2ND CONFERENCE ON CONSERVATION AGRICULTURE FOR SMALLHOLDERS (CASH-II)

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CONFERENCE PROCEEDINGS

Bangladesh Agricultural University, Mymensingh, Bangladesh

Proceedings of the
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Messages

Message from Chairman of the Organizing Committee on the 2nd Conference on Conservation Agriculture for Smallholders (CASH-II), 14-16 February, Mymensingh, Bangladesh

It is my pleasure to welcome all participants to the 2nd Conference on Conservation Agriculture for Smallholders. We expect 280 participants to gather from 14 to 16 February 2017 at the Bangladesh Agricultural University, in the city of Mymensingh, Bangladesh. During the conference, 55 scientific and research papers on conservation agriculture will be presented including four keynote papers. The aim of the conference is to consider advances made in developing and applying conservation agriculture for smallholder farmers in Bangladesh. The conference is organized by Murdoch University, Bangladesh Agricultural University, FAO, the Australian Centre for International Agricultural Research (ACIAR), Bangladesh Agricultural Research Council, Bangladesh Agricultural Research Institute, Bangladesh Rice Research Institute, CIMMYT, IRRI, and Hoque Corporation. We are grateful to ACIAR for support of much of the research being reported and for the conference itself.

Research over the last decade in Bangladesh has demonstrated that conservation agriculture practices could have a major role in overcoming scarcity of farm labour and rising costs of production through mechanization. While conservation agriculture covers 161 million hectares globally it has mostly been a system adopted by large farmers with heavy machinery. Only a small percentage of conservation agriculture is practiced in Asia and Africa. Bangladesh has been developing the elements of conservation agriculture for small farms for 20 years, but the adoption of full conservation agriculture on farms is just beginning to take off. In 2016, 1,500 ha were planted using minimum soil disturbance and crop residue retention. With lower costs of crop production, and the capacity to establish 2-3 times greater area of crops in the same time period, increased profits can be achieved by smallholder farmers. It is estimated that practicing conservation agriculture can bring an extra US$ 560/ha for smallholder farmers. This conference is timely so that researchers can understand what has been learnt to date on conservation agriculture for smallholder farmers, what bottlenecks exist to greater adoption and how to engage smallholder farmers, researchers, and the private sector in overcoming these bottlenecks.

Small scale mechanization is a key technology for implementing conservation agriculture in Bangladesh. Low cost machines which can be attached to 2-wheel tractors are needed for planting seeds in rows into soil with minimum soil disturbance while retaining standing crop residues. The Bangladesh-developed and manufactured Versatile Multi-crop Planter, whose development was supported by ACIAR, is now being manufactured by Hoque Corporation and sold through project support and through a loan programme by the National Bank Ltd.

One of the outcomes of the conference will be to strengthen partnerships between farmers, machinery manufacturers, farmer-network groups and researchers to speed up technology adoption and adaptation to different soils, climates and crop types. During the Conference scientists, will be mixing with innovative farmers and service providers and they will visit a field demonstration and a long-term experiment to observe conservation agriculture practices. The conference delegates will be developing a briefing note on conservation agriculture for policy makers and preparing a Declaration about the benefits of conservation agriculture and recommendations for further action in Bangladesh to advance the adoption of conservation agriculture by farmers. When 10 % of farmers in Bangladesh practice conservation agriculture, the national benefit will exceed US$72 million/year. I encourage the delegates to work towards this outcome.

Dr Richard W. Bell
Chair, Organizing Committee, CASH-II Conference
and Professor, Sustainable Land Management
Murdoch University, Australia

2ND CONFERENCE ON CONSERVATION AGRICULTURE FOR SMALLHOLDERS (CASH-II)
BANGLADESH AGRICULTURAL UNIVERSITY, MYMENSINGH, BANGLADESH
SYED NAZRUL ISLAM CONFERENCE HALL
14-16 FEBRUARY, 2017

DETAIL PROGRAM

13 February, 2017 (Monday)	
1830 hrs.	**Informal Interactions followed by Pre-Conference Dinner at the Community Centre, Bangladesh Agricultural University (BAU)**

14 February, 2017 (Tuesday)

0900-1000	**Registration at Syed Nazrul Islam Conference Hall, BAU**

INAUGURAL SESSION:

[in Syed Nazrul Islam Conference Hall]

Chair	Professor Dr Lutful Hassan, Chairman, Local Organizing Committee, CASH-II Conference
Chief Guest	Professor Dr Md. Ali Akbar, Honorable Vice Chancellor, BAU, Mymensingh
Special Guest	Professor Dr Md. Jashimuddin Khan, Pro Vice Chancellor, BAU, Mymensingh
Guests of Honor	Dr Akram Hossain Chowdhury, Chairman, Barind Multipurpose Development Authority
	Dr Mohammad Jalal Uddin, Executive Chairman, Bangladesh Agricultural Research Council (BARC)
	Mr. Md. Manzurul Hannan, Director General, Department of Agricultural Extension (DAE)
	Ms. Sally-Anne Vincent, Deputy High Commissioner, Australian High Commission, Dhaka, Bangladesh
	Dr Abul Kalam Azad, Director General, Bangladesh Agricultural Research Institute (BARI)
	Dr Bhagya Rani Banik, Director General, Bangladesh Rice Research Institute
	Dr Evan W. Christen, Program Manager, Australian Centre for International Agricultural Research (ACIAR), Australia
0955-1000	Guests will take their seats
1000-1005	Recitation from the holy Quran
1005-1010	Recitation from the holy Gita
1010-1015	Recitation from the holy Bible
1010-1055	Welcome address and Keynote Paper Presentation - Professor Dr Richard W. Bell, Murdoch University, Australia ***Conservation Agriculture and Mechanization for Smallholder Agriculture: A Win-win for Agriculture and the Environment***
1055-1150	Speech - Guests of Honor
1150-1200	Speech - Special Guest
1200-1215	Speech - Chief Guest
1215-1220	Vote of Thanks - Dr Md. Enamul Haque, Executive Secretary, CASH-II
1220-1230	Recognition Award and Closing Remarks - Session Chair
1230-1240	Group Photo Session
1240-1300	Conservation Agriculture (CA) Machineries Exhibition Opening Ceremony
1300-1400	Lunch at Community Centre, BAU

2ND CONFERENCE ON CONSERVATION AGRICULTURE FOR SMALLHOLDERS (CASH-II)
BANGLADESH AGRICULTURAL UNIVERSITY, MYMENSINGH, BANGLADESH
SYED NAZRUL ISLAM CONFERENCE HALL
14-16 FEBRUARY, 2017

DETAIL PROGRAM

TECHNICAL SESSIONS

14 February 2017 (Tuesday)

Session 1:	**Agronomy and Soils** [in Syed Nazrul Islam Conference Hall]		
Session Chair:	**Dr Evan W. Christen, Program Manager, ACIAR, Australia**		
Rapporteurs:	Prof Dr Md. Rafiqul Islam (2), Department of Soil Science, BAU, Mymensingh Prof Dr Md. Mokter Hossain, Department of Horticulture, BAU, Mymensingh		
Time	**Paper Title**	**Authors**	**Presenter**
1400-1415	Productivity of Triple Cereal System Shifted from Conventional to Conservation Agricultural Practice	M. Ataur Rahman, and M. A. Khaleque	M. Ataur Rahman
1415-1430	Strip Tillage with Residue Retention Increases Soil Organic Carbon, Nitrogen Requirement and System Productivity of a Rice-Wheat-Mungbean Cropping System	M. Jahiruddin, R. Hossain, M.R. Islam, M.A. Kader, M.E. Haque and R. Bell	M. Jahiruddin
1430-1445	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. Gathala	M. Ilias Hossain
1445-1500	Short to medium term effects of tillage and residues on cool dry season crops in a rice-based system of Bangladesh	M.A. Islam, R.W. Bell, C. Johansen, M. Jahiruddin, M.E. Haque	M.A. Islam
1500-1515	Development of a high yielding rice mutant for rainfed dry direct seeded culture in *Aus* season in Bangladesh	Md. Abul Kalam Azad and Md. Hasanuzzaman Rani	Md. Abul Kalam Azad
1515-1530	Nutrient management in relay mustard with T.*aman* rice under zero tillage condition at Ishwardi region of Bangladesh	M.A.K. Mian, J. Hossain, M.R. Islam, M.A. Aziz, M.N. Islam	M.A.K. Mian
1530-1545	Zero tillage planting with rice straw mulch can be a good practice for higher productivity of garlic and reducing CO_2 emission	M. A. Rahim and M. S. Alam	M. A. Rahim
1545-1615	Question, Answer and Open Discussion		
1615-1645	**Tea/Coffee break [in the Farm Machinery Exhibition Booth]**		

Session 2:	Posters Presentation [in Farm Machinery Exhibition Booth]		
Session Chair:	**Professor Dr Richard W. Bell, Murdoch University, Australia**		
Rapporteurs:	Prof Dr Mrityunjoy Biswas, Department of Agronomy and Haor Agriculture, Sylhet Agricultural University, Sylhet Prof Dr Asadul Haque, Patuakhali Science and Technology University, Patuakhali		
Time (1645-1745)	**Paper Title**	**Authors**	**Presenter**
2 minutes	Phosphorus and Zinc content in Aman rice and post-harvest soil	M.A. Hye, K.M. Mahbubur Rahman, P.P.Das, B.P.Ray, M.Mahiudin	M.A. Hye
2 minutes	Efficacy of botanical extracts on Weed management and productivity in rice-mustard-green gram crop sequence under alluvial soil of West Bengal	Debesh Pal, Sudeshna Das and Swapan Kumar Paul	Debesh Pal
2 minutes	Assessment of Fertilizer Requirement for Sweet gourd-Fallow- T. Aman Cropping Sequence in Saline Area	S. M. Shamsuzzaman, H. A. K. Chowdhury, S. M. Rasel and A. B. M. M. Hasan	S. M. Shamsuzzaman
2 minutes	Effect of different herbicides on weed infestation and yield in Boro rice (Binadhan-14)	M. S. Islam, M. M. Islam, M. H. Rahman and S. Khanam	M. S. Islam
2 minutes	Drought tolerance of Aus rice genotypes and irrigation methods on yield and water use	MH Ali	MH Ali
2 minutes	Increasing Crop productivity while Reducing Greenhouse Gas Emissions through Resource Conservation Technologies in Rice-Wheat-Mungbean Cropping System	Ilias Hossain, T.P. Tiwari, M. K. Gathala, M.R.I. Mondal and M.E.Haque	Ilias Hossain
2 minutes	Growth and Yield of Recently Release Wheat Varieties under Raised Bed System in Drought Prone Areas	Ilias Hossain, M. R. I. Mondal, M. J. Islam and M. E. Haque	Ilias Hossain
2 minutes	Effect of herbicides on weeds and crop performance of wheat in northwest Bangladesh	J. Hossain, M. A. Islam, M.R. Islam and M.A.K. Mian	J. Hossain
2 minutes	Effect of strip tillage, residue mulching and weeding regimes on yield performance of T. *aman* rice	M.M. Hossain, M. Begum, M.M. Rahman, A. Hashem, R.W. Bell and M.E. Haque	M.M. Hossain
2 minutes	Improving winter crop yield through no-till agronomy and summer weed management	Mohammad Amjad and Abul Hashem	Mohammad Amjad
2 minutes	Changes in Soil Organic Matter, Plant Nutrients and System Productivity under Conservation Agricultural Practices in the Rice-Jute Cropping System	N. Salahin, M. Jahiruddin, M.R. Islam, R.W. Bell, M.E. Haque and M.K. Alam	N. Salahin
2 minutes	Adoption Offline Fertilizer Recommendation Among Smallholders Farmers Through Mobile Apps	Md. Safiqul Moula and Rafeza Begum	Md. Safiqul Moula

2 minutes	Broadleaved Weed Management in Wheat with Post-emergence Herbicides under strip tillage system	T. Zahan, M.M. Rahman, M. Begum, R.W. Bell and A.S.M.M.R. Khan	T. Zahan
2 minutes	Mechanical Weed Control by Versatile Multi-crop Planter in Strip-planted Wheat	M.E. Haque, R.W. Bell, R.K. Menon, M.M. Hossain	M.E. Haque
2 minutes	Transplanting Rice Seedling in Dry Strip-tilled Soil: A Strategy to Minimize Soil Disturbance during Non-puddled Transplanting	M.E. Haque, R.W. Bell, M.M. Hossain and R.K. Menon	M.E. Haque
2 minutes	Mulching and weed management effects on performance of non-puddled transplanted rice (Oryza sativa L.)	M.M. Hossain, M. Begum, A. Hashem, M.M. Rahman, R.W. Bell, M.E. Haque	M.M. Hossain
2 minutes	Yield Improvement of Non-Puddled Transplanted *Aman* Rice as Influenced by Effective Weed Control under Conservation Agricultural Systems	Taslima Zahan, Md. Moshiur Rahman, Richard W. Bell, Mahfuza Begum and M.E. Haque	Taslima Zahan
2 minutes	Chickpea Emergence Responses to Compaction by 2-Wheel Tractor in Two Soils of Northwest Bangladesh	M.N.H. Mahmud, R. W. Bell and W. Vance	M.N.H. Mahmud
2 minutes	Non-puddling practice for rice-based cropping system increases carbon sequestration in soil	Md. Khairul Alam, Richard W. Bell and M.A. Kader	Md. Khairul Alam
2 minutes	Non-puddled transplanting of rice reduces life cycle greenhouse gas emission	Md. Khairul Alam, Richard W. Bell, Wahidul K. Biswas	Md. Khairul Alam
2 minutes	Performance of Boro rice to weeding regimes and crop residues under strip tillage system	M.M. Hossain, M. Begum, A. Hashem, M.M. Rahman, R.W. Bell and M.E. Haque	M.M. Hossain
2 minutes	Short-term Effects of Tillage and Water Management on Soil Aggregate Size Distribution and Stability in Subtropical Rice Cultivation	M.Z. Alam, A. Bakr and M.M.R. Jahangir	M.M.R. Jahangir
2 minutes	Performance of wheat varieties as relay crop in the transplanted aman rice field under Rice-Wheat system	Dr Md. Abdul Khaleque and Dr Md. Mustafa Khan	Md. Dr Abdul Khaleque
2 minutes	Effect of Row Spacing, Nitrogen and Weed Control on Crop and Weed in Low Rainfall Zones of Western Australia	A. Hashem, W. Vance, R. Brennan and R. W. Bell	A. Hashem
2 minutes	Screening of promising biofortified short duration lentil cultivars for conservation agriculture in North-west Bangladesh	Alam M.S., Islam M. A, Begum M; Kader M. A., Sarker A., and Haque M.E.	MS Alam
30 minutes	Questions, Answers and Open Discussion		
1830-2100	**Informal Interactions followed by Dinner at Community Centre, Bangladesh Agricultural University**		

15 February 2017 (Wednesday)

Session 3: NARS and CGIAR Programs of Conservation Agriculture
[in Syed Nazrul Islam Conference Hall]

Session Chair: **Dr Md. Aziz Zillani Chowdhury, Member Director (Crops), BARC, Dhaka**

Rapporteurs: Prof Dr Md. Zakir Hossen, Department of Agricultural Chemistry, BAU, Mymensingh
Dr Tamanna Haque, Department of Horticulture, BAU, Mymensingh

Time	Paper Title	Authors	Presenter
0900-0930	***Keynote paper:*** Climate Smart Agriculture in Intensive Cereal Based Systems: Scalable Evidence from Indo-Gangetic Plains of South Asia	M.L. Jat	M.L. Jat
0930-0945	BRRI - Status Paper on CA (Past, Present and Future)		
0945-1000	Present status and prospect of conservation agriculture based tillage technology for crop production in Bangladesh	M. Lufur Rahman, M. Israil Hossain, and M. Ayub Hossain	M. Lufur Rahman
1000-1015	Sustainable and resilient farming system intensification in Easter Indo-Gangatic Plains	M.K. Ghatala	M.K. Ghatala
1015-1030	Question, Answer and Open Discussion		
1030-1045	Tea/Coffee Break		

Session 4: Weed Management in Conservation Agriculture
[in Syed Nazrul Islam Conference Hall]

Session Chair: **Prof. Dr. Md. Moshiur Rahman, Department of Agronomy, BAU, Mymensingh**

Rapporteurs: Dr. Md. Omar Ali, PSO, Pulses Research Centre, BARI, Joydebpur, Gazipur
Dr. Md. Harunur Rashid, PSO, BARC, Dhaka

Time	Paper Title	Authors	Presenter
1045-1115	**Keynote Paper:** Weed Management is an Integral Part of Agronomy and Soil Management in Conservation Agriculture	A. Hashem	A. Hashem
1115-1130	Weed seed bank dynamics in long term trials of conservation agriculture	M.M. Hossain, M. Begum, M.M. Rahman, A. Hashem, R.W. Bell and M.E. Haque	M.M. Hossain
1130-1145	Tolerance of rice varieties to higher rates of two post-emergence herbicides under strip tilled non-puddle transplanted establishment	M.M. Rahman and T. Zahan	M.M. Rahman
1145-1200	Growth and Yield Response of Transplanted *Aman* Rice Varieties to Herbicides in Strip Tilled unpuddled Soil	T. Zahan, M.M. Rahman, A. Hashem and M. E. Haque	T. Zahan
1200-1215	Adoption of Raised Bed Technologies with Heat & Drought Tolerant Wheat Varieties in Drought Prone Areas: A Miracle Success in Bangladesh	M. Ilias Hossain, M.R.I. Mandal, M.N.A. Siddique, M.J. Islam and M.E. Haque	M. Ilias Hossain
1215-1230	Reduced Tillage and Mechanized Transplanting of Rice Enhances the System	M.H. Rashid, P.C. Goswami, B.J. Shirazy	M.H. Rashid

	Productivity of Rice-Mustard-Rice Cropping Sequence		
1230-1300	Question, Answer and Open Discussion		
1300-1400	Lunch at Community Centre, BAU		

Session 5: Research, Development, and Commercialization of Conservation Agriculture Machineries

[in Syed Nazrul Islam Conference Hall]

Session Chair: **Professor Dr. Monjurul Alam, Director, BAURES, BAU, Mymensingh**

Rapporteurs: Professor Dr. Md. Abdus Salam, Dept. of Agronomy, BAU, Mymensingh
Professor Dr. Gopal Das, Dept. of Entomology, BAU, Mymensingh

Time	Paper Title	Authors	Presenter
1400-1415	Development and Validation of Unpuddled Riding-type Rice Transplanter for Wetland Rice Establishment	M.A. Hossen, M.M. Hossain, R.W. Bell, M.E. Haque, and M.A. Rahman	M.A. Hossen
1415-1430	Performance of Versatile Multi-Crop Planter	M.E. Haque and R.W. Bell	M.E. Haque
1430-1445	Comparative Levels of Soil Disturbance Under Reduced and Minimum Tillage Types with Two-wheel Tractor Planting Operations	M.E. Haque, RW Bell, RK Menon, NN Mia and M.M. Hossain	M.E. Haque
1445-1500	Effect of Minimum Tillage Systems on Water Balance for Rice-Based Rotations in Northwest Bangladesh	M.N.H. Mahmud, R.W. Bell, W. Vance, and M.E. Haque	M.N.H. Mahmud
1500-1515	Commercialization Approach for Versatile Multi-Crop Planter: Lessons Learnt	M.E. Haque, R.W. Bell, R.K. Menon, M.M. Hoque, M.M. Hossain, MA Rahman, M.I. Hossain, A.H. Chowdhury, and M.A.H. Mortuza	M.M. Hoque
1515-1530	Impact of versatile multi-crop planter on service providers' livelihood at farm level in some selected areas of Bangladesh	M.A. Monayem Miah, M.A. Rashid, M.E. Haque and R.W. Bell	M.A. Monayem Miah
1530-1600	Question, Answer and Open Discussion		
1600-1630	Tea/Coffee Break		
1630-1745	**Field Visit at BAU Soil Science Farm**		
1830-2100	Bangladesh Night (Cultural Event) followed by Conference Dinner at the Community Centre, BAU, Mymensingh		

16 February 2017 (Thursday)

Session 6: Rice Establishment Technology for Conservation Agriculture

[in Syed Nazrul Islam Conference Hall]

Session Chair: **Dr. Ansar Ali, Director Research, BRRI, Gazipur**

Rapporteurs: Dr. Md. Abdur Rahman, Chief Scientific Officer, FMPHT Division, BRRI, Gazipur
Dr. Md. Ilias Hossain, PSO and Station In charge, RWRC, BARI, Rajshahi

0900-0930	**Keynote paper**: Minimum Tillage Non-puddled Transplanting of Rice: An Overview	R.W. Bell and M.E. Haque	R.W. Bell
0930-0945	On-farm non-puddled rice yield response to crop residue retention	M. Begum, M.M. Hossain, M.M. Rahman, A. Hashem, R.W. Bell and M.E. Haque	M. Begum

0945-1000	Effect of Seed Rate and Basal N Management Options in Dry Seeded Aman Rice under Zero Tillage Condition	M.H. Rashid, J. Timsina, M.S. Kabir	M.H. Rashid
1000-1015	Conservation Tillage and Crop Residue Retention under Dry Seeded Rice-Maize-Mungbean System Affected Bulk Density and Soil Organic Matter	M.H. Rashid, J. Timsina, N. Islam, M.A. Ali, M.R. Islam	M.H. Rashid
1015-1030	On-farm Performance of Non-puddled Boro and Aman Season Rice	M.E. Haque, R.W. Bell, and R.K. Menon	M.E. Haque
1030-1045	Evaluating the Performance of Water Conserving Technologies in Rice Cultivation to Mitigate Greenhouse Gas Emission	M. Akter, M.A. Kader, S. Pierreux, P. Boeckx, A.M. Kamal and S. Sleutel	M. Akter
1045-1115	Question, Answer and Open Discussion		
1115-1145	Tea/Coffee Break		

Session 7: Plenary Session: Recommendation and Road Map for Future Conservation Agriculture in Bangladesh

[in Syed Nazrul Islam Conference Hall]

Session Chair:	**Dr. Richard W. Bell, Professor, Murdoch University, Australia**
Rapporteurs:	Prof. Dr. A. Kader, Department of Soil Science, BAU, Mymensingh Md. Anwar Hossen, SSO, FMPHT Division, BRRI, Gazipur
Time	**Panelists**
1145-1245	– Prof Dr Md. Jahiruddin, BAU, Mymensingh – Dr Md. Sultan Ahmed, BARC, Dhaka – Mr. Md. Nuruzzaman, Director (Crops Wing), Director Field Crops, DAE – Dr MA Razzaque, KGF, Dhaka, Bangladesh – Ms. Sue Lautze, FAO Representative in Bangladesh – Dr Craig A Meisner, Ex-CIMMYT Scientist, Dhaka – Dr Md. Lutfur Rahman, Director of Research, BARI, Gazipur – Dr Md. Ansar Ali, Director of Research, BRRI, Gazipur – Dr Abul Hashem, DAFWA, Australia – Dr Evan Christen, ACIAR, Australia – Dr Ross Brennan, DAFWA, Australia – Prof Dr Lutful Hassan, BAU, Mymensingh – Prof Mosharraf Hossain, Department of Farm Power and Machinery, BAU, Mymensingh
1245-1300	**Concluding Remarks:** Prof. Dr. Lutful Hassan, Chairman, Local Organizing Committee, CASH-II Prof. Dr. Richard W. Bell, Chairman, Program Committee, CASH-II
1300-1400	Concluding lunch at the Community Centre, Bangladesh Agricultural University

Oral and Poster Papers

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Inaugural Session

Session 1

Agronomy and Soils

Session 3

NARS and CGIAR Programs of Conservation Agriculture

Session 4
Weed Management in Conservation Agriculture

Session 5
Research, Development and Commercialization of Conservation Agriculture Machineries

INAUGURAL SESSION

KEYNOTE PAPER

Conservation agriculture and mechanization for smallholder agriculture: A win-win for agriculture and the environment

R.W. Bell[1]* and M.E. Haque[2]

[1]School of Veterinary and Life Science, Murdoch University, WA 6150, Australia; [2]Project Implementation Office-Murdoch University, Uttara, Bangladesh

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Conservation agriculture (CA) is now practiced on over 157 million hectares worldwide but adoption is still limited in smallholder farms of Asia and Africa. The practice of CA involves crop production with minimum soil disturbance, soil cover with crop residue or mulch and rotation of diverse crops. Research in Bangladesh demonstrates the benefits of CA for smallholders: yields are maintained or increased; crop production costs are reduced; savings of fuel; savings of labour, and; more timely sowing of crops. In addition, the benefits for the environment include: decreased greenhouse gas emissions, and increased soil organic carbon. Development of CA in rice-based cropping systems is under way in Bangladesh and the Eastern Gangetic plain. A prerequisite for a system-based CA is to use minimum soil disturbance for rice. Transplanting of rice into non-puddled soil with minimum soil disturbance is feasible by strip tillage followed by inundation to soften the soil in the strip. The Non-puddled transplanting was reliably able to produce as much grain yield as the conventional tilled and puddled soils. Moreover, with continuation of minimum soil disturbance by strip planting methods, the yield of both aman and boro rice crops equal or exceed those of the conventional puddling and transplanting of rice. With mechanised transplanting, the grain yield was similar between non-puddled soil with minimal disturbance and conventional soil puddling for rice establishment. We conclude that changing to transplanting in non-puddled soil with minimal disturbance represents minimal risk of yield loss for rice producers while providing labour, fuel and water savings. Ongoing studies are examining the water balance in rice fields after the adoption of CA practices in rice as well as the other crops in the rotation. The accumulation of increased soil organic carbon takes 2-3 years after adoption CA to be measurable in soil in 3-crop per year rotations. Shortages of labour and intensive crop production (cropping intensity in Bangladesh is 190 %) are driving interest among farmers in small-scale mechanization of planting based around the Chinese-made two-wheel tractor (2WT; 12-15 horsepower). A number of planters, attached to the 2WT, are available in Bangladesh for sowing seeds with minimum soil disturbance. In the present project, the Versatile Multi-crop Planter (VMP) has been designed and extensively tested on a range of soils and crop species, with many design and performance improvements over time. At this stage strip planting (rotating blades till a strip 5-8 cm wide for planting seeds and placing fertiliser but < 25 % of the soil is disturbed) is

favoured over tyne or disk openers. Agronomic practices for mechanised seeding are under development including systems for effective weed control. Integrated weed control involves the use of herbicides, retained crop residue and row planting to suppress and optimise control of weeds. Further challenges are to develop a supply chain for planters and planting services. Commercialisation plans for scaling out the use of planters for CA involve demand creation among farmers and then support to local service providers (LSP) and manufacturers to develop profitable business models. High level dialogue is required to create an enabling policy environment in which the private sector can promote CA and small-scale mechanization so that benefit to farmers and the environment can be realised.

Session 1

AGRONOMY AND SOILS

Productivity of triple cereal system shifted from conventional to conservation agricultural practice

M. Ataur Rahman* and M. A. Khaleque

Regional Wheat Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.*Corresponding author: Email: ataur67@yahoo.com

Introduction

Triple cereal cropping is important because it can produce more food and feed where arable land is scarce and where food demand is increasing, as in Bangladesh. The triple cereal system with HYV rice and wheat, and hybrid maize under conventional practices of crop residue removal and tillage may lead exhaustion of nutrients and a decline in productivity. Before adoption and up-scaling of the system, it is important to assess the conservation agricultural practices (CA) to arrest productivity decline. The major concepts of CA are the minimum disturbance of soil and maintaining crop residue in the field which improves soil quality preventing erosion and nutrient leaching (Erenstien 2002). This can improve system productivity (Wall, *et al.* 2010). Also, crop residue retention contributes to productivity by conserving residual moisture (Sharma and Acharya 2000), controlling weeds and improving N use efficiency (Rahman et al., 2005). However, most of CA is from either single or double cropping systems. The present experiment was under taken to evaluate the CA practices in improving the productivity in wheat, maize and rice cropping systems. Another objective was to study the changes in soil fertility due to shifting the agricultural practices from conventional to conservation.

Materials and methods

The field experiment was initiated at BARI, Gazipur starting with wheat crop in 2010-11. Four levels of conventional and conservation practices were imposed on the component crops in wheat-maize-rice cropping system in randomly complete block design. The treatments were: T_1 = Conventional practice consisting broadcasting wheat seeds on well tilled soil followed by line sown maize then puddle transplanted (PTP) aman rice, all with full tillage; T_2 = Conservation practice, consist of wheat sown by single pass of PTOS (Power tiller operated seeder) with standing rice straw (20-25 cm) followed by no-till maize in plot with standing wheat straw of about 25 cm height and then PTP rice; T_3 = Bed Planting of wheat using power tiller operated bed planter followed by no till maize then PTP rice without straw retention; T_4 = Conservation practice in bed planting was similar to T_3, but included standing rice and wheat straw retention as in T_2. The crop varieties of BARI GOM 26, BARI hybrid Maize-7 and BINA Dhan 7 were introduced as the first, second and third crop, respectively, in the system. The recommended rates of fertilizers for wheat ($N_{120}P_{30}K_{50}S_{20}B_1$), maize ($N_{200}P_{50}K_{80}S_{40}Zn_5B_2$) and rice ($N_{80}P_{30}K_{50}S_{20}$) were applied manually for all the plots. All intercultural operations were done duly. At maturity, the crops samples were harvested and threshed, grains were sun dried and then moisture content of grain samples were measured to converted grain yields (t ha^{-1}) at 12% moisture content for wheat and maize, and 14% moisture for rice. All the data were statistically analyzed and the mean values were tested by the least significant difference (LSD) at 5% level of significance.

