6) under CT, NT1 and NT2

Impact of Phosphorus Placement Methods after Three Years of Different Tillage Practices on Maize Productivity and Soil Properties

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Introduction

Minimal soil disturbance under conservation agriculture may limit the supply of immobile nutrients (such as phosphorus) to plant roots due to stratification of these nutrients close to the soil surface. Maize (*Zea mays* L.) roots usually do not proliferate into the middle of the rows until the plant has six to seven fully emerged leaves but a high P concentration in maize prior to the 6-leaf stage will significantly increase final grain yield (Aldrich et al. 1986). Phosphorus availability is critical during the early stages of plant growth when the movement of P to plant roots (P absorption by the plant) is reduced with cold soil temperatures (Alley et al. 2009). This can occur during winter (rabi season) when most maize is grown in Bangladesh (Ali et al. 2009). Also P moves very little in soils, and thus, available soil P levels can be built with P fertilizer application appropriate for the tillage practice. The aim of present study was to determine the effects of tillage practices and P placement methods on soil physical, chemical and yield of maize crops on a Grey Terrace Soil in Bangladesh.

Materials and methods

The experiment was situated at BARI, Gazipur in agro-ecological zone 28 (Modhupur Tract). The soil belongs to the *Chhiata* series of the Grey Terrace Soils (*Aeric Albaquept*). Phosphorus was placed by a) broadcast according to farmers' practice during final land preparation, b) surface banding (application on the soil surfaces 3-5 cm apart and on both sides of the row), and c) deep band (application at 6-8 cm below the surface 4-6 cm apart on both sides of the row. Both the band placements were done at five leaf stage, i.e. at 30 DAS) along with three tillage practices: a) zero tillage (ZT)- a single slit is opened by furrow opener and seeds were sown, b) conventional tillage (CT)- ploughed by rotary tiller up to 10-12cm depth (2 passes), and c) deep tillage (DT)- tillage by chiseling up to 25 cm depth followed by rotavator (3 passes). Treatments were arranged with tillage assigned to main plots and P placement methods in sub-plots. The maize residue was retained by weight over the three years of experimentation (2009-10, 2010-11 and 2011-12).

Results and Discussion

The surface band P placement method gave higher yield ($P < 0.05$) than other placement methods (Fig. 1). In 2011-12 ($P < 0.05$), the highest grain yield (9.4 t ha^{-1}) was obtained by surface band P placement with ZT followed by CT and DT under surface band P placement. The minimum tillage practices under broadcast and deep band placement methods showed the highest available and total P content in soil after harvesting of maize in 2012. The highest available P (24 mg kg^{-1}) and total P (288 mg kg^{-1}) was in 0-6 cm soil treated by ZT along with surface band applications, followed by broadcast applications under ZT. The deep band placement under CT and DT showed the highest values of P for total and available P at 7-12 and 13-18 cm soil depth. These were followed by surface band under CT in the same depth increments (Fig. 2).

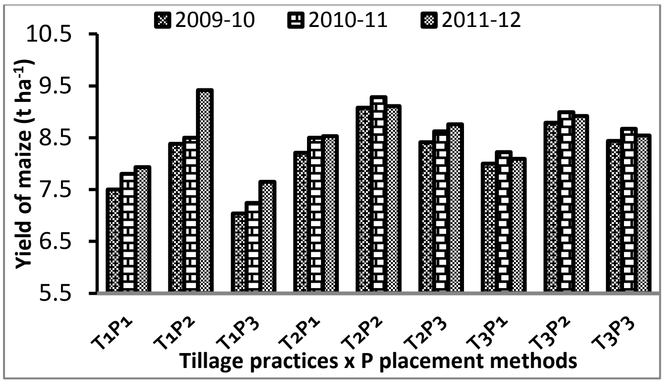

Figure 1. Effect of tillage practices and P placement methods on maize yield per hectare over three years of experimentation. The standard error values (±) are 0.25, 0.26 and 0.29 for the years 2009-10, 2010-11 and 2011-12, respectively. (Legend: T_1=Zero Tillage, T_2=Conventional Tillage, and T_3=Deep Tillage, whereas P_1= Broadcast, P_2=Surface band and P_3=Deep band).

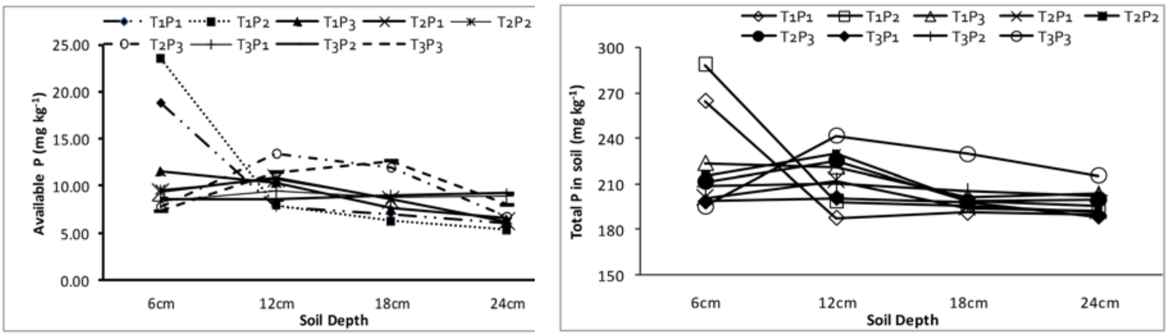

Figure 2. Effects of tillage and P placement methods on available and total P in soil after three years of maize cultivation. See Fig. 1 for abbreviations. (Standard errors (±) are 1.27, 0.66, 0.65 and 0.35 for Available P and 8.8, 6.8, 4.7 and 4.7 for total P at 0-6, 7-12, 12-18 and 19-24 cm soil depth respectively).

The effects of ZT with 30 % straw retention after three years of maize cultivation on soil organic matter (OM) status, total N and moisture content at field capacity as well as permanent wilting point and available water content were also significantly higher than CT and DT. Tillage practices did not influence other physical and chemical properties. Neither did P placement methods influence soil physical properties and OM status of soil.

Conclusions

The surface band P placement method with ZT, CT and DT gave significantly higher yield than broadcast and deep band placements. The minimum tillage practices under broadcast and deep band placement methods showed the highest available and total P content in soil after harvesting of maize. Phosphorus was stratified in the topsoil with zero tillage along with broadcasting and surface band applications but the CT and DT practices under broadcast and deep band placements resulted in the almost similar distribution of P with soil depth up to 24 cm.

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Grain yield and phosphorus accumulation of field grown chickpea to subsoil phosphorus under a dry topsoil in the High Barind Tract

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Introduction

Chickpea usually responds poorly to surface applied phosphorus (P) fertilizer under dry topsoil condition as in the High Barind Tract (HBT) soil of Bangladesh. However, in a pot study, chickpea responded positively in respect of grain yield and P accumulation when P was placed in the subsoil (10–30 cm) (Kabir et al. 2013). To test this response in the field, chickpea was grown (by Versatile Multi-crop Planter, VMP, Johansen et al. 2012) in a HBT soil. It was hypothesized that chickpea will produce significantly higher amount of grain and accumulate more P if P fertilizer is placed below the surface. A positive yield response of chickpea from this study would indicate the necessity of future modification of tynes of the VMP to place P fertilizer deeper into the soil.

Materials and Methods

Chickpea was grown in 2013–14 season in a sandy loam soil (10 mg Olsen P /kg) in Jogpur village of Godagari, Rajshahi. One level of triple superphosphate (TSP, 18% P) was placed in the topsoil (7 cm) or subsoil (15 cm). A Nil-P treatment was also included. Initially the strips made by the VMP (~7 cm). Then, all strips were dug 15 cm deep manually. After placing TSP at 15 cm in subsoil-P treatments, all furrows were filled up by soil up to 8 cm from the furrow bottom. Seeds were placed manually at 7 cm in the furrow (at the same depth of topsoil P placement) and 10 cm apart. The seeds were covered manually. There were four blocks. Half of each block was kept dry (dry treatments) under rain-out shelters; the remaining half was kept well-watered by irrigation until maturity of the crop. For P accumulation, plants samples were collected at five different stages and P concentration was measured following standard method. All treatment plots were harvested at maturity. Data were statistically analyzed by performing ANOVA for a randomized complete block design. The treatment means were compared by least significant difference test (lsd) at 5% level of significance.

Results and Discussion

Chickpea grain yield was not influenced either by water or P fertilizer placement treatments (Table 1). From flowering to maturity, under well-watered condition, plants accumulated significantly higher amount of total P when P was applied in either the topsoil or subsoil, which was statistically similar to that of subsoil P treatment under dry topsoil condition only at mid-podding stage. The Nil-P treatment accumulated the lowest amount of P. However, the shoot P content was highest at mid-podding in all treatments then it started to decrease. Grain P concentration was highest under well-watered plants with P supplied in the subsoil; the lowest concentration of P was found in the Nil-P plants.

In this study, grain yield did not respond to added P suggesting that the initial topsoil P (10 mg/kg) was sufficient to meet the P requirement of chickpea. Moreover, the canopy of the crop almost covered the soil surface that helped maintain better moisture availability in the topsoil (moisture data not shown). In addition, the subsoil P was also substantial (data not shown) and chickpea has access to the subsoil P (Kabir 2013). In contrast, very low soil P of the study of Kabir (2013) (~1 mg Olsen P/kg) might be the cause of positive response of chickpea to subsoil P placement under a dry topsoil condition. However, the lack of grain yield response in the current study suggests that placement of P fertilizer should not go deeper than the current depth (~7 cm) of the VMP in a high P soil of the HBT. As the topsoil dries (~10 cm, more than the TSP placement depth by VMP) out during winter cropping in the HBT, placement of P below this depth for a positive response still remains a matter of investigation particularly in deep rooted crops. Because this study was at a single site; further studies in lower P sites might provide better response of chickpea to subsoil P.

Table 1: Phosphorus (P) accumulation at different growth stages of chickpea and grain P concentration and grain yield at maturity. "+P" means P applied as TSP in the topsoil or subsoil. "-P" refers to no P applied. "+W" represents water was to the topsoil, or the subsoil which was assumed to be well-watered (water was not applied to the subsoil). "-W" means no water was applied to the topsoil. "P" and "W" in the left side of the slash (/) refer to the P and water treatment of the topsoil while on the right side, P and water treatments were in the subsoil.

Phosphorus and water treatment	Shoot phosphorus content (mg/plant)				Grain P (%)	Grain yield/plot (g)
	At flowering	At mid-podding	At maturity			
			Shoot	Grain		
+P-W/-P+W	13.9 c	24.8 bc	19.2 ab	49.0 bc	0.40 b	1447 a
-P-W/+P+W	15.5 b	32.4 a	25.0 a	59.9 b	0.42 b	1515 a
-P-W/-P+W	8.4 d	19.9 cd	12.9 b	44.0 c	0.35 c	1585 a
+P+W/-P+W	17.0 ab	30.1 ab	23.5 a	75.6 a	0.42 b	1713 a
-P+W/+P+W	18.4 a	32.3 a	25.0 a	79.3 a	0.46 a	1646 a
-P+W/-P+W	9.8 d	24.0 d	15.0 b	53.1 bc	0.35 c	1634 a

Different letters indicate significant differences between the treatments.

Acknowledgement

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Effect of Tillage Type on Soil Water Content and Chickpea Yields

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Introduction

The development of 2-wheel tractors (2WT) with planters attached has given rise to one-pass seeding, and the possibility of minimum tillage and conservation agriculture suitable for smallholder agriculture. The main advantages of minimum tillage techniques include: soil water conservation, targeted placement of seed and fertiliser, lower rates of fertiliser and seed, less labour and fuel required, and less time required to sow a crop (Haque et al. 2010). Germination, emergence and early seedling growth of cool and dry (*rabi*) season crops (such as chickpea and lentil) grown on residual soil moisture can be limited in the silty clay soils of the High Barind Tract, Bangladesh due to rapid drying and hard-setting of the surface soil. One-pass seeding can minimise the time taken from rice harvest to sowing of the next crop and increases the probability that the surface soil retains sufficient moisture for crop establishment (Kumar et al. 2007). Minimum tillage is also a practice often used to conserve water in the soil profile and it has been reported that in conditions of less tillage there was greater soil water storage in the profile or greater soil water storage at depth in the profile later in the growing season (Barzegar et al. 2003). The objective of this work was to determine the effect of tillage type on: (i) seed-bed conditions and early chickpea establishment; and (ii) available water content and crop water use.