Results and Discussions

The initial soil analysis report indicated that experimental field was deficient in organic matter (OM), total N and most of the nutrients. The changes in soil fertility in such a soil due to

intensive triple cereal cropping system is presented in table 1. Soil OM did not decline in the triple cereals cropping over 5 years, but improved under CA (T_2 and T_4) compare to conventional practices (T_1 and T_3). Total N, available K and P content were slightly reduced in convention practices with years but the availability of all those nutrients were improved in soils under CA practices. The result indicated that the intensive wheat-maize-rice cropping system under conservation practice of reduced tillage with crop residue retention did not caused decline in soil fertility. Furthermore, CA practices positively contributed to soil fertility. After five cropping cycles, OM and most of the nutrients contents in soil were almost similar under the conventional tillage and bed planting without crop residue retention. Crop residue retention resulted in improved stocks of nutrients in the soil and less tillage or no-tillage practices in such a soil resulted slower decomposition of residues, thus soil OM and nutrient contents in soil were appear to have been improved under CA and Bed + CA treatments.

Most of the yield components of crops, especially spikes/m^2 in wheat and cobs/m^2 for maize, were significantly improved by CA treatments thus yield of wheat and maize was higher under CA treatments (T_2 and T_4, data not shown) compare to conventional practices (T_1 and T_3) from the initial year (Table 2). In conventional practice, wheat seed was broadcasted on well tilled soil followed by plough and laddering thus the seeding depth, seed distribution, germination and stand establishment were affected producing the least spikes/m^2 at harvest that resulted in least yield of wheat under conventional practices. Use of a seeder or bed planter ensures seed improved placement at desired soil depth (3-5cm), which appears to result in better germination. Furthermore, the retention of straw in the soil is likely to have influenced the hydraulic properties of the soil, resulting in an improved crop stand and more spikes/m^2 in wheat and cobs/m^2 in maize over five years. Conservation practice can reduce evaporation from the soil (Sharma and Acharya 2000), and helps to mediate soil temperatures so that they are more suitable for germination and stand establishment (Erenstien, 2002). CA practices contributed to the yield of upland wheat and maize crop by conserving soil moisture and indirectly by influencing crop growth factors and contributing soil nutrient contents. As the rice crop was cultivated under the saturated to submerge soil conditions; the direct effect of CA treatments on soil moisture content was not applicable in rice and thus different CA treatments had statistically similar effect on rice yield until the 2nd year. The benefit of CA practices in improving rice yield was noticed in 3rd cropping cycle, with statistical differences observed from the 4th cropping cycle.

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Table 1. Effect of CA treatments on OM (%) and nutrient content in surface soil (0-15 cm) over the years

Treatment	OM (%)			Total N (%)			P (µg/g)			K (meq/100g)		
	2011	2013	2015	2011	2013	2015	2011	2013	2015	2011	2013	2015
T_1	0.91	0.88	0.93	0.071	0.066	0.074	11.2	10.6	12.3	0.11	0.104	0.106
T_2	0.91	1.04	1.25	0.071	0.072	0.089	11.2	12.8	18.7	0.11	0.126	0.142
T_3	0.91	1.02	0.97	0.071	0.067	0.077	11.2	10.9	16.4	0.11	0.114	0.107
T_4	0.91	1.12	1.34	0.071	0.076	0.093	11.2	13.1	19.6	0.11	0.132	0.148
$LSD_{.05}$	-	0.13	0.14	-	0.008	0.01	-	1.30	2.5	-	0.013	0.011
CV (%)	-	9.8	7.6	-	8.7	8.1	-	9.4	7.9	-	8.4	11.2

Table 2. Grain Yield (t ha^{-1}) of component crops in Wheat-Maize-Rice Cropping System under conservation practices over the years

Treatment	Wheat					Maize				Rice			
	2011	2012	2013	2014	2015	2011	2012	2013	2014	2011	2012	2013	2014
T_1	3.15	3.51	3.83	3.92	4.21	5.78	4.74	6.84	5.88	4.28	4.48	4.80	5.42
T_2	4.35	4.38	5.85	5.18	4.91	6.76	7.15	8.05	6.74	4.35	4.65	5.12	5.83
T_3	4.22	4.04	4.54	4.38	4.93	6.02	5.67	6.65	5.56	4.02	4.32	4.67	5.26
T_4	4.48	4.55	5.56	5.05	5.57	6.60	6.86	7.88	6.38	4.24	4.84	5.15	5.90
$LSD_{.05}$	0.38	0.35	0.47	0.41	0.52	0.55	0.61	0.70	0.55	NS	NS	NS	0.41
CV (%)	7.8	8.5	7.6	9.2	8.3	10.3	9.8	8.4	8.5	10.2	9.4	9.2	8.2

Strip tillage with residue retention increases soil organic carbon, nitrogen requirement and system productivity of a rice-wheat-mungbean cropping system

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Introduction

Effects of conservation agriculture (CA) on crop yield may be positive or negative (Pittelkow et al., 2015) depending upon the crop species, growing e nvironment, and the duration and extent of the CA system. CA involves use of minimum tillage, stubble retention and Minimum tillage can slow down the residue decomposition and reduce the release of mineral forms of nitrogen (N) (Hobbs et al., 2008). Hence, N in the system might be less available under minimum tillage, at least in the initial years. However, no data are yet available to assess the requirement of N fertilizer under CA in the rice-based cropping systems. Lundy et al. (2015) found in the tropical and subtropical regions that decreased yield with the implementation of minimum tillage was sensitive to the rate of N fertilization. Thus, the present study was undertaken to determine the effect of strip tillage with increased residue retention on system productivity, soil organic matter and N requirement in a rice-wheat-mungbean cropping system.

Materials and methods

The experiment was done on an Aeric Haplaquept soil type located at the Bangladesh Agricultural University (BAU) farm that is part of the Old Brahmaputra Floodplain agro-ecological zone. The tillage systems were strip and conventional tillage, the residue levels were the current practice (20% of cereal residue retained) and increased retention (40% of cereal residue retained) and the N rates were 60, 80, 100, 120 & 140 % of recommended fertilizer dose (RDF). The 100% N rate was 70, 100 and 20 kg N ha^{-1} for rice, wheat and mungbean, respectively. All plots received a recommended rate of P, K, S, Zn & B. The grain/seed yields were reported at 14% moisture basis. The yields are expressed as rice equivalent yield over four cycles during 2012-2016. Soil organic carbon (SOC) and soil N contents were analysed after harvest of the 8^{th} crop (wheat).

Results and Discussion

Strip tillage produced significantly higher system productivity (T. aman rice-wheat-mungbean) in all years (Table 1). Increased residue retention increased system productivity only in the 4th year which may indicate a cumulative effect of residue retention. System productivity increased as the rate of N application increased, showing an optimum rice equivalent yield at 100 – 120 % RFD. However, there was no significant interaction between tillage × N and residue × N rate on the parameters studied. After 4 years, there was no evidence that the N requirement for crops changed under CA. Soil organic carbon and Soil N content increased under strip tillage, particularly at 0-5cm soil depth, but not at 5-15 cm depth. These two soil properties did not vary significantly with residue levels and N treatments. The higher S OC content in strip Tillage might be due to slower decomposition of residues.

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Table 1. Effects of tillage systems, residue levels and N rates on system productivity, SOC and N content in the rice-wheat-mungbean cropping system

Factors	System productivity (Rice equivalent yield, $t^{-1}ha^{-1}yr^{-1}$)[A]				SOC (%)		Total N (%)	
	2012-13	2013-14	2014-15	2015-16	0-5 cm	5-15 cm	0-5 cm	5-15 cm
Tillage systems								
Conventional	11.1b	10.0b	9.57b	11.0 b	1.58 b	1.50	0.150 b	0.137
Strip	12.3a	11.2a	10.6a	13.0 a	1.83 a	1.45	0.164 a	0.131
Significance	*	*	*	**	**	NS	**	NS
Residue levels								
Current	11.4	10.2	10.0	11.4b	1.68	1.46	0.153	0.133
Increased	12.0	10.9	10.3	12.6a	1.73	1.48	0.161	0.136
Significance	NS	NS	NS	*	NS	NS	NS	NS
N rates								
60% RFD	8.9 c	9.0c	8.3 c	9.5 d	1.59	1.41	0.146	0.127
80% RFD	11.3b	10.2 b	9.6b	10.9 c	1.68	1.47	0.160	0.130
100% RFD	12.4a	10.6 a	10.1a	12.2 b	1.85	1.57	0.161	0.136
120% RFD	13.3a	11.3a	10.8a	13.0 a	1.73	1.45	0.161	0.136
140% RFD	12.5a	11.3a	11.0a	14.2a	1.68	1.46	0.158	0.141
Significance	**	**	**	**	NS	NS	NS	NS

RFD = Recommended fertilizer dose; *, P < 0.05, **, P < 0.01, NS = Not significant; In a column, values having same letter do not differ significantly at p<0.05 by DMRT.
Interactions: Tillage x Nitrogen = NS, Residue x Nitrogen = NS
[A]Rice equivalent yield was calculated as total crop (grain & seed) yields of a year converted

Improving soil and crop productivity through resource conservation technologies in drought prone area

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Introduction

Resource conserving technologies (RCTs) enhance input use efficiency and provide immediate identifiable and demonstrate economic benefits such as reduction of production costs, savings in water, fuel and labor requirements and timely establishment of crops resulting in improve yields. 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). Wheat is then planted in structurally disturbed soils, often after many tillage operations to prepare the seedbed. Growing crops on the raised beds offers more effective control of irrigation water and drainage management. Permanent raised beds might offer significant advantages for crop yields and be further increased by using residue retention (Sayre *et al*. 2005). Yields of rice and wheat in heat and water-stressed environments can be raised significantly by adopting RCTs, which minimize unfavorable environmental impacts, especially in small and medium-scale farms. Inclusion of grain legumes in rice-wheat cropping system may be another option for increasing cropping intensity, soil fertility and productivity. Limon-Ortega *et al*. (2000) observed that permanent beds with straw retention had the highest wheat grain yields with positive implications for soil health. Thus, crop residue management along raised bed strategies, are likely to be key components of increase crop productivity and soil fertility in rice-wheat system.

Materials and methods

A wheat-mungbean-rice cropping pattern was implemented over 12 years, starting with wheat sown in November 25, 2004 at the Regional Wheat Research Centre, 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 850 mm mean annual rainfall, about 97% of which occurs from May to September is drought prone area. Soil at the experimental site is a calcareous silty loam with slightly alkalinity (pH 7.5), low organic matter (0.8%) and low N (35 µ/g soil). The experiments consisted of 12 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) with three replications. 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).

Results and Discussions

Total system productivity (TSP)

System yields on PRB consistently increased as SR increased from 0% to 30%, but the differences between 0% and 30% SR were always significant for all three crops. TSP increased about 10-12% for all crops in 30% straw retention with permanent bed planting system over conventional (Fig. 1). TSP of rice, wheat and mungbean (R-W-M) was 12 t ha^{-1} per year. Yields tended to be lower in lower levels of straw retention for all crops. Lower system

productivity also occurred from 0% SR with CTP due to reduced crop growth. Similar observations were made by Singh *et al.,* (2003) in Mexico.

Environmental impact

RCTs perform better with minimum disturbance of soil. Soil erosion was comparatively less compare to conventional method. 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

Soil organic matter (SOM)

After 12 years (2004 to 2015), increased organic matter by 0.78% (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 both rice and wheat straw and full residue retention from mungbean crops. Increase in soil organic C with 30% SR at 50-150% N was almost double that with 0% N. Kumar and Goh (2000) reported that, in the longer term, residues and untilled roots from crops can contribute to the formation of SOM. It is clear that further increases in the productivity of the RW system will depend on proper management of residue.

Conclusions

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 with increase microbial activities. Compared with all treatments, the raised bed system with residue retained appears to be a very promising technology for sustainable intensification of RW systems in Bangladesh

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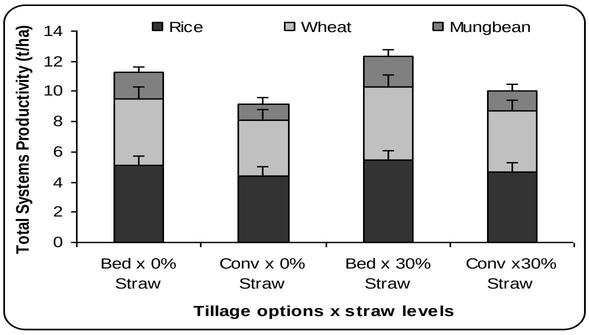

Figure 1: TSP under tillage options & straw levels

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 12 years crop cycles

Characteristics	Initial	Final	Difference
Organic Matter (%)	0.90	1.62	+ 0.78
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 12 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

Short to medium term effects of tillage and residues on cool dry season crops in a rice-based system of Bangladesh

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Introduction

The densely-populated region of the Eastern Indo-Gangetic Plain relies on rice-based cropping systems. However, the sustainability of the system under conventional cultivation is jeopardized by soil and water resource degradation, and increasing scarcity and cost of inputs (Gathala et al., 2011). In rice-dryland crop systems, rice is grown in puddled and submerged soil while the dryland crop is grown after rice with intensive tillage and limited residue retention. Although puddling is beneficial for establishing rice by transplanting, it can harmful for the next dryland crop (Gathala et al., 2011). Conservation agriculture (CA), comprising minimum soil disturbance along with increased residue retention and suitable crop rotation may hold the key to address these problems (Johansen et al., 2012). Conservation agriculture practices are emerging but there is still limited understanding on dryland crop performance in rice-based systems of Bangladesh. This paper focuses on the effects of CA on grain yields of cool dry season crops over three years in a rice-based system.

Material and methods

A field study was conducted from 2010 to 2013 on rice-based systems at two different agro-ecological zones and soil types (Alluvial area—24°28´ N, 88°46´ E and High Barind Tract—24°31´ N, 88°22´ E) in Northwest Bangladesh. The crop rotation was lentil (*Lens culinaris* Medik.) or wheat (*Triticum aestivum* L.)-mung bean (*Vigna mungo* L.)-transplanted rice (*Oryza sativa* L.). Cool dry season (rabi) crops in the rotation: lentil or wheat. Three types of tillage (strip tillage - ST, bed planting - BP and conventional tillage - CT) in the main plot and two residue levels — high residue (HR - 50 % of previous cereal crop residue and 100 % of legume residue); low residue (LR - 20 % of previous cereal crop residue and 0 % of legume residue but root dry matter was retained in soil) in the sub-plot, replicated four times in a split-plot design. The ST and BP (made by versatile multi-crop planter) were implemented for non-rice crops followed by unpuddled rice cultivation while conventional tillage (CT) was implemented for non-rice crops followed by puddled (wet tillage) rice cultivation. Experimental details and results for the mung bean in the early wet season and transplanted rice in the main wet season are presented elsewhere (Islam, 2016).

Results and discussion

Although yield of lentil at Alipur was lower in BP than CT in Year 1, by the third season it was higher by 23 % in ST and 18 % in BP, compared to CT (Figure 1a and c). The positive effect of HR over LR was apparent by Year 2 (Figure 1b). At Digram, no treatment effects were apparent for wheat yield in Year 1 and yield was lower with BP in Year 2 due to to poor crop establishment and a lower plant population as a result of lack of experience of the machine operator in seeding on beds with residue (Figure 1d, e). Marginal yield increases by 9 % in ST and 7 % in BP over CT, and of HR (3 %) over LR, could be detected by the Year 3 (Figure 1f).

Conclusion

Although there were some operational problems in implementing conservation agriculture techniques initially (e.g. improper seed placement in strip with residue impaired seed-soil contact), yields of both lentil and wheat were comparable between ST and CT in the first two years. By the third year, the yield advantage of both ST and BP over CT; and HR over LR, had become apparent, suggesting the feasibility of adopting CA practices in these rice-based cropping systems. However, further studies are required over a longer time period under different soil, climatic, and socio-economic conditions in the eastern Indo-Gangetic Plain.

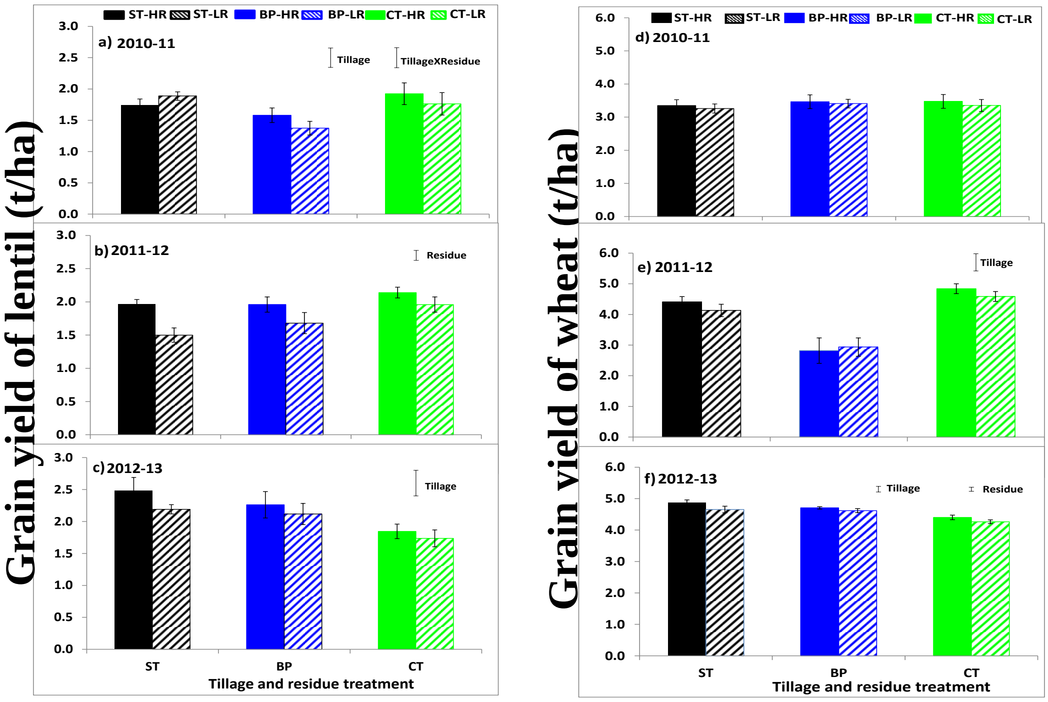

Figure 1. Effects of tillage and residue retention on grain yield of lentil (Figure a-c) at Alipur and wheat (Figure d–f) at Digram over three growing seasons. ST — strip tillage, BP — bed planting, CT — conventional tillage; HR — high residue, LR — low residue. Values are means of four replicates ± standard error of mean and the floating error bar on each figure represents the least significant difference (LSD) for significant effects at P≤0.05.

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Development of a high yielding rice mutant for rainfed dry direct seeded culture in *Aus* season in Bangladesh

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Introduction

Rice is the staple food for more than 160 million people of Bangladesh. To feed this large population, she has to produce a huge amount of rice which needs extraction of enormous amount of ground water to irrigate the rice fields. This exerts heavy pressure on the underground water table of Bangladesh. Moreover, every year drought affects about 2.32 and 1.20 million hectares of cropped land during July to October and November to June, respectively (Ibrahim, 2001). To combat this problem, it needs to develop *Aus* rice variety(s) that can be sown directly in the field without puddling the soil followed by supplemental irrigation as per need of the crop. Therefore, this study aims at developing *Aus* rice variety(s) for direct seeding (without puddling) culture with supplemental irrigation.

Methodology

Drought tolerant rice variety NERICA-10 was irradiated with 40 Gy doses of carbon ion beams from Japan Atomic Energy Agency in 2013 and was transplanted on 2 April. From this M_1 and M_2 generation was obtained. M_2 plants were transplanted and three M_3 mutants *viz.*N_{10}-40(C)-1-1, N_{10}-40(C)-1-5 and N_{10}-40(C)-1-7 were selected based on grain yield and shorter duration for further yield trial under direct seeding and rainfed conditions in *Aus* season. No supplemental irrigation was applied but lifesaving irrigation during severe drought period especially in the Barind areas and at Magura at farmer's fields. For lifesaving one flood irrigation was applied. Advanced yield trial was conducted with M_4 mutants in T. aman season, 2014 following RCB design with three replications at two locations such as Barind area of Chapainawabgonj and at Mymensingh. The seeds were sown directly in the field following dibbling method at 20 cm x 15 cm spacing using 3-4 sprouted seeds per hill. The mutant N_{10}-40(C)-1-5 performed the best of all mutants in Zonal yield trial, on farm and on station trials conducted in M_5 and M_6 generations, respectively, during *Aus* and T. aman seasons, 2015 following the same method, design and replications and spacing. Field evaluation trial was conducted with the mutant N_{10}-40(C)-1-5 along with two check varieties at 11 locations including the Barind and hilly areas once again following the same method, design and replications during 7 April to 12 May 2016. Data on grain yield and yield attributing traits were recorded and were subjected to statistical analyses following Gomez and Gomez (1984). Total rainfall of the experimental sites during the experimental period, averaged over 10 years (2007-2016) has been shown (Table 1).

Results and Discussion

It is evident from the means, averaged over 11 locations, that the mutant N10-40(C)-1-5 had significantly shorter plant height, more filled grains but lower unfilled grains and higher grain yield than both the check varieties under direct seeded rainfed conditions (Table 2). Location wise grain yield of the mutant was also the highest at all locations (Fig 1). It was also observed that the mutant produced almost similar yield under low rainfall condition at Nachole and under

high rainfall condition at Raicha (Table 1, Fig.1). This indicates this mutant could be the most potential mutant for growing under direct seeding and rainfed conditions in *Aus* season.

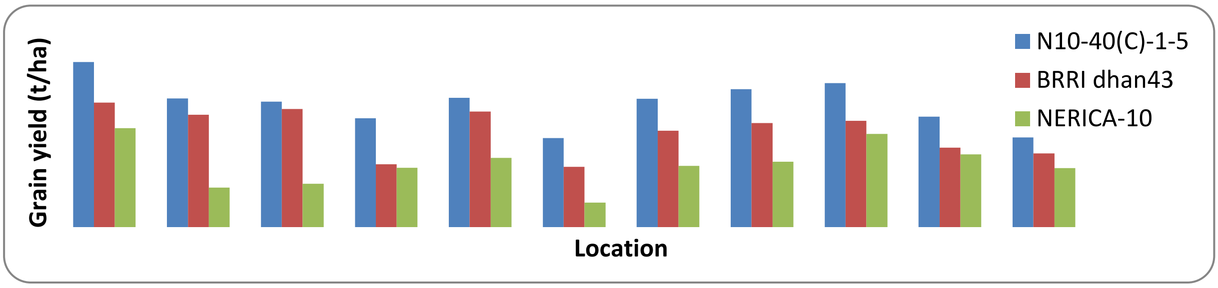

Figure 1. Grain yield of the mutant and the check varieties at different locations

Table 1. Total rainfall during the crop growing period averaged over ten years of the experimental sites, duration of the mutant and two check varieties at different locations

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
Total rainfall (mm)	1264	1921	1921	1552	782	762	1127	1127	2194	2194	1854
Duration of the mutant (days)	93	95	95	101	105	116	101	106	107	117	107
Duration of Ck-1 (days)	93	97	97	99	105	116	103	104	107	117	108
Duration of Ck-2 (days)	101	100	100	103	105	116	117	125	107	108	95
Lifesaving irrigation	No	No	No	No	Yes	Yes	No	Yes	No	No	No

Ck-1, BRRI dhan43, Ck-2, NERICA-10
L1=Mymensingh HQ, L2=Nalitabari sub-station, L3=Nalitabari farmer's field, L4=Rangpur farmer's field, L5=Nachole, Chapainawabgonj, L6=Godagari, Rajshahi, L7=Magura sub-station, L8=Magura farmer's field, L9=Raicha, Bandarban, L10= Mrulongpara, Bandarban, L11= Alutila, Khagrachari

Table 2. Yield and yield attributes of the NERICA mutant along with the check varieties

Variety/Line	Plant height (cm)	Effective tiller/plant (no.)	Panicle length (cm)	Filled grain /panicle(no.)	Unfilled grain/ panicle (no.)	1000-grain weight (g)	Yield (t/ha)
N10-40(C)-1-5	93.84	10.64	21.76	65.05	15.43	23.0	3.74
BRRI dhan43	111.0	10.54	22.12	58.30	26.84	21.0	2.90
NERICA-10	106.5	6.27	22.10	55.59	27.41	22.0	1.88
LSD $_{(0.05)}$	1.0	0.38	1.0	3.66	1.98	-	0.08

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Nutrient management in relay mustard with T.aman rice under zero tillage condition at Ishwardi region of Bangladesh

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Introduction

Suitable nutrient management practice for improving yield of mustard (*Brassica campestris and Brassica juncea*) in rotation with T.*aman* rice (*Oryza sativa*) under zero tillage condition in high Ganges river floodplain soil (Agro-ecological zone 11) of Bangladesh was assessed. Mustard is an important oilseed crop in Bangladesh covering an area of 325053 ha with annual production of 359452 metric ton (BBS, 2016). Relay mustard with T. *aman* rice is a traditional cropping system practiced by farmers in Bangladesh. However, there is no recommended nutrient management practice in existing relay mustard with T. *aman* rice cropping system. Farmers generally do not use any fertilizers in relay mustard cultivation (Mian *et al.,* 2016). In conservation agriculture, crop is grown with minimum disturbance of soil and natural biodiversity through tillage and no burning of crop residues (Anonymous, 2016). In this study mustard with T. *aman* rice was grown under zero tillage with nutrients to improve the yield of mustard and to conserve soil health.

Materials and Methods

Crop residue of T.*aman* (30-40 cm) was left standing in the field. Mustard seed was broadcast before harvesting of T. *aman* rice. After harvesting of mustard the residues of both T. *aman* and mustard was incorporated into the soil to add organic matter into the soil. Treatments were three nutrient management practice viz. F_0=Farmers practices (no nutrient application), F_1=All recommended nutrients (120-35-45-30-2-2 kg ha^{-1} of N-P-K-S-Zn-B) applied at 7 days before relaying time, F_2= All recommended nutrients (35-45-30-2-2 kg ha^{-1} of P-K-S-Zn-B and ½ N=60 kg ha^{-1}) applied at relaying time + top dress rest ½ N (60 kg ha^{-1}) during first irrigation at 20-25 days after sowing), and two mustard varieties BARI Sarisha-14 (*Brassica campestris)* and BARI Sarisha-11 (*Brassica juncea)*. The experiment was a randomized complete block design with three replications. Mustard was sown in 15-18 November in both years. BARI Sarisha-14 was harvested on 10-12 February and BARI Sarisha-11 was harvested on 1-3 March in 2014-15 and 2015-16. Initial soil analysis was done. Recommended nutrients were applied according to soil analysis as per Fertilizer Recommendation Guide (2012). Texture of the experimental soil was silty clay with pH 7.6 and organic matter of 1.17%. Nutrient status of N-P-K-S-Zn-B represented as 0.11%, 16 ppm, 0.17 meq/100 g soil, 15 ppm, 1.19 ppm, 0.27 ppm respectively in the soil. Temperature ranged 16.10-23.21 ^{0}C in 2014-15 and 16.61-21.30 ^{0}C in 2015-16 during growing period. Crop rainfall was zero mm in 2014-15 and 0.92 mm in 2015-16. Crop received total sunshine hours of 301 in 2014-15 and 268 in 2016. Crop was irrigated at 20-25 and 40-45 days after sowing. One hand weeding was done at 27-30 days after sowing. Data on crop characters was collected at maturity of the crop. Means were compared by LSD (0.05) after analysis of variance. Economic evaluation of the study was also done.