Materials and methods

The trial was conducted in the Choighati village, Godagari, Rajshahi, Bangladesh, from November 2009 to March 2010. It was conducted on Aeric Haplaquept which was representative of the region in a randomised block design with four replications. The trial had four tillage treatments applied using the Versatile Multi-crop Planter (VMP) attached to a Dongfeng type 2WT: strip tillage (ST); zero tillage (ZT); broadcast; single pass shallow tillage (SPST); and there was also a fallow plot. In the ST, ZT, and SPST treatments, the fertiliser was delivered approximately 2 cm below the seed. Desi chickpea cv. Bari Chola 5 was sown at a rate of 45 kg/ha on 25 November 2009. Triple superphosphate (TSP) was applied at sowing at a rate of 100 kg/ha. The TSP was drilled with the seed for the ST, ZT and SPST treatments. Seed was primed with water for six hours, and dried for an hour prior to sowing. Volumetric soil water content (θv) was measured by the MP406 capacitance sensor (ICT International, Armidale NSW) intermittently in the soil surface of the seed row (0-6 cm) from 5 days before sowing to 23 days after sowing. Profile soil water content (SWC) to 60 cm depth was measured at sowing, 50% podding and physiological maturity. From sowing to harvest there was no rainfall. Analysis of variance (ANOVA) was used to test the effects of treatments using GenStat v11.1 (VSN International Ltd, UK).

Results and Discussion

At sowing, θv in the seed-bed was 26 %, within the range where successful chickpea crop establishment will occur, and slightly wetter than judged to be optimum. The rate of soil drying in the seed-bed changed with tillage technique. Uncovered furrows (in ZT) and the fallow soil lost more surface soil water than the other seed-beds created with variable levels of soil disturbance (Fig. 1). In ST and ZT under the higher soil water contents there is potential of smeared furrow walls and poor soil covering of the seed in the seed-bed which can limit seed-soil contact. In addition, soil aggregate size and distribution in the seed-bed is altered with the different tillage types. The difference in the aggregate size, pore distribution and openness of furrows in the seed-bed may account for the difference in drying of the seed-bed.

There was significant loss of SWC across all tillage treatments from sowing to podding (Fig. 2). The extraction of θv in the fallow treatment was limited to 20 cm from sowing to podding, whilst in the tillage treatments θv was extracted to 60 and 80 cm (data not shown). From podding to harvest there was little change in θv at each depth increment to 40 cm for sown plots, however in the fallow treatment during this period losses of θv did occur. The θv in 0 to 40 cm depth at podding was less than 50 mm indicating there was very little water remaining in that layer for pod filling, suggesting that plant roots were able to access water deeper in the profile to achieve grain yields of 1087 to 1817 kg/ha. Frequent measurements to monitor SWC of the profile between sowing and podding would determine if the different tillage techniques had varied drying patterns that altered the allocation of water to the plants during that period. Measurements only at podding and physical maturity have shown no difference in SWC between tillage types. The SWC was below wilting point to 40 cm depth at podding; indicating that any additional conservation of water in the profile due to minimum tillage in a conservation agriculture system would be an advantage.

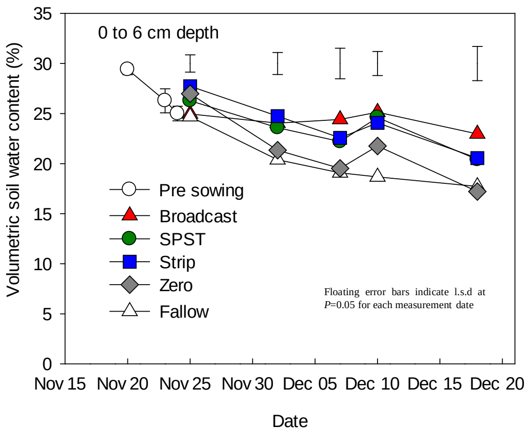

Figure 1. Volumetric soil water content pre and post-sowing at 0 to 6 cm depth.

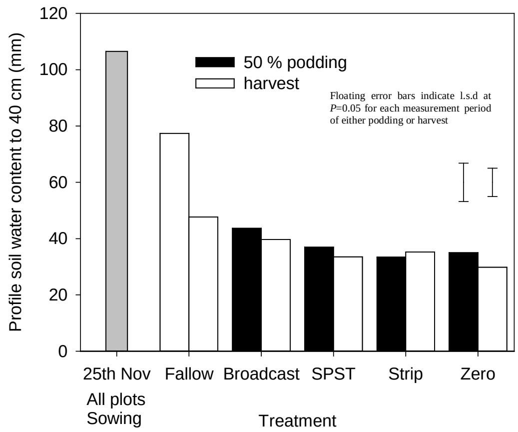

Figure 2. Profile soil water content (mm/40 cm) at sowing, 50 % podding and harvest.

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Tillage and Nutrient Management in Boro Rice under Rice-Mustard-Rice Cropping System

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Introduction

The dominant cropping pattern in Bangladesh is transplanted (t.) aman (wet season rice) – fallow – boro (dry season rice). Recently effort is paid to fit mustard in–between two rice crops (Islam, 2013). This would increase the productivity of rice cropping systems based on the cultivation of two rice crops a year under reduced tillage system. Field observations indicate that land to be used for cultivating boro rice that follows a mustard crop needs little or no tillage allowing rice to be transplanted into unpuddled soil. Further residual phosphorus and potassium fertilizer from the mustard crop allows boro rice to be grown with lower fertilizer rates. This study was designed to test the validity of these field observations and conducted at farmers' fields in southwest Bangladesh.

Materials and Methods

The field trials were conducted during 2013–2014 on fields in Bashghata village in Sadar Upazila under Satkhira district (22.75° N and 89.41° E) in Bangladesh. The area belongs to the Ganges Tidal Flood Plain agro-ecological zone (AEZ13) and the soils are loamy in texture. Rice was grown on tilled, reduced tilled and zero tilled soils on 13 February 2014. The study was conducted with two factors - tillage and nutrient management. The tillage options were- conventional tillage (CT), unpuddled single tillage (ST) and zero tillage (ZT), and the nutrient options were recommended NPK, recommended NK+50% P and recommended NP+ 50% K. The recommended N, P and K rates were 120, 24, and 52 kg ha^{-1}, respectively. The experiment was laid out in a split-plot design with tillage options to the main plots and nutrient options to the sub-plots with six replications each one being a farmer's field. The medium duration popular boro rice variety, BRRI dhan28 was used as the test crop. The other crop management options were followed as per BRRI recommendation. Grain yield was taken from a 10 m^2 area in the centre of each plot and expressed at 14% moisture. The statistical analysis was done using CropStat Version 7.2. Unless indicated otherwise, differences were considered significant only at $P \leq 0.05$. Economic analysis using farm gate grain and inputs prices was performed to determine the efficiency of different treatment combinations.

Results and Discussion

The interaction effect between tillage and nutrient management options was not significant; however their individual effect was significant for grain yield of boro rice. The highest grain yield was found in conventional tillage (4.91 t ha^{-1}) followed by unpuddled reduced tillage (4.81 t ha^{-1}). The lowest grain yield was produced in zero tillage (4.57 t ha^{-1}). Conventional and unpuddled tillage plots had higher panicle numbers m^{-2} and more grains $panicle^{-1}$. This may account for their higher grain yield. The overall lower grain yields were due to late transplanting of boro rice. Irrespective of nutrient management, total variable cost (TVC) was higher in zero tillage followed by conventional tillage (Table 1). The lowest TVC was recorded in reduced tillage of unpuddled transplanting. The higher TVC was mainly due to a higher labour cost for transplanting and irrigation cost. Unpuddled and zero tilled transplanting required more irrigation because of higher percolation loss. Conventional tillage had the highest net return and benefit cost ratio (BCR) ($ 305 ha^{-1}, 1.27, respectively) followed by 50% P reduced treatment with the same tillage ($ 281 ha^{-1}, 1.25, respectively). Reduced P and K rates reduced net return compared to recommended nutrient doses for all the tillage options. The lowest net return was recorded on zero tillage plots due to lower grain yield and higher labour costs for transplanting and higher irrigation cost.

Table 1. Cost and return of boro rice (US dollar ha^{-1}) under different tillage and nutrient management options

Tillage	Nutrient option	Tillage cost ha^{-1}	Transplanting cost ha^{-1}	Fertilizer related cost ha^{-1}	Irrigation cost ha^{-1}	TVC ha^{-1}	Gross return (ha^{-1})	Net return (ha^{-1})	BCR
CT	RR	77	77	139	474	1112	1417	305	1.27
	50% P	77	77	120	474	1093	1370	277	1.25
	50% K	77	77	129	474	1102	1371	269	1.24
ST	RR	19	96	139	504	1103	1384	281	1.25
	50% P	19	96	120	504	1084	1341	257	1.24
	50% K	19	96	129	504	1093	1346	253	1.23
ZT	RR	-	115	139	621	1220	1347	127	1.10
	50% P	-	115	120	621	1201	1263	62	1.05
	50% K	-	115	129	621	1210	1259	49	1.04

CT = Conventional tillage, ST = Unpuddled single tillage, ZT = Zero tillage

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Session 5

Commercialisation, adoption and continuous improvement of conservation agriculture-based technologies

KEYNOTE PAPER

Commercialisation, Adoption And Continuous Improvement of Conservation Agriculture-Based Technologies

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No-Tillage Systems in Brazil started with the experiences of Herbert Bartz, a farmer of grains in Northern Paraná State in 1972. The first ten years were of basic learning on system development. The 1982-92 period was considered the decade of studies when all the components of the system were studied, mainly mechanization aspects and weed control, including in, Animal Traction No-Till.

Within this period several studies on general aspects of animal traction were supported in Southern Brazil specifically in Parana State where the number of adopters at that time was an impressive 80 % of the total number of farmers despite their small size. In 1984 the Government of Parana State launched a special project to increase and support the use of animal traction, according socioeconomic and environmental regional features, in order to rationalize and improve the productivity of human labour. There were research actions to evaluate and develop appropriate equipment and also breeding and reproduction centres to improve the animals themselves. Publically-funded research, extension, promotion and animal health agencies were involved. This project was the seed Small Farmers Oriented No-Tillage System in Brazil. It was connected with two World Bank-supported Programs: Parana Small Farmers Program (PRORURAL) and Parana Soil Conservation Program (PMISA/ PARANARURAL).

The NT seeder "Gralha Azul" together with “Queixada” knife-roller were developed in 1985 and showed the viability of no-till cropping under animal traction. Other complementary studies on adapted soil management practices, weed control and cover crops were carried out. Validation units at farm level were conducted from 1989 to 1993. From this initial step around 30 small family factories of equipment were interested to develop improved no-till equipment for the small farmers’ market. Because initially Gralha Azul was too heavy (100 kg), the major effort was to develop lighter equipment with better characteristics of adaptation to difficult environments. Another crucial factor to promote small farmers’ no-till adoption in southern Brazil was support of the Brazilian No-Till Farmers Federation in acquiring 32 improved Gralha Azul seeders to be used at the farm level and promote the system across 63 municipalities in Southern Parana. From the first 1,000 ha in 1994 adoption jumped to around 90.000 ha in Paraná and an estimated 250.000 ha in the three states of Southern Brazil in 2000 compared with total surface under NT around 20 million hectares in this year. This example shows what the association of innovative and concerned small farmers, efficient technical support of research and extension, existence of mechanical small factories, government political will and a little bit of money can do. In this way, small farmers achieved not only environmental conservation but also higher incomes and with reduced labour permitting them to focus in other activities with higher added value. After 2000, the Small Farmers Conservation Agriculture in Brazil shifted its trajectory in four different ways:

1. Decrease in Animal Powered No-Till in Brazil and Equipment Sales for Exports

After 2003/04, animal powered NT equipment total sales and exports decreased, giving way to small motorized equipment for smallholders. There is now not much more research and development in animal traction for NT. Even the perspectives created by the FAO Project 2009 in order to create joint ventures among Brazil, Kenya and Tanzania seems to have stagnated.