Results and Discussion

Plant population ranged 39-46 m^{-2} in 2014-15 and 49-54 m^{-2} in 2015-16 with average of 46-50 m^{-2}. Plant height indicating better plant growth was highest (96 cm in BARI Sarisha-14 and 154 cm in BARI Sarisha-11) in F_2 compared to F_0 and F_1. Mean number of branches $plant^{-1}$ was highest (4.69) in BARI Sarisha-11 with F_2 and lowest (1.27) in BARI Sarisha-14 with F_0. Siliqua $plant^{-1}$ was highest (165) in BARI Sarisha-11 with F_2 but the lowest (17) in BARI Sarisha-14 with F_0 while giving higher trend of siliqua $plant^{-1}$ in BARI Sarisha-11. On the contrary, seed $silqua^{-1}$ was found higher (21.00-40.05) in BARI Sarisha-14 but lower (7.20-10.50) in BARI Sarisha-11 producing the highest value (38.90-41.20 with mean of 40.05) in BARI Sarisha-14 with F_2. Weight of 1000-seed was highest (3.16-3.35 g) in BARI Sarisha-14 with F_1 and F_2. Seed yield was highest in BARI Sarisha-11 (1496-1633 kg ha^{-1} with mean of 1565 kg ha^{-1}) with F_2 but lowest seed yield (369-722) was produced in both varieties with F_0. However, BARI Sarisha-14 had a seed yield of 1046-1167 kg ha^{-1} with mean seed yield of 1107 kg ha^{-1} with F_2. Seed yield increased 54% in BARI Sarisha-11 and 67% in BARI Sarisha-14 with F_2 compared to F_0. Gross return (Tk. 93900 ha^{-1}), margin (Tk. 65470 ha^{-1}) and benefit cost ratio (BCR) (3.30) were higher in BARI Sarisha-11 with F_2 as compared to other treatments. Soil analysis after two years cropping cycle (mustard relayed with T. *aman* cv. BRRI dhan 28) indicated that soil fertility was maintained as a positive balance of nutrient except N (organic matter content ranged 1.21-1.24% and P-K-S-Zn-B represented as 17-19 ppm, 0.18-0.20 meq/100 g soil, 16-18 ppm, 1.21-1.22 ppm, 0.29-0.30 ppm respectively) in F_1 and F_2 was calculated. BARI Sarisha-11 relayed with T. *aman* rice when recommended nutrients (35-45-30-2-2 kg ha^{-1} of P-K-S-Zn- B and ½ N=60 kg ha^{-1}) were applied at relaying time + top dressed rest ½ N (60 kg ha^{-1}) during first irrigation at 20-25 days after sowing was found as suitable technology for utilization of fallow land at Ishwardi region. The technology involves less costs and is economically profitable. The technology also would help to sustain organic matter and soil fertility in the cropping system of relay mustard with T. *aman* rice in conservation agriculture.

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Table 1. Seed yield and straw yield of mustard relayed with T. *aman* rice under zero tillage as influenced by nutrient management

	Seed yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
BARI Sarisha-14 with F_0	386	351	369	1528	1506	1517
BARI Sarisha-14 with F_1	875	753	814	1963	1866	1915
BARI Sarisha-14 with F_2	1167	1046	1107	2467	2381	2424
BARI Sarisha-11 with F_0	561	882	722	1725	1702	1714
BARI Sarisha-11 with F_1	1125	1065	1095	2631	2468	2550
BARI Sarisha-11 with F_2	1633	1496	1565	3925	3798	3862
LSD $_{(0.05)}$	46	41	-	37	41	-
CV (%)	3.78	4.07	-	5.68	6.39	-

Table 2. Economic evaluation of mustard relayed with T. *aman* rice under zero tillage as influenced by nutrient management

Treatment	Cost of cultivation (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR #
BARI Sarisha-14 with F_0	13380	22140	8760	1.65
BARI Sarisha-14 with F_1	27530	48840	21310	1.77
BARI Sarisha-14 with F_2	28430	66420	37990	2.34
BARI Sarisha-11 with F_0	13380	43320	29940	3.24
BARI Sarisha-11 with F_1	27530	65700	38170	2.39
BARI Sarisha-11 with F_2	28430	93900	65470	3.30

BCR is the gross return divided by cost of cultivation

Table 3. Soil analysis (initial and after two year of cropping cycle)

Soil analysis	OM (%)	N (%)	P (ppm)	K (meq/100 g)	S (ppm)	Zn (ppm)	B (ppm)
Initial	1.17	0.11	16	0.17	15	1.19	0.27
After two-year cycle	1.21-1.24	0.08-0.10	17-19	0.18-0.20	16-18	1.21-1.22	0.29-0.30

OC (OM=OC×1.73) by wet digestion method (Nelson and Sommers, 1982), N by semi-micro-Kjeldahl method (Bremner and Mulvaney, 1982), P by Olsen method (Olsen and Sommers, 1982), K by NH_4OAc extraction method (Knudsen *et al.*,1982), S by Turbidimetric method ((Tabatabai *et al.*, 1982), Zn by DTPA extraction method (Lindsay and Norvell, 1978), B by mono-calcium biphosphate extraction method (Page *et al*., 1982)

Zero tillage planting with rice straw mulch can be a good practice for higher productivity of garlic and reducing CO_2 emission

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Introduction

In Bangladesh, about 2.6 Mha land (30%) is affected by water-logging which covers beels, jheels, haors and baors. Of them, beels are potential wet land for crop cultivation. Chalan beel (under Natore district) is a good example for it where land remains under water at varying depths over 6-7 months of a year. In Chalan beel area, deep water (DW) rice is mainly grown as broadcast aman rice and after harvest in late October to early November long rice straw masses are burnt to ashes producing CO_2 emissions to the atmosphere. Straw burning is thought to control insect and disease infestation. This land either remains fallow or goes under crop cultivation with conventional tillage plantings. Alternatively, some farmers cultivate crops like onion in the muddy land without tilling and with straw as mulch, no straw burning. Indeed, this practice has started to increase with time, as seen in Fig. 1. However, research is needed in this aspect. We have undertaken a study towards that end with conservation agriculture (CA) concept which has both economic and environmental benefits.

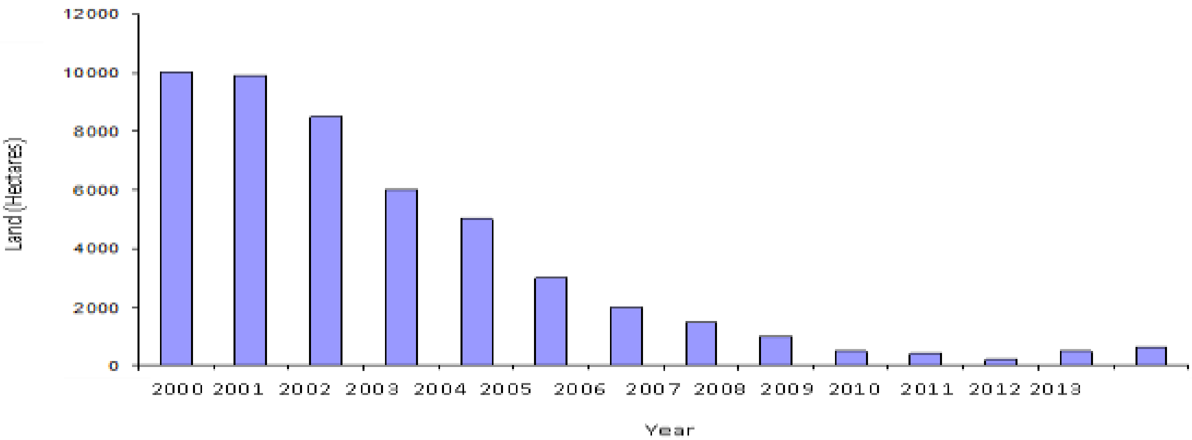

Figure. 1 Increasing hectareage under garlic cultivation with advancement of time

Materials and Methods

A number of experiments have been done in the chalan beel area under Natore district and in the areas under Bogra and Mymensingh districts. The objective was to compare zero tillage plus straw mulch practice (CA technology) with intensive tillage plus straw burning (conventional practice) in onion cultivation. Planting was done in early November. For zero tillage plantings, cloves were planted in the untilled muddy land at narrow spacing of 10cm x 10cm. After planting, cloves were covered with rice straw that helped soil moisture conservation. For conventional tillage plantings, land was intensively tilled by ploughing and cross- ploughing and cloves were planted in 15-20 cm rows at 10-15 cm plant spacing. No fertilizers were added. One or two irrigation was done. Harvesting was done in late February. The yield data were collected and statistically analyzed using MSTAT package program.

Results and Discussions

Zero tillage (ZT) with rice straw mulch always produced higher bulb yield at all locations compared to conventional tillage (CT), for example in BAU farm (Fig. 2). So, this practice based on CA concept is a very practice for crop cultivation in low lying areas of Bangladesh.

T1: ZT planting
T2: CT planting

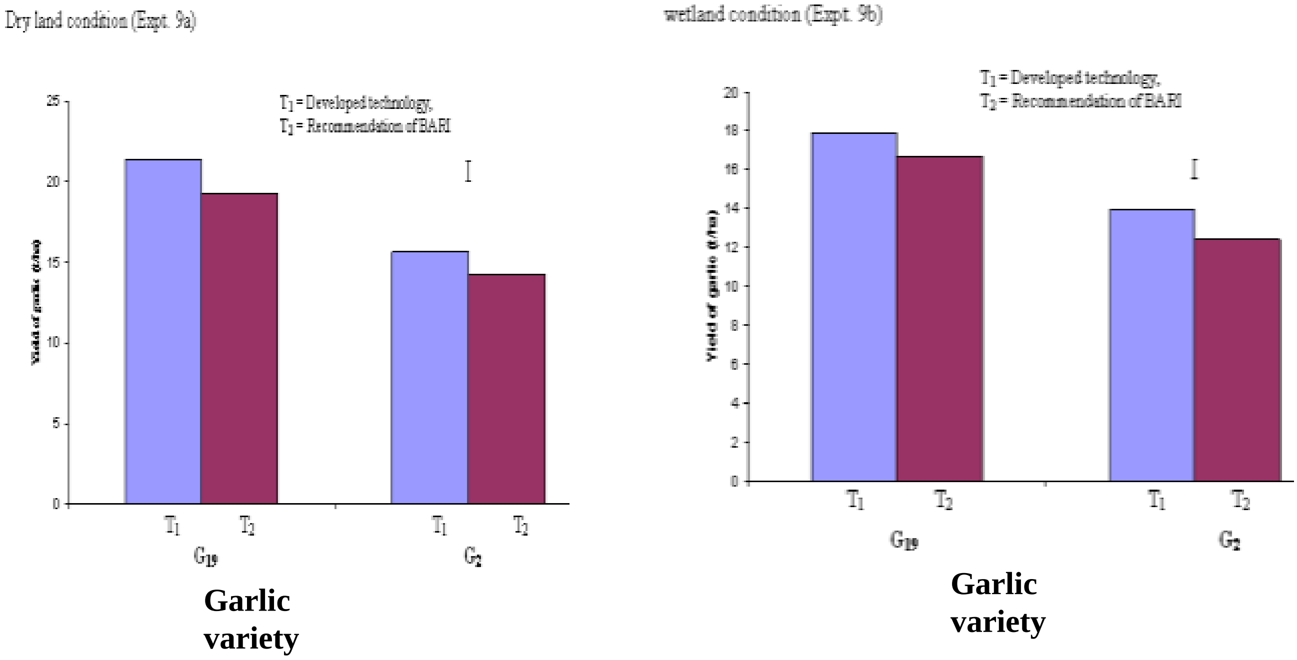

Figure. 2 Effects of zero and conventional tillage plantings on the yield of bulbs (garlic), vertical bar represents LSD at 5% level

Session 3

NARS AND CGIAR PROGRAMS OF CONSERVATION AGRICULTURE

KEYNOTE PAPER

Climate smart agriculture in intensive cereal based systems: Scalable evidence from Indo-Gangetic Plains of South Asia

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Introduction

South Asia, home to about 1.5 billion people, over 30 per cent of whom are still living in poverty, faces a major challenge in achieving rapid economic growth to reduce poverty and attaining other Millennium Development Goals under emerging challenges of natural resource degradation, energy crisis, volatile markets and risks associated with global climate change (Jat et al., 2016; Lal., 2016). During past half century (1965-2015); in process of achieving multi-fold increase in crop production in the region, inefficient use and inappropriate management of non-climate production resources (water, energy, agro-chemicals) have vastly impacted the quality of the natural resources and also contributed to climatic variability affecting farming adversely. The natural resources in South Asia specially in Indo-Gangetic plains (IGP) are 3-5 times more stressed due to population, economic and political pressures compared to the rest of the world and can potentially add to adversity of climatic risks, making a large number of people in the region vulnerable to climate change. Increasing climatic variability affects most of the biological, physical and chemical processes that drive productivity of agricultural systems including livestock and fisheries (Easterling et al., 2007).

With no scope left for horizontal expansion of farming; we need to produce 70% more food to feed the projected world population of 9.7 billion by 2050. Nonetheless, having high risks of climate change induced extreme weather events, the crop yields in the region are predicted to decrease from 10 to 40% by 2050 with risks of crop failure in several highly vulnerable areas. Increase in mean temperature, increased variability both in temperature and rainfall patterns, changes in water availability, shift in growing season, rising frequency of extreme events such as terminal heat, floods, storms, droughts, sea level rise, salinization and perturbations in ecosystems have already affected the livelihood of millions of people. Studies (Sivakumar and Stefanski., 2011) show that there would be at least 10% increase in irrigation water demand in arid and semi-arid region of Asia with a 1 ^{o}C rise in temperature. Thus, climate change could result in the increased demand for irrigation water, further aggravating resource scarcity. Moreover, climate change on the one hand, can intensify the degradation process of natural resources which are central to meet the increased food demand, while on the other hand, changing land use pattern, natural resource degradation (especially land and water), urbanization and increasing pollution could affect the ecosystem in this region directly and also indirectly through their impacts on climatic variables (Lal., 2016). For example, about 51% of the Indo-Gangetic Plains may become unsuitable for wheat crop, a major food security crop of region, due to increased heat-stress by 2050 (Lobell et al., 2012; Ortiz et al., 2008). Therefore, adaptation to climate change is no longer an option, but a compulsion to minimize the loss due to adverse impacts of climate change and reduce vulnerability (IPCC., 2014). Moreover, while maintaining a steady pace of development, the region would also need to reduce its environmental footprint from agriculture.

Considering these multiple challenges, agricultural technologies that promote sustainable intensification and adapting to emerging climatic variability yet mitigating GHG emissions (climate smart agriculture practices; CSAPs) are scientific research and development priorities in the region. There are a wide range of agricultural practices that have the potential to increase adaptive capacity of production system, reduce emissions or enhance carbon storage yet increasing food production. In this paper, I provide scalable evidence on climate smart agriculture practices (CSAPs) in intensive cereal based systems of IGP.

Methods

Under the aegis of CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS); WHEAT; MAIZE and other related projects, CIMMYT and other organizations in collaboration with range of partnerships including ICAR, SAUs, CGIAR Institutions (IRRI, IFPRI etc.), ARIs, NGOs, development departments, farmer organizations, service provider and community based organizations have been engaged in mainstreaming CSAPs through generating science backed scalable hard evidence across the range of farm typologies in the Indo-Gangetic plains (CIMMYT-CCAFS, 2014). Climate-Smart Villages (CSVs) are the sites where researchers from national and international organizations, farmers' cooperatives, local government leaders, private sector organizations and key policy planners come together to identify which CSAPs are most appropriate to tackle the climate and agriculture challenges in the village. In CSVs, a portfolio of CSAPs adapted to local farming system is adopted by the community for multiple benefits of increased productivity, income and resilience to climatic variability. The idea is to integrate climate-smart agriculture into village development plans, using local knowledge and expertise and supported by local institutions. We piloted over 65 CSVs across Indo-Gangetic plains and the evidence from these community participatory pilots have been generated. Across various CSV sites, we evaluated and demonstrated the performance of individual CSAPs over conventional practices and generated evidence on various indicators. In various CSVs; the sites of participatory learning on CSA, we generated hard evidence on *"portfolios of climate smart agriculture interventions"* through participatory strategic research in intensive rice-wheat system so as to demonstrate what combination of practices (portfolio) have synergistic and multiplier effects on various indicators.

Results and Discussion

Analysis of data from large number of field trials for their response to key climate smart indicators (yield, income, water, energy, NUE, GHG emission) were performed to generate evidence across IGP. The results of a review revealed that conservation agriculture (CA) based management (zero tillage, residue retention, direct seeded rice), precision water and nutrient management and laser land leveling practices qualifies as CSAPs (Jat et al., 2015). CA based management practices reduces production cost, increase yields and economic benefits. Analysis of forty farmers' participatory field trials conducted for three consecutive years in Haryana demonstrated that the total cost of wheat production in zero tillage using turbo happy seeder technology (Sidhu et al., 2015) was on an average, 23% less than that of conventional tillage (CT) whereas the net income was significantly higher in CA. Similarly, through long-term trial on tillage and crop establishment methods in rice-wheat system of eastern IGP, we found that the productivity of rice-wheat was higher under CA-based system (ZT rice-ZT wheat with and without residue retention) as compared to CT systems irrespective of the climate risks. The results from the another set of participatory trials in eastern IGP also showed the complementarity of various practices, for example layering of no-till maize-wheat

rotation with residue recycling, inclusion of legume and site-specific nutrient management enhances yield (2.35 t ha^{-1} yr^{-1}) and income (USD 941) along with resource conservation benefits. However, higher yields and income does not provide the evidence of technology to be called as climate smart. We therefore, evaluated these practices for their role in adapting to climate risks as well as their mitigation potential to identify their multiple wins and verify as climate smart practices.

We evaluated the role of CA and other sustainable intensification practices for their adaptive capacity to reduce climate risks in the intensive cereal based systems in IGP. Our studies on CA in rice-wheat system in western IGP (Sapkota et al., 2015), showed that retention of rice residue on soil surface lowered the canopy temperature in wheat by 1-2 ^{o}C at grain filling period (between 138-153 days after sowing). Surface retention of crop residues (no-till systems) is strategically located at soil-atmosphere interface and offers profound water conserving effect by reducing run-off and evaporative losses which buffers the abiotic stresses. Adoption of ZT in cereal cropping system in IGP has also been reported to advance the planting time thereby increasing the thermal window for wheat and thus escaping from terminal heat effect specially in eastern IGP. We analyzed the data from 208 farmers in Haryana for the 2 contrasting wheat seasons; 2013–14 (a period with normal rainfall i.e., normal year) and 2014–15 (a period with untimely excess rainfall i.e., bad year). Our analysis shows that whilst average wheat yield was greater under CA than CT during both bad and normal years, the difference was two-fold greater during the bad year (16% vs. 8%). This provides new hard evidence that CA can cope better with the climatic extremes, in this case untimely excess rainfall, compared to CT. Absolute yield of the CA and CT was 10% and 16% lower in the bad year compared to the normal year, respectively. The Govt had to pay huge compensation to farmers for this yield loss in wheat during 2014-15. Whereas our study revealed that if, as targeted by the Haryana government in 2011, one million ha of wheat was brought under CA, the state would have produced an additional 0.66 million tonnes of wheat in 2014-15, equivalent to US$ 153 million (Aryal et al., 2016).

These practices not only help in adaptation to climate risks but also contribute to reduction in environmental foot prints. Reduced power and energy requirements in CA translates into less fuel consumption, lower working time and slower depreciation rates of equipment, all leading to mitigation from farm operations as well as from the machinery manufacturing processes. On an average, by adopting of ZT in rice-wheat system of IGP, farmers could save 36-liter diesel ha^{-1} equivalent to a reduction in 93 kg CO_2 emission ha^{-1} yr^{-1}. Through our continuous monitoring of GHGs by using static chamber method in a rice-wheat production system of western IGP, we found much higher emission of CH_4 from rice production in puddled transplanted field with continuous flooding (50-250 mg CH_4 m^{-2} day^{-1}) compared to direct seeded rice (DSR) production system (<50 mg CH_4 m^{-2} day^{-1}). In this study, total cumulative GHGs emission (soil flux of CO_2, N_2O and CH_4) in terms of CO_2-equivalent was about 27% higher in the conventional tillage than in CA-based rice-wheat system. Through life-cycle analysis (using Cool Farm Tool) of wheat production in western IGP, we found that global warming potential of conventional till wheat with ad-hoc nutrient management was significantly higher than in ZT- with precision nutrient management (Sapkota et al., 2014).

Above results provide the evidence on food security (yield, income), adaptive capacity and mitigation; the 3 key components of CSA but in isolation. However, our results from synthesis of the participatory strategic research on portfolio of CSAPs in intensive rice-wheat rotation of western IGP indicates that system yield, net income, water use, energy use efficiency & GHGs

mitigation varies greatly with layering (portfolio) of various CSAPs. Results revealed that improved management with low intensity practices (residue incorporation) does not lead to immediate gains (yield, income, water, energy) over business as usual (residue burning) except marginal (7%) reduction in GHGs. However, CSA practices with varying degree of intensity (layering of various practices) have led to progressive gains in yield (5-9%); income (15-25%), water savings (21-28%), energy efficiency (3.6-5.7%) with 13-28% lower environmental foot prints.

These evidences from our research have led to stakeholder buy-in for mainstreaming CSAPs and scaling through CSV approach. The CSV model demonstrates strong scalability through unique and interrelated elements of CSA-led business models, innovation platforms, knowledge networks, ICTs, gender and youth empowerment; thereby facilitates convergence of AR4D programs to fill in a bigger umbrella of National Action Plan on Climate Change (NAPCC).

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BRRI status paper

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Present status and prospect of conservation agriculture based tillage technology for crop production in Bangladesh

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Introduction

Bangladesh agriculture is characterized by small land holding where two wheel tractors (2WT) are the common tillage tool and popular among the farmers for easy access to fields with affordable price. About 700,000 2WT are operating in Bangladesh. Conservation agriculture (CA) based tillage technology was first introduced in the farmers' field by CIMMYT-Bangladesh for wheat crops in late 90's with minimum till technology by 2WT operated seeder under a WRC, BARI research programme. The 2WT operated CA based planting technology has been developed by different research organizations and promotional activities are being conducted in the farmers' fields for yield gap minimization, water saving, efficient input utilization, soil health improvement, sustainable crop production, and crop diversification (Hossain *et al.*, 2015). Agricultural labour is decreasing in farming operations, where CA technologies can mitigate labour shortage to some extend especially no till and strip till technology look in drought stress areas where seeding operation and initial plant establishment can be done utilizing the residual soil moisture available immediate after monsoon rice harvest (Bell and Johansen, 2009). Presently, most of the CA planters are improved with inclined plate seed metering devices for small to large size seed handling. The planters are robust, lighter in weight, capable of planting through medium level crop residue, and to fabricate within short period of time. Number of tillage and planting service provider is increasing but the rate of acceleration is slow compare to expectation. There are prospect of increase cropping intensity and food production by adopting CA technology in the farmers' field of Northern part, North-West, South, and middle part of the Bangladesh.

Materials and methods

There are available 2WT operated CA based seeding machinery such as minimum till (single pass), strip till, and no-till planter in the farmers' field as well as in the promotional organizations like BARI, BRRI, BAU, DAE, CSISA, IDE, RDRS, RDA. There are also a few 4WT driven zero till and bed planters in the research farm for project work purposes. These planters are pull type and hitched at the drawbar point of Chinese 2WT (9 kW) replacing the regular rotavator (Fig.1). All accessories of the seeding components were set up under the handle bar of the 2WT. Farmers are using these planters for wheat, maize, pulses, jute, sesame, oilseeds, and vegetables production. In Rajshahi area, some farmers are dry direct seeding rice and unpuddled rice transplanting. There are considerable numbers of machinery manufacturers now start to make CA based planters and spare parts in different locations of the country. The CA related information was collected from machinery manufacturers, local service providers, lead farmers, agricultural department, and machinery traders from different corners of Bangladesh. Personal communication was applied in most of the cases for

Fig.1: 2WT operated no till planter

collecting the data especially number of implement, number of CA adopted farmers, and area coverage. Data were analyzed over the years (combined) using statistical software “R” version 3.2.4.

Results and Discussion

The number of CA planters is increasing and the promotional activities are being conducted by the NARS institutes, donor agencies, department of agriculture extension, and lead non-government organizations. (Table 1). Most of the 2WT based CA planters are versatile with all agronomic adjustments and it can be used as strip till, no till or minimum till. Local manufacturers are fabricating complete set.

Table 1. Numbers of two wheel tractors based CA planter in Bangladesh

Sl#	Name of CA planter	Number	Remarks
1	Minimum till planter	2275	Locally made as well as imported from China
2	Strip till planter	175	Locally made as well as imported from China (VMP number excluded with this figure)
3	No till planter	12	Locally made

The CA based technology looks more suitable for upland crops such wheat, maize, lentil, mung, sesame, groundnut compared to rice cultivation. Presently, unpuddled rice transplanting is being adopted by the farmers in some selected areas. Direct dry seeding rice is also practicing in Rajshahi area under ACIAR-SRFSI programme. The area coverage under CA planting is increasing during last four years and culminated to about 29,444 ha (Table 2). The numbers of service providers are also increasing, in Rajshahi, it is 43.

Table 2: Area coverage under conservation agriculture planting system in Bangladesh

CA planting	2010-11(ha)	2011-12 (ha)	2012-13 (ha)	2013-14 (ha)
Minimum till (Single pass)	9864	17527	21850	29005
Strip till	72	106	108	374
No till	79	59	97	65
Total	**10015**	**17692**	**22055**	**29444**

The CA based long term trial in Rajshahi, after 23 crops in the rotation of “wheat-mungbean-rice” with 30% crop residue retained showed that wheat, mungbean yields under strip till and no till planting were higher than conventional method. But, rice yield under conventional transplanting method showed higher yield than that of strip till, no till dry direct seeding (DSR) method. Moreover, rice transplanting cost and puddling water can be saved by DSR method. Weed control is major challenges for DSR.

Table 3. Long term **y**ield (t/ha) **c**omparison between CA planting and conventional planting under wheat-mung-rice rotation

Year	Wheat			Mungbean			Rice		
	Strip till	No till	Conv.	Strip till	No till	Conv.	Strip till	No till	Conv.
2009	0	0	0	1.01	0.87	0.82	4.10	4.10	4.93
2010	3.87	3.45	3.2	1.04	0.89	0.81	3.93	3.90	3.86
2011	3.88	3.45	3.3	1.05	0.90	0.80	4.10	4.00	4.50
2012	4.12	3.50	3.3	1.08	0.90	0.80	4.07	4.00	4.10
2013	4.08	3.55	3.4	0.97	0.97	0.90	4.04	4.13	4.13
2014	3.97	3.70	3.5	1.07	1.07	0.90	4.27	4.10	4.30
2015	4.02	3.83	3.5	0.77	0.84	0.60	4.13	4.07	4.27
2016	3.35	3.10	2.9	0.79	0.97	0.70	4.13	4.23	4.43
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS denotes values were not significantly different at 5% level.

There were significant planting cost and fuel savings differences between CA planting and conventional method (Fig. 2 & 3). There is huge prospect of resources savings, increasing cropping intensity, and additional food production using CA planting technologies. The impact of CA looks that currently NARS institutes like BARI, BRRI have taken programme on adopting in farmer's field. Department of Agriculture Extension involves promoting CA technology in some selected areas. Agricultural universities also include CA in academic course, producing graduates with more CA knowledge and promoting CA technologies in the farmers' field. Promotional activities, training to young farmers, manufacturers, extension workers need to be strengthened. Besides, policy support as well as backing support from national and international organization is the key for its sustainability.

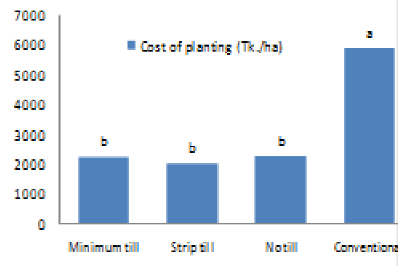

Fig.2: Comparison of cost of planting

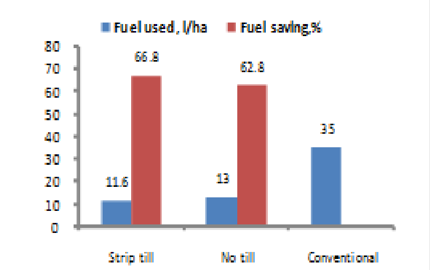

Fig.3: Fuel use and fuel saving, %

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Sustainable and resilient farming system intensification in Easter Indo-Gangatic Plains

M.K. Ghatala

Paper Not yet received

Session 4

WEED MANAGEMENT IN CONSERVATION AGRICULTURE

KEYNOTE PAPER

Weed management is an integral part of agronomy and soil management in conservation agriculture

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Annual loss in crop yield due to competition from weeds in North America alone is worth US$28 billion in corn (Soltani et al. 2016) and 16 billion in soybean (Dille et al. 2016). Herbicides will remain an integral part of modern integrated weed management (IWM) to minimise the yield gaps and feed the 9 billion people on earth by 2050. In addition to good agronomy and soil management, maximum achievable crop yields depend, among other factors, on the capacity of farmers to access and use weed management inputs and knowledge. Conservation Agriculture (CA) is gaining a lot of recognition among farmers all over the world (FAO 2016). About 157 million ha of cropping area is in CA (Kassam et al. 2015) that provides stable crop production and farm profits via conservation of soils, water, energy, time, labour, soil organic matter, and soil microbial contents.

Weed risks of CA

Conservation agriculture greatly relies on herbicides for weed control, leading to enhanced evolution of herbicide resistance, increases in production cost, risks to environment and wildlife, and a reduction in livestock. The use of herbicide-resistant crops (HRCs) combined with the application of broad-spectrum herbicides make the process of CA easier, but it also runs the risk of bringing in new weed problems, either by a shift in the weed populations via changes in farming practices and gene flow, or selection for evolved resistance to the herbicides being used repeatedly. In Australia, 90% farmers have adopted CA (Llewellyn and D'emden 2010) and it has got one of the highest levels of herbicide resistance in the world. Increases in herbicide resistance in Australia are strongly correlated with the increases in the adoption of CA practices.