2. Increase in Small Motorized No-Till in Small Farms

There was a strong increase in use of small and medium scale seeders for grains by Brazilian smallholders. There is no more space for low labour productivity practices in soybeans, corn, beans, wheat and rice in the country because of low profitability.

3. No-Till Expansion in Vegetables and Perennial Trees with Permanent Soil Cover

There was a strong development leaded by EPAGRI (research and extension institution of Santa Catarina state) in tomato, onion, cucumber, squash and pepper. Fruits like orange, mango, grapes among others can also be grown in CA. Presently these are more profitable activities for Brazilian smallholders.

4. Organic No-till and Agroecological Farming with Integrated Commercialisation

Within CA only organic farming has a differentiated market for products. The challenge is to reach soil minimum disturbance because of the weeds. But the best examples of commercialisation are from this sector including farmers-consumers partnerships.

Adoption and Impact of the Raised Bed Technology in Rajshahi District of Bangladesh

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Introduction

Crop establishment through bed planting is a good technique in the farming systems of Bangladesh. It facilitates more optimum planting time for rice, wheat, maize, and pulses by providing timelier field access because of better drainage. Once the beds are established there are new opportunities to reduce crop turn-around time by re-using the same bed without tillage (Sayre, 2003). This system has many advantages, such as reducing the seed rate, requiring less irrigation water, imparting higher nitrogen use efficiency, reducing crop lodging, and increasing crop yield over the conventional tillage/sowing systems (Meisner et al., 1992; Hobbs et al., 1997; Fahong et al., 2003; Lauren et al., 2008). On-farm research results revealed that this system saved 20-34 % irrigation water, 16-69 % planting cost, and ensured higher crop yield compared to conventional systems (Hossain et al., 2010). The objectives of the study were to evaluate the adoption and farmers' practice of raised bed technology at farm level since the close of the Soil Management Collaborative Research Support Program (SMCRSP). Feedback from raised bed using farmers can be used to ensure the success of the new project.

Materials and Methods

The study was conducted in those areas where the raised bed technique of crop production was first introduced through SMCRSP between 2003 and 2008. Besides, the population of this survey was those farmers who are currently using the raised bed practice or have used the technique in the recent past. Primary data were collected from 13 villages under Durgapur *Upazila* of Rajshahi district during May-June, 2011. A total of 195 raised bed technology using farmers taking 15 farmers from each village were selected for interview. Again, 65 non-using farmers taking five farmers from each village were interviewed to know the causes of non-adoption of this technology. Thus the total number of sample was 260. Data were gathered through a pre-tested interview schedule. The collected data were analyzed through tabular method using descriptive statistics to fulfill the objectives of the study. Probit regression model was used to ascertain the probability of adoption of raised bed technology at farm level.

Results and Discussion

Raised bed technology in crop production showed various positive benefits such as higher crop yield, reduction in input use, reduction in production cost over conventional practice in the study areas and were adopted well (56 %) by the respondent farmers. The probability of adopting this technology was significantly influenced by extension contact, societal membership, and the number of male members in the household (Table 1). Due to lack of machine (96 %), most respondent farmers prepared raised bed by hand (83 %) without maintaining recommended bed size which was due to farmers' ignorance. The most cultivated crops on bed were wheat (cultivated by 98 % farmers), maize (28 %), onion (16 %) and mungbean (12 %). About 88 % respondent farmers were willing to continue this practice in future with increased area of land. Most farmers mentioned about the livelihood improvement but types of improvements were not clear to them since it was associated with overall socio-economic development of the society. However, this immerging technology increased farmers' food security by 21.8 %, income by 13.5 % and livelihoods to some extent (Table 2).

Table 1. Maximum likelihood estimates of variable determining adoption of raised bed technology among respondent farmers

Explanatory variable	Coefficient	Marginal effects (dy/dx)	Standard Error	z-statistic
Constant	-1.3541***	--	0.52117	-2.60
Age (year)	0.0039	0.00108	0.00904	0.44
Male member (No./HH)	0.3804***	0.10322***	0.00904	3.24
Education (year of schooling)	0.0037	0.00099	0.02283	0.16
Cultivated land (decimal)	0.0004	0.00011	0.00089	0.45
Extension contact (score; 0-20)	0.1239***	0.03364***	0.03075	4.03
Membership of society (score; 0-24)	0.1925***	0.05224***	0.07403	2.60

Note: No. of observation = 260; LR Chi-square (6) = 50.86; Log likelihood = -120.77505
***Co-efficient significant at 1% level

Table 2. Percent responses on the impact of bed technology on crop yield, food security, income and livelihood

Particulars	Farmers' responses	
	Frequency	Percentage
Impacts on food security/income/livelihood	*n* = 195	
Positive impact	195	100
No impact	-	-
Type of positive impacts		
1. Increase in production	136	69.7
2. Increase in household income	160	82.1
3. Increase in livelihood	113	57.9
4. Increase in food intake	26	13.3

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Conservation Agriculture Packages in the Subsistence farming System of Eastern India

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Introduction

In eastern India dependency on monsoon for planting and crop production, small holdings (90 % less than 1 ha), poor infrastructure for irrigation and ground water development, severely affect agriculture resulting in low crop yields and even crop failures. Further, nearly 40 % of summer rice area (3 Mha) in Bihar and West Bengal remains fallow during the winter season forming a rice fallow system. Planting a second crop after rice in this region depends on availability of residual moisture in the soil. Intensification and diversification of the rice-fallow system using no till wheat and food legumes provide an opportunity to strengthen food as well as nutrition security in the region. Conservation agriculture (CA) based technologies can meet dual aims of reducing production costs and improving productivity and profitability.

Keeping this view, a study on CA-based rice-wheat cropping system was undertaken in 2007-08 in the experimental field of the University. The tailoring of rice and wheat varieties, incidence of weeds and their management, incidence of diseases and assessment of soil health have been studied after five years continuous practice of CA.

Materials and Methods

The experimental plots were maintained at Pundibari, Coochbehar since 2007-08 with the following cropping sequences:

A. Conventional tillage wheat- conventional tillage cowpea (var.CP-4) –puddled transplanted rice
B. No-till wheat –no- till cowpea - direct seeded rice (DSR) by zero-tillage planter
C. No-till wheat –no- till cowpea - direct seeded rice by zero-tillage planter with residue retained in the field
D. No-till wheat –no- till cowpea -direct seeded rice with addition of bio-fertilizers (consortia of Azotobacter/Rhizobium/Azospirillum, Phosphate solubilizers and Trichoderma) in each season

Another plot was maintained to study the varietal performance of rice and wheat crop under tilled and no-tilled condition and to take notes on diseases and weed problems as occurred. Observations recorded were i) yield of rice and wheat with system productivity, ii) Incidence of diseases, iii) Incidence of weeds and its management, iv) Soil health parameters like soil dehydrogenase and acid phosphatase activity (Page et al.1994), microbial biomass carbon (Jenkinson and Powlson, 1976) and organic carbon percentage (Ziblske et al.2002).

Results and Discussion

Yields of rice varieties under direct seeded conditions with brown manuring were Hybrids: NK Sahadri (6.4t/ha), NK 3325 (6.0t/ha), Arize 6444 (6.3t/ha), PHB 71 (5.6t/ha); HYVs: Swarna sub 1(4.7t/ha), IET 15847(4.2t/ha), Nilanjana (4.1t/ha). Under no-till conditions the yields of the different wehat varieties were: for timely sown conditions: HD 2733 (4.3t/ha), PBW 343 (4.1t/ha), DBW39 (4.2t/ha); for late sown conditions: NW 2036 (3.6t/ha), Francolin (3.7t/ha).

Disease dynamics in no-till rice and wheat

Rice: The severity of sheath blight (*Rhizoctonia solani*) disease indicates that the DSR plots had higher (9 to 38%) Percent Disease Index (PDI) than puddled transplanted plots in the initial years but the differences have been narrowed down (0.8 to 6% PDI) after five years continuous practice of no till.

Wheat: No tilled wheat had more disease severity (138 to 342 higher Area Under Disease Progress Curve, AUDPC) than conventional tillage irrespective of the varieties, however, after five years continous practice of no- till, the differences in disease severity was reduced and recorded less (-37 to 120) AUDPC .

Weed management in DSR

Integrated weed management practices that encompasses Glyphosate @ 1.5 kg/ha as pre-plant desiccators+ butachlor @ 1.5 kg/ha as pre-plant surface application + brown manuring (*Sesbania*rice co-culture) + 2,4-D @ 0.50 kg/ha at 35 days after sowing (DAS) was found to be effective in controlling weeds in DSR during rainy season. Bispyribac sodium @ 25 g/ha applied at 20 DAS was found to be effective in controlling grasses.

Weed management in no- till wheat

Considerable reduction of growth of dominant weed flora *Polygonum persicaria* L., *P pensylvanicum* L.and *P orientale* L. was recorded in no till wheat, however, growth of other broadleaved weeds *Stellaria media* Cyrill, *S.aquatic* Cyrill, *Oldenlandia diffusa* L., *Vicia sativa*L.and*V.hirsuta*L.and grasses *Cynodondactylon* (L) Pers., *Setaria glauca* (L.) Beauv and *Digitaria sanguinalis* (Retz.)Koel was increased considerably in succeeding years.

Application of glyphosate (1.50 kg ha^{-1}) at 5 days before sowing followed by pre-emergence application of metribuzin (0.20 kg ha^{-1}) and post-emergence application of carfentrazone-ethyl (25 g ha^{-1}) at 32 days after sowing (DAS) was effective for controlling weeds in no till wheat for profit maximization and controlling 2,4-D tolerant weeds (Mukherjee et al, 2011).

Measurement of soil health parameters in no-till fields:

It is observed that after five years of consecutive use of CA, no-till plots with bio-fertilizers have significantly (P=0.05) higher soil enzyme activity (Dehydrogenase and Acid Phosphatase), microbial biomass carbon and oxidizable organic carbon than conventional fields than Conventional tillage plots (Table-1).

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Table1. Soil health parameter in conventional tillage (CT) and No-till bioprimed plots

Soil health parameter	CT	No –Till -Bioprimed
DHA (µg/g)	6.17	9.94
Acid Phospatase (µg/g /h)	180.6	206.0
Oxidiazable organic carbon (g/kg)	8.24	9.32
Microbial Biomass carbon (µg/g)	159.57	273.39
Wheat Yield (t/ha)	3.18	4.53
Rice Yield (t/ha)	5.38	6.15
System Productivity (t/ha)	9.43	11.92

Agronomic performance of Pigeon pea Relay Intercropping with Maize or Sorghum under Minimum-Tillage of Ghana and Burkina Faso

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Introduction

Mulching with crop residues and cover crops are important for realizing conservation agriculture. Cover crop mulching gives opportunities for small holders to improve soil fertility and weed management. However, the potential of cover crop mulching seems to be restrained to the (sub) humid zones (Olaf.et al.). A study on the agronomic performance of different intercropping systems, therefore, has been tested to evaluate the potential of intercropping with maize or sorghum in several climatic zones of Ghana and Burkina Faso.

Materials and methods

We conducted on-station experiments in 6 sites of Ghana and Burkina Faso, where the cropping pattern is single or dual with 800 to 1500 mm of annual rainfall (Fig. 1). Maize was cultivated with mono, or intercropped with one of three different leguminous crops (mucuna, pigeon pea, cowpea) under minimum-tillage (MT) or full-tillage (FT) conditions with four replications according to the cropping calendar in Ghana. Maize was replaced by sorghum in Burkina Faso. Once after pigeon pea was planted, it was continuously grown by pruning just before each cropping season. Maize and leguminous residues were mulched in MT or incorporated in FT plots except one plot where all crop residues were removed.

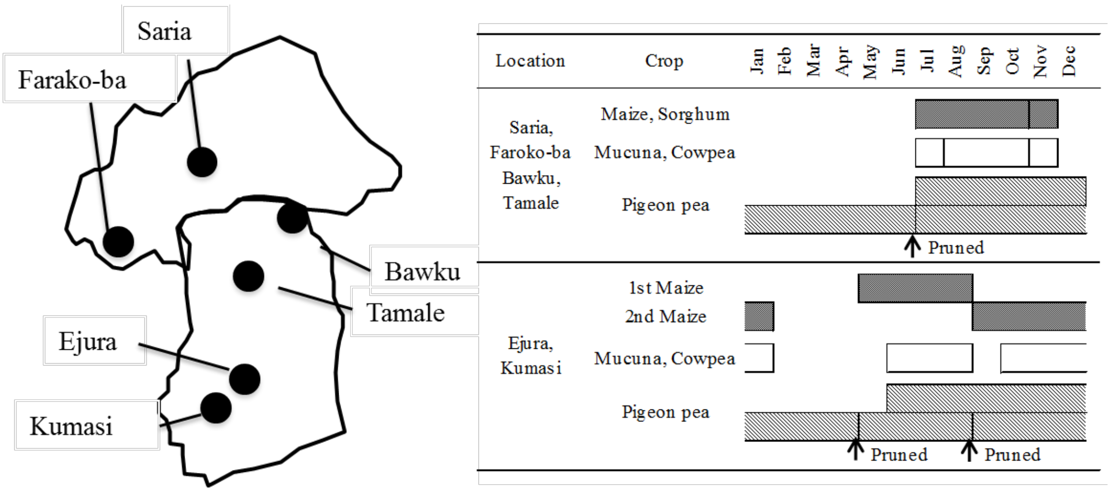

Figure 1. Location of Experimental sites and cropping calendar in the experiment

Results and Discussions

Owing to continuous growth during the off-season, pigeon pea gave highest turnover except for Farako-ba where termite or birds disturbed its growth (Fig. 2). The volume of turnover in pigeon pea seemed to reflect the volume of withdrawal or rainfall in off-season. Effective utilization of off-season resources is, therefore, quite important for small holders who survive under limited-resources conditions. The pigeon pea canopy suppressed weeds growth very well during the off-season except for Farako-ba and Saria (Fig. 3). In Saria, existence of hardpan (petroferric) in the surface or lower layer restricted elongation of pigeon pea root to deeper layer. As the result, more than 80% of pigeon pea died during off-season. This contrasts to the case of Bawku, where pigeon pea survived and continued vigorous growth during off-season, because of no existence of hardpan although annual rainfall is similar (800mm) to Saria. Maize or sorghum yielded highest in pigeon pea plot in the following crop season, 2013 except for Tamale (Fig. 4). These results were observed regardless of whether cultivated in minimum or full tillage.

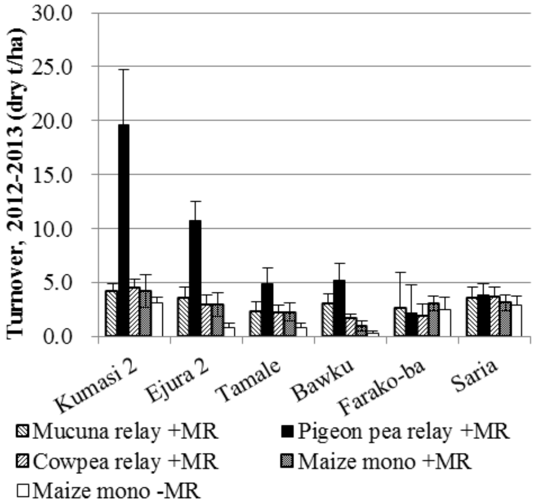

Figure 2. Turnover produced in off-season

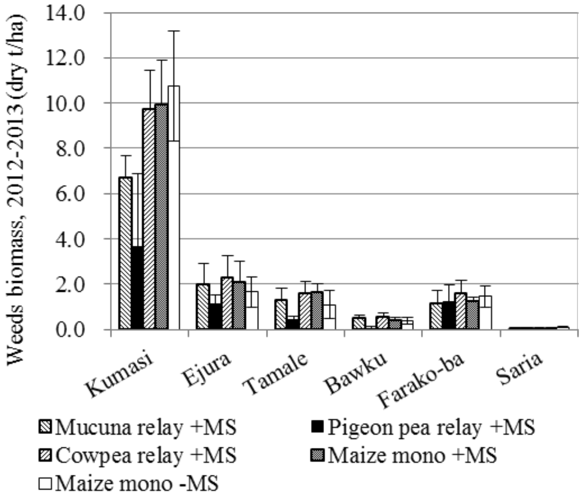

Figure 3. Weeds biomass in off-season

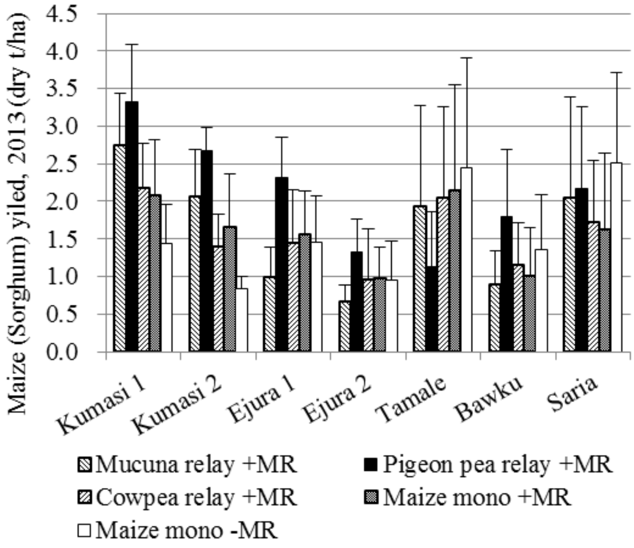

Figure 4. Maize (Sorghum) yield in 2013

As conclusion, pigeon pea intercrop gives us profits as resources of mulch and nitrogen fertilizer if we allow it to grow perennially in fields. Performance test of minimum-tillage seeder is now going on with pigeon pea alley cropping at the farmer’s demonstration fields.

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Adoption of Conservation Agriculture in South-western Bangladesh

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Introduction

There are 0.83 million hectares of arable land in coastal Bangladesh dominated by rice-based cropping sequences. Cropping systems in coastal Bangladesh occur mostly on medium highlands where only medium to long duration transplanted monsoon (T. Aman) rice varieties are grown. The low cropping intensity in the area is largely due to unfavorable soil salinity and unavailability of quality irrigation water in the dry season, though other factors such as land tenure and poor water management systems also contribute. Soils remain saturated due to poor drainage after T. Aman rice harvest delaying the preparation of land for dry season winter and pre-monsoon crops. This results in planting of dry season crops during early February. By this time residual soil moisture from the monsoon season has been lost and soil salinity has greatly increased. Further crops planted in February will mature in May when they are at risk of being damaged by early monsoon rains. The successful cultivation of dry season crop in this situation requires agronomic practices that will permit early planting into saturated soils. The USAID financed CSISA-BD project in collaboration with BRRI has tested a number of reduced tillage systems to allow early planting of sunflower (Dibble planting direct into rice stubble (Rashid et al. 2012a), oil seed mustard (broadcast sowing over maturing Aman rice (Rashid et al. 2012b), direct drill plant of sesame into rice stubble using a power tiller operated seeder (PTOS) and Boro rice grown in *ghers* (unpuddled direct transplanting, Rony et al. 2013). Farmer-managed field trials and demonstrations were conducted. The present study was undertaken to validate the performance of these reduced tillage systems on farms.

Materials and methods

The farmers' participatory trials and demonstrations were conducted during 2013–2014 in fields of trained farmers in Khulna, Satkhira and Bagerhat districts of coastal southwest Bangladesh. The area belongs to the Ganges Tidal Flood Plain (AEZ13). The rice varieties, BRRI dhan41, BRRI dhan54 were grown on saline soil sites in the 2013 T. Aman season followed by sunflower or sesame in the 2013/14 dry season. The hybrid sunflower Hysun33 was dibbled into rice stubble in moist soil without tillage. In sesame growing areas, sesame was sown earlier than normal by planting into single pass tilled fields with a PTOS. The mustard varieties, BARI sarisha14 and BARI sarisha15 were sown by either broadcast sowing over ploughed land or by broadcast sowing over maturing short duration T. Aman rice varieties, BRRI dhan39 and BINA dhan7. The Boro (winter irrigated rice) variety, BRRI dhan28 was grown on tilled and zero tilled soils in *ghers* (land surrounded by wider bund mainly for shrimp and prawn cultivation). Other crop management practices were chosen by the farmers. Grain yield was taken from a 10 m^2 area in the centre of each plot and expressed as t ha^{-1} at 14 % grain moisture for rice and 9 % moisture for oil seed crops. Statistical analysis was done using CropStat Version 7.2.

Results and Discussions

Zero tilled dibbled and ploughed sunflower produced similar grain yield but due to lower production costs (68 \$ $ha^{-1)}$ dibble sunflower gave a higher net return (15 \$ ha^{-1}) (Table 1). Importantly the dibbled sunflower matured on 15th April, 15 days earlier than ploughed sunflower reducing the risk of damage in pre-monsoon rains. The highest sesame seed yield was recorded from 5th February sown reduced tillage plots (0.95 t ha^{-1}) followed by reduced till sesame sown on the 25 January and 15 February. The first planting was affected by cold at the initial growth stage. The lowest seed yield was gained from conventional tillage plots (0.56 t ha^{-1}) which was probably caused by lower plant population compared with reduced till plots. The reduced tillage sesame seeded on 5 February matured 10 days earlier than conventionally tilled plots. Although the relay mustard avoided the ploughing cost, it produced significantly lower seed yield and net return than conventionally tilled plots. This is attributed to the difficulty of applying phosphate and potassium basal fertilizers and irrigating young seedlings under maturing rice. Despite this the system is promising as it allows early planting and hence early harvesting of mustard in an T. Aman – Mustard – Boro rice sequence where planting using conventional tillage methods is delayed by excess soil moisture at T. Aman harvest time. Early mustard harvest then allows the earlier transplanting of Boro rice which for most farmers has a higher priority than the mustard crop. This then allows farmers to grow mustard as a third crop in a T. Aman rice – Boro rice cropping sequence. The zero tilled Boro rice in *gher* produced a grain yield of 6.54 t ha^{-1} which was significantly higher than tilled Boro rice (6.30 t ha^{-1}). The adoption of zero tillage Boro reduced the production cost (57 $ ha^{-1}) significantly and earned higher net return (147 $ ha^{-1}) compared to existing system. The results show that adoption of CA based technology could form the basis for cropping system intensification and reduced risk of pre-monsoon rain storm crop damage in coastal southwest Bangladesh. However, suitable nutrient and water management methods are needed in zero tilled dibbled and relay cropping systems to maximize system productivity.