Herbicide resistance is the acquired ability of a weed population to survive and reproduce following an herbicide application that previously was known to control the same population when treated under ideal conditions. Currently, 251 weed species (146 dicots and 105 monocots) have evolved confirmed resistance to 160 herbicides belonging to 23 out of 26 known sites of action in 88 crops (including rice, wheat, corn, oats, barley, sorghum, cotton, pulses, and canola/mustard) of 66 countries (Heap 2016). Starting in 1994 in Australia, weeds in rice crop have now developed resistance in 22 countries of Asia, Europe, North America and South America to ACCase-, ALS-, long chain fatty acids-, cellulose-, PSII- and lipid synthesis-inhibitors, and synthetic auxins.

Pathway to solution

To delay or prevent the evolution of herbicide resistance in weed species and prolong the life of herbicide for continued profitable farming under CA systems, it is highly important that growers adopt integrated weed management (IWM). IWM is a systems approach to vegetation management (Swanton and Murphy 1996) that includes weed management techniques such as <u>physical control</u>, <u>chemical control</u>, <u>biological control</u>, and <u>cultural control</u>

options. The fundamental requirements for developing the IWM for each paddock, management zone or landscape, among other factors, should include:

(a) review history of farming practices including use of herbicides; (b) assess the current weed status and cropping systems; (c) identify alternative biological, physical and cultural weed management options; (d) implement the principle of farm hygiene; (e) manage stubble to smother weeds; (f) grow competitive crop and crop cultivars; (g) practice effective pre-planting and in-crop weed control; (h) weed seed removal and destruction at and after harvest; (i) strategic fallowing; (j) rotation of crop and herbicides; and (k) packaging chemical and non-chemical options into a rotation plan.

Regulatory compliance

Herbicidal weed control practice introduced in the recent years in Bangladesh is fast becoming popular among growers. Complete reliance on herbicides use for weed control, repeated use of the same mode of action, and off-label rate and time of application could lead to evolution of herbicide resistance within 4-6 years. Following the correct procedures at registration, undertaking adequate trials for crop tolerance, herbicide efficacy, knowledge of handling and application of herbicides, herbicide persistence in soil, knowledge of maximum residue level (MRL) in food and feed, are essential.

Research: To sustain weed management with heavy reliance on herbicides in countries like Bangladesh, agronomic research on weed management under zero or reduced tillage, direct drill, unpuddled rice transplanting, and stubble retention; soil and herbicide interaction, herbicide efficacy, farm hygiene, non-chemical weed control (cultural and physical), soil seed bank, biology and ecology of weed species, and availability of affordable spraying equipment, need to be undertaken.

Education

Strong and effective stewardship program by chemical companies, effective training and education program by government agencies and universities, and surveillance of compliance are keys to safe of food, feed, health and environment.

Vocational training: Growers, scientists and contractors should be trained on herbicides mode of action, herbicide selectivity, handling and storage of herbicides, and improved spraying technology including sprayer calibrations, protection and safety requirement, labelling and storage of herbicides based on toxicity, and principles of effective spraying following label and material safety data sheet (MSDS).

Safety

Unlike other pesticides, if a wrong herbicide is sprayed on the wrong crop at the wrong time or rate will severely damage the crop plants. Being chemicals, all herbicides are likely to have acute or chronic effects on humans, environment, wild life and off-target organisms when used in a non-compliant way. Some herbicides (e.g., synthetic auxins, dinitroanilines or benzamides, and bipyridyls) are quite toxic to lives, some (e.g., ALS-inhibitors and PSII-inhibitors) may have long toxic residues in soils while some other herbicides pose high risks of drift effects to off-target plants. However, all recommended herbicides are expected to be safe when they are used following the appropriate protocols prescribed in the Label and MSDS. Adequate knowledge and training is mandatory to ensure safety from any adverse effects from herbicides on humans, environment and wildlife. Personal protection equipment (PPE) must be available and used during handling, application, storage and transportation.

Advances in weed research

A critical review of the advances in weed management in Bangladesh will be presented.

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Weed seed bank dynamics in long term trials of conservation agriculture

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Introduction

Conservation agriculture (CA) has been identified as an effective tool for sustainably increasing the crop yields but weed control is perceived as one of the most challenging issues (Pittelkow *et al.,* 2015). Due to the reduction in tillage operations, weed seed bank composition and dynamics in CA will change compared to conventional tillage. Soil weed seed bank is the reservoir of weed seeds in the soil which determines the species composition. The seed bank is the most important source of weeds and represents a significant point in the weed life cycle and weed population is directly related to their seed bank. Knowledge of the seed bank size and its composition can be used to predict the future weed infestation and control strategies, weed seed production after the cropping season, estimation of crop-weed competition and crop yield loss and the crop economics as well (Begume *et al.,* 2006). There are very few studies examining the effects of CA principles on weed seed bank dynamics. These types of studies are needed to include weed control in cost-benefit analyses concerning the adoption of CA. Considering this fact, long terms CA trials were conducted to examine the effect of CA principles on weed seed bank dynamics.

Materials and Methods

The net house experiment was conducted at Bangladesh Agricultural University, Mymensingh, Bangladesh from October 2013 to November 2016. Soil was collected from the field of long term CA trials located at the Durbacahra village of Gouripur upazila under Mymensingh district of Bangladesh. In a *T. amna-mustard- boro rice* cropping rotation, crops were grown under conventional tillage (CT) and strip tillage (ST) with the retention of 50% crop residues compared to no-residue. Before the setting up of the trials, five soil samples from each plot were collected from 0-5 cm, 5-10 cm and 10-15 depth following “W” shape pattern. One kilogram of soil from each plot were placed in individual plastic dish having 32 cm diameter. The samples were kept moist to facilitate good weed germination. The emerged seedlings were identified, counted and removed at 30 days’ intervals throughout 1 year period. Seedlings of questionable identity were transferred to another dish and grown until maturity to facilitate identification. After the removal of each batch of seedlings, soils were thoroughly mixed and re-wetted to permit further emergence. This process was repeated 12 times. Counted seedling were converted to numbers per m^2. After the end of 2-years field trials of Gouripur, soil samples were collected again following similar procedure and the same experimental protocols were performed at the net house.

Results and Discussion

Effect of tillage practice and residue mulching on the number of weed species

Effect of ST and retention of 50% crop residues was significant on the number of weed species. Before setting the long-term CA trials in 2013, there was no significant difference in the weed species for CT and ST. During this time, there was 59 species in CT and 62 species in ST indicating the homogeneity of weed seed bank in the field. After 6 field trials of two-year

study, there was 20% higher weed species in CT (71 species) but 7% less species in ST (58 species) (Fig. 1). Retention of 50% crop residue in the field caused to decrease the weed species by 9% after 2-year study compared to the before study (Fig. 2).

Effect of CT, ST and residue mulching on weed density (number per m^{-2}) at different soil depth

The highest weed density was recorded from 0-5 cm depth followed by 5-10 and 10-15 cm depth both in CT and ST during both of before and after field trials (Table 1). After 2-year crop cultivation CT caused to increase the weed density by 13%. Data recorded from after 2-year study also reveals that, heavy pulverization in CT caused to increase density by 11% at 0-5 cm depth and 25% at 5-10 cm depth but decreases by 53% at 10-15 cm depth which might be attributed from continuous upward movement of weed seeds to the upper layer of soil.

After 2-year cropping, ST reduced the seed bank size by 22%. It was also found that, ST reduced the weed seeds by 24% at 0-5 cm and 57% at 10-15 cm depth but increased by 25% at 5-10 cm depth. Minimal soil disturbance may cause to emerge the weeds from upper most layer leading to reduce seed bank size and deposition of seed to the middle layer leading to enrich seed bank. Soil compactness at the lowest layer may have increased seed dormancy and mortality and reduced seed bank size. Two year cropping with the retention of 50% residue reduced the seed bank by 11% and there was a decreasing trend in seed numbers from upper to lower soil layer. Residue may hinder weed growth and favour weeds seed predation by soil fauna and reduce the weed seed bank. The seed bank was more or less stable after 2-year study in no-residue practice. From these results, it is clear that, CA practice may lead to a reduction in the soil weed seed bank.

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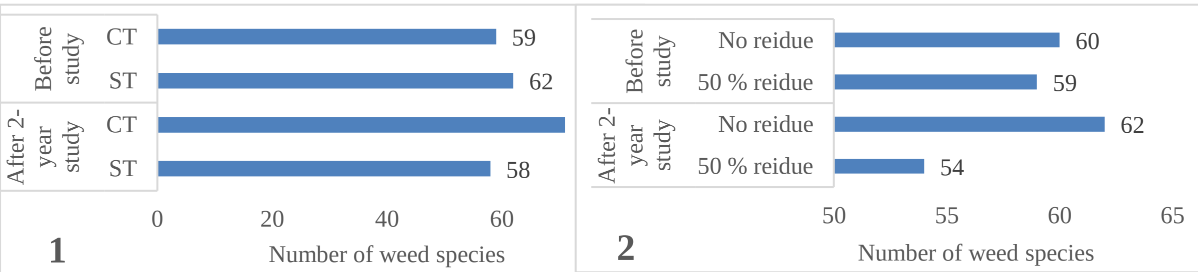

Figure 1: Effect of **(1)** CT and ST and **(2)** crop residue mulching on weed seed bank composition after 2- year filed trials of CA practices

Table 1: Effect of CT, ST and residue on weed density (number per m^{-2}) at different soil depth

+ reflect increase, - reflects decrease

Soil depth (cm)	CT		ST		no-residue		50% residue	
	Before study	After 2-year study	Before study	After 2-year study	Before study	After 2-year study	Before study	After 2-year study
0-5	6189	6890	8301	6323	7082	7194	6838	6241
5-10	1507	1878	1498	1819	1872	1653	2153	1899
10-15	567	269	320	137	349	472	280	116
Total (n)	**8263**	**9037**	**10119**	**8279**	**9303**	**9319**	**9271**	**8256**
Change	(+) 13%		(-) 22%		(+) 0.17%		(-) 11%	

Tolerance of rice varieties to higher rates of two post-emergence herbicides under strip tilled non-puddled transplanted establishment

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Introduction

Rice establishment by transplanting in non-puddled soil is a new practice having many beneficial effects on soil physico-chemical properties and the performance of succeeding crops (Islam et al., 2014). Non-puddled transplanting, a new dimension of conservation agriculture practice in rice cultivation, is highly constrained by weed infestation. Manual weeding is becoming more difficult and costly due to labour scarcity and higher wages. It is being replaced by herbicide that provides effective and economic weed control (Ahmed and Chauhan, 2014). Farmers generally use the labelled rate of herbicides but sometimes they attempt to apply higher rates to counter severe weed infestation. The effects of higher rates of post-emergence herbicides on the rice varieties under non-puddled establishment have not been determined. Moreover, there is a need for clear understanding on the effect of different herbicides on growth and yield performance of rice varieties apart from their weed control efficacy. The present study was undertaken to evaluate the response of short duration *aman* rice varieties to post-emergence herbicides under non-puddled transplanting.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh in 2014 aman (rainy) season. Five rice varieties (BRRI dhan33, BRRI dhan39, BRRI dhan56, BRRI dhan57 and BINA dhan7) were tested against three rates (recommended dose (RD), double the RD (2RD), and triple the RD (3RD) of two herbicides (Acetochlor + Bensulfuron and 2, 4 D amine) in a strip-plot design with 3 replications. The recommended rates of Acetochlor+Bensulfuron, and 2, 4 D amine were 0.75 kg ha^{-1} and 1 L ha^{-1}, respectively. Repeated hand weeding was done to keep the field weed free in control plots. Before setting up the present experiment, pre-planting non-selective herbicide, Roundup® (glyphosate 41% SL- IPA salt), was applied @ 75 mL/ 10 L water (2.25 L ha^{-1}) at 5 days before strip tillage (at 20 cm line spacing) by Versatile Multi-Crop Planter (Haque *et al.*, 2016). Just before strip tillage, the land was fertilized as per recommended practice and then the land was inundated to 3-5 cm depth of standing water for 48 hours. Twenty-five day-old seedlings of all the rice varieties were transplanted on 3 August 2013 at 15 cm spacing between hills allocating three seedlings per hill. Data on growth parameters, yield and related attributes were recorded and were subjected to 'ANOVA' and means were compared by Tukeys's HSD using 'STAR nebula' developed by IRRI (version 2.0.1, January 2014).

Results and Discussion

Overall, 2,4 D amine produced higher number of panicle and grain yield than Acetochlor + Bensulfuron (Table 1). The 2,4 D amine at recommended rate had the same yield as control plots for all the varieties except BRRIdhan 57. Rice yields were not depressed by 2,4 D amine even at 3-fold rates except in case of BRRI dhan39 and BINA dhan7. By contrast, Acetochlor + Bensulfuron reduced yield of BRRI dhan33, BRRI dhan56 and BRRI dhan57at recommended rate and all varieties at three-fold rates. Therefore, some rice varieties were

sensitive to recommended rates of Acetochlor + Bensulfuron and all were more sensitive to higher rates of Acetochlor + Bensulfuronthan and 2, 4 D amine. Systematic screening for sensitivity to a range of commercial herbicides is recommended for current rice varieties and for new cultivar releases in Bangladesh to avoid phytotoxicity effects in farmers' rice crops.

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Table1. Number of panicle (m^{-2}) and grain yield ($t\ ha^{-1}$) of five rice varieties as influenced by different rates of herbicide application

Herbicides	BRRI dhan33	BRRI dhan39	BRRI dhan56	BRRI dhan57	Bina dhan-7
Panicle number					
Control (untreated)	260 bcd	271 ab	220 b	368 a	354 ab
Aceto+bensul (1 ×)	277 ab	275 ab	232 ab	323 b	350 abc
Aceto+bensul (2 ×)	245 cd	252 bc	243 ab	285 cd	327 cd
Aceto+bensul (3 ×)	239 d	2301 c	245 a	282 cd	313 d
2,4-D amine (1 ×)	268 abc	286 a	254 a	266 d	359 a
2,4-D amine (2 ×)	285 ab	278 a	255 a	279 cd	339 abc
2,4-D amine (3 ×)	286 a	237 c	255 a	301 bc	332 bcd
Level of significance	***		***	*	***

Herbicides	BRRI dhan33	BRRI dhan39	BRRI dhan56	BRRI dhan57	Bina dhan-7
Grain yield					
Control (untreated)	3.92 a	4.05 a	4.71 a	5.03 a	4.24 a
Aceto+bensul (1 ×)	2.95 b	3.84 a	3.96 b	3.62 c	3.84 ab
Aceto+bensul (2 ×)	2.77 b	3.72 ab	3.40 c	3.22 cd	3.20 cd
Aceto+bensul (3 ×)	2.65 b	3.02 c	3.32 c	3.06 d	2.98 d
2,4-D amine (1 ×)	3.93 a	4.12 a	4.86 a	4.16 b	4.17 a
2,4-D amine (2 ×)	4.12 a	3.89 a	4.72 a	4.25 b	3.90 ab
2,4-D amine (3 ×)	4.14 a	3.31 bc	4.55 a	4.59 ab	3.63 bc
Level of significance	***	***	***	***	***

Growth and yield response of transplanted *Aman* rice varieties to herbicides in strip tilled unpuddled soil

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Introduction

The use of herbicide is increasing rapidly in Bangladesh (Hossain, 2015) since it provides more cost-effective and labour-saving weed control than manual weeding (Ahmed and Chauhan, 2014). In Bangladesh, there are 52 registered herbicides in the market at present, among which 36 were used for rice (BCPA, 2016). However, the rice herbicides are being used by farmers frequently without any assessment of their possible phytotoxic effects on the existing rice varieties. Some previous studies reported that rice varieties response differentially to different herbicides, even if applied at the recommended rate (Bond and Walker, 2012; Moore and Kröger, 2010). Moreover, minimum tillage might have some effect on the activity of herbicides especially pre-emergence herbicides. We evaluated the varietal response of transplanted *aman* rice to different herbicides at recommended rates in strip-tilled non-puddled soil with residues retention.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from July to December, 2013. Twelve transplanted *aman* rice varieties were tested against six herbicides (2 pre-emergence: pyrazosulfuron-ethyl and butachlor, 1 early post-emergence: orthosulfamuron and 3 post-emergence: acetochlor + bensulfuron methyl, butachlor + propanil and 2,4-D amine) along with a weed-free (hand weeded) control. Before setting up the experiment, pre-plant non-selective herbicide, Roundup® (glyphosate 41% SL- IPA salt), was applied @ 2.25 L ha^{-1} at 20 days and 5 days before strip tillage (at 20 cm line spacing) by Versatile Multi-Crop Planter (VMP) (Haque *et al.*, 2016). Just before strip tillage, the land was fertilized as per recommended practice and then the land was inundated to 3-5 cm depth of standing water for 48 hours. Twenty-five-day-old rice seedlings of all the rice varieties were transplanted on 03 August 2013 at 15 cm spacing between hills allocating three seedlings per hill. Crop phytotoxicity was visually assessed from the day of herbicide application up to 25 days. Data on growth parameters were recorded from randomly selected 10 hills per plot on different days after transplanting (DAT). Rice varieties were harvested at maturity from 05 November to 12 December 2013 and data on yield and related attributes were recorded before harvesting of all rice varieties. Data were subjected to one-way analysis of variance and means were compared by Tukey's HSD using 'STAR nebula' developed by IRRI (version 2.0.1, January 2014).

Results and Discussion

Plant height and grain yield of twelve transplanted *aman* rice varieties responded differently after application of six herbicides at their recommended rates. Plant heights of all rice varieties were significantly reduced at 30 DAT after application of acetochlor + bensulfuron methyl compared to weed-free control (Table 1). Plots treated with acetochlor + bensulfuron methyl gave the lowest grain yield in all rice varieties while pyrazosulfuron-ethy, orthosulfamuron, butachlor + propanil and 2,4-D amine gave higher yields in most of the varieties than weed-

free plots, suggesting good weed control and acceptable crop tolerance (Table 2). However, most of the rice varieties had the highest grain yield from the label application rate of pyrazosulfuron-ethyl. This preliminary study highlights the variation in varietal tolerance of rice to the existing herbicides suggesting that routine screening of herbicide phytotoxicity needs to be incorporated in rice breeding programs in Bangladesh.

Table 1. Effect of herbicides on plant height (cm) of 12 transplanted *aman* rice varieties at 30 days after transplanting in strip tilled non-puddled soil during 2014

Treatments	H_0	H_1	H_2	H_3	H_4	H_5	H_6	LSD	CV (%)
V_1	45.4 ab	47.3 a	46.2 ab	43.1 ab	35.3 c	41.1 b	43.3 ab	***	2.85
V_2	52.7 bc	58.9 a	52.1 bc	52.6 ab	47.4 c	56.5 ab	50.9 c		
V_3	54.3 ab	54.9 ab	49.3 bc	55.1 a	37.7 d	54.0 ab	46.7 c		
V_4	57.0 a	57.9 a	52.5 a	56.2 a	41.2 b	57.8 a	52.3 a		
V_5	56.9 ab	57.4 ab	52.4 bc	55.6 abc	40.7 d	58.7 a	50.9 c		
V_6	55.1 a	55.1 a	49.5 b	54.8 ab	43.5 c	55.5 a	56.3 a		
V_7	44.4 ab	44.2 ab	39.0 bc	40.7 abc	37.1 c	45.6 a	42.4 abc		
V_8	52.6 a	53.6 a	45.0 bc	52.5 a	43.6 c	49.5 ab	48.0 abc		
V_9	62.0 a	63.1 a	53.3 b	58.7 ab	40.3 c	59.4 a	58.3 ab		
V_{10}	59.6 a	60.1 a	60.9 a	60.4 a	47.2 c	60.9 a	53.1 b		
V_{11}	60.9 a	57.1 ab	52.2 bcd	59.7 a	49.1 d	55.5 abc	51.3 cd		
V_{12}	50.9 a	52.0 a	49.1 a	50.1 a	41.7 b	51.2 a	42.4 b		

Table 2. Effect of herbicides on grain yield (t ha^{-1}) of 12 transplanted *aman* rice varieties in strip tilled non-puddled soil during 2014

Treatments	H_0	H_1	H_2	H_3	H_4	H_5	H_6	Level of sig.	CV (%)
V_1	3.83 bcd	4.02 abc	3.71 cd	3.52 d	3.08 e	4.15 ab	4.30 a	***	4.09
V_2	4.79 cd	5.40 a	4.84 bc	4.95 bc	4.42 e	5.13 ab	4.52 de		
V_3	4.94 c	5.08 bc	4.78 c	5.81 a	3.60 d	5.03 bc	5.35 b		
V_4	3.98 cd	5.12 a	3.79 de	4.81 ab	3.63 e	4.57 b	4.20 c		
V_5	4.40 c	5.21 a	4.77 b	4.63 bc	3.67 d	4.39 c	5.10 a		
V_6	3.59 d	4.32 bc	4.15 c	3.54 d	3.09 e	4.51 ab	4.82 a		
V_7	3.54 cd	4.69 a	4.27 b	3.78 c	3.26 d	4.35 b	3.59 c		
V_8	3.68 bc	3.89 ab	3.49 c	3.73 bc	3.07 d	4.15 a	3.90 ab		
V_9	5.18 bc	5.78 a	4.71 d	4.86 cd	4.24 e	5.92 a	5.19 b		
V_{10}	3.68 cd	4.01 b	3.49 de	3.98 bc	3.14 f	4.85 a	3.23 ef		
V_{11}	4.65 bc	4.68 bc	5.09 a	4.84 ab	4.25 d	4.45 cd	3.68 e		
V_{12}	4.68 c	5.02 b	4.93 bc	4.72 bc	4.08 d	5.51 a	4.66 c		

Here, H_0 = control, H_1 = pyrazosulfuron-ethyl, H_2 = butachlor, H_3 = orthosulfamuron, H_4 = acetochlor + bensulfuron methyl, H_5 = butachlor + propanil and H_6 = 2,4-D amineV_1 = BR11, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan44, V_5 = BRRI dhan46, V_6 = BRRI dhan49, V_7 = BRRI dhan51, V_8 = BRRI dhan52, V_9 = BRRI dhan56, V_{10} = BRRI dhan57, V_{11} = BRRI hybrid dhan-4 and V_{12} = Bina dhan-7

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Adoption of raised bed technologies with heat & drought tolerant wheat varieties in drought prone areas: A miracle success in Bangladesh

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Introduction

Tillage practices contribute greatly to the labor cost in any crop production system (Limon *et al.* 2006). Intensive tillage systems result in increased soil compaction and decreased soil organic matter (Singh *et al*. *2003)* and biodiversity (RWC-CIMMYT*et al.* 2003). Reduced tillage practices, such as bed planting, can offset the production cost and other constraints associated with environment and socio-economic conditions. Raised bed planting of different crops helps achieve good plant establishment, save water, seed, production cost and increases input efficiency, and increases yields in rice-wheat systems (Sayre *et al*. 2000). The present study examined adoption of raised beds should be needed for farmer's income and livelihood in drought prone areas.

Materials and Methods

On farm raised bed demonstration trials were conducted from 2003-04 to 2014-15 on 13,250 farmer's fields on 6,325 hectares in Rajshahi, Natore, Chapai and Pabnadistricts. In Durgapur Upazila of Rajshahi district no support was given to the farmers except training. The demonstration trial stated from wheat season in 2003 in that area and farmers are very much motivated to bed planting. Land preparation, seed sowing, furrow making and leveling were completed by both machine and hand. There were two level of tillage options bed and farmers practice was used in the whole demonstrations in 4 districts. Three wheat varieties like Shatabdi, Bijoy and Prodip were used in the farmer's field. Specify how the farmer adoption statistics were gathered.

Results and Discussion

In Rajshahi (Table 1), farmers used Prodip and Shatabdi varieties in their own field on raised beds and got higher yield over the conventional tillage practice. Yield increased by 13.5-15.5% in bed over farmers' practice. In Natore, farmers used Prodip, Bijoy and Shatabdi and achieved 11.3-12.5% yield increase over the conventional tillage practice. In Pabna and Chapai where Prodip, Shatabdi and Bijoy varieties were grown yield advantage was 13.5-18.0% on raised beds relative to the conventional tillage practice. Yield advantage was more due to get more border effect, efficient N uptake and water use efficiency (Lemon *et al.* 2005).

From 2003 to 2014, 13,250 farmers used raised bed systems and they covered 6,325 hectares of land (Table 2). All dissemination trials compared with farmers' own technology. Among them, all trials were significantly higher grain yield from farmers' own practices. Grain yield of wheat was 10-20 %, lentil was 15-25%, mungbean 15-25%, maize 12-20% higher yield over farmers practice and other crops were at least 5-10% higher yield over farmer's own technology. Some of these experiments are permanent while some were conducted for at least 5 seasons. Crop growth and performance of trials were good and farmers were expecting clear benefits from raised bed technology with kept residue in their field.

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Table 1. Effect of raised bed planting on wheat grain yield on farmers' fields in districts of Rajshahi Region

Location District	Number of farmers	Tillage options	Varieties	Yield (t/ha)	% yield increase over farmer's practice (FP)
Rajshahi	3750	Raised bed	Prodip	4.20	15.5
			Shatabdi	4.45	
		FP	Prodip (Check)	3.80	
Natore	550	Raised bed	Prodip	4.10	13.5
			Bijoy	4.40	
		FP	Shatabdi(Check)	3.60	
Pabna	380	Raised bed	Prodip	4.50	18.0
			Shatabdi	4.20	
			Bijoy	4.20	
		FP	Shatabdi(Check)	3.80	
Chapai	250	Raised bed	Prodip	4.20	13.5
			Shatabdi	4.60	
		FP	Prodip(Check)	3.70	

Table 2. Crop wise area (ha) coverage under bed planting system from 2003 to 2014 in districts of Rajshahi region

Crops	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Wheat	6	25	180	375	785	1250	2275	3150	3345	3545	3925	4260
T. aman	6	15	45	110	165	225	185	225	235	210	160	160
Mung	6	25	75	120	155	225	375	875	925	945	995	1050
Maize		10	45	120	210	240	350	550	640	665	820	1025
Sesame				2	5	15	25	30	40	45	50	60
Jute				1	4	9	25	50	62	67	70	70
Okra						1	3	5	15	21	30	35
Radish						4	5	5	8	12	15	15
Lentil					1	1	2	2	15	20	30	40
Total	18	75	345	728	1325	1970	3245	4892	5274	5485	5850	6325

Reduced tillage and mechanized transplanting of rice enhances the system productivity of rice-mustard-rice cropping sequence

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Introduction

The dominant cropping pattern in Bangladesh is transplanted (t.) aman (wet season rice) – fallow – boro (dry season rice) where effort is paid to fit mustard in–between two rice crops for increasing cropping intensity and to increase the availability of food oil (Islam, 2013). The growing labor shortages are likely to adversely affect the intensification and productivity of the rice-based cropping systems. The reduced tillage and mechanized transplanting or direct seeded rice could save time, energy and labour of this system. Furthermore, the adoption of mechanized unpuddled transplanting in single pass and zero tilled land in both the rice or combining of unpuddled transplanting and direct seeding in boro and aman rice, respectively, might enhance the overall system productivity. Therefore, the present study was designed to compare the productivity of rice-mustard-rice adopting reduced tillage and mechanized transplanting with conventional practice.

Materials and Methods

The field trial was conducted during 2015–2016 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 sandy loam in texture. Mustard was grown in tilled soil after harvesting of blank crop, t. aman rice. Rice was grown on tilled (CT), single pass tilled (SPT) and zero tilled (ZT) soils following mustard. The tested tillage and establishment combinations imposed in rice-mustard-rice cropping sequence were –i) conventional tillage and broadcasting of mustard and manual transplanting of boro and aman rice (CT-CT-CT); ii) conventional tillage and broadcasting of mustard, single pass tillage unpuddled transplanting of boro and aman rice using transplanter (CT-SPT-SPT); iii) conventional tillage and broadcasting of mustard, zero tilled unpuddled transplanting of boro and aman rice using transplanter (CT-ZT-ZT) and iv) conventional tillage and broadcasting of mustard, single pass tillage unpuddled transplanting of boro rice using transplanter and dry seeded aman rice using power tiller operated seeder (CT-SPT-DSR). The experiment was laid out in a randomized complete block design with four replications. Mustard variety, BARI sarisha14 and boro variety, BRRI dhan28 was used in the study. The short duration Aman variety, BRRI dhan62 was grown under different treatment except DSR where BRRI dhan49 was used. The other crop management options were followed as per BRRI and BARI recommendations. Grain and seed yields of rice and mustard was taken from a 10 m^2 area in the centre of each plot and expressed at 14 and 9% moisture, respectively. 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, seed and inputs prices was performed to determine the efficiency of different treatment combinations.

Results and Discussion

Seed yield of mustard and grain yield of following boro and aman rice was not affected by tillage and crop establishment methods. The system productivity in terms of REY was similar among the treatments (Table 1) due to similar yields of mustard, boro and aman rice under all

the treatments. The reduction of tillage in SPT and mechanized transplanting in boro and aman rice reduced the total variable cost (TVC) of \$104 ha^{-1}. Zero tillage both in boro and aman rice and SPT in boro and DSR in aman rice reduced the TVC (Table 2) further due to reduction of cost for tillage in CT-ZT-ZT, and tillage and labour cost in CT-SPT-DSR. The gross return from CT-SPT-DSR treatment was slightly lower than the other treatments. More than 12 and 13% gross margins (GM) were recorded in CT-SPT-SPT and CT-ZT-ZT compared to CT-CT-CT. The gain of gross margin from CT-SPT-DSR was 6.2% higher than CT-CT-CT but lower than other conservation treatments. Results indicated the superiority of CT-SPT-SPT and CT-ZT-ZT in rice-mustard-rice cropping system.

Table 1. Yield of mustard, boro, aman rice and rice equivalent yield of the mustard-rice-rice cropping sequence under different tillage and crop establishment methods at Satkhira in 2015-16

Tillage and crop establishment methods	Seed/Grain yield (t ha^{-1})			REY of mustard (t ha^{-1})	System REY (t ha^{-1})
	Mustard	Boro	T. Aman		
CT-CT-CT	1.72	5.37	3.94	4.12	13.44
CT-SPT-SPT	1.61	5.58	4.40	3.82	13.80
CT-ZT-ZT	1.73	6.35	4.23	4.09	13.68
CT-SPT-DSR	1.65	5.56	3.89	3.91	13.36
$LSD_{0.05}$	ns	ns	ns	ns	ns

CT-CT-CT= Conventional tillage and broadcasting of mustard and manual transplanting of boro and aman rice, CT-SPT-SPT: Conventional tillage and broadcasting of mustard, single pass tillage unpuddled transplanting of boro and aman rice using transplanter, CT-ZT-ZT: Conventional tillage and broadcasting of mustard, zero tilled unpuddled transplanting of boro and aman rice using transplanter, CT-SPT-DSR: Conventional tillage and broadcasting of mustard, single pass tillage unpuddled transplanting of boro rice using transplanter and dry seeded aman rice

Table 2. Cost and return of rice-mustard-rice cropping sequence under different tillage and crop establishment methods, Satkhira, 2015-16

Tillage and crop establishment methods	Cost of production and system productivity (\$ ha^{-1})			Increased gross margin over conventional practice (%)
	TVC	GR	GM	
CT-CT-CT	2080	3508	1428	-
CT-SPT-SPT	1976	3581	1604	12.3
CT-ZT-ZT	1935	3551	1617	13.2
CT-SPT-DSR	1948	3465	1517	6.2

TVC= Total variable cost, GR = Gross return, GM = Gross margin

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Session 5

RESEARCH, DEVELOPMENT AND COMMERCIALIZATION OF CONSERVATION AGRICULTURE MACHINERIES

Development and validation of unpuddled riding-type rice transplanter for wet land rice establishment

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Introduction

Manual transplanting is tedious and time consuming which often the causes of delayed planting resulting yield loss of rice in Bangladesh. Mechanized rice transplanting is seen as a solution of labor problems. Likewise, using mechanized rice transplanting ensures uniform plant spacing as well as fast and efficient planting that contributes to high productivity (Manjunatha et al., 2009). 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 has significantly mechanized in Bangladesh, 16-18 % of total production cost are involved in 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 the farmers. No significant work to date has been conducted in Bangladesh to develop a rice transplanter for minimum tillage unpuddled soil conditions. Therefore, the following development and validation study was conducted during 2013-15 with modifying and evaluating 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 (Figure 1). Fabrication was conducted according to a design made at the FMPHT Division, BRRI. Engine power available at a 3600-rpm speed 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. 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 1.0 kW. The tine was designed in such way that depth of strip should not more than 25-50 mm and width 20-25 mm (Figure 1). Specific draft of soils for making strip was taken as design force for strip tillage arrangement. The developed rice transplanter was evaluated for transplanting seedlings under unpuddled minimum tillage condition and compared with mechanized and manual transplanting on puddled soil at BRRI research farm during Boro/2014-15 season.

Results and discussion

Development of the riding type rice transplanter as unpuddled transplanter (URRT)

The values of specific draft of the soil was assumed as force 5.2 N cm^{-2} for torque calculation considering a soil specific draft for clay loam and heavy clay soil 8 Ncm^{-2} and 35% reduction for saturated condition (Kepner *et al.,* 1978). It was calculated that about 1.0 kW power is required to cut strips simultaneously across the width of the rice transplanter in operation considering all losses in power transmission from engine to strip tillage rotary shaft. A double-groove pulley of 125 mm 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. A pulley (200 mm 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 20 mm considering the combined twisting and bending moments. The maximum shear stress induced in the shaft was found less than the allowable stress in calculation (16.15 <41.4 Mpa). 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 622 N and design tangential load was calculated as 2007 N. However, the dynamic load (W_D), static load or endurance strength (W_s) and maximum load for wear (W_W) were found in calculation 2540 N, 5082 N and 2841 N, respectively. Therefore, the design is safe from the stand point of tangential load, dynamic load, static load and maximum load for wear, respectively. 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 was connected two shafts whose axes intersected at 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 233 mm along with 175 mm spline shaft and hub. Torque of the spline shaft is same as the main shaft torque of 21.23 N-m for same rpm and power carried which is less than the allowable torque of 49.22 N-m to the resistance of the shaft. The shear stress under roots of external teeth of an external spline was found 14.68 Mpa. However, the shear stress at the pitch diameter of teeth was found 10.35 Mpa. The compressive stress on sides of spline teeth for flexible splines was also found in calculation 9.05 Mpa. The estimated value is also less than allowable shear and compressive stress.

Field evaluation of the developed riding type rice transplanter (URRT)

Transplanter performance

Fuel consumption of the URRT (4.8 hrs. ha^{-1} and 10.3 l ha^{-1}) did not vary significantly with the riding type rice transplanter (RRT) (4.4 hrs. ha^{-1} and 9.2 l ha^{-1}) whereas manual hand transplanting (MHT) take significantly higher time (206 hrs. ha^{-1}). Rate of area coverage in unpuddled and puddled conditions was not also varied significantly between URRT (4.78 man-hr. ha^{-1}) and RRT (4.44 man-hr. ha^{-1}), respectively whereas rate of area coverage of MHT was found 205.6 man-hr. ha^{-1} (Table 1). Planting depth varied significantly with transplanting methods. Plant to plant spacing was found identical between URRT (155) and RRT (152). URRT gave more accurate spacing compared to RRT. Contrary to, number of seedling per hill also varied with the transplanting methods (Table 1).

Percentage of missing hills

Floating, damage and total missing hills varied significantly with the transplanting methods (Table 2). MHT (2.2%) demonstrated significantly higher floating hills followed by URRT (0.7%). Contrary to, RRT (1.3%) demonstrated significantly higher buried hills whereas it was zero in MHT.

Yield and economic performance

URRT gave significantly higher yield (6.97 t ha^{-1}) which was identical with RRT (6.80 t ha^{-1}) whereas significantly lower for MHT (5.66 t ha^{-1}). Contrary to, URRT gave significantly lower straw yield (5.56 t ha^{-1}) followed by RRT (5.71 t ha^{-1}). However, URRT gave higher BCR (1.78) followed by RRT (1.66) whereas MHT gave lower BCR (1.33)**.** Variation of BCR was observed due to the effect of yield on gross margin and to some extent from input costs (Table 2).

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. Collectively, field performance results suggest that farmers can establish rice in unpuddled conditions to save fuel and labor costs while also achieving increased yield over RRT and MHT using URRT.

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Table 1. Unpuddled transplanter performance as affected under different mode of transplanting

Treatments	Fuel (l ha^{-1})	Rate of area coverage (Man-hrs ha^{-1})	Depth of planting (mm)	Plant to plant distance (mm)	[1]Deviation %	Seedlings $hill^{-1}$ (nos.)
T_1	10.27	4.78	16	155	3.13	3.33
T_2	9.2	4.44	19	152	5	3
T_3	0	205.6	13.67	200	0	4.67
LoS	**	**	*	**	NS	*
$LSD_{0.05}$	3.33	15.48	3.02	7.63	-	1.31

Table 2. Percentage of missing hills and yield performance as affected under different mode of transplanting

Treatments	Picker missing hills (%)	Floating hills (%)	Damaged hills (%)	Buried hills (%)	Total % missing hills	Yield (t ha^{-1})	Straw yield (t ha^{-1})	BCR
T_1	1.33	0.67	1.33	0.33	3.67	6.97	5.56	1.78
T_2	1.33	0.33	1.67	1.33	4.67	6.80	5.71	1.66
T_3	0.00	2.17	0.00	0.00	2.17	5.66	7.02	1.33
LoS	NS	*	*	NS	*	**	*	**
$LSD_{0.05}$	-	0.76	0.93	-	1.31	0.61	0.97	0.17

Note: NS-Not significant, *-significant at 5 %, **-significant at 1 %, LoS-Level of significance and T_1= Unpuddled transplanting using the 6-row developed unpuddled riding type rice transplanter (URRT), T_2= Puddled transplanting using the 6-row riding type rice transplanter (RRT) and T_3= Puddled manual hand transplanting (MHT).

Figure 1. Unpuddled strip transplanting unsing developed rice transplanter

Performance of the Versatile Multi-crop Planter (2010-2017)

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Introduction

In South Asia where cropping intensity is high, small farms may grow three or more crops in a year and over a 5-year cycle due to changing profitability of crops cultivate 4-6 crops with diverse seed sizes, seed rate, row spacing, fertiliser rates, seeding depth etc. Hence a planter for such diverse cropping systems needs to have multi-functional capabilities. Service providers also need to be able to hire out their planter for business all-year-round to justify the investment cost. There are a number of other criteria and challenges that would need to be satisfied by potential purchasers of a planter including low purchase price; sufficient earning capacity; flexible set up in the field with capability to be modified quickly for different seed rate, fertiliser rate, row spacing, seed size, planting depth; durable and reliable in operation, and; light weight with minimal vibrations. The VMP was designed to meet the above criteria and has successfully established a diverse range of crops in Bangladesh since 2008 (Haque et al., 2011).

Materials and Method

The VMP was powered by a Dongfeng or Saifeng 12 - 16 horsepower 2-wheel tractor (2WT). The VMP has designed with capability for seeding and fertilizing with fluted roller or vertical plate meters in lines for: 1) Single-pass shallow-tillage (SPST); 2) strip planting (SP); 3) zero tillage (ZT); 4) bed planting (BP) (for single-pass new bed-making or re-shaping of permanent beds together with simultaneous planting and fertilizer application); and 5) conventional tillage (CT) using full rotary tillage following broadcast seeding and fertiliser spreading. On-station and on-farm replicated trials were conducted with different tillage options and seed calibration to assess effective field capacity, fuel consumption, crop establishment and yield; and analyzed by MSTAT-C. A typical example of performance is shown in Table 1 from a clay soil of the High Barind Tract, Rajshahi, Bangladesh, 2010-11, but many other examples are available on request.

Results and Discussion

The field capacity of VMP was 0.07 ha hr^{-1} for SP which was 57 % higher than for CT. Land preparation cost by VMP was decreased by up to 75 % for single pass compared to CT. The VMP was capable of sowing many crops from small jute seed (2 g/1000 seeds) up to maize (160 g/1000 seed). The VMP weighs 152 kg and ex-factory price is US$900. Significant variation was observed on field capacity when operated for CT, SPST, SP, ZT and BP: 0.03, 0.07, 0.07, 0.06 and 0.05 ha hr^{-1}, respectively (Table 1). Fuel consumption was highest for CT (33.1 l ha^{-1}) and lowest in SP (5.83 l hr^{-1}) by VMP (Table 1). The SPST, SP, ZT and BP by VMP saved 38, 82, 50 and 13 % diesel fuel over CT. The maximum cost (US$ 41.47 ha^{-1}) of land preparation and seeding was incurred in case of CT system and the lowest (US$ 10.27 ha^{-1}) for SP (Table 1). Compared to CT, planting by SPST, SP, ZT, and BP systems lowered costs by 52, 75, 23, and 13 %, respectively (Table 1). The VMP with a vertical plate seed meter placed 96 % of maize plants 180 to 260 mm apart (mean 205 mm; SE ± 3.9 mm) with a single-pass operation. Indeed, the spacing between plants was more consistent than maize planted by hand in well-prepared land after four tillage operations (data not shown here).

Based on feedback from operators who found seed rate calibration difficult, seven vertical meters for different seed size have been developed to regulate the seed rate without further calibration. Also, to optimize the price, minimize the weight, and balance the weight, substantial improvement was made on VMP during 2015 and 2016. Significant improvements were made on the shank of the furrow opener to increase its strength, and the seed-boot and fertilizer-orifice of the furrow opener were modified to minimize seed and fertilizer contact.

Since 2010, a total of 198 units of different models of VMP have been manufactured and sold (98, 63, 23, 12, and 2 units by Hoque Corporation, Alam Engineering, Alim Industries, Janata Engineering, and Tongi Engineering) locally and 40 units exported to 9 countries (Mexico - 15, India - 11, Ethiopia - 6, Vietnam 2, Zimbabwe 2, Kenya 1, Myanmar 1, Tanzania 1, and Uganda 1). During 2012 to 2015, 2016, and 2017; a total of 6, 18, 50 VMPs were monitored closely to collect performance data. Total area coverage of the monitored VMPs were 39, 70, 150, 246, and 943 ha; and service was provided to 187, 523, 1115, 1014, and 3772 farmers during 2012-13, 2013-14, 2014-15, 2015-16, and 2016-17.

Hoque Corporation, Dhaka is involved to commercialize the VMP, and sold 115 units since the rabi season of 2016. In collaboration with Barind Multipurpose Development Authority (BMDA) and National Bank Ltd., Hoque Corporation identified 62 new LSP in Naogaon district, where, National Bank provided a 3-year loan package of Taka 170,000 to each LSP without any property mortgage. During the VMP handover program to LSPs, the BMDA and National Bank Ltd. agreed to extend the loan program for VMP in other districts of Bangladesh.

Conclusions

The VMP is a unique multi-functional and multi-crop planter powered by 12-16 hp 2WT with capability for seed and fertilizer application at variable rates, depth and row spacing using SPST, SP, ZT, BP, and CT. The square shaft and brackets designed for the VMP achieve improved flexibility for multi-crop planting and capacity for rapid adjustment of row spacing on a field-by-field basis. By using the VMP, the establishment costs for various crops in different tillage systems were significantly reduced compared to CT. Planters such as VMP could be used to develop CA practices across a wide range of cropping systems used by smallholder farmers in Bangladesh, and other regions of South and Southeast Asia and Africa.

Acknowledgement

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Haque, M.E., Bell, R.W., Islam, A.K.M.S., Sayre, K., Hossain, M.M., 2011. Versatile multi-crop planter for two-wheel tractors: an innovative option for smallholders. In: 5th World Congress of Conservation Agriculture. 26–29 September 2011, Brisbane, Australia, pp. 102-103.

Table 1. Effect of tillage mode by the Versatile Multi-crop Planter on fuel consumption, field capacity, labour requirement and cost of land preparation and seeding of lentil, chickpea, mung bean and black gram in clay soil at High Barind Tract, Rajshahi, Bangladesh, 2010-11.

Tillage type	Field capacity (ha hr^{-1})	Fuel consumption (l ha^{-1})	Labour requirement (person-hr ha^{-1})	Cost of land preparation and seeding[a], (US$ ha^{-1})
Conventional tillage (4 tillage passes)	0.03c	33.1a	48.1a	41.5a
Single pass shallow tillage	0.07a	20.6c (38)	15.4c (68)	19.8d (52)
Strip planting	0.07a	5.83e (82)	15.3c (68)	10.3d (75)
Zero tillage	0.06ab	16.6d (50)	17.3c (64)	18.1c (23)
Bed planting	0.05b	28.9b (13)	23.9b (51)	28.8b (13)
LS	**	**	**	**

Values in parentheses indicate the percent saving over CT. Values in a column, followed by a common letter are not significantly different at P < 0.01 by Duncan's Multiple Range Test.

[a]Considering variable costs for labour (land preparation @Taka 30 and seeding @Taka 20/ha); diesel fuel (@Taka 45/l). 1 US$ = 68 Taka

Comparative levels of soil disturbance under reduced and minimum tillage types with two-wheel tractor planting operations

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Introduction

Minimum soil disturbance is one of the key principles of conservation agriculture (CA). However, little is known about levels of soil disturbance caused by 2-wheel tractor (2WT) -based planters being used in small farms to practice CA (Haque et. al., 2013). Several types of single pass minimum soil disturbance are being used to establish crops in Bangladesh. To quantify the impact of various tillage types on soil disturbance, breakage of soil aggregates, and operational cost, a study was carried out during 2015 at two long-term CA sites at Godagari upazila, Rajshahi; and Baliakandi upazila, Rajbari. The aim was to determine which forms of planting involve minimum soil disturbance according to the requirements of CA.

Materials and Method

The single pass tillage treatments were zero tillage (ZT), single pass full tillage (SPFT), strip tillage with straight blade (STSB), strip tillage with bent blade (STBB), permanent bed -reshaping (PBR), new bed forming (NB), all of which were compared with four full tillage passes by 2-wheel tractor (2WT) as conventional tillage (CT). The Versatile Multi-crop Planter (VMP, Haque et al., 2011) was used for all single pass tillage operations and a Dongfeng brand 16hp 2WT was used for CT. The soil types were silty clay, and sandy-loam in Godagari and Baliakandi sites, respectively. The experiments were laid out as a randomized complete block design with three replications. Data on effective field operating capacity of the machinery, fuel consumption requirements, amount of loosened soil, tillage depth, etc. were recorded and analyzed by MSTAT-C program.

Results and Discussion

Significantly ($P<0.01$) higher field operating capacity was recorded for all single pass tillage operations than for CT. The maximum effective field operating capacity was recorded for ZT, SPFT, STBB, STSB in Gogagari followed by NB and PBR. In Baliakandi, the highest field operating capacity was recorded for STBB which was statistically similar to SPFT and STSP, but higher than NB and ZT. The effective field operation capacity for PBR at Baliakandi was significantly higher than CT but significantly lower than all other tillage methods (Table 1). The highest fuel consumption was reported for CT in both locations in Godagari and Baliakandi, respectively) and lowest was reported for STSB in both locations (Table 1). Highest amount of soil disturbed (loosened soil due to tillage) was reported for CT in both locations, in Godagari and Baliakandi, respectively and for SPFT in Baliakandi which was statistically similar to NB at Godagari. The lowest amount of soil disturbance was reported for ZT in Godagari and Baliakandi followed by STBB at Godagari, STBB at Baliakandi and STSP in same location (Table 1). The maximum tillage depth was reported for NB and PBR in Godagari; and the lowest was for SPFT in Baliakandi and STBB in Godagari (Table 1).

Conclusions

The results confirmed that SPFT, PBR and NB cannot qualify for minimum soil disturbance tillage systems as the soil disturbance was comparable to CT, while soil disturbance by the ZT, STBB and STSB involved minimum soil disturbance.

Acknowledgement

The research was conducted under the LWR-2010-080 project funded by Australian Centre for International Agricultural Research (ACIAR) with the strong collaboration of Conservation Agriculture Service Providers Association (CASPA) and the authors are highly acknowledging the contribution.

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Table 1. Evaluation of different tillage type on fuel consumption, effective field operating capacity, amount of loosened soils, and depth of tillage at Godagari and Baliakandi upazilas of Bangladesh.

Tillage type	Effective field operating capacity (ha hr^{-1})	Fuel Consumption (l ha^{-1})	Amount of loosened soils (t ha^{-1})	Maximum depth of tillage (cm)
Godagari				
ZT	0.08a	11.8cd	83d	6.3cd
SPFT	0.08a	12.5c	476b	5.9cd
CT	0.03d	34.2a	558a	8.9b
STBB	0.08a	11.7cd	172c	5.7d
STSB	0.08a	10.5d	139cd	6.4c
PBR	0.05c	15.4b	464b	10.9a
NB	0.06b	14.3b	539ab	11.5a
LS	**	**	**	**
Baliakandi				
ZT	0.06b	11.7e	87d	6.08c
SPFT	0.07a	12.1e	648a	5.08d
CT	0.03d	33.7a	587a	6.26c
STBB	0.08a	9.30f	285c	6.23c
STSB	0.07a	14.1d	301c	6.53c
PBR	0.05c	31.4b	417b	10.20b
NB	0.06b	25.4c	408b	11.06a
LS	**	**	**	**

ZT - zero tillage; SPFT - single pass full tillage; CT - four full tillage passes by 2-wheel tractor as conventional tillage; STBB-strip tillage with bent blade; STSB - strip tillage with straight blade, PBR - permanent bed - reshaping, NB - new bed forming, LS = Level of significance; ** mean significant at 1%.

Effect of minimum tillage systems on water balance for rice-based rotations in Northwest Bangladesh

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Introduction

Controlled traffic and minimum tillage are expected over time to alleviate degraded soil structure, particularly in rice –based cropping soils that experience annual soil puddling and intensive tillage. However, minimum tillage over time may weaken the plough pan and in turn alter water balance in the rice-based systems. This implication of a change of water balance may be detrimental for rice but beneficial for following crops and for groundwater recharge. The aim of the current study is to determine how soil structure changes over time under continuous minimum tillage system and how changes in soil structure, particularly in the plough pan, affects water balance in rice-based cropping system. This paper reports the magnitude of water balance components in different tillage practices for the Boro rice period of the crop sequence.

Materials and methods

Experiments were conducted in 2015 and 2016 on a silty loam soil (Alluvial soil) at Rajshahi, Bangladesh (24°29 N, 88°46 E). The experiments were completed on a long-term experiment site, which was established in 2010. The experiment had a split-plot design (plots 7 m × 15 m) with 4 replicates. The main plot was tillage treatment (Strip tillage (ST), Bed planting (BP) or Conventional Tillage (CT)) and the sub-plot was residue treatment (20% or 50% of straw retained). In 2015, all plots were irrigated by continuous flooding (CF). For the 2016 experiment the whole field was divided into two groups each consisting of two replications. Two replicate blocks were devoted to CF irrigation and the other two to Alternate Wetting and Drying (AWD) irrigation. In 2015, plastic sheets were installed in the centre of the bunds down to 15 cm. In 2016, no plastic sheets were installed. All the components of the water balance were measured daily, except for daily evapotranspiration which was calculated as the residual term in the water balance equation $PD_i=PD_{i-1}+R+I-ET-DP-S$ (cm), where *PD* is the ponding depth, *i* is the time index (days), *I* is the irrigation, *R* is the rainfall, *ET* is the evapotranspiration, *DP* is the percolation below root zone, and *S* is the seepage. Daily deep percolation was calculated from the daily decline of water level in the closed top lysimeters (PVC pipe 25 cm in diameter and 60 cm high) embedded into the hardpan to a depth of 30 cm. Seepage was calculated from the difference in the daily decline of water level in the plots and open lysimeters of the same dimensions as the closed top lysimeters. In 2016, as in the AWD irrigation the field is subjected to both wet and dry conditions, both ponded and unsaturated phases are taken into consideration to calculate the actual evapotranspiration and percolation from the rice field. The calculating procedure followed the method of Agrawal, Panda, and Panigrahi (2004), and Khepar, Yadav, Sondhi, and Siag (2000). Change in soil moisture storage (ΔSMC) was calculated by measuring soil moisture content to a depth of 30 cm prior to pre-irrigation and at harvest of each season of the Boro rice crops.

Results and Discussion

In 2015, there was no difference in the amount of water applied with tillage or residue treatments. In 2016, ST received 40-42 cm more water than CT with CF (*P*<0.05) (Table 1). BP-CF treatment received 30-45 cm more water compared to CT-CF treatment. Shifting from CF to AWD reduced the amount of irrigation water by an average of 19 % (20 cm) for all tillage treatments. In 2015 with plastic lining in the bunds to 15 cm below the soil surface, irrigation water was less than the 2016 CF plots, suggesting that the lining reduced seepage losses. High amount of under-bund seepage in 2016 might be attributed to the high hydraulic conductivity of the bunds. In addition, the fields surrounding the plots were not irrigated until 20 days later which may have exacerbated water movement under the bunds to these adjacent fields.

In 2016, higher amounts of irrigation water required for BP and ST were associated with increased deep percolation. Each year, there was a significant effect of Tillage treatment on percolation beyond 30 cm soil depth (*P*<0.05). Deep percolation in BP treatment was 32 cm in 2015 and 52 cm in 2016, and significantly higher than CT each year. In 2016, deep percolation of ST-CF was 19-27 cm higher than that of CT-CF treatment, and 30-35 cm higher than that of CT-AWD treatment. Higher amount of deep percolation was probably because of higher permeability of soil in the unpuddled soil of the strip tillage and furrows, and greater macropore development on the permanent beds in the BP. This study was conducted with groundwater level 10-12 m below ground level from transplanting to harvest of the season, which is also a determining factor in increasing percolation losses in the minimum tillage plots. Changes in water balance components for other cropping seasons should also be examined, particularly for Aman season.

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Table 1. Components of the seasonal water balance (cm) of Boro Rice in 2015 and 2016.

2015

Treatments[a]		**Water Balance Components (cm)**					
Tillage	**Residue retention**	**I**[b]	**R**[c]	**DP**[d]	**S**[e]	**ET**[f]	**ΔSMC**[g]
ST	20%	80.2	5.0	29.9	19.2	33.0	3.1
	50%	75.2	5.0	26.5	17.6	33.7	2.4
BP	20%	84.2	5.0	32.2	20.8	32.5	3.7
	50%	86.6	5.0	32.5	23.0	33.4	2.7
CT	20%	66.1	5.0	23.5	11.1	32.7	3.8
	50%	64.1	5.0	21.9	10.6	32.7	4.0
LSD(p≤0.05)[h], Tillage		NS	-	4.1	NS	NS	NS

2016

Treatments[a]			**Water Balance Components (cm)**					
Irrigation Practice	**Tillage**	**Residue retention**	**I**[b]	**R**[c]	**DP**[d]	**S**[e]	**ET**[f]	**ΔSMC**[g]
CF	ST	20%	120.9	8.6	50.2	40.8	34.8	3.6
		50%	122.4	8.6	56.5	38.3	33.8	2.4
	BP	20%	110.8	8.6	48.4	33.5	33.0	4.5
		50%	126.5	8.6	54.9	43.7	32.8	3.7
	CT	20%	80.4	8.6	31.6	18.5	35.1	3.8
		50%	81.1	8.6	29.3	21.8	35.3	3.4
LSD(p≤0.05)[h], Tillage			10.4	-	7.3	7.1	0.8	NS

Treatments[a]			Water Balance Components (cm)					
Irrigation Practice	Tillage	Residue retention	I[b]	R[c]	DP[d]	S[e]	ET[f]	ΔSMC[g]
AWD	ST	20%	98.7	8.6	37.5	36.0	30.7	3.1
		50%	96.9	8.6	41.5	32.1	30.6	1.3
	BP	20%	99.2	8.6	36.6	37.0	30.2	4.0
		50%	99.9	8.6	45.2	30.3	29.2	3.8
	CT	20%	64.4	8.6	20.7	18.2	32.0	2.2
		50%	63.9	8.6	20.3	19.7	30.9	1.6
LSD(p≤0.05)[h], Tillage			8.0	-	8.1	3.5	NS	NS

[a]Treatment abbreviations are explained in the text. [b]*I* is the irrigation, [c]*R* is the rainfall, [d]*DP* is the deep percolation below root zone (0.3 m), [e]*S* is the seepage, [fET] is the evapotranspiration, [g]ΔSMC is the change in soil water storage in the root zone.
[h]interaction effect of Tillage × Residue and the main effect of Residue was not significant.

Commercialization approach for Versatile Multi-Crop Planter: Lessons learnt

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Introduction

A Versatile Multi-crop Planter (VMP) was designed and built for seed and fertilizer application in lines when driven by 2-wheel tractors (2WT) for: single-pass shallow-tillage (SPST); strip planting (SP); zero tillage (ZT); bed planting (BP) and conventional tillage (CT). Land preparation cost by VMP was decreased by up to 75 % for single pass compared to CT (Haque at el., 2011). The VMP was capable of sowing many types of crop seeds from small jute seed up to maize seed. Demand for mechanized planters by smallholder farmers is growing rapidly due to the shortage of farm labour for operations such as planting or transplanting. Despite the promising seeder and planter developments, few of the present planters for 2WT are commercialized in Bangladesh. With the funding support from the Australian Centre for International Agricultural Research (ACIAR), the VMP commercialization activities commenced in 2012. Initially (2012 to 2014), the VMP commercialization activities were led by International Development Enterprises (IDE) and that approach was followed by a different approach implemented by the Project Implementation Office (PIO) of Murdoch University, Australia. In this paper, we will synthesis the VMP commercialization approaches and outcomes to identify key lessons learnt.