Table 1. Agro-economic productivity of various crops under different cropping systems

Crop	Tillage option	Farmer no.	Grain/ seed yield (t ha^{-1})	Total variable cost ha^{-1}	Gross return ($$ha^{-1}$)	Net return ($$ha^{-1}$)	BCR
Sunflower	Dibbled	150	2.29	461	1172	711	2.75
	Ploughed	90	2.39	529	1225	696	2.50
	$LSD_{0.05}$	-	**0.12**	**43**	**62**	**72**	**0.21**
Sesame	RT1	18	0.73	221	417	197	1.93
	RT2	14	0.95	237	551	314	2.32
	RT3	16	0.75	204	433	229	2.38
	CT	12	0.56	226	321	95	1.43
	$LSD_{0.05}$	-	**0.15**	**25**	**87**	**90**	**0.57**
Mustard	Relay	109	1.33	254	770	516	3.38
	Ploughed	104	1.75	295	1010	715	3.63
	$LSD_{0.05}$	-	**0.04**	**28**	**25**	**39**	**0.24**
Boro	Zero tilled	6	6.54	1072	1572	500	1.47
	Ploughed	6	6.30	1162	1515	353	1.30
	$LSD_{0.05}$	-	**0.08**	**7**	**20**	**22**	**0.02**

RT = Reduced tillage, CT = Conventional tillage

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Strip Tillage in Maize: Farmers' preferences and profit potential in Charland of Bangladesh

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Introduction

Cropping intensity in Mymensingh, Bangladesh is 212%, and 53% of the cropped area is under T. Aman-Boro rice system. These crops are grown under conventional tillage i.e. 4-5 passes of tilling followed by 2-3 passes of laddering (Hossain et al., 2014) with inadequate addition of organic matter. During Boro harvest some amount of residue is retained on the soil surface but not after T. Aman. This repeated plowing and cross plowing causing land degradation (Bezuaychu et al., 2002) and soil organic matter (SOM) declined <1%. Recently, the adoption of maize cultivation has increased in this area replacing *Boro* rice due to higher production cost of the later. In this situation, strip tillage with crop residue retention on the soil surface is essential for sustaining soil productivity through the retention of higher soil moisture content, replenishing SOM and so forth. Evidence suggests that strip tillage lowers production cost compared to conventional tillage, and increases soil-water conservation, and N and P availability (Zhang et al., 2009). To further field test and popularize this technique in *Rabi* maize, farmers' participatory strip tillage demonstrations with 25-30% straw retention from the previous Aman crop were compared with conventional tillage as control were established in 2011-12, 2012-13 and 2013-14.

Materials and methods

The farmers' participatory demonstrations were conducted in Old Brahmaputra Flood Plain soils, mostly on Charland, characterized by sandy loam to loam soils with low water holding capacity and formed due to sedimentation from the Brahmaputra River. The soil formed comparatively earlier has already come under rice cultivation and in comparatively younger soils mainly Blackgram, Groundnut, vegetables are grown. Demonstrations were conducted at four farmers' fields as dispersed replications, each in paired plots; one seeded by strip tillage planter and the other by conventional methods in *Rabi* season of 2011-12. Conventional tillage in demonstrations entailed two times plowing and cross plowing, followed by laddering by power tiller, and hand seeding. Twenty one demonstrations in 2012-13, and 10 demonstrations in 2013-14 were also conducted. Seeds of hybrid variety 'Elite' were sown during the last week of November to 3rd week of December depending on locations each year in collaboration with farmers. Both treatments of a replication were seeded in the same day. Spacing (row to row 60 and seed to seed 20 cm), fertilizer, irrigation and other cultural practices were followed as per recommendation of Bangladesh Agriculture Research Institute (Elahi MNE et al., 2009). Plot size was 1333 m^2 each for strip and conventional seeding. All crop management practices were done by farmers under the guidance of CIMMYT staff. Data were recorded on yield, lodging, and economic parameters. Tillage systems in each demonstration were evaluated by 10 farmers of the village. They scored the tillage systems using a scale (1-10) where 10 was the best, and commented on the prospects and problems of the tillage systems. Data were analyzed by two tailed paired t-test using MSTAT-C program (Version 2.10, Michigan State University, Michigan, USA) after verifying normality and homogeneity of variances.

Results and Discussion

There was no significant yield difference between strip and conventional tillage systems in any of the three years. Lodging in strip tillage plots was significantly lower than conventional in all years, but it had no impact on yield as it was at the later stage of grain filling. The lack in yield advantage may have been due to sowing on the same day, as maize yield typically declines as the season progresses with late sowing. Where strip tillage is used to advance sowing because less time is needed to prepare land, yield results may have been more positive. Further research is needed to investigate this hypothesis. Farmers' preference score (FPS) was always significantly higher for strip tillage than conventional tillage, because production cost in the strip tillage system was reduced due to its lower tillage cost and lack of seeding labor cost. Gross margins from strip tillage maize were always higher in all years. Similarly, the benefit cost (B:C) ratio was higher in strip tillage than conventional. Participating farmers understood the advantages of strip tillage including that of straw retention on the soil surface, and provisionally indicated they would be willing to maintain 1/3rd of *aman* residue on the soil surface, whereas the remainder is typically used as household fuel. However, they raised the issue of weed control, because, no herbicide except broad spectrum glyphosate and pre-emergent Pendimethylene is yet widely available in the market. Farmers suggested that viable markets are needed to facilitate the commercial viability of post emergent herbicide for maize. They advised that if the herbicide issue can be solved, adoption of strip tillage cultivation in maize and other upland crops will increase rapidly. During the study, some farmers expressed interest in becoming service providers to carry out strip tillage on a fee-for-service basis with their neighbors.

Table 1: Yield, FPS, lodging tolerance and profit from strip tillage maize, Mymensingh, Bangladesh

	Yield (t/ha)		Lodging (%)		FPS (no)		Gross margin ($/ha)		B:C Ratio	
Year	Strip	Conv.	Strip	Conv.	Strip	Conv	Strip	Conv	Strip	Conv.
2011-12	9.54	9.41	7.97	30.7 **	7.12 **	5.38	1042	813	2.46	1.88
2012-13	9.32	8.66	10.4	32.7 **	7.81 **	5.62	1351	1024	2.78	2.09
2013-14	9.89	9.48	5.81	18.9 **	8.65 **	6.25	1348	1062	2.71	2.07

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Session 6

Policy and institutional framework of conservation agriculture

Improving Soil and Crop Productivity through Resource Conservation Technologies in Drought Prone Area

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Introduction

Resource conserving technologies (RCTs) provides immediate economic and environmental benefits of crop establishment and thus improve systems yield. Rice is transplanted in flat fields that are typically ponded for long periods that negatively affect soil properties for the non-puddled crop (Kumar et al. 2000). Yields of rice and wheat in heat and water-stressed environments can be raised significantly by adopting RCTs, which minimize unfavorable environmental impacts, small and medium-scale farms (Kataki, 2001). Inclusion of grain legumes in rice-wheat cropping system may be another option for increasing cropping intensity, soil fertility and productivity. Crop residue, raised beds along with efficient N fertilization strategies are likely to be key components of increase crop productivity and soil fertility. Thus, crop residue management under bed systems along with efficient N fertilization strategies were assessed the potential productivity and soil fertility in rice-wheat system.

Materials and methods

A wheat-mungbean-rice cropping pattern was implemented over 9 years at RWRC, BARI, Rajshahi, Bangladesh ($24^0$3'N, $88^0$41'E, 18 m above sea level). The site has a drought prone environment and is located in AEZ 11 with course-textured soil (BARC 2007). The area receives only 757 mm mean annual rainfall, about 97% of which occurs from May to September. Soil at the site is a calcareous silty loam with slightly alkalinity (pH 7.5), low OM (0.8%) and low N (35 µ/g soil). The experiments consisted of 20 subplots with four tillage/straw treatments (30% straw retention(SR)+permanent raised bed(PRB), 30% SR +conventional tillage (CTP), 0% SR + PRB and 0% SR + CTP) and five N levels (0, 40, 80, 100 and 120% of recommended nitrogen) with three replication. Total system productivity (TSP) for each treatment was calculated based on equivalent yields as follows: (rice grain yield*1.35) + (wheat grain yield*1.39) + (mungbean grain yield*1.54). N-uptake by grain and straw were calculated by the following formulae:

N-uptake by grain (kg ha^{-1}) = Total N (%) in grain x grain yield (kg ha^{-1})/ 100

N-uptake by straw (kg ha^{-1}) = Total N (%) in straw x straw yield (kg ha^{-1})/ 100

Results and discussions

a) Total system productivity

TSP increased 10-12% for all crops in 30% straw retention with PRB over conventional (Figure 1). TSP of rice, wheat and mungbean was 12 t/ha per year. Lower TSP also occurred from 0% SR with CTP due to reduced crop growth. Similar observations were made by Singh (2003) in Mexico. TSP significantly increased by 11% in rice, 14% in mungbean with increasing N levels up to 100%; and by 16% in wheat up to 120% N level (Figure 2). Highest TSP occurred in PRB with 120 kg N/ha in wheat and 80 kg N/ha in rice, 20 kg N/ha in mungbean. Lower TSP also occurred from 0% N with CTP due to less N uptake. Similar observations were made by Yadvinder Singh et al. (2006). Averaged over 9 years, PRB + 30% SR increase 17% wheat yield, but there was no significant mungbean yield increase with additional N with 30% SR. Average rice yield on PRB + 30% SR with 80% N was significantly higher than with 0% SR at the same N rate, and there was no further yield increase at higher N rates.

b) Nitrogen uptake

N uptake was significantly (P<0.5) influenced by straw retention and N levels. Increased N uptake was 31% in rice, 25% in wheat and 19% in mungbean over conventional (Figure 3). In PRB+30% SR plots, total N uptake was maximum at 50-100% by rice, 80-120% by wheat and 50-100% by mungbean. Limon-Ortega et al. (2000) observed that permanent beds with straw retention gave the highest average wheat grain yields (5057 t/ha), N use efficiency (28.2 kg grain/kg) and total N uptake (133 kg/ha).

c) Environmental impact

Fuel used both conventional and reduced tillage system was showed in (Table 1). 54 litre/ha/year diesel used for PRB system where 96 litre/ha/year also used in conventional method. PRB tillage system saved 42 litre/ha/year of costly diesel fuel which 44% less emission of CO_2 into the atmosphere. Witt et al. 2002 reported same results from their experiment.

d) Soil organic matter (SOM)

After 9 years (2004 to 2013), increased organic matter by 0.72% (Table 2) from 30% SR both rice and wheat straw and full residue retention from mungbean crops with PRB system into the soil. Also P, K, S, Zn, B availability increased from 30% SR in same cases of residue retention. Kumar and Goh (2000) reported that, in the longer term, residues and untilled roots from crops can contribute to the formation of SOM.

e) Changes of soil physical propertise

After 9 years, lower bulk density was found from PRB over conventional from different depth, increased infiltration rate and total pore space in same due to create loose soil into bed with increase soil microorganisms.