Materials and Method

The main role of IDE in LWR-2010-080 project was to provide business development services and value chain linkages to facilitate the VMP commercialization. As such, IDE signed Letters of Agreement with Alim Industries and ACI Motors in 2012 and 2013, respectively were targeting sales of 161 VMPs. During 2012 to 2014, the major thrust was given to supply side approaches through marketing for high sales volumes. Hence, in the same period demand creation in the target market and quality assurance of VMP was given lower priority. Once the project disengaged from IDE in 2015, the PIO contracted Hoque Corporation (HC), Dhaka to initiate a commercialization strategy by the sale of 54 units (18 and 36 units in 2015 and 2016, respectively) of VMP. In collaboration with PIO, HC fostered demand creation among farmers/local service providers (LSPs) through demonstrations, focus group discussion; quality assurance; service after sales; price support for LSP (50 and 25 % in 2015 and 2016, respectively);inclusion of financing institutions (e.g., National Bank Ltd.); establishment and involvement of the Conservation Agriculture Service Providers Association; inclusion of government extension agencies (e.g., Department of Agricultural Extension [DAE] and the Barind Multipurpose Development Authority [BMDA]).

Results and Discussion

During 2012 to 2014, IDE developed strategies for the commercialization of VMP through the involvement of Alim Industries Ltd., Sylhet and ACI Motors Ltd., Dhaka; and sold 8 and 12 units of VMP to projects in 2012 and 2013, respectively; a further 24 units of VMP were exported to Mexico (15 units), Zimbabwe (3 units), Ethiopia (3 units), Kenya (2 units), and 1 (unit) to India through HC. ACI Motors engaged Janata Engineering Workshop in 2014 to manufacture and sell the VMPs. However, due to low quality of materials used to manufacture the VMPs, most of them had repeated breakages during field operation. Six VMP were procured from Alam Engineering Workshop to replace the defective planters. Neither of the strategies were successful in attracting additional sales; indeed, the poor quality VMP hampered attempts to interest LSP. Furthermore, due to the unproven market demand for VMP, the bigger manufacturers were unwilling to invest in demand creation activities or further development and production of VMP. However, since 2015, the LWR-2010-080 project has implemented two models for VMP commercialization that are showing promising signs of success as follows:

Model 1: Since the rabi season of 2015, HC has sold115 units (21 and 94 units in 2015 and 2016, respectively) of VMP, and one unit was exported to Myanmar in 2016. Hoque Corporation and the PIO worked together for demand creation in six target hubs and ensured quality production and delivery of VMP on time. In 2015 and 2016, both PIO and HC identified interested new 2WT service provider groups in nine districts (including six project working hubs), because - i) most of the service providers have 2WT which is essential to operate planters/implements and they had the financial means to buy VMP; ii) they are well known in their community for selling tillage services; iii) they are business-minded, risk takers who are open to try and adopt new ideas and technologies compared to traditional farmers; iv) they have mechanical skill and require minimal training on VMP operation and maintenance; v) they already are a trusted source of advice to farmers in their locality; vi) service providers have established linkages with extension agencies, local administration and farmers of their community.

The live demonstration/hands-on training on VMP operation and on-farm demonstration of crop performances to service providers for establishing wheat, onion, garlic, lentil, chickpea, mungbean, jute, etc. were organized at Union level by PIO and HC to create demand for VMP. The interested LSPs were asked to register with a deposit of Tk. 10,000 as a down-payment by 15 October. The PIO arranged VMP operation, repair and maintenance training programmes in mid-October to early-November of each year prior to handover of the VMP to LSP. During the training program, the LSP deposited 50%of the VMP price with HC. During mid-November to early-December, HC handed over the VMP to the LSP. Service providers paid the remaining 50 % of the cost during takeover of the VMP. For initial demand creation from new LSP, the LWR-2010-080 project provided 50 % and 25 % price support for 18 and 33 units of VMP in 2015 and 2016, respectively. Additionally, the project provided free training to LSP on repair and maintenance of VMP, follow-up meetings with LSP, and with HC organized farmers' field days for demand creation at farmers' level. These activities created confidence by farmers, LSP, and involved stakeholders (e.g., DAE, BMDA, National Bank Ltd.) in VMP adoption and commercialization.

Model 2: As the use of VMP could save irrigation water up to 34% (Hossain et al., 2010) and reduce the cost of crop cultivation, the BMDA sought assistance from PIO and HC to promote VMP in Naogaon district in 2016. In collaboration with BMDA and National Bank Ltd., the PIO

and HC identified 62 new LSP in Naogaon district, where, the National Bank Ltd. provided a 3-year loan package of Taka 170,000 to each LSP (after registration, Tk. 50,000 to buy a VMP and Tk. 120,000 for a 2WT) without any property mortgage. Each LSP provided a down payment of Tk. 10,000 to HC to confirm registration. The project organized the VMP training program as in Model 1. The BMDA engaged Chittagong Builders to deliver 62 units of 2WT in Naogaon. On behalf of the LSPs, the National Bank Ltd. has settled the payment with HC and Chittagong Builders after successful handover of the VMP and 2WT.

Since 2010, a total of 198 units of different models of VMP have been manufactured and sold (98, 63, 23, 12, and 2 units by Hoque Corporation, Alam Engineering, Alim Industries, Janata Engineering, and Tongi Engineering, respectively) locally and 40 units exported to 9 countries (Mexico - 15, India - 11, Ethiopia - 6, Vietnam 2, Zimbabwe 2, Kenya 1, Myanmar 1, Tanzania 1, and Uganda 1). During 2012 to 2015, 2016, and 2017; a total of 6, 18, 50 VMPs were monitored closely to collect performance data. The adoption of VMP by farmers to grow various crops has been increasing over the period. On an average, each VMP covered 6.5 ha during 2012-2013; average planting area increased to 11.7, 12.5, 13.7, and 18.9 ha and served 31, 87, 93, 56, and 75 farmers per VMP during 2012-13, 2013-14, 2014-15, 2015-16, and 2016-17, respectively.

Working with multi-stakeholders is critically important for commercialization of new agricultural technology. The LSPs and farmers are cautious to invest money for new farm implements as many of them had been cheated or had bitter experience to get proper services from private companies after purchasing implements. Involvement of universities (e.g., Bangladesh Agricultural University, Murdoch University), research institutions (e.g., Bangladesh Agricultural Research Institute and Bangladesh Rice Research Institute) extension agencies (e.g., Department of Agricultural Extension and BMDA) and strong coordination through PIO has built the trust among the LSPs and farmers to buy and adopt the VMP.

Based on farmers' and service providers' demand, ongoing modification of the VMP during 2015 and 2016 has significantly reduced the market price, and its weight, and improved weight balancing, while maintaining assurance of high quality production. Seven vertical meters with different seed apertures have developed and supplied with the VMP to regulate the seed rate without further calibration. Also, further improvement was done on the shank of furrow openers to increase the strength, while the seed-boot and fertilizer-orifice of the furrow opener were modified to minimize seed and fertilizer contact. This improvement has strengthened confidence by LSP and farmers in the use and performance of the VMP.

In conclusion, both the commercialization models implemented by PIO are showing signs of success, although, the scenarios, mode of operation and strategies of both models were different. Continuation of these two models of expansion of VMP use for another two to three years is likely to lead to commercialization by the private sector.

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Impact of Versatile Multi-crop Planter on service providers' livelihood in some selected areas of Bangladesh

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Introduction

The cropping intensity of Bangladesh is increasing year after year because most small holders start growing three or more crops in a year. Over a 5-year cycle due to changing profitability of crops, farmers cultivate 4-6 crops with diverse seed sizes, seed rate, row spacing, fertilizer rates, and seed depth. Hence a planter for such diverse cropping systems needs to have multi-functional capabilities. Service providers also need to be able to hire out their planter for business all year round to justify the investment cost. There are a number of other criteria and challenges that would need to be satisfied by potential purchasers of a planter. The VMP (Versatile Multi-crop Planter) is such a unique machine for two-wheel tractor which can meet the above criteria and successfully establish a diverse range of crops since 2008 (Haque et al., 2011). It has designed with capability for seeding and fertilizing with fluted roller or vertical plate meters in lines for single-pass shallow-tillage, strip planting, zero tillage and bed planting. The service providers remove seeding unit from VMP and convert only for high speed rotary tiller (HSRT). Most of the grain seeds like wheat, paddy, maize, jute, pulses, oilseeds etc. can be sown in line using VMP. It owners are using this device for their own land cultivation and earning cash income through custom hiring to other farmers and could improve their livelihood through this machine. Therefore, an attempt was made to assess the profitability of VMP operations at farm level and the impacts of its operations on service providers' livelihood.

Methodology

The present study was conducted in Rajshahi, Thakurgaon, Mymensingh and Rajbari district. A total of 18 local service providers (LSP) of VMP who provided at least one year tillage service to the farmers were purposively selected and interviewed for this study. Data and information were gathered from selected service providers of VMP through conducting household survey using pre-tested interview schedules in the month of December, 2016. The collected data were scrutinized, edited, tabulated, and analyzed for fulfilling the objectives of the study. The impacts of VMP on the livelihoods of service providers were assessed through analyzing *'Before'* and *'After'* socio-economic standings of the service providers. Data regarding land holdings, livestock resources, yearly household income, farm equipment, household assets, liability status, and food intake were analyzed and compared for measuring the impacts of VMP service on its provider's livelihoods. The values of different household assets were collected based on present value.

Results and Discussion

The average age of the respondents was 34 years with minimum age of 22 years and the maximum of 58 years. More than 56% of them completed primary level of education, followed by 22% of higher secondary levels. The average length of experience of service providers in VMP operations was three years ranging from two to six years. All of the respondents bought VMP by own cash with subsidy from Australian government funded CA project in Bangladesh.

Many service providers owned a number of farms implement namely power tiller, power thresher, shallow tube well (STW), sprayer and hand weeder that were mostly used for renting out to others for earning cash income.

The study revealed that the custom hiring of VMP service was a profitable business to the local service providers in the study areas. Most LSPs provided VMP services during *Rabi* season. The average area under VMP tillage was 161 bigha (15.31 ha) per year. The net income received by local service providers was Tk. 37,634 (with subsidy on VMP) and Tk. 36,059 (without subsidy) per year (Table 1). Considering these present returns, the average payback periods will be 2.74 years and 3.69 years respectively. In the coming years, the adoption of VMP seems to be high and in that case the net income and payback period will be higher and lower than current estimations. The custom hiring of VMP created many positive impacts on the livelihoods of the service providers. The respondent service providers experienced a considerable increase in their land holdings (6.4%), annual income (33%), livestock resources (32%), farm equipment (31%), household assets position and dwelling houses (46%). The increased income of beneficiaries is mostly spent on farm machinery, nutritious food, cloths, health care, education, and making of houses that indicate higher standard of riding to some extent, compared to pre VMP service period. Although renting out VMP service was profitable, it was constrained by some minor problems such as unable to use this machine in the wetland condition (58%), no seating arrangement on the machine during ploughing (58%), required higher time (42%), heavy weight (16%), and lack of trained driver (11%). Financial support and technical assistance regarding VMP should be made available by the government or by NGO for service providers and local manufacturers, redesign (if possible) this machine with seating arrangement and able to run in wetland condition will helps for the higher adoption of VMP in Bangladesh.

Conclusions and Recommendations

The custom hiring business of VMP is opined to be a profitable business in the study areas. The increased income of LSP are mostly spent on farm machinery, nutritious food, cloths, health care, education expenses and making of houses that indicate higher standard of living of service providers. However, the custom hiring business has made a notable improvement in the livelihoods of its service providers. Due to higher adoption of VMP, financial support and technical assistance should be made available by the government of Bangladesh for service providers and local manufacturers. Training on repair and maintenance of VMP for operators is highly required. Furthermore, research work should be carried out to improve the machine with seating facilities during ploughing.

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Table 1. Financial analysis of VMP operation at farm level

Particular	With subsidy	Without subsidy
A. Gross income (Tk/year)	**71092**	**71092**
Total area under tillage (bigha)	160.96	160.96
Average rental charge (Tk/bigha)	441.67	441.67
B. Variable cost (Tk/year)	**27659**	**27659**
Fuel and oil	16919	16919
Wage for driver	8113	8113
Repair and maintenance	933	933
Spare parts	1694	1694
C. Fixed cost (Tk/year)	**5799**	**7374**
Depreciation on machinery	2320	2995
Depreciation on machinery shed	386	386
Interest on investment	3093	3993
D. Total cost (Tk/year)	**33458**	**35033**
E. Net income (Tk/year)		
Over variable cost	43433	43433
Over total cost	37634	36059
F. Rate of return		
Over variable cost	2.57	2.57
Over total cost	2.12	2.03
G. Payback period (year)	2.74	3.69

Note: Average price of VMP (including PT) = Tk. 1,33,111 (without subsidy), and 1,03,111 (with subsidy);
Diesel cost (Tk/bigha) = Tk. 105.11; Interest rate = Tk.12/year for 3 months; Life of VMP &PT = 10 years;
Salvage value VMP = 10% of purchase price, Depreciation has been considered for 3 months.

Session 6

RICE ESTABLISHMENT TECHNOLOGY FOR CONSERVATION AGRICULTURE

KEYNOTE PAPER

Minimum tillage non-puddled transplanting of rice: An overview

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Introduction

Labour-intensive and water-demanding practices for rice cultivation such as soil puddling and transplanting of rice seedlings are no longer feasible in many parts of Asia due to declining labour and irrigation water availability. Non-puddled transplanting into soils with minimum soil disturbance (NPT) is a possible approach for rice seedling establishment that could decrease the labour and water requirements and cost of establishment of rice while maintaining some of the advantages that transplanting and flooding of soils bring, namely weed control and increased nutrient availability. The present paper reviews earlier work on the NPT technology in the Indo-Gangetic plain and then examines the findings for minimum tillage NPT of rice seedlings in Bangladesh.

Results and Discussion

Zero tillage and strip tillage are the most common methods of NPT. Generally, experiments examined a single crop of NPT of rice and showed that the first rice crop established by NPT produced similar yield to the conventional rice seedling establishment by transplanting on puddled soils (Ladha et al. 2009; Saharawat et al. 2010; Haque et al. 2014, 2016). In the monsoon season, 38 on-farm paired comparisons in northwest Bangladesh produced no grain yield difference between NPT and puddled transplanted rice. However, in the dry-season irrigated season of 2012 (boro) the NPT increased average yield over 29 paired comparisons by 0.26 t ha^{-1}. From a further 66 rainfed monsoon (aman) and 84 boro crops during 2013 to 2015 in north and north-west Bangladesh, NPT of rice seedlings in strips produced similar or significantly greater grain (boro season of 2015) and straw yield (Haque et al. 2017).

In three long-term experiments with up to 15 consecutive crops since commencing strip tillage, NPT gave the same grain yield of rice as conventional puddling and transplanting (Haque et al. unpublished data). By contrast, at another three long term experiments, rice grain yield increased by 0.7 to 1.7 t ha^{-1} in all crops under NPT following strip tillage. Collectively, the replicated experiments and on-farms assessments of NPT demonstrate that it is reliably able to produce as much grain yield in the first crop as the conventional puddling of soils. Moreover, with continuation of minimum tillage by strip tillage the yield of both aman and boro rice crops equal or exceed those of the conventional puddling and transplanting of rice. With mechanised transplanting, the grain yield was similar between NPT and conventional soil puddling for rice establishment (Hossen et al. 2017). We conclude that changing to NPT represents minimal minimal risk of yield loss for rice producers while providing labour, fuel and water savings (Haque et al. 2016).

First impressions of the performance of NPT are important for acceptance by farmers. Generally, results shown no yield change with NPT in the first crop compared to the conventional puddling of soil and transplanting. However, there are immediate savings in labour and water although for transplanting itself the labour requirement may increase (Haque

et al. 2016). With continuous minimum soil disturbance and residue retention about 50 % of cases report increased grain yield with NPT rice and the remainder report no yield difference (Haque et al. 2017). Increased profitability is consistently reported from experiments and on-farm experiments and demonstrations.

Farmers' practice of NPT will provide a pathway for the adoption of conservation agriculture in rice-based systems. The knowledge base for NPT is still limited compared to puddling and transplanting. Hence many questions still remain about this practice. Further research is needed to define the domain of soil types, hydrology and farmer typology within the lowland rice-growing areas where this technology is suitable. The main consideration is whether enough of the key questions about its feasibility and profitability have been answered so that it can now be recommended to farmers. If not, what are the remaining research and practical questions that remain? There is also a need to demonstrate NPT in long term trials to establish confidence among target farmers in the technology and to identify emergent trends that need to be studied in detail before they become limiting factors for widespread adoption or practice.

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On-farm non-puddled rice yield response to crop residue retention

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Introduction

In Asia, rice (*Oryza sativa* L.) is established generally by seedling transplanting in puddled soil. Generally, lands are prepared by 3-4 ploughing and cross ploughing operations followed by levelling in standing water. This traditional method is costly in terms of labour, fuel, time and irrigation water, and is detrimental to soil health (Islam *et al.,* 2014). Adoption of non-puddled transplanting may be a good alternative to soil puddling which has potential to achieve savings in labour, energy, water and time during rice establishment (Islam *et al.,* 2012). Retaining previous crop residues maintains soil microbial activity which can also lead to weed suppression by the biological agents leading to increases in crop yield (Kennedy, 1999). Considerable research work has been done on puddled transplanting, but there is a limited information on the effect of crop residue retention level on the performance of non-puddled transplanting of rice.

Materials and Methods

The experiment was conducted at a farmer's field located at Durbacahra village of Bangladesh (between 24.75^0 N and 90.50^0 E) during summer rice season (July-November, 2013) and winter rice season (December-June, 2014). The summer and winter rice were 10^{th} and 12^{th} crop of a long-term trial using the rice-mustard-rice pattern. The treatments (four replicates) were: in puddled condition (i) Conventional tillage (CT) and in non-puddled condition (ii) Strip tillage (ST) with two levels of crop residue *viz*., No residue (R_0) and 50% residue retention (R_{50}). CT was completed by 2-wheel tractor (2WT) and ST by Versatile Multi-crop Planter (VMP). Three days before ST, glyphosate (Roundup) was applied @ 75 mL/10 L water. After ST, the land was inundated with 3-5 cm standing water one day before the transplanting operation to allow the land to soft enough to transplant seedlings. For aman rice, 25 day-old seedlings of summer rice (*Hybrid Krishan2)* and 40 day-old seedlings of winter rice (*BRRI dhan28)* were transplanted. Recommended cultural operations were performed. The crops were harvested at maturity from three 3 × 3m quadrats per plot. Grain yield was adjusted to 14% moisture content. Data were subjected to ANOVA using *STATISTIX* and means were separated by Duncan's Multiple Range Test.

Results and discussions

ST and 50% residue retention yielded the highest grain yield of both summer rice (5.97 t ha^{-1}) and winter rice (4.81t ha^{-1}) which could be attributed from the highest number of effective tillers m^{-2}, the highest and lowest number of fertile and sterile grains $panicle^{-1}$, respectively. The highest grain yield generated the highest BCR both in summer rice (3.08) and winter rice (2.78). CT without residue yielded the least grain both of summer rice (5.17 t ha^{-1}) and winter rice (4.12 t ha^{-1}), and consequently earned the lowest BCR 1.63 and 2.08, respectively.

The higher rice yields in ST obtained in this study are in the conformity with results of Mahajan *et al*. (2002) who concluded, crop yield in minimum tillage are greater than conventional practice when crops are managed successfully. Residue is mineralized during crop growth and releases nutrients which promote crop growth and facilitates higher yield over no residue.

Similarly, Devasinghe *et al.* (2011) concluded that residues prevents weed growth and supplies organic matter for heterotrophic N fixing microorganisms, which could be utilized by succeeding crops and lead to higher yield.

Conclusion

Considering the rice grain yield and BCR, it may be concluded that, non-puddled rice transplanting might a very good alternative to the conventional practice without sacrificing yield or profit. Farmers are likely to be benefited from the adoption of non-puddled rice establishment with the retention of crop residues in the field

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Table 1. Effect of tillage practice and residue level on yield attributes and yield of rice

Tillage practice	Residue level	Effective tillers m^{-2}	Panicle length (cm)	Fertile grains $panicle^{-1}$	Sterile grains $panicle^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Benefit Cost Ratio
Summer rice								
CT	R_0	207cd	24.2	119d	53a	28.5	5.17cd	1.63c
	R_{50}	211 c	24.6	140c	43b	31.3	5.20c	1.76c
ST	R_0	241b	24.7	154b	29c	30.8	5.57b	2.76b
	R_{50}	280a	24.5	160a	26c	31.4	5.97a	3.08a
LS		**	NS	*	*	NS	**	**
$LSD_{0.05}$		2.0		5.8	3.6		0.32	0.18
Winter rice								
CT	R_0	359a	24.4	100c	41a	21.6	4.12d	2.08d
	R_{50}	363a	24.5	121b	30b	22.2	4.24c	2.24c
ST	R_0	376b	24.4	129ab	18c	22.9	4.60b	2.56b
	R_{50}	388c	24.2	139a	15c	23.1	4.81a	2.78a
LS		**	NS	**	**	NS	**	**
$LSD_{0.05}$		6.5		11.7	4.1		0.13	0.045

In column, figure with similar letter do not differ significantly whereas dissimilar letter differs significantly. CT= Conventional tillage, ST= Strip tillage, R_0= No residue, R_{50}= 50% residue, LS=Level of significance, LSD=Least significant difference, NS= non-significant, **= significant at 1% level, *= significant at 5% level

Effect of seed rate and basal N management options in dry seeded Aman rice under zero tillage condition

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Introduction

The development of mechanical device or power operated machineries for tillage and seeding purposes have created an opportunity in zero tilled direct-seeded rice cultivation. Seed rate is an important issue for DSR and the farmers use seeding rates from 20to 40 kg ha^{-1} in DSR under conventional tillage systems (Mahajon et al., 2013). Nitrogen fertilizer management in emerging DSR cultivation is important and a challenging task to achieve high yield with increased N use efficiency. Nitrogen uptake patterns over the growing season depend on the availability of soil N, timing of fertilizer application, and amount of fertilizer N available (Ladha et al., 2005). Generally, slightly higher dose of N is suggested in DSR compare to TPR to compensate for the higher losses and lower availability of N from soil mineralization at the early stage as well as the longer duration of the crop in the main field in Dry-DSR (Gathala et al., 2011; Kumar and Ladha 2011). With the above points in view, the experiment was undertaken in dry seeded rice to evaluate the seed rate and N distribution options under zero tillage condition.

Materials and Methods

The experiment was conducted in BRRI regional station, Rajshahi in Aman season of 2010 and 2011with randomized complete block design in a factorial combination of three seed rates (S1: high or 60 kg ha^{-1}, S2: Medium or 40 kg ha^{-1} and S3: low or 25 kg ha^{-1}) and three N management options (N1: zero basal N, N2: low basal N - 25 kg basal N, and N3: high basal N - 75 kg basal N) with three replications. The variety was BRRI dhan39 and the direct seeding was done under zero tillage condition. The land was applied with glyphosate before seeding and the locally made lithao was used for making furrow and then seed was sown manually within the furrow. Except N, other fertilizer management was followed with BRRI recommendation. The total N rate for the crop was 125 kg ha^{-1} of which the basal application was done following of N management options while the remaining N fertilizer was applied in two equal installments at active tillering and panicle initiation stages. The data were analyzed using CROP Stat version 7.2 program.

Results and Discussion

Seed rate and basal N management options showed significant interaction on grain yield where medium seed rate plus low basal N management options gave higher yield in both the years. Irrespective of basal N management options, the number of panicles m^{-2} and grains $panicle^{-1}$ were not influenced by the seed rate options although the higher number of panicle was found in S2 treatment in both the years (Table 1). The grains $panicle^{-1}$ remained higher in S2 and S3 treatments, respectively during 2010 and 2011. The lower grains $panicle^{-1}$ was found in S1 treatment in both the years. Higher seed rate might be resulted in higher spikelet sterility and fewer grains per panicle which was supported by the findings of Kabir et al. (2008). The grain yield affected significantly by the seed rate the highest grain yield (4.27 t ha^{-1}) was found in S2 (40 kg ha^{-1}) followed by S3 (25 kg ha^{-1}) treatment in both the years. Ahmed et al.

(2014) found the similar findings. Like seed rate, the number of panicle m^{-2} was not influenced due to basal N management options (Table 2) although the markedly higher number of panicles m^{-2} were found in N2 treatment. The basal N management options affected the grains $panicle^{-1}$ and it remained higher in N3 and N2 treatments, respectively during 2010 and 2011 while the lower number of grains $panicle^{-1}$ was found in N1 treatment in both the years. The grain yield affected by the basal N management options and the significantly higher grain yield remained in low basal N management options (N2 treatment) in both the years. The lower grain yield was found in N1 treatment which was statistically similar with N3 treatment. Thus, the results concluded that the medium seed rate (40 kg ha^{-1}) with low basal N management option (N2 treatment) can be used for DSR Aman rice cultivation under zero tillage system.

Table 1. Effect of seed rate on yield and yield components for DSR Aman under zero tillage condition, BRRI R/S Rajshahi, 2010 and 2011

	Panicle/m2 (no.)		Grains/panicle (no.)		Grain yield (t ha^{-1})	
	2010	2011	2010	2011	2010	2011
S1	234	252	137	138	3.70	4.32
S2	246	255	149	153	4.27	4.75
S3	232	241	142	155	3.79	4.58
LSD (0.05)	32	22	21	17	0.29	0.39

Table 2. Effect of seed rate on yield and yield components for DSR Aman under zero tillage condition, BRRI R/S Rajshahi, 2010 and 2011

	Panicle/m2 (no.)		Grains/panicle (no.)		Grain yield (t ha^{-1})	
	2010	2011	2010	2011	2010	2011
N1	231	245	120	134	3.93	4.12
N2	249	264	147	158	4.19	5.08
N3	232	239	161	154	3.64	4.45
LSD (0.05)	32	22	21	17	0.29	0.39

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Conservation tillage and residue retention under dry seeded rice-maize-mungbean system affected bulk density and soil organic matter

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Introduction

Rice-maize (R-M) cropping systems have potential in all climates ranging from tropical to sub-tropical and even warm temperate regions of Asia (Chauhan *et al.,* 2011). Maize cultivation area has increased rapidly to about 0.20 M ha in 2007–2008 and to 0.36 M ha in 2012–2013 in Bangladesh. At present, conventional tillage poses concerns for sustainability and profitability e.g. high fuel, time and labor requirements, soil compaction and deterioration in soil structure. One of the strategies is to grow crop with the introduction of conservation tillage systems through the use of direct mechanical drilling. Day by day soils become squirmy and fail to regenerate nutrient supplying capacity due to intensive cropping without replenishment. This scenario is particularly true for the R-M system where residues of both the crops are generally removed from fields. Hence residue retention may be one way to sustain soil fertility and productivity in R-M systems. This study was undertaken to investigate the effect of conservation tillage and residue management on bulk density and organic matter content soil.

Materials and methods

The trial studied the rice-maize-mungbean system, and was conducted from 2010-11 to 2012–2013 at the BRRI, Regional Station, Rajshahi. The main plot treatments were Zero tillage (ZT), Strip tillage (ST) using power tiller operated seeder (PTOS), Minimum tillage (MT) using PTOS, Permanent bed (PB) using bed planter Fresh bed (FB) using bed planter and Conventional tillage (CT). Except CT, other treatments were termed as conservation tillage. The subplot treatments were 0% (S_1), 50% (S_2) and 100% (S_3) previous crop residue return. Glyphosate was applied before sowing of seeds of all crops in all conservation tillage treatments. Except for CT and ZT, seeds of all crops were sown on during tillage either by PTOS or by bed planter. In CT, rice was transplanted and maize and mungbean were conventionally seeded. In ZT, small slits were made in untilled soil and then seeds of all crops were sown on manually. Strip tillage was done by making strips in untilled using a PTOS with blades removed to achieve the desired slot spacing. Minimum tillage was done through one pass with PTOS. Beds were prepared by a bed planter through one pass and permanent beds and fresh beds were remained same for the first crop; the next crops were grown in PB with only renovating the beds. Residue of each crop was returned to the next crop following the treatments. BRRI and BARI recommended fertilizer were applied to all the crops. For determining bulk density of soil, cores of undisturbed soil at upper depth were taken in each subplot by cylinders after completion of each year cycle (after harvest of Aman rice). For determining organic matter, the soil samples were collected after completion of the 3rd year cropping cycle in 3 different depths from each sub plot. ANOVA for different parameters was done by software package CROP STAT version 7.2.

Results and Discussion

The bulk density values in upper depth (0-15 cm) did not differ among the tillage treatments in the initial two years. This may be attributed to minimum changes in the structure in the first two years. Pandey et al. (2008) reported the similar. After final year, the CT (1.28 Mg m^{-3}) recorded the highest bulk density of soil. This differed from other tillage treatments. The bulk density remained lower in PB (1.25 Mg m^{-3}), which was statistically similar with other conservation tillage treatments. Settlement of aggregates after long period due to puddling in conventional tillage increased the soil bulk density which was reported by Jat *et al.,* 2009. Naresh (2014) reported that CT-TPR system had higher bulk density due to compaction.

In contrast, several studies reported higher bulk density under zero tillage compared with the tilled soil (Singh and Kaur, 2012). Irrespective of tillage options, soil bulk density decreased with the increase of residue incorporation. Tillage and residue management showed significant interaction on soil bulk density. The two combinations as ZTxCR_{100} and PBxCR_{100} demonstrated the lowest bulk densities which were differed from CT with CR_0 after the final year experiment. Tran Quang Tuyen and Pham Sy Tan (2001) reported that no tillage with left over of crop residues lowered the bulk density.

Table 1. Effect of tillage and residue management options on soil bulk density (Mg/m^3) after rice harvest at 0-15 cm depth of soil under rice-maize-mungbean-system, 2010-11 to 2012-13

Residue mgt. options	Tillage options							F-probability
	CT	ZT	ST	MT	FB	PB	Mean	
2010-11								
CR_0	1.33	1.31	1.30	1.33	1.29	1.29	1.31	Tillage (T) = NS
CR_{50}	1.30	1.28	1.29	1.29	1.32	1.31	1.30	Residue (R) = NS
CR_{100}	1.30	1.29	1.28	1.29	1.29	1.28	1.29	T x R = 0.04
Mean	1.31	1.29	1.29	1.30	1.30	1.29		CV (%) = 1.7
2011-2012								
CR_0	1.31	1.30	1.31	1.31	1.32	1.29	1.31	T = NS
CR_{50}	1.29	1.29	1.31	1.29	1.28	1.27	1.29	R = 0.02
CR_{100}	1.29	1.29	1.28	1.27	1.27	1.26	1.28	T x R = NS
Mean	1.29	1.30	1.30	1.29	1.29	1.27		CV (%) = 2.1
2012-2013								
CR_0	1.30	1.27	1.28	1.28	1.28	1.27	1.28	T = 0.02
CR_{50}	1.29	1.26	1.25	1.26	126	1.25	1.26	R = 0.02
CR_{100}	1.28	1.24	1.25	1.26	1.26	1.24	1.25	T x R = 0.04
Mean	1.29	1.26	1.26	1.27	1.27	1.25		CV (%) = 1.6

Significant variation in soil organic matter (SOM) content at 0-15 cm depth of soil was observed either by tillage or by residue management options. The SOM at 0-15 cm depth remained higher (($P<0.05$) in MT (1.53%) which was statistically similar with other tillage treatment except CT (1.32%). Conventional tillage practices can result in loss of carbon contents of agricultural top soils due to increase decomposition rates and carbon redistribution which is supported to the finding of Kahlon and Singh (2014) and Singh and Yadov (2006). Unlike 0-15 cm depth, the SOM at 16-30 and 31-45 cm depth did not vary significantly due to tillage as well as residue management options. Bhattacharyya *et al.* (2008) reported the similar findings. Significant variation in SOM content at 0-15 cm depth was observed among the residue management options and the higher level of SOM remained in CR_{100} followed by CR_{50}. Crop residue incorporation might be largely attributed beneficial effect on microbial activity and to enhance SOM, supported by Singh and Yadov (2006). The tillage and residue

management showed significant interaction on SOM content at 0-15 cm depth where SOM remained higher in ZT plus CR_{100} and was lower in CT plus CR_0. Increased SOM at 0-15 cm depth was also observed CR_{100} or CR_{50} plus all the conservation tillage treatments. Consistent residue removal with full tillage may result in loss of SOM due to oxidation of soils at shallow depths. These results were similar to the findings of Kahlon and Singh, 2014.

Table 2. Effect of tillage and residue management on soil organic matter (%) at different depth of soil after completion of 3rd year cropping cycle under rice-maize-mungbean system

Residue Mgt.	Tillage option							F-probability
	ZT	ST	MT	PB	FB	CT	Mean	
0-15 cm								
CR_0	1.27	1.31	1.51	1.32	1.31	1.22	1.32	T = 0.19
CR_{50}	1.47	1.41	1.57	1.58	1.40	1.36	1.46	R = 0.13
CR_{100}	1.64	1.55	1.52	1.56	1.59	1.38	1.54	T x R = 0.33
Mean	1.46	1.52	1.53	1.49	1.44	1.32		CV (%) = 13.6
16-30 cm								
CR_0	0.83	0.85	0.83	0.91	0.84	0.81	0.85	T = NS
CR_{50}	0.91	0.81	0.91	0.91	0.91	0.84	0.88	R = NS
CR_{100}	0.93	0.87	0.93	0.95	0.86	0.93	0.91	T x R = NS
Mean	0.89	0.84	0.89	0.93	0.87	0.86		CV (%) = 11.2
31-45cm								
CR_0	0.55	0.51	0.52	0.58	0.56	0.52	0.54	T = NS
CR_{50}	0.53	0.54	0.55	0.60	0.54	0.55	0.55	R = NS
CR_{100}	0.62	0.58	0.60	0.64	0.57	0.51	0.59	T x R = NS
Mean	0.57	0.54	0.56	0.61	0.56	0.53		CV (%) = 16.5

ZT=Zero tillage, ST=Strip tillage, MT=Minimum tillage, PB=Permanent bed, FB=Fresh bed

CT=Conventional tillage, CR_0=Without previous crop residue return, CR_{50}=50% previous crop residue return, CR_{100}=100% previous crop residue return

Conclusion

Conservation tillage and crop residue incorporation resulted in lower soil bulk density in course of time which may likely to improve the physical condition of soils at shallow depths. Compared with CT, SOM content remained higher (9-16%) in all conservation tillage treatments. Crop residue incorporation under conservation tillage systems also increased (11-22%) SOM that may facilitate better crop growth and maintain soil health.

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On-farm performance of non-puddled Boro and Aman season rice

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Introduction

Continuation of soil puddling for rice transplanting will negate the benefits of minimum soil disturbance practiced in other crops in the rotation (e.g. see Singh et al. (2011) for rice–wheat system). Generally, the methodology of non-puddled transplanting of rice seedlings is the same as for puddled transplanting except for the absence of soil puddling (Haque et al., 2016). Several hundreds of farmers have adopted non-puddled rice cultivation methods where the technologies were demonstrated earlier in Bangladesh. However, the acceptance and profitability of the technology when managed by farmers was not well understood. The aim of the present study was to understand acceptance and profitability of farmers managed non-puddled transplanted rice.

Materials and Method

A total of 150 on-farm studies on non-puddled aman and boro season rice were conducted in eight locations during 2013, 2014, and 2015 in different Agro-ecological Zones of Bangladesh. Focus group discussions were also held over three successive years to elicit farmers' opinions about the suitability of the strip tillage non-puddled transplanting and how their perceptions changed over time. In on-farm experiments, two tillage treatments were arranged in a farmer's field with each field treated as a replicate for both tillage types. Treatments consisted of two rice establishment methods i) conventional-puddled transplanting (CP) and ii) non-puddled transplanting of rice seedlings (NP). Farmers in aman season used a range of rice cultivars. During boro seasons in all locations, they used only cv. BRRIdhan-28. Depending on rice varieties, 25- to 36-day-old seedlings were transplanted in aman seasons, whereas, 35- to 55-day-old seedlings were transplanted in boro seasons. Data on input uses, yield contributing characters, grain and straw yields, and economics were collected and analyzed by MSTAT-C.

Results and Discussion

Between NP and CP no significant differences were observed on the total labour cost for aman season rice cultivation during 2013 and 2014; but significantly higher ($P<0.01$) cost for total labour uses was recorded in 2015 in CP (Table 1). Significantly higher total labour cost for boro season rice cultivation was reported for CP than NP during 2013, 2014, and 2015 (Table 1). The interaction effect between location and treatments was observed in the boro season of 2015 where highest ($P<0.05$) grain yield (6.10 t ha^{-1}) was recorded in NP. During the aman and boro seasons of 2015, significantly higher straw yield was recorded for NP than CP (Table 1). In aman season, 53 out of 66 farmers who practiced NP reported higher net returns than in CP while 49 out of 66 farmers reported higher yield with NP (data not shown here). In boro season of 2013, 2014 and 2015, the net return was higher in 90 - 92 % of cases in NP than with CP while 75 % had the same or higher grain yield (data not shown here). During the boro season of 2013, about 55 % of farmers reported that the adoption of NP could reduce land preparation cost, but after 6th season (aman season of 2015) that perception increased up to 92 % (data not shown here). While 50 % farmers in the boro season of 2013 reported higher grain yield that increased to 70 % of farmers at the end of aman season of 2015. Farmers'

perception and experience on the negative aspects of NP declined over time at Alipur, Choighati and Digram locations (data not shown here).

Conclusions

From 150 farmer-managed comparisons in both aman and boro seasons during 2013, 2014, and 2015, we conclude that transplanting of rice seedlings in non-puddled soils following strip tillage was feasible, reduced cost of rice cultivation, and increased gross margin. Within three consecutive years comprising six rice seasons, there was generally no significant yield difference between NP and CP; however, in the boro season of 2015 NP produced significantly greater grain and straw yield of rice than CP. In farmers' fields, strip tillage, flooding soils for 24 hours and then transplanting rice into non-puddled soil could be an option for rice establishment under conservation agriculture systems.

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Table 1. Total labour cost, grain yield, straw yield, and net return on NP vs CP for on-farm aman and boro rice cultivation in Bangladesh

Year	Total labour cost (hired +family labour) US$ ha^{-1}			Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Net return (US$ ha^{-1})		
	NP	CP	LS	NP	CP	LS	NP	CP	LS	NP	CP	LS
Aman												
2013	181	192	NS	3.97	3.96	NS	4.13	4.16	NS	109	108	NS
2014	276	278	NS	4.75	4.60	NS	5.09	4.89	NS	108	88	NS
2015	168b	184a	***	4.54	4.45	NS	4.92a	4.77b	***	-60a	-139b	***
Boro												
2013	167b	179a	***	5.58	5.34	NS	5.85	5.69	NS	411a	317b	***
2014	163b	178a	***	4.97	4.85	NS	5.26	5.13	NS	82a	-22b	***
2015	170b	184a	***	5.36a	5.07b	***	5.65a	5.39b	***	408a	281b	***

NP = Non-puddled transplanting of rice seedling; CP = Conventionally-puddled transplanting of rice seedling; LS = Level of significance [*** mean significant at 1 %]; NS = Not significant; US$1 = Tk. 78. Values with the same small letter in a column for means of the transplanting methods are not significantly different by DMRT.

Evaluating the performance of water conserving technologies in rice cultivation to mitigate greenhouse gas emission

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Introduction

Upcoming threats of unavailable irrigation water, low water use efficiency (WUE) and fall off ground water level in continuously flooded (CF) field are causing adoption of alternate wetting and drying (AWD) and direct dry seeded rice (DSR) in South-East Asia including Bangladesh (Price et al. 2013). Both techniques could enhance water productivity, minimize non-beneficial water flows and influence the extent of greenhouse gases (GHG) emission. Rice grown under AWD and DSR reduces CH_4 but enhances N_2O emission, often in contrast to CF field (Maris et al. 2015). The depth profiles of abiotic drivers of GHG emissions such as moisture level, soil redox potential (Eh), status of dissolved OC (DOC) and utilization of oxidants (Fe and Mn) for SOM degradation also differ strongly between DSR, AWD and CF. But relation of these dynamic depth profiles with bulk soil CH_4 and N_2O emissions have not been resolved, particularly in young floodplain paddy soils of Bangladesh. This study was aimed to understand how depth distributed Eh, levels of moisture, DOC, Fe and Mn drive CH_4, N_2O and CO_2 emissions.

Materials and Methods

The cultivated rice variety (BRRI dhan28) was grown under DSR, AWD and CF, with 120 kg N ha^{-1} (N_{120}) or without (N_0) N fertilization at the paddy field (silt loam) of Bangladesh Agricultural University during January to May, 2015. Soil Eh at four depths and temperature at two depths were monitored continuously by Eh/T°-probes connected to a HYPNOS III data logger (MVH, The Netherlands). Greenhouse gas emissions were monitored with timely gas sample collection and GC-analysis. Simultaneously, soil solution from three depths were sampled with rhizon samplers to track DOC, Fe and Mn in solution.

Results and Discussions

Over the growing season, soil and air temperatures were increased by 8°C. In all depths of AWD and CF, Eh dropped sharply to methanic conditions (-200mV) within 21 days after transplanting (DAT), and continued until 77DAT in all cases, except in the puddle layers under AWD, where Eh raised to +200mV during drainage (Figure 1). In contrast, the Eh in DS plots remained higher (about +600mV) during most of the season and sudden lower peaks of Eh (around -200mV) coincided with irrigation events at 28, 45 and 62DAT. Overall solution Fe and Mn increased gradually over the growing season, and the concentrations were 2-5 folds greater in AWD and CF than DSR indicating more pronounced reductive dissolution of Fe and Mn (hydro-)oxides. Dissolved OC increased continuously in all depths of AWD and CF, whereas, in DSR plots the concentration remained almost stable until 28DAT and increased gradually from 33DAT to 84DAT. Besides the release of DOC bound to pedogenic oxides upon their reductive dissolution, higher plant and soil microbial activity with increasing soil temperature (till 28°C) through the season explains the increasing DOC levels. Increasing methanogenic activity as indicated by the high CH_4 emissions at 70-84DAT under all three irrigations are logically linked. The elevated redox potential during AWD drainage events, and

higher Eh level during most crop growing in DSR significantly ($p<0.01$) declined overall cumulative CH_4 emission by 47 and 94 % when compared to CF. Moreover, seasonal CH_4 emissions in N-fertilized fields (N_{120}) decreased by 29 and 8% under CF and AWD, respectively, relative to the control (N_0), possibly due to promotion of methanotrophs, which were N-limited in N_0. Though draining-flooding stimulated cumulative N_2O emission and we found greater emission in DSR, no significant difference existed between water and N managements. Lower CH_4 emissions due to less frequent flooding significantly ($p<0.01$) increased cumulative CO_2 emissions in the DSR by 2586 and 2049 kg ha^{-1} compared to the CF and AWD, respectively. Even though statistically similar grain yields were attained in CF and AWD plots, but significantly the lowest ($p<0.01$) grain yield was obtained in N_0- and N_{120}-DSR plots with yield reduction by13 to 31% and 16 to 24% compared to respective CF and AWD plots. Overall global warming potential was the highest in CF (8774 kg CO2-eq. ha^{-1}) and decreased by 54 and 37% in DSR and AWD, respectively (Figure 2). Our results generally indicate that in young floodplain paddy soil of Bangladesh during Boro season, evolutions in soil solution chemistry and GHGs emissions are strongly depending on course soil temperature, Eh, irrigation management and only secondarily on N fertilization.

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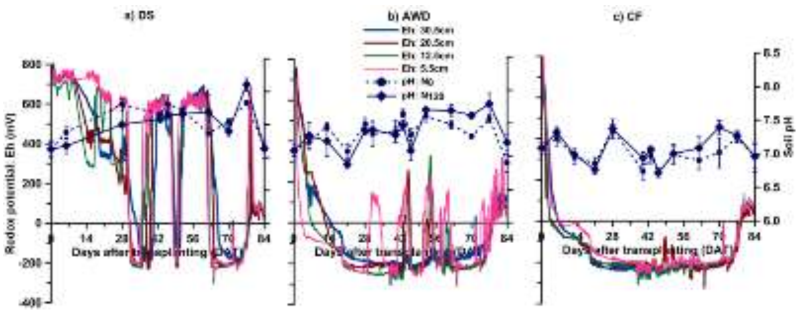

Figure 1. Seasonal variations of soil Eh under different irrigation and N managements

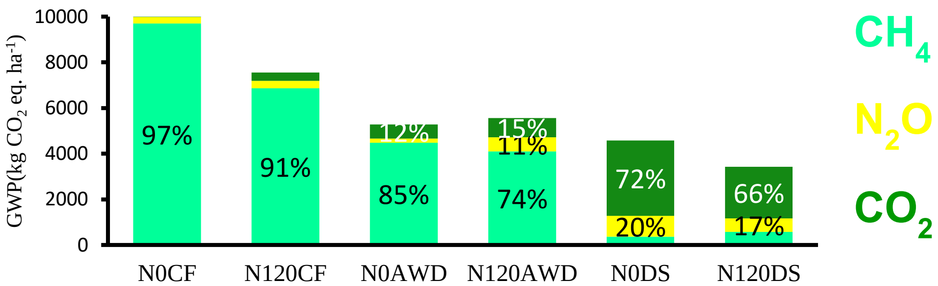

Figure 2. Total global warming potential under different irrigation and N managements

Session 2

POSTERS

Phosphorus and Zinc content in Aman rice and post-harvest soil

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Introduction

The inherent nutrient supply capacity of Bangladesh soil has declined due to continuous cultivation of more than one crop in the same piece of land in each year. The intensive cropping with modern varieties has caused a marked depletion of inherent nutrient reserve in soils of Bangladesh. Hence, in addition to N, P and K deficiencies other nutrient such as B, Zn, and S deficiencies are being observed in many parts of the country (Jahiruddin *et al.,* 1981; Hague & Jahiruddin, 1994). Annual crops planted after the application of P fertilizers often recover only 1-20% of the applied-P. A large part of the applied-P rapidly becomes insoluble as a result of chemical reactions involving the formation of iron, manganese aluminum & magnesium phosphate. & unavailable for plant uptake Under reduced condition the oxide bound-P become available hence wetland crops do not respond to P application. Both P and Zn are two essential plant nutrient elements in wetland rice production in Bangladesh. Therefore, the objective of the study was to evaluate the effect of P & Zn on yield and yield attributes of rice, and to determine the optimum doses of P & Zn fertilizers for rice cultivation in the region.

Methods and Materials

The experiment was conducted at Bangladesh Agricultural University with a view to determining of the effect of phosphorus (P) and zinc (Zn) on yield, P and Zn content by rice (BR11) and also soil P distribution in soil fractions after harvest. The experimental field was sited in the agro ecological region of the Old Brahmaputra Flood plan. The region occupies a large area of Barahmaputra sediments deposited before the river shifted into its present Jamuna channel about 200 years ago. The experimental design was in Randomize Complete Block Design (RCBD) having 12 fertilizer combinations each replicated 3 times. Phosphorus was determined from the extract by adding ammonium molybdate and $SnCl_2$ solution and measuring the color by Spectrophotometer at 660 nm. (Olsen *et al.,* 1954). Zinc concentrations in the extract of grain and straw samples were determined directly by atomic absorption spectrophotometer in Central laboratory (McLaren *et al.,* 1984). The data of crop characters and nutrient content of plant and soil samples were analyzed statistically by means of computer package MSTAT.

Result and Discussion

The application of P and Zn alone had significant effect of the grain yield over control. The Zn_{IO} P_{50} treatment combination produced the highest grain yield (5.97 t ha^{-1}) due to suitable availability of P and Zn. The P concentration in grain and straw increased with increasing rate of P application but the content decreased with the increasing rate of Zn application. Phosphorus application significantly decreased the Zn content in grain and straw while zinc application increased the zinc content. The highest Zn content in grain (27.46 ppm) and straw (39.15 ppm) were observed in the P control (P_0) treatment while the highest Zn content in grain (29.54 ppm) and straw (46.93 ppm) was found in the highest rate of applied Zn (Zn_{20}).

Phosphorus application gradually increased the water soluble-P and labile-P in soil but decreased with increasing rate of Zn application. The maximum and minimum amount of water soluble-P and labile-P was Zno P_{50} (4.5 mg keg' and 1.8 mg kg^{-}') and Zn_{20} Po (1.5mg keg' and 0.30 mg kg^{-}') treatment respectively. The results reflected that the combined application of Zn_{10} and P_{50} treatment played a significant role on production of the highest yield. The combined application of Zn10 and P50 also had a positive effect on yield contributing characters. However, application of Zn decreases P concentration in both grain and straw and also water soluble-P and labile-P in soil but consequently increases AUFe-P, Mg/Ca-P and total-P in the soil resulting a Zn-P interaction in soil solution.

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Efficacy of botanical extracts on weed management and productivity in rice-mustard-green gram crop sequence under alluvial soil of West Bengal

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Introduction

In spite of the use of costly chemical herbicides, crop yield loss still exists. On the contrary, the overuse of synthetic herbicides has resulted in pollution in the environment, hazard to human health and evolution of herbicide resistant weeds. As demand increases for sustainable and environmentally safe agriculture against the extensive use of costly synthetic chemicals, organic weed management as alternative strategies is the only main option in today's world. Weed management through natural plant extracts which contain allelochemicals and produce herbicidal effect can be utilized as bio-herbicide which is eco-friendly and less costly for sustainable crop production. An experiment was conducted with the objectives (i) to study the complexity of weed flora and its infestation in rice crop, (ii) to find out the efficacy of plant extracts for their bio-herbicidal potentiality and (iii) to study effect of botanical extract on productivity of rice.

Materials and Methods

The experiment was conducted in 2011 and 2012 at Instructional Farm, Jaguli, BCKV under New Alluvial soil (Inceptisol) of West Bengal, India to study the efficacy of some botanical extracts on weeds management and productivity of rice crop. The eight treatments (shown in Table 1) in randomized block design replicated three times. Each botanical extract was applied @25 lit ha^{-1} as pre-emergence at 1 DAS added with surfactant @0.5%. Weed density, biomass and weed control efficiency were recorded at harvest stage of rice crop. The grain yield and Weed Indices of rice were also calculated for comparison of the treatments.

Results and Discussion

Total weed density was highest (18.14 m^{-2}) in T_1 (unweeded control) treatment and lowest population (11.75m^{-2}) and biomass (17.51 gm^{-2}) recorded in T_2 (hand weeding) treatment (Table 1). Among the botanical treatments, T_7 (bamboo leaves methanol extract) recorded lowest population (15.62 m^{-2}) and dry weight (9.72 gm^{-2}) followed by T_3 (teak leaves) treatment. Bamboo leave and teak leave decreased the weed population due to the presence of phenols and alike compounds. Kole et.al., (2011) also revealed bio-herbicidal property of teak leaves methanol extract. The difference of suppression of weeds by different botanical treatments might be due to variation in concentration of allelopathic plants as also supported by Alagesaboopathi and Thamilazhagan (2010). Maximum weed control efficiency (60%) was recorded by the treatment T_2 (hand weeding) treatment. Among the botanical treatments, maximum weed control efficiency (48%) was found in T_7 (bamboo leaves) treatment followed by T_3 (Teak leaves) treatment. Maximum (2.04 t ha^{-1}) grain yield was recorded in T_2 (hand weeding) treatment which was statistically at par withT_8 (oxyfluorfen) treatment. Botanical treatment, T_7 (bamboo leaves) recorded maximum grain yield (1.72 t ha^{-1}) which was closely followed by T_3 (teak leaves) treatment.

Lowest weed index was associated to highest grain yield. Among the botanical treatments, minimum weed index (15.02%) was recorded in T_7 (bamboo leaves) treatment followed by T_3 (teak leaves) treatment (17.76%) and T_6 (calotropis+parthenium leaves) treatment. Other botanical treatments failed to show their better performance in weed control may be due to poor herbicidal potentiality. However, the inhibitory potential of *Ocimum sanctum* on weeds was also reported by Sharma et.al., (2004). The combined mixture of *calotropis* and *parthenium* leave extract showed inhibitory effect on population and biomass of weeds to some extent due to bio-herbicidal property which was also reported by Srivastava and Kumar in 2007. The inhibition of weeds might have occurred through different toxic mechanism. No phytotoxic effect of the treatments on crop was observed here. Tripathi et.al., (1999) also reported similar result.

With regard to benefit cost (B/C) ratio, highest value (2.26) was achieved by T_8 (oxyfluorfen) treatment. Among the botanical treatments, maximum B/C ratio (2.06) was recorded in T_7 (bamboo leave) treatment which was followed by T_3 (teak leave) treatment (2.02).

Conclusion

It may be concluded that though hand weeding twice recorded maximum grain yield of rice, but considering the benefit cost ratio, promising weed control treatments were bamboo leave methanol extract and teak leave methanol extract which were also eco-safety and less costly. Side by side, costly chemical herbicide can be carefully avoided by replacing with some alternative botanical extracts which possess phenols and alike compounds having bio-herbicidal potentiality to a great extent and control weeds. So, the less costly, easily available botanicals having potentiality to control weeds without hampering the environment and achieve promising yield can fulfill the need of the small holders for conservation agriculture.

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Table 1. Effect of treatments on total density (no. m^{-2}), dry weight (g m^{-2}) of total weed at harvest, weed control efficiency (%), grain yield (t ha^{-1}) of rice, weed index and benefit cost ratio of rice cultivation (pooled)

Treatments	Density of total weed (no. m^{-2})	Dry weight of total weed (g m^{-2})	Weed control efficiency (%)	Grain yield (t ha^{-1})	Weed index (%)	B/C Ratio
T_1	18.14 (328.50)	45.92	**--**	1.33	34.54	1.70
T_2	11.25 (137.67)	17.81	59.84	2.04	0.00	1.98
$^T3$	15.82 (250.18)	25.27	44.97	1.68	17.76	2.02
T_4	17.24 (296.76)	36.37	21.15	1.42	29.81	1.76
T_5	16.87 (284.29)	36.42	20.70	1.52	24.92	1.85
T_6	16.69 (278.30)	36.90	19.64	1.62	22.15	1.95
T_7	15.62 (243.81)	24.03	47.67	1.72	15.02	2.06
T_8	14.94 (222.83)	21.08	54.10	2.02	9.50	2.26
SEm (±)	0.016	0.120		**0.017**	**-**	
CD(P=0.05)	0.047	0.347		**0.049**		

[1][T_1: Untreated control, T_2: Hand weeding at 15 DAS and 30 DAS, T_3: 5% (w/v) Teak leaves (*Tectona grandis*) methanol extract, T_4: 5% (w/v) *Ocimum sanctum* leaves methanol extract, T_5: 5% (w/v) *Ageratum coniziodes* leaves methanol extract, T_6: 5% (w/v) *Calotropis sp.*+ *Parthenium sp.* leaves methanol extract, T_7: 5% (w/v) Bamboo (*Bambusa vulgaris*) leaves methanol extract, T_8: Oxyfluorfen 23.5EC @100g ha^{-1} as pre-emergence at 1DAS.]

Assessment of Fertilizer Requirement for Sweet gourd- Fallow- T. Aman Cropping Sequence in Saline Area

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Introduction

As sustainable crop production depends on balance use of fertilizer nutrients, soil test based (STB) fertilizer recommendation and monitoring the soil and water salinity is needed to enhance the crop production in saline soil. The coastal zone of Bangladesh, an area covering 19 districts accounts for 30% of the cultivable land and 28% of the population has a great potential for agricultural production (SRDI, 2009). But the agriculture of coastal belt is vulnerable because of soil and water salinity remains above permissible limit during dry (Rabi and Kharif-1) seasons (SRDI, 2009). Several new and suitable cropping patterns like Sweet gourd- Fallow- T. Aman, Okra- Fallow- T. Aman, Sesame- Fallow- T. Aman and Maize- Fallow- T. Aman have been introduced for coastal belt increasing cropping intensity in recent ages. Bangladesh Agricultural Research Council has provided STB fertilizer doses of the mentioned crops (FRG, 2012). But often STB fertilizer doses cannot produce the optimum yield of the respective crop in saline soil due to salt concentration. Plant growth in these soils is adversely affected due to reduced water uptake, salt toxicity, and nutrient imbalances (Munns *et al.,* 2006). Beneficial effect of higher doses of N, P and K fertilizers has been reported in potato, tomato, brinjal and okra under saline soils (SRDI, 2009). Therefore, the present study was undertaken to verify and update the existing soil test based fertilizer recommendation for Sweet gourd (Hybrid sweety)- Fallow- T. Aman (cv. BR23) cropping sequence in saline soil of coastal region of Bangladesh.

Materials and methods

This experiment was set up at the farmer's field of Ghagramari village under Batiaghata Upazila of Khulna district (N-22°41´36.6˝, E-89°31´52.4˝). Initial soil sample was analyzed for assessing soil fertility and soil test based (STB) fertilizer recommendation for tested crops. Soil samples from the experimental plots and water from river, pond and deep tube well adjacent to the experimental plot were collected on mid of the months for monitoring salinity. The land was prepared and laid out in a RCBD with three replications. The treatments were T_1= 100% of soil test based (STB) fertilizers ($N_{45.62}P_{29}K_{11}Zn_{1.79\ g/pit}$ for sweet gourd and $N_{68.5}P_{15}K_{9.7}Zn_{1.5kg/ha}$ for T. Aman), $T_2 = T_1$ + 25%N of STB fertilizers, $T_3 = T_1$ + 25%NP of STB fertilizers, $T_4 = T_1$ + 25%NK of STB fertilizers, $T_5 = T_1$ + 25%PK of STB fertilizers, $T_6 = T_1$ + 25%NPK of STB fertilizers, T_7 = 75% of STB fertilizers, and T_8 = Control. During Kharif-1 season sweet gourd was cultivated. Fruits were harvested at full maturity and yield and yield attributes were recorded. T. Aman (cv. BR23) was cultivated during Kharif-2 season. The crop was harvested at full maturity to record the yield contributing characters and yield. The analysis of variance for various yields and yield attributes were done following the F-test. Mean comparisons of the treatments were made by the Duncan's Multiple Range Test (DMRT).