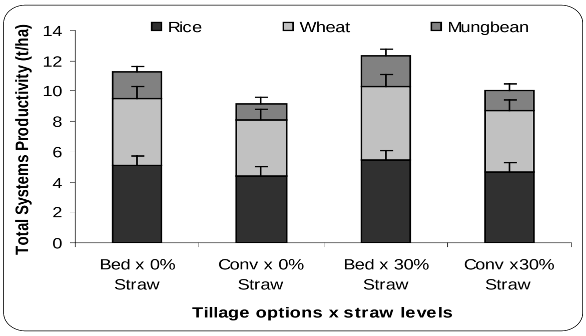

Figure 1. TSP under tillage options & straw levels in rice-wheat-mungbean system

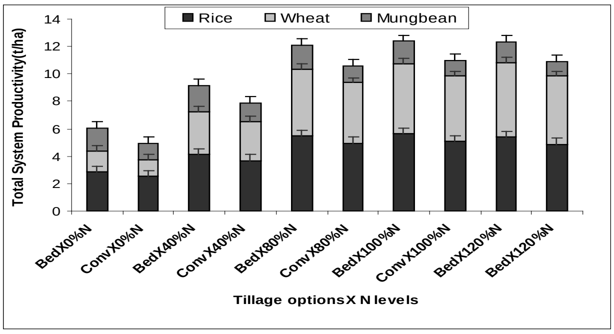

Figure 2. TSP under tillage options & N levels in rice-wheat-mungbean system

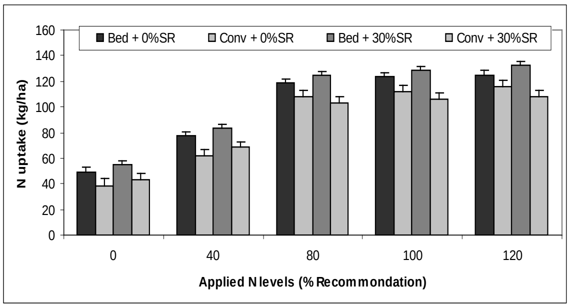

Figure 3. Total N uptake under different tillage options & N levels

Table 1: Comparative use of diesel fuel and CO_2 emission on raised bed & traditional

Tillage options	Diesel used (litre/ha /year)	CO_2 emission (kg/ha /year)	Less CO_2 emission (%)	Fuel saved (litre/ ha/year)
PRB	54	140.4	44	42
Conv.	96	249.6	-	-

Table 2. Chemical properties changes after 9 years crop cycles

Characteristics	Initial	Final	Differ
Organic Matter (%)	0.90	1.62	+ 0.72
Total N (%)	0.12	0.19	+ 0.07
Exch.K (ml eq/100g soil)	0.26	0.48	+ 0.22
Avail. P (mg / g soil)	24.5	52.5	+ 38.0
Avail. S (mg / g soil)	25.6	38.9	+ 13.3
Avail.Zn (mg/g soil)	0.84	6.13	+ 5.29
Avail. B (mg /g soil)	0.19	0.37	+ 0.18

Table 3. Physical properties changes after 9 years crop cycles

Tillage options	Bulk density (mgm^{-3})			Infiltration rate (cmh^{-1})	Total pore space (vol.%)
	0-10 cm	10-20 cm	20-30 cm		
Bed	1.37	1.59	1.74	0.85	53-59
Conv	1.57	1.79	1.95	0.59	43-48
LSD(0.05)	0.037	0.025	0.034	0.032	NS

Findings

Permanent beds with 80, 100 and 120% recommended N application were found similar performances over all treatments with 30% straw retention. It was also found that 120% N application with conventional tillage practice were obtained similar yield compare with 80% N under permanent bed system for 30% straw retention. 0.72% OM increased after nine years crop cycles for 30% residue retention from wheat & rice and full residue retained from mungbean crops. Save 20% N after nine years crop cycles after residues retention from all three crops.

Conclusions

80% N with 30% straw retention from wheat & rice and full residue retained from mungbean crops under permanent beds were the best combination for getting higher productivity as well as improve soil fertility in Bangladesh.

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Wheat Requires Less Amount of Applied Fertilizers in Long Term Zero Tillage

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Introduction

Upland crops can be grown successfully with zero tillage in the wheat-mungbean-rice cropping pattern in a light soil (WRC 2009). In a long-term experiment, at WRC, Dinajpur, it was observed that wheat yield was similar or higher in zero tillage than in conventional tillage. Although only di-ammonium phosphate (DAP) was applied as basal fertilizer for wheat according to recommendation for zero tillage, no symptoms of nutrient deficiency were observed before top-dressing of other fertilizers. Hence it was hypothesized that lower amounts of fertilizers (i.e., applied nutrients) in zero tillage than in conventional tillage might be enough for optimum yield of wheat. This was tested by adjusting the fertilizer rates based on soil test results in zero tillage compared to conventional tillage.

Materials and Methods

The experiment was conducted for 2 consecutive years in a field where the wheat-mungbean-rice cropping pattern was followed in zero, conventional and alternate tillage (zero for wheat and mungbean, and conventional for Aman or monsoon rice) in separate plots. The alternate tillage was included since the establishment of monsoon rice was difficult in zero tillage. The experiment was conducted in the cool-dry (*rabi)* season of 2011-12 and 2012-13 at WRC, Dinajpur. Each replication was divided into 3 main plots in 2005-06. One plot was assigned to conventional tillage and has been producing crops by ploughing conventionally for decades. The other 2 plots were assigned to zero tillage from wheat in 2005-06. Of these 2 plots, one remained permanent zero i.e., all crops are produced in permanent zero tillage condition, and in other plot alternate tillage has been being practiced from 2008-09. After harvesting of monsoon rice i.e., before sowing wheat in every year (2011 and 2012) soil samples from 0-15cm depth were collected from each sub-plot (Table 1). The fertilizer treatments (sub-plots) were (i) F_1 = recommended fertilizer (RF) (FRG 2005, BARC) and WRC recommended application method (WRA), (ii) F_2 = 75% RF and WRA, (iii) F_3 = RF, and only DAP was used as basal (during sowing) and other fertilizers were applied after 1st irrigation i.e., 17-22 DAS (DAP), and (iv) F_4 = 75% RF, and DAP. Two-third of urea and other fertilizers were applied as basal and the rest of urea was applied as top-dressing after 1st irrigation according to WRC recommendation. The unit plot size was 4.2×7.0m.

Table 1. Soil properties of different tillage options (before wheat sowing)

Tillage option	pH		organic matter (%)		Total N (%)		Available P (µg/g soil)		Exchangeable K (meq/100g soil)		Available S (µg/g soil)		Mg (meq/100g soil)		B (µg/g soil)	
	'11	'12	'11	'12	'11	'12	'11	'12	'11	'12	'11	'12	'11	'12	'11	'12
ZT	6.29	6.61	1.24	1.08	0.060	0.059	29.1	23.5	0.108	0.107	13.3	8.3	1.03	1.15	0.14	0.93
CT	5.83	6.41	1.10	0.87	0.058	0.043	19.6	14.6	0.093	0.090	13.9	2.5	0.74	0.97	0.18	0.55
AT	5.67	6.36	1.06	0.80	0.053	0.040	23.7	19.1	0.100	0.100	15.0	7.5	0.76	0.95	0.24	0.94

ZT = Zero tillage, CT = Conventional tillage, AT = Alternate tillage

Fertilizer dose for wheat was calculated according to soil analysis for each treatment to achieve 4.5±0.45 t ha^{-1} (BARC 2005). Provax-200 treated seed of wheat variety BARI Gom

26 was sown @ 130 kg ha^{-1} in lines 20cm apart on 01 December in 2011-12 and 08 December in 2012-13. After 1st irrigation different fertilizers were top-dressed according to treatment. Grain yield was adjusted to a moisture level of 12%.

Results and Discussion

The difference among the sub-plots for soil properties was negligible. Therefore, average data were considered for calculating the fertilizer dose. The soil analysis report before wheat sowing in both the years showed that long term zero tillage improved the soil properties (Table 1). It increased pH, organic matter, N, P, K and Mg of the soil. Based on soil analysis, less fertilizer N, P, K and Mg were required compared to conventional tillage (data not presented). In alternate tillage, the soil for rice after 2 zero tillage crops (wheat and mungbean) reverses some of the effects of zero tillage, although P, S and B were higher than conventional tillage.

Higher grain yield was obtained from zero tillage in both the years (Table 2). Lowest grain yield was found in conventional tillage but it produced higher straw in 2011-12. In 2012-13 lower grain yield was also found in conventional tillage. Use of only DAP as basal fertilizer (followed by top-dressing of all others after 1st irrigation) and fertilizer application according to WRC recommendation produced almost similar yield in 2011-12 (Table 2). Reduced amount of fertilizer produced lower yield than the recommended amount of fertilizers. Lower grain yield in 2012-13 than in 2011-12 might be due to late sowing.

Table 2. Grain and dry matter yield of wheat (var. BARI Gom 26) as influenced by tillage options and different fertilizer management

Treatment	Grain yield (kg ha^{-1})			Dry matter (kg ha^{-1})		
	2011-12	2012-13	Average	2011-12	2012-13	Average
Tillage options						
ZT	4,767	3,761	4,264	9,864 ab	9,788 b	9,826
CT	4,565	3,585	4,075	10,386 a	8,851 c	9,619
AT	4,695	3,687	4,191	9,703 b	9,540 b	9,621
CV (%)		8.23			6.38	
Fertilizer management						
F_1	4,773	3,903	4,338 a	10,248	10,026	10,137 a
F_2	4,655	3,607	4,131 ab	9,862	9,159	9,511 bc
F_3	4,735	3,671	4,203 ab	10,150	9,493	9,821 ab
F_4	4,540	3,529	4,034 b	9,678	8,894	9,286 c
CV (%)		7.60			7.57	

For details of the treatments see Materials and Methods, and Table 1. Means followed by different letters (within a factor or interaction between year and tillage) are significantly different by least significant difference at 5% level.

Conclusion

The applied fertilizer dose on the basis of soil test result was lower in long term zero tillage but with this lower amount of fertilizer wheat achieved higher yield in zero tillage than conventional tillage. For any tillage options optimum amount of nutrient should be supplied for optimum yield.

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Conservation systems improves soil physical health and resource use efficiency in rice-wheat rotation

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Introduction

Rice-wheat cropping systems occupy 13.5 Mha of land in South Asia, spread from the Indo-Gangetic Plains to the foothills of Himalayan mountains. Conventional puddling is done in rice fields followed by rice nursery transplanting in the puddled soils. After harvesting rice, wheat is sown in the pulverized soil. This shows an edaphic divergence in conventional soil management practice for rice and the requirements of the subsequent wheat crop (Farooq et al., 2008). Puddling usually results in erratic crop establishment owing to poor contact of seed with soil in cloddy post-rice puddled soils (Ringrose Voase et al., 2000; Farooq et al., 2008).

Conservation agriculture has been found eco-friendly, with minimum soil disturbance and offers a pragmatic option to resolve the edaphic conflict in the conventional rice-wheat system (Hobbs et al., 2007). In this context, aerobic direct seeded rice helps in resolving the edaphic conflict in the rice and proceeding crop accomplished with reduction in water input, labor requirement, greenhouse gas emission (Farooq et al., 2009), and improved the input use efficiency. The present study evaluated the conventional and conservation systems for soil physical health and paddy yield.

Materials and Methods

This study was conducted on a sandy loam soil at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan (31°N, 73°E and altitude 184.4 masl). The experiment was conducted in randomized complete block design with four replications of the following treatments viz. T_1= Direct seeded rice (DSR) - zero tilled wheat (ZTW); T_2 = DSR + sesbania (brown manuring) – ZTW; T_3 = DSR – ZTW + rice residues; T_4 = Puddled transplanted rice (Pu TPR) – ZTW; T_5 = Puddled transplanted rice (Pu TPR) – conventional till wheat (CTW). Rice in DSR treatments was directly drilled on 25 June in 2012 and on 24 June in 2013 at a seed rate of 50 kg ha^{-1} in 22.5 cm spaced rows. In direct seeded rice, aerobic conditions were maintained throughout the crop growth period. In transplanted rice, thirty day old nursery seedlings (two seedlings per hill, 22.5 cm row spacing) were manually transplanted in puddled field in the last week of July in both years. In all treatments irrigation and fertilizer was applied given as per requirement of the crop. For brown manuring, seeding of sesbania was done at the time of planting between the rows of direct seeded rice with the help drill at seed rate of 65 kg ha^{-1}. Sesbania crop was treated with a weedicide (MCPA @ 625 ml ha^{-1}) at the age of 30 days to kill it. Soil bulk density at 0-5 cm, and whole plot grain yields were recorded. Benefit: cost ratio was calculated as the ratio of benefits to the total cost. Data collected was analyzed by MSTAT-C software. Least significance difference (LSD) test at 5% probability level was applied to compare the treatments means

Results and Discussion

During both years, maximum soil bulk density was recorded in conventional rice production systems while it was lowest in conservation rice production systems (Table 1), which may be due to soil compaction which was developed due to puddling before rice transplanting and continuous flooding of water in these systems. During the first year, maximum grain yield was obtained in TR while it was lowest in DSR systems (Table 1), because continuous rainfall made it impossible to control weeds effectively in DSR systems. However, during second year, maximum grain yield was observed in DSR with sesbania manuring which might be due to better weed management and improved soil health due to sesbania brown manuring. Earlier it has been reported that simultaneous sowing of DSR and sesbania and killing of young sesbania plants at 30–45 days after sowing could help to reduce weed pressure and build up soil fertility in the RW system (Singh et al., 2007). Our study also indicated that the maintenance of crop residues in zero-tilled improved yield of direct seeded rice in the second year of experimentation. It might be possible that maintenance of crop residues might have increased the organic matter content in that specific treatment resulting in better water and nutrient acquisition, ultimately better crop yields. Benefit-cost ratio highest in DSR systems during second year which might be due to less input requirement in these systems interms of saving of water and labour resources.

Table 1: Impact of conventional and conservation rice systems on soil bulk density and paddy yield and benefit-cost ratio

	Bulk density ($g\ cm^{-3}$)		Paddy yield ($t\ ha^{-1}$)		Benefit:cost ratio	
Treatments	2012	2013	2012	2013	2012	2013
DSR – ZTW	1.37 b	1.38 b	2.24 b	3.28 b	1.37	2.47 b
DSR + SM –ZTW	1.36 b	1.37 b	2.43 b	3.76 a	1.58	2.98 a
DSR – ZTW + CR	1.37 b	1.35 b	2.26 b	3.75 a	1.39	2.97 a
TR – ZTW	1.42 a	1.43 a	2.85 a	3.06 b	1.52	1.71 c
TR – CTW	1.43 a	1.44 a	2.82 a	3.16 b	1.49	1.80 c
LSD Value	*0.02*	*0.04*	*0.28*	*0.26*	***ns***	***0.24***

DSR= Direct seeded rice; TR= Transplanted rice; ZTW= Zero tilled wheat; CTW= Conventional tilled wheat; SBM= Sesbania brown manuring; CR= Crop residues

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Effects of Conservation Agriculture and Nitrogen Fertilization on Carbon Footprint in the Wheat-Mungbean-Rice Cropping System

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Introduction

Recent trends towards mechanization on small farms create an opportunity to develop conservation agriculture in Bangladesh. However, a range of soil processes under conservation agriculture in rice-based cropping systems will differ from those in dry land cropping systems. The emission of greenhouse gases for example may favour methane under flooded conditions rather than carbon dioxide. The effect of nitrous oxide emission under conservation agriculture in rice-based systems also needs to be determined. Thus, a study was undertaken to determine whether minimum tillage by strip tillage, different levels of N fertilizer and residue management altered the carbon footprint (CF) of wheat and mungbean and whether unpuddled transplanting affected CF of monsoonal rice relative to puddled soils.

Materials and Methods

The experiment was conducted at Bangladesh Agricultural University (BAU) Farm, Mymensingh on an Aeric Haplaquept during November 2012-March 2013 (wheat), April 2013-June 2013 (mungbean) and July 2013-November 2013 (rice). There were two tillage systems - conventional tillage and strip tillage, two residue retentions- low (20% of cereal residue retained) and high (60% of cereal residue retained) retention and five nitrogen rates as a % of the recommended fertilizer dose (RFD)- 60% RFD, 80% RFD, 100% RFD, 120% RFD and 140% RFD. The recommended N (RFD) dose for wheat was 100 kg ha-1, 20 kg ha-1 for mungbean and 75 kg ha-1 for rice. The experiment was designed in a split-plot design with tillage systems and residue retentions distributed to the main-plots and N application to the sub-plots. Carbon footprint was calculated using emission factors from the literature as default values following Hillier et al. (2009) as per guidelines of ISO14040-44 (ISO 2006) and IPCC (2006).

Results and Discussion

Fertilizers were among the highest sources of CF for all three crops. The contribution of fertilizers in the CF of wheat, mungbean and rice were 77%, 55% and 69%, respectively. On average the contribution of fertilizers in the CF over the year was 71%. Among the fertilizers, N fertilizer contributed 92% of the overall CF of the year. This large contribution of N fertilizer in CF is attributed to the fact that the manufacturing of N fertilizer requires high energy inputs (Yan, 2012) and it is the principal source of CO_2 and NO_2 emission (Lal, 2004). Mitigation of greenhouse gases emission from crop production should be focused on reducing N fertilizer use and N losses as N_2O. The contribution of irrigation, machinery and labor inputs to the overall CF of the year was 19%, 4% and 6%, respectively in addition to 71% from fertilizers.

The grain yield of the crops did not differ significantly between the two tillage systems (except mungbean) as well as between two residue retention treatments. However, it varied significantly with different rates of N application. The grain yield increased with increase in N from 60 to 100% RFD for all the three crops then generally decreased with further increase in N rates it mostly. Comparatively higher yield was observed in strip tillage than conventional tillage (mungbean and rice) and might have resulted from lesser decomposition of soil organic matter, better water conservation and increased biological activities in strip tillage.

There was no difference in CF for all the crops between two tillage systems (except mungbean) as well as between two residue retention treatments (except rice). Comparatively higher CF was observed in conventional tillage than strip tillage (mungbean and rice) due to higher soil disturbance and more carbon emission from fuel used by the tractor. In case of residue retention, higher CF was observed in 60% residue retention than 20% residue retention (wheat and mungbean). The CF varied significantly with different rates of N application in mungbean and rice but did not differ significantly in wheat. Comparatively higher CF was observed in mungbean followed by wheat and rice. However, when converted into rice equivalent CF, then the highest value was observed in wheat (207 kg t-1) followed by rice (99.5 kg t-1) and mungbean (85.6 kg t-1). The rice equivalent CF of wheat was almost double that of rice and mungbean. The rice equivalent total CF for wheat-mungbean-rice cropping system differed significantly between two tillage systems but did not differed significantly between two residue retention and different rates of N application (Fig.1). Comparatively higher rice equivalent total CF was observed in conventional tillage than strip tillage (mungbean and rice) due to higher soil disturbance and more carbon emission from fuel used by the tractor.

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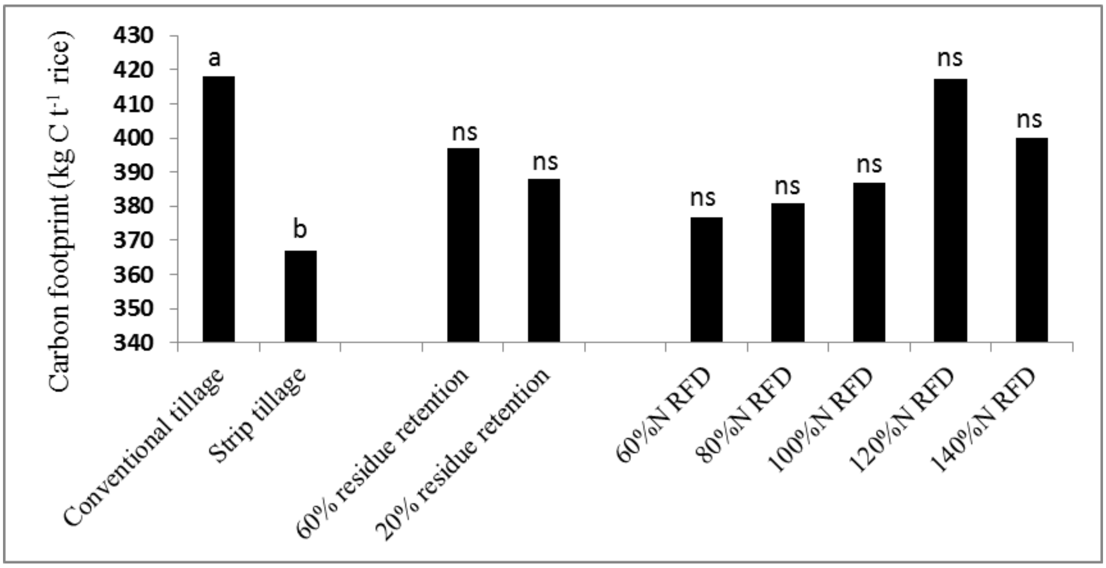

Figure 1. Carbon footprints of wheat-mungbean-rice cropping system under different tillage, residue and N fertilizer management systems

The Impact of Conservation and Conventional Tillage Systems on Hydro-physical Properties of a Ferric Acrisol

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Introduction

Soil hydro-physical properties have significant impacts on soil moisture storage and availability, the magnitude of runoff and soil loss, plant growth and yield on arable land (Lal and Shukla, 2004). Among the major soil hydro-physical parameters, this study focused on bulk density, porosity and saturated hydraulic conductivity. Proper and efficient soil conservation planning requires adequate knowledge of the responses of these parameters to different management practices on cropland. Such information is however limited on tropical soils. On the other hand, since plants store very little water compared to their daily requirements, they must rely on the reserves of water stored in the soil (Ramos and Martínez-Casasnovas, 2014). Optimizing in-situ moisture conservation on smallholder farms is therefore pertinent to sustaining high crop growth and yield, particularly in rainfed agriculture. In this context, this study assessed the relative performance of different tillage on in-situ moisture storage and properties that affect its availability during critical dry spells.

Materials and Methods

The study was carried out on a Ferric Acrisol in the semi-deciduous forest zone of Ghana. The treatments comprised no-till (NT) and plough-plant (PP) grouped as conservation tillage, and plough-harrow-plant (PHP) as conventional tillage; arranged in Randomized Complete Block Design with three replications. The NT has crop residues with no soil disturbance while the PP was disc ploughed with two traffic passes to a depth of 20 cm, then planting was done manually. The PHP was tractor-driven, disc ploughed and harrowed with four to five traffic passes to 30 cm soil depth; planting was done manually.

All measurements were taken after 3 consecutive cropping seasons of treatment application except the control (initial) which was taken before treatment imposition. Bulk density was determined by the core method (Blake and Hartge 1986). Soil total porosity was assessed using $Tporosity = 1 - \frac{bulk\ density}{particle\ density}$x *100%*. Volumetric water content (θv) was measured gravimetrically on the soil core. Aeration porosity was determined as: $\varepsilon a = Tporosity - \theta v.$ Saturated hydraulic conductivity (Ks) was measured by the falling head permeameter method. Soil moisture storage was calculated as: $Sms = \theta v\ x\ soil\ depth\ (mm)$. The data were analysed using the repeated measurement ANOVA procedure in Genstat package 9th edition. Means were compared using LSD (0.05).

Results and Discussion

The PP and PHP respectively increased the initial bulk density of 1.43 Mg/m^3 at the 0-15 cm depth by 19 % and 7 % and 1.54 Mg/m^3 at 15-30 cm depth by 5 % and 3 % (Table 1). NT virtually maintained the initial bulk density through to the end of the experiment. Given that the initial bulk density was increased by the mechanical action of PP and PHP, it was not surprising that total and aeration porosities were reduced. This was more so at the 0-15 cm depth where initial total porosity decreased by 20 % and 10 % under PHP and PP respectively.

The relative sensitivity of total and aeration porosities to increases in bulk density is exemplified by the magnitude of their exponents in their relationship with bulk density where the former is -1.36 and the latter is -2.27. Percent Ks reduction was in the order of PP < NT <PHP relative to the control. This reduction may be ascribed to soil compaction due to the impact of raindrops and the increases in bulk density resulting from higher intensity of wheel traffic of the tractor on PHP. The PP treatment recorded greater moisture storage at the 15 -30 cm depth than the NT and PHP treatments (Table 2) but its availability seems to be greater with no-till which had lower bulk density, higher porosity and implicitly greater root growth for moisture abstraction. During dry spells, conservation tillage practices that store greater cumulative moisture, such as the PP (plough-plant), are preferable, especially in rainfed agriculture. Such effect could be obtained on no-till field with adequate cover.

Table 1: Some soil hydro-physical properties as affected by conservation and conventional tillage systems

Tillage System	Bulk density (Mg/m^3)		Total Porosity (%)		Aeration porosity (%)		Ks (mm/h)
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15
Control	1.43	1.54	49	42	38	31	634
NT	1.44	1.59	46	40	32	25	85
PHP	1.6	1.62	39	38	25	23	49
PP	1.53	1.59	42	40	28	18	128
LSD (P<0.05)	0.11		5		15		46
CV (%)	7		6		10		22

Table 2: Soil water storage at different depths during dry spells under different tillage practices

	Soil water storage (mm)								
	1st Sampling			2nd Sampling			3rd Sampling		
Depth (cm)	0-15	15-30	Total	0-15	15-30	Total	0-15	15-30	Total
NT	19.2	29.5	48.7	20.8	27.4	48.2	20.5	78.5	99.0
PHP	19.5	52.3	47.8	21.1	50.5	71.6	23.1	32.3	55.4
PP	25.3	51.3	76.6	27.4	56.9	84.3	10.9	92.2	103.1
LSD (P<0.05)	12.3								
CV (%)	28								

1st sampling=24th October; 2nd sampling = 7th November and 3rd sampling = 21st November. All in 2013

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Direct Seeded Rice (DSR) - Sustainable Rice Production System in East India Plateau

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Introduction

The East Indian Plateau (EIP) comprises much of the state of Jharkhand and parts of adjoining West Bengal, Bihar and Orissa. The EIP is characterised by high but variable rainfall (1,100-1,600 mm, 80% received in June-September), frequent and sometimes long dry spells within the monsoon, little irrigation (~10% of area), high runoff and soil erosion, terraced mono-cropped paddy lands and subsistence agriculture. The whole area is characterised by endemic poverty, food insecurity, comparatively paddy rice yield **(**<1.9 t/ha**)**. Traditional cropping systems are characterised by mono-crop rice production that experiences high climate-related risk, and is particularly vulnerable to subtle changes in rainfall distribution associated with climate variability/change. Population pressure has pushed rice cultivation onto the medium uplands, but these lands are poorly suited to transplanted rice production systems. Cropping in the post-rainy (rabi) season is limited due to lack of irrigation resources, and uncontrolled grazing by village cattle and goats. Most villagers achieve only 50-60% food grain requirement, so forced migration in the non-monsoon season is important for off-farm income at the cost of social upheaval. The outcome of these forces is widespread malnutrition, limited medical care and low levels of literacy. Perhaps not surprisingly, the region is a strong-hold for left wing extremist groups.

Within this context, overall objective of the research is to improve livelihoods by enabling local farmers to develop flexible and responsive cropping and livestock systems that better utilise available water resources including the residual water in soil after the monsoon, thereby building resilience to climate change/variability at the household level.

Materials and methods

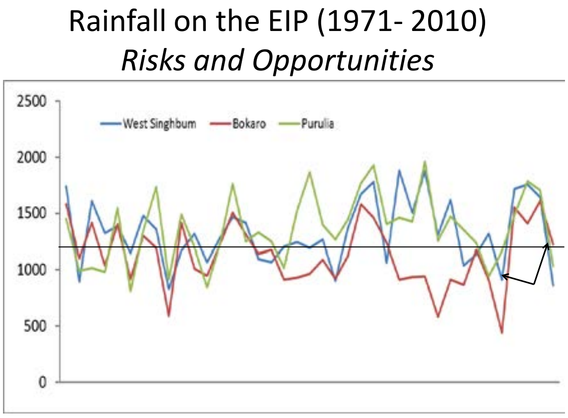
The research activities are being implemented in 3 research villages, 2 are in Jharkhand and 1 in west Bengal. Participatory on-farm research (OFR) in farmer's fields and Action Learning Cycle is followed rigorously to facilitate experiential learning for all. The cyclic process of Plan—Do—Observe—Reflect—Plan is followed as core process. Women's self-help groups are the primary groups to take decisions on research questions, selection of farmers and overall management of the research activities in the villages. Regular research planning, review and learning meetings are held in the villages during each cropping season. During the cropping seasons frequent field walks with the farmers are done to observe the treatment effects and discuss what it means to them. The scientific data collection is done by trained village resource persons and researchers. The soil and plant analysis is done in a reliable laboratory.

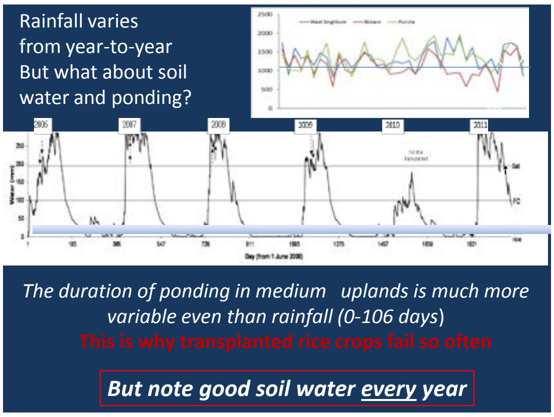
The experimental design is paired fields. Two adjacent fields which are hydrological and bio-physically similar are selected to compare DSR with farmers practice. Three online automatic weather stations are installed in research villages to record and report local weather real-time and long term (42 years) weather data are analysed to comprehend the climatic conditions. Short duration (90 days) rice variety Anjali (IET 16430) and medium duration (120 days) maturity rice variety Abhisek (IET 17868) were planted in the treatment plot while in the control plot is under farmer's practice.

Soil Fertility, Crop management, Yield, Biomass, labour requirement etc. and residual water at harvest of paddy are recorded both for DSR and control plots. Regular learning workshops are organized with the farmers and researchers to share observations and reflections to articulate the learnings from research.

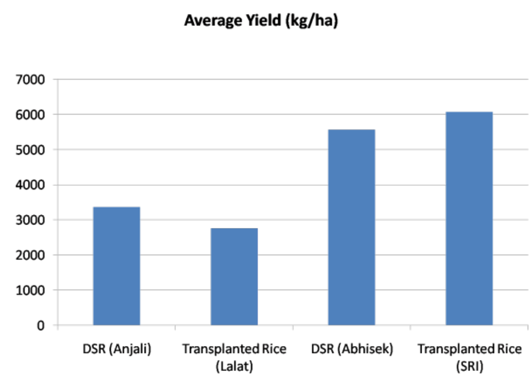
Results and Discussion

Data and results show that there is huge regional variation in annual rainfall, and the duration of ponding water in the paddy fields of medium uplands was much more variable than the rainfall itself. This makes transplanted paddy a risky crop in medium uplands because it requires ponding of water. Although ponding duration is variable, there is good soil moisture available every year which can support any crop that doesn't require ponding.





Under these circumstances Direct Seeded Rice (DSR) has huge potential as it doesn't require ponding, puddling and transplantation. The DSR interventions include: 1. Short/medium duration (90- 120 days) varieties; 2. Line planting with a furrow opener tool; 3. Weeding twice (first at 15-20 DAS, second 30-35 DAS) with dry-land weeder. The yields from the experiments are as below.



Rabi cropping opportunities based on residual water - no irrigation!

Prior kharif crop	Planting water (mm)		
	Mean	Min	Max
90-day crop:			
Transplanted rice	193	96	281
Un-bunded alternative	127	80	181
125-day crop:			
Transplanted rice	111	41	239
Un-bunded alternative	68	38	132

October rainfall (av. 37 mm) is a bonus

The DSR was harvested almost one month before the transplanted rice creating opportunity for early planting of Rabi crop. The DSR required 35 % less labour than transplanted rice which reduces women's drudgery and when implements arrive generally men use them, further reducing women's work.

There is a potential for use of seed cum fertilizer drill (VMP tiller) which will further increase the efficiency of DSR system and conserve the soil as it can sow seeds without ploughing. One such planter was brought from IDE Bangladesh and it is under trial.

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KEYNOTE PAPER

Policy and institutional arrangements for the promotion of conservation agriculture for small farmers in Asia and Africa

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Agriculture in Africa and Asia faces unprecedented challenges, among them population growth, energy scarcity, natural resource degradation, market globalization and climate change. Conservation agriculture (CA) can help address these challenges while enabling sustainable intensification of small farm systems. Policies and institutional arrangements, however, have a heavy influence on the pace of adoption and use of CA in Africa and Asia (Rai et al. 2011).

Relevant policies and institutional arrangements that affect the use of CA may be found at global, regional, national and local levels.

At the global level, the United Nations Millennium Goals (MDGs) present time-bound and quantified targets for tackling extreme poverty by 2015. CA should be developed in the context of these MDGs. At the regional level, some policies favor the use of CA. In 2003, for example, The New Partnership for Africa's Development (NEPAD) launched its Comprehensive African Agricultural Development Program (CAADP) and secured agreement from African governments to increase expenditures on agriculture from 2.4 to 10% by 2010. CAADP has developed a framework to involve key partners in spearheading the roll-out of CA in Africa.

At the other extreme, community- and landscape-level policies and institutions can also affect the feasibility of CA. Community-enforced arrangements for no burning of crop residues or for control and regulation of animal grazing can be critical to the success of CA.

It is at the national level, however, that the most compelling and influential policies and institutional arrangements are found that affect the use of CA, including those related to: environment and sustainable development; availability of equipment, inputs and credit; market development and market access; public-private sector relationships; smallholder access to land and water resources; access to information; investment in agricultural research and training; and cross-institutional coordination. Finally, there is the issue of gaps between policy formulation and approval on the one hand and practical implementation on the other.

Policies and institutions focusing on environment and sustainable development affect CA in many ways, for example: the presence of perverse incentives such as subsidies on tillage equipment or diesel fuel vs. positive incentives such as payments for environmental services to encourage CA practices. The national stance and policies towards climate change may also be relevant: where threats of climate change are taken seriously and CA is seen as an important mitigation strategy, powerful support for CA can be forthcoming.

Policies and institutions focusing on the availability of equipment, inputs and credit can also be important. Import tariffs can increase the price of imported CA equipment and discourage sharing of prototype equipment across regions, or at least spare parts for their repair and maintenance. Credit facilities, even micro-credit, may make all the difference in determining whether farmers or service providers can afford to purchase CA equipment. Seed sector policies may also be relevant if they encourage vs. discourage the development and dissemination of crop varieties suitable for use in CA systems. Policies on public-private sector relationships are important here. Equipment development has been found to go faster when in private sector hands, supported by public sector research.

When CA enables farm system intensification or diversification, availability and access to markets for an expanded product range may affect CA profitability. Similarly, when farmers enjoy secure access to land (land titling) and water resources, they are more likely to invest in resource conserving practices with a long-term time horizon, such as CA. Readily-accessible information on CA best practices will help farmers apply these practices wisely on their own fields.

Service providers can help farmers adopt CA practices when they cannot afford to buy tractors or CA equipment. Training service providers in CA also improves the likelihood that it will be introduced successfully. Use of farmer-to-farmer extension and promotion of farmer organizations to facilitate exchange of ideas and experiences can assist in accelerating adoption. CA is a complex technology that is best promoted in participatory mode with a network of stakeholders. Policies are needed to change the way research is carried out. Farmer and local manufacturer participation and experimentation at the farm field level is a key factor in fine tuning CA practices at the local level and accelerating adoption. All of these can be supported by appropriate policies and institutional arrangements.

The fragmented nature and variety of institutions involved in natural resource or sustainable land management (agriculture, forestry, national parks, energy, water, for example) in Africa and Asia often inhibit fully effective implementation of new technologies. Institutional coordination can lead to enhanced partnerships and harmonization of efforts to maximize the benefits of CA. Examples include Intra- and inter--ministerial coordination, partnerships between the private sector and civil society organizations and coordination between and with development partners. There are also weak institutional and training capacities of the various stakeholders to implement CA.

Finally, to enable CA to live up to its promise, countries must invest in local adaptation of CA principles. Research investment must be adequate. And, for the long term, this investment should include advanced training programs in CA leading to a cadre of trained scientists, engineers, extension workers and other network members able to assist and enable farmers to adopt eco-friendly technologies like CA.

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