Results and Discussion

The soil salinity was very slightly saline (2.40 dS/m) to moderately saline (10.35 dS/m) during January to June with its peak in June, while during July to December it was non-saline (1.34

to 1.73 dS/m). The river water EC was harmful (0.85 dS/m) to very harmful (15.8 dS/m) with moderate to severe restriction in usage during January to June with its peak in April, while during July to December river water EC was safe (0.24 to 0.64 dS/m) with no restriction in usage. At the same time the pond water EC was harmful (1.01 to 2.47 dS/m) with moderate restriction in usage throughout the year with its peak in July. Similarly, the deep tube well water EC was harmful (1.11 to 1.54 dS/m) with moderate restriction in usage throughout the year with its peak in June (Fig. 1). Related distribution pattern in different months of soil and water salinity was reported by SRDI (2014).

Increase of 25%N, P and K fertilizer doses alone or in different combinations over 100%STB fertilizers doses increased fruit and grain yield of sweet gourd and BR23 rice, respectively (Table 1). It also increased fruit/plant, and individual fruit weight of sweet gourd, straw yields, effective tillers/hill, panicle length, filled grains/panicle and 1000 grain weight of BR23 rice. While a decrease of fertilizer doses from STB recommended doses (75%STB) significantly decreased fruit and grain yield of sweet gourd and BR23rice, respectively in comparison to those of 100% STB doses. Considering yield and yield attributes greatest performance was shown by T_6 (T_1+ 25%NPK of STB fertilizers) treatment in both the crop which resulted 79% fruit yield increase of sweet gourd and 14% grain yield increase of BR23 rice over 100%STB fertilizers (T_1). These types of findings were also reported by Chaudhary *et al.* (2011). As a result, 25% increase of N, P and K fertilizer doses in STB fertilizer can be suggested for sweet gourd (Hybrid sweety)- Fallow- T. Aman (cv. BR23) cropping sequence in saline soils of coastal region.

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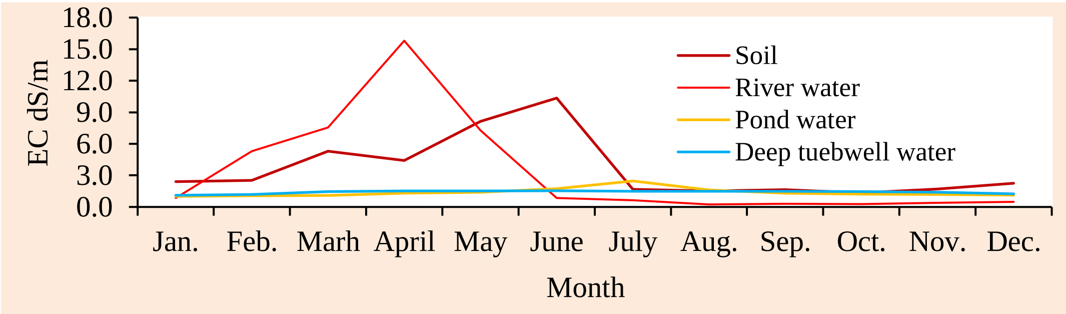

Figure 1. Soil and water salinity (dS/m) during the experimental period.

Table 1. Effect of different fertilizer packages on the yield attributes and yield of BR23 rice and sweet gourd

Treatment	Rice						Sweet gourd		
	Effective Tillers hill (no.)	Panicle Length (cm)	Grains/ Panicle (no.)	1000-grain Weight (gm)	Grain Yield (t/ha)	Straw Yield (t/ha)	Fruit/ plant (no.)	Fruit weight (gm)	Fruit yield (t/ha)
T_1	13.00b	26.00bc	119.20bc	26.21ab	4.81b	5.38bc	2.29c	2.08c	11.91d
T_2	13.67b	26.58ab	122.13b	28.38a	5.30a	6.18ab	2.51bc	2.37b	14.88c
T_3	14.67ab	25.45bc	117.83bc	26.31ab	5.35a	6.16ab	2.78b	2.53ab	17.62b
T_4	15.00ab	26.07bc	127.83ab	26.60ab	5.38a	6.69a	2.76b	2.51ab	17.35b
T_5	13.67b	26.50abc	129.59ab	27.46ab	4.84b	5.45bc	2.80b	2.47b	17.27b
T_6	15.33a	27.75a	131.79a	27.90a	5.47a	6.10ab	3.25a	2.74a	21.31a
T_7	12.00bc	24.87c	117.88c	27.36ab	4.05c	4.78cd	1.97d	1.72d	8.52e
T_8	9.67c	22.39d	104.66d	25.33b	3.09d	4.31d	1.41e	0.88e	3.04f
CV (%)	6.01	3.30	5.01	4.27	4.11	7.00	6.70	5.81	7.72

Effect of different herbicides on weed infestation and yield in Boro rice (Binadhan-14)

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Introduction

Agriculture is facing numerous problems due to unfavorable weed infestation events. The people in Bangladesh depend on rice (*Oryza sativa* L.) as staple food. Rice alone constitutes of 95% of the food grain production in Bangladesh (Julfiquare *et al.,* 1998). In Bangladesh, transplanted *Boro* rice grown in 4.68 million hectares of land with a production of 18.60 million metric tons (USDA, 2015). Weeds not only cause huge reduction in crop yields but also increase cost of cultivation, reduce input use efficiency, reduce grain quality, serve as alternate hosts for pests, reduces aesthetic picture of ecosystem, reduce biodiversity and affect human and cattle health. Continuous use of the same group of herbicides over a period of time on a same piece of land leads to ecological imbalance in terms of weed shift, herbicide resistance in weeds and environmental pollutions (Gnanavel *et al.,* 2014 & Sharma, 2014). In Bangladesh, weed infestation reduces the grain yield by 70-80% in Aus rice (early summer), 30-40% for transplanted *Aman* rice (late summer) and 22-36% for modern *Boro* rice cultivars (BRRI, 2006). This loss is a serious threat for the food deficit countries like Bangladesh. Traditional methods of weed control practices include preparatory land tillage and hand weeding. Usually two or three hand weeding is normally done for growing a rice crop depending upon the nature of weeds and their intensity of infestation. Bensulfuran methyl 4%+acetachor 14% Bensulfuran methyl 4%+acetachor 14% 18 WP, Pyrazosulfuron-ethyl 10 WP, Metsulfuron-methyl 20 WDG, Pretilachlor 500 EC, 2, 4 D Amine 480 SL, Butachlor 5G are good selective herbicides with post-emergence activity against mono- and dicotyledonous weeds in rice field. Now-a-days the chemical methods of weed control are gaining popularity all over the world because of their efficacy. In Bangladesh, a very little information is available on the effectiveness of the herbicides mentioned above in controlling weeds in rice, especially in *Boro* rice. The present study was, therefore, undertaken to assess the weed control efficacy of different herbicides in *Boro* rice and to assess the effect of herbicides on growth and yield parameters of *Boro* rice.

Materials and Methods

A field experiment was conducted at the Agronomy field of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh under wet land condition during November 2015 to May 2016. Six selected post emergence herbicides i, e., H_1 =Bensulfuran methyl 4%+acetachor 14% 18 WP 500 g ha^{-1}, H_2 =Pyrazosulfuron-ethyl 10 WP 125 g ha^{-1}, H_3 =Metsulfuron-methyl 20 WDG 50 g ha^{-1}, H_4 = Pretilachlor 500 EC 1 L ha^{-1}, H_5 =2, 4 D Amine 480 SL 1.8 L ha^{-1}, H_6 =Butachlor 5G 25 Kg ha^{-1} were tested along with two hand (HW) weeding, 30 days after transplanting and 45 days after transplanting and control treatments (H_0). The aim was to see the effects of the weed control treatments on weed control crop growth and yield in transplanted *Boro* rice. In all cases herbicides were applied in 4-5 cm standing water in the plots after 7-10 day after transplanting of rice. In case of manual weeding treatment, it included 2 weeding at 30 and 50 days after transplanting (DAT), whereas in weed-free treatment weeding was done by hand when weeds were found. Treatments were assigned in a unit plot

of 3 m x 3 m. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Weed density was collected from each plot at vegetative stage of rice locations per plot using a 0.5m x 0.5m quadrat. The weed plants within each quadrat were counted species wise and converted to number m^{-2} After counting the weed density the weeds inside each quadrat were collected by uprooting, cleaned, separated into species and dried first in the sun and then in an electric oven for 72 hours at a temperature of 80^0 C. The dry weight of each species was recorded and expressed in g m^{-2}. Rice grain yield was recorded at maturity of the crop. Data were compiled and subjected to ANOVA using M- stat program (Gomez and Gomez, 1984) and the means were separated by LSD.

Results and Discussion

Eight weed species belonging to five families namely Shama (*Echinochloa colomum*), Angta (*Paspalum scrobiculatum*), Panikachu (*Monochoria vaginalis*), Arail (*Leersia hexandra L.*), Chechra (*Scirpus mucronatus*L.), Choto angule ghash (*Digitaria sanguinalis*), Purple mutsedge (*Eyperus rotundus*) and Keshuti (*Eclipta alba Hassk.*) were found to grow in the experimental plots. Among them two were broad- leaved, four were grasses and two were sedges (Table 1). The density and dry weight of weeds varied considerably in different weed control treatments. The highest weed density (23.3 m^{-2}) was found in the weedy check treatment and the lowest weed density m^{-2} was found in the treatment with the recommended dose of Pretilachlor 500 EC 1 L ha^{-1} (4.9 m^{-2}) followed by two hand weeding (HW) (5.7 m^{-2}) at vegetative stage. The weed management practices at vegetative stage had a significant effect on the total fresh and dry weight. The highest weed fresh weight (15.61 g m^{-2}) was found in the weedy control and the lowest weed fresh weight (2.86 g m^{-2}) was found with Pretilachlor 500 EC 1 L ha^{-1} (Table 2). The dry weight of weed followed the similar trend (Table 2). Among the weed treatments, highest grain yield (5.00 tha^{-1}) was obtained in Pretilachlor 500 EC 1 L ha^{-1} followed by statistically similar yield with two hand weeding (4.97 t ha^{-1}). The results of this study suggest that Binadhan-14 variety could be grown with Pretilachlor 500 EC 1 L ha^{-1} followed by the treatments of two hand weeding (HW) to maximize yield of *Boro* rice (Table 1).

Table 1. Particulars of weed species in the weeded plots of the experiment at vegetative growth

Sl. no.	Local name	Scientific name	Family	Morphological type	Life cycle
1.	Shama	*Echinochloa colomum*	Gramineae	Grass	Annual
2.	Angta	*Paspalum scrobiculatum*	Gramineae	Grass	Perennial
3.	Panikachu	*Monochoria vaginalis*	Pontederiaceae	Broad-leaved	perenial
4.	Arail	*Leersia hexandra L.*	Gramineae	Grass	Annual
5.	Chechra	*Scirpus mucronatus*L.	Cyperaceae	Sedge	Perennial
6.	Choto Angule ghash	*Digitaria sanguinalis*	Gramineae	Grass	Annual
7.	Purple mutsedge	*Eyperus rotundus*	Cyperaceae	Sedge	Annual
8.	Keshuti	*Eclipta alba Hassk.*	Compositae	Broad leaved	Perennial

Table 2. Effect of herbicide and hand weeding on the weed density, weed fresh and dry weight at vegetative stage and grain yield at harvest

Treatment	Weed Density (no. m^{-2})	Weed Fresh weight (g m^{-2})	Weed dry weight (g m^{-2})	Grain yield (tha^{-1})
H_0= Control	23.3	15.61	7.76	3.47
H_1 = Bensulfuran methyl 4%+acetachor 14%18 WP 50 g ha^{-1}	21.7	13.55	6.99	4.90
H_2= Pyrazosulfuron-ethyl 10 WP 125 g ha^{-1}	13.0	5.76	2.84	4.67
H_3 = Metsulfuron-methyl 20 WDG 50 g ha^{-1}	6.33	5.24	2.84	4.17
H_4 = Pretilachlor (Seavafit) 500 EC 1 L ha^{-1}	4.9	2.86	1.51	5.00
H_5 =2, 4 D Amine 480 SL 1.8 L ha^{-1}	13.0	10.46	5.82	4.30
H_6 = Butachlor 5G 25 Kg ha^{-1}	9.00	5.75	2.96	4.60
HW = Hand weeding (30 DAT and 45 DAT)	5.7	2.90	1.89	4.97
$LSD_{0.05}$	11.60	7.62	5.12	0.78
CV (%)	11.00	16.52	13.12	4.10

DAT= Days after transplanting of rice

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Drought tolerance of Aus rice genotypes and irrigation methods on yield and water use

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Introduction

Irrigated rice occupies the largest share of water in agriculture in Asia. At recent days, climate change and continuous declination of groundwater table urges for demand-side management. Development and/or identification of water-efficient and drought-tolerant rice cultivar(s) is one of the solution options. Information on impact of drought tolerant cultivars and their tolerance level to drought are yet lacking in the country, but are required for advising farmers and build policies for agricultural water management. The objective of the present study was to examine the drought tolerant level and observe the water savings under different irrigation levels on several Aus rice mutants and cultivars.

Materials and Methods

The study was conducted during Aus season (April-July) of 2014 and 2015 at farmer's field (irrigation management treatments) at Nachol (Chapai Nawabgonj) and Tanur (Rajshahi) and control condition (drought screening treatments, at Mymensingh). The soil of the experimental field was silty loam (AEZ-26). The experiment was laid out in Split-Plot Design with 3 replications. The irrigation treatments were assigned in the main-plot which were: T_1 = Control (3 days Alternate Wetting and Drying, AWD); T_2= normal levee (farmer's practice, 10~12 cm) and supplemental irrigation (throughout the growing season) when plant available soil-moisture (PASM) drops below 50% ; T_3 = 20 cm height levee around the plot, and rainfed; T_4 = 20 cm height levee around the plot, and supplemental irrigation during booting to soft-dough, if PASM drops below 50%, T_5 = 20 cm height levee around the plot, and supplemental irrigation during booting to soft-dough, if PASM drops below 75%. The Aus genotypes and varieties, V1 = N_4/350/P-4(5), V2 = N_{10}/350/P-5-4, V3= NERICA-4 (N_4/250/P-2(6)-26 for control study), V4= Binadhan-17, V5 = BRRI dhan48 (check) were assigned in the sub-plot. Common irrigation (at 3 days AWD) was applied to all up to 28 days from transplanting, and then the irrigation treatments were imposed.

Control study (in 1.5 m $\times$1.0 m $\times$ 0.28 m container, with rain-shelter) was done to fully materialize the stress and find out the maximum tolerable stress, in which the treatments were: T_1 = Control (normal irrigation, 3 days AWD); T_2 = Irrigation when plant available soil-moisture (PASM) drops below 60% (throughout the growing season); T_3= Irrigation during booting to soft-dough stage, if PASM drops below 60% and normal irrigation for the rest period; T_4= Irrigation when PASM drops below 75% (throughout the growing season). T_5 = Irrigation when PASM drops below 85% (prior to booting stage), and from booting to soft-dough stage at 75% PASM. Two series of container (2 replicates) were used. The seedlings (28 days old) were transplanted on last week of April, and harvested during 31 July – 7 August. The irrigation numbers under T_1, T_2, T_3, T_4 and T_5 were 6, 4, 4, 3 and 3, respectively. The statistical analysis was performed using statistical software "STAR" (of IRRI).

Results and Discussions

The grain yield and irrigation water used under different treatments at two locations have been presented in Table 1.1 to Table 2.2.

The irrigation treatments, and interaction of irrigation and cultivar showed insignificant yield difference, while the cultivars showed significant difference (Tables 1.1 and Table 2.1). Normal irrigation (4 nos.), rainfed (only 01 life irrigation) and soil moisture basis irrigation (50 and 75% depletion of PASM – 02 and 01 frequency, respectively) (Table 1.2) showed insignificant yield difference, indicating that the cultivars had the capability to produce good yield under water stress condition. The cultivar, N_4/350/P-4(5) produced the highest yield for all irrigation management conditions at Nachol (6.0 – 6.4 t/ha) and Tanur.

Results of pot experiments also showed insignificant yield variation due to water stress, indicating stress tolerant of the cultivars, although V2 and V3 yielded low. When considered the irrigation water savings compared to normal irrigation, the stressed treatments saved 25 – 39% irrigation water with insignificant yield reduction. Under both field and control study, mutant N4-4(5), Binadhan-17, and BRRIdhan48 produced good yield indicating their tolerance capacity under drought (12 – 18 days). It is revealed from the results that one or two irrigations are sufficient to achieve good yield for the above three cultivars, which would save substantial amount of irrigation water (Table 1.2, Table 2.2).

Table 1.1. Effects of irrigation and cultivars on grain yield (Field study, 2016)

Irrigation management. Treatments	Grain yield (t ha^{-1})		Cultivars	Grain yield (t ha^{-1})	
	Nachol	Tanur		Nachol	Tanur
T_1	5.05	4.79	V_1	6.23a	5.06a
T_2	4.87	4.62	V_2	5.73b	4.39c
T_3	4.87	4.40	V_3	2.47e	4.34c
T_4	4.95	4.80	V_4	4.87d	4.43c
T_5	4.91	4.44	V_5	5.35c	4.83b
F-test (5%)	***NS***	*NS*	*F-test* (5%)		

Means with the same letter were not significantly different at 5 % probability level by Tukeys's Honest Significant Difference (THSD) test.

Table 1.2. Irrigation amount and water savings under different treatments (Field study, 2016; Nachol)

Irri. treatment	Common irri. for (establishment), cm	Irriigation frequency after establishment.	Applied Irri. amount (cm)	Total applied water (cm)	Water savings compared to T1 (%)
T1	25	4	19	44	-
T2	25	2	8	33	25
T3	25	1- life irrigation	2	27	39
T4	25	2	7	32	27
T5	25	1	4	29	34

Table 2.1. Effects of irrigation and cultivars on grain yield (Pot culture, 2016)

Treatment	Grain yield (gm/m^2)	*Cultivars*	Grain yield (gm/m^2)
T_1	401.5	V_1	424.7 b
T_2	384.0	V_2	269.3 c
T_3	381.4	V_3	270.2 c
T_4	356.4	V_4	493.37 a
T_5	357.6	V_5	423.4 b
F-test (5%)	NS	*F-test (5%)*	

Means with the same letter were not significantly different at 5% probability level by Tukeys's Honest Significant Difference (THSD) test.

Table 2.2. Irrigation amount and water savings under different treatments (Pot culture, 2016)

Irrigation treatment	Irrigation up to establishment (cm)	No. of irrigation after treatment started (nos.)	Total irrigation applied (cm)	water savings (%, compared to T_1)
T1	16	06	44	-
T2	16	04	35	20
T3	16	04	34	23
T4	16	03	29	34
T5	16	03	30	32

Increasing crop productivity while reducing greenhouse gas emissions through resource conservation technologies in rice-wheat-mungbean cropping system

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Introduction

Resource conserving technologies (RCTs) enhance input use efficiency and provide immediate identifiable economic benefits like reduced production costs, savings in water, fuel and labor requirements and timely establishment of crops resulting in improved productivity. They can also reduce GHG emissions with less global warming impact (Aggarwal *et.al*. 2002). The CO_2 mitigation strategy for intensive rice-wheat-mungbean cropping systems has not been well studied. Crop residue management, tillage type and N fertilization strategies are likely factors to increase crop productivity and alter fuel consumption. The objective of this trial is to assess the potential productivity and reduction in GHG emissions by using RCT in rice-wheat system.

Materials and Methods

A 12-year trial was conducted at the RWRC, BARI Rajshahi (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. The area receives only 850 mm mean annual rainfall, about 97% of which occurs from June to September. Soil at the experimental site is a calcareous silty loam with slightly alkalinity (pH 7.5), low OM (0.8%) and low Total N (0.07% soil). The experiments consisted of four tillage/straw treatments (30% straw retention(SR)+permanent raised bed(PRB), 30% SR +conventional tillage (CTP), 0% SR + PRB and 0% SR + CTP) with three replications. Another five tillage options such as direct seeded rice (DSR) and non-puddled transplanted rice (TPR) in zero tillage, DSR and non-puddled TPR in raised bed and farmer practice (FP) were also used in rice-wheat systems on the farmer's fields for determination of diesel consumption and global warming potential (GWP).The total system productivity (TSP) for each treatment was calculated as the total annual productivity based on equivalent yields where TSP (rice-wheat-mungbean) = (rice grain yield*1.35) + (wheat grain yield*1.39) + (mungbean grain yield*1.54). The analysis of GWP is simply based on diesel consumption on different tillage options including farmers practice.

Results and Discussion

Total system productivity (TSP)

System yields on PRB consistently increased as SR increased from 0% to 30%, but the differences between 0 and 30% SR were always significant for all 12 crops cycle. The TSP increased by10-12% for all crops in 30% straw retention with PRB over conventional (Fig. 1). Annual TSP of rice, wheat and mungbean (R-W-M) was 12 t ha^{-1}. Yields tended to be lower in lower levels of straw retention for all crops. Lower system productivity also occurred from 0% SR with CTP due to reduced crop growth. Similar observations were made by Singh et al., (2003).

Irrigation water

Amount of irrigation water required at different growth stages of rice, wheat and mungbean varied remarkably between the conventional method and beds in all three years. The conventional method required higher amount of water at each irrigation time (Fig. 2). The total amount of irrigation water required for conventional method was 320, 350,155 liters in 15 m^2 in wheat, rice and mungbean, respectively. But in PRB the total amount of irrigation water was 240, 270 and 110 liters 15 m^{-2} in wheat, rice and mungbean, respectively. The total water saved by beds over conventional method was 25 %, 23% and 29% for three crops, respectively

Global warming potential

The diesel use varied between 2250 kg CO_2 equivalent ha^{-1} in direct seeded rice and wheat on beds and 3620 kg CO_2 equivalent ha^{-1} in conventional both puddle transplanted rice and wheat (Table 1)**.** Compared to the conventional practice all RCTs reduced the GWP by 13 to 37% (Figure 3). Kumar et al. (2006) found similar results from their experiments.

Environmental impact

Fuel used both conventional and reduced tillage system was showed in (Table 2). 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 (Kataki. *et al*. (2001) reported same results from their experiment

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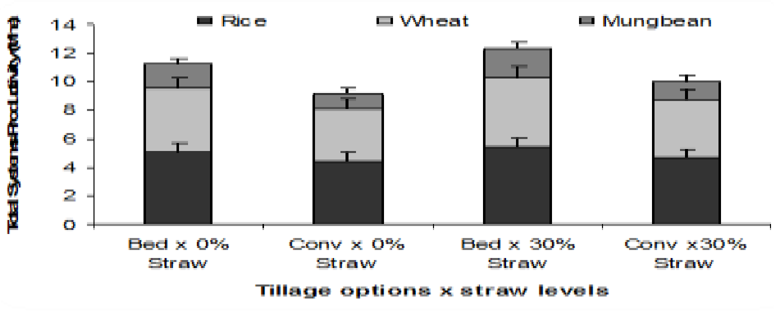

Figure 1. TSP under different tillage and residue management in R-W system

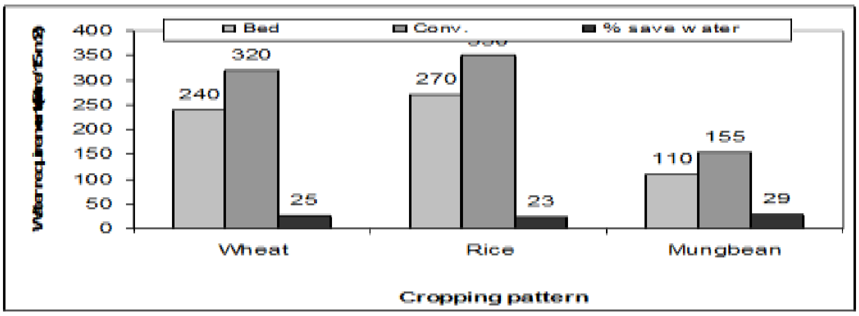

Figure 2. Irrigation water saved under beds and conventional method

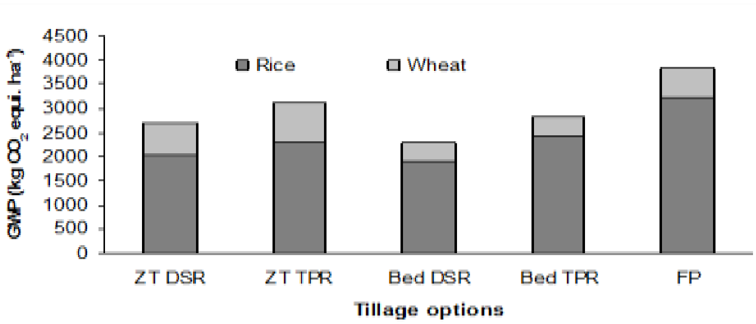

Figure 3. Global warming potential in R-W system under different tillage systems

Table 4. Comparative use of diesel fuel and CO_2 emission on raised bed & traditional method

Tillage options	Diesel used (L ha^{-1} yea^{-1})	CO_2 emission (L ha^{-1} yea^{-1})	Less CO_2 emission (%)	Fuel saved (L ha^{-1} year^{-1})
RB	54	140	44	42
Conv.	96	250	-	-

Growth and yield of recently release wheat varieties under raised bed system in drought prone areas

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Introduction

In Bangladesh, the cereal, pulse and other crops have traditionally been planted after 3-4 ploughing operations followed by laddering which is slow, laborious, time consuming and also costly (Singh *et al.* 2003 and Timsina *et al.* 2001). Added to this is the increasing labor shortage especially in the peak period. Raised bed planting reduce production cost, save labor and water increases input efficiency, increases yields (Witt *et al.*2000). This experiment was undertaken to select the best genotypes bed planting and to determine their growth characteristics under this system.

Materials and Methods

The trial was conducted with six recently released wheat varieties at the Regional Wheat Research Centre, BARI, Rajshahi in 2014-15 and 2015-16. The experiment was laid out in randomized complete block design with three replications. Seeds were sown by bed planter plots25 meter long x 2.4 m wide with 8 rows for six varieties namely Shatabdi, Prodip, Bijoy, BARI Gom 25, 26 and 27. Recommended management practices were followed to raise the crop with irrigation and other practices. Data were recorded on different agronomic parameters as well as phenological and physiological characteristics. At maturity, four rows with 2 m long plot size were harvested to estimate grain yield expressed as tone per hectare. The collected data were analyzed with Crop Stat Model and means were compared by same model.

Results and Discussion

Growth parameters

Raised bed systems significantly influenced on the crop growth duration and as results Shatabdi, Bijoy and BARI Gom 27 varieties were longer crop duration compared to Prodip, BARI Gom 25 and BARI Gom 26 due to their varietal characters. Days to heading, anthesis and physiological maturity were 3-4 days earlier in Prodip, BARI Gom 25 and BARI Gom 26 varieties under raised bed system over Shatabdi, Bijoy and BARI Gom 27 varieties (Table 1).

Total Dry Matter (TDM) and Leaf Area Index (LAI)

TDM increase with increased over time up to grain filling stage among all the varieties under raised bed systems and then slowly decreased (Fig. 1). Maximum dry matter production was higher in Shatabdi, Bijoy and BARI Gom 27 varieties due to their longer growth duration and minimum in BARI Gom 25 and Prodip varieties due to leaf senescence and mutual shading. Govaerts*et al.* (2006) found maximum dry matter in grain filling stage from mutual shading of genotypes under raised bed systems. Leaf area index increase with increased the duration up to booting stage and then decreased up to late grain filling stage. Maximum leaf area index was found from BARIGom27, Shatabdi and Bijoy varieties due to their longer duration and due to leaf senescence and minimum was Prodip and BARI Gom 25 and 26 varieties (Fig 2).

Grain yield and yield components

Average two years were significantly influenced among the varieties. The maximum grain yield was found from BARI Gom 26 (4.71 tha^{-1}), BARI Gom 25(4.37 tha^{-1}), Shatabdi (4.53 tha^{-1}) and Bijoy (4.65 tha^{-1}) variety. The minimum yield (4.02 tha^{-1}) was found from Prodip and BARI Gom 27 variety due to less tillering. Spike m^{-2}, spike length, grains $spike^{-1}$ and TGW were found higher from BARI Gom 26, Shatabdi and Bijoy and lower spike m^{-1}, spike length and grains $spike^{-1}$ were found from Prodip variety.

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Table 1. Growth parameters of wheat varieties under raised beds

Varieties	DB	DH	DA	DPM
Shatabdi	65	74	79	113
Bijoy	64	72	77	111
Prodip	63	73	76	105
BARI Gom 25	63	72	76	106
BARI Gom 26	63	74	76	107
BARI Gom 27	65	75	79	112
SE	0.43	0.55	0.51	0.36
LSD (0.05)	1.17	1.74	1.62	1.13

Table 2. Effect of wheat varieties on yield & yield attributes under raised beds

Varieties	Spike m^{-2}	Spike length (cm)	Spikelet $Spike^{-1}$	Grains $Spike^{-1}$	TGW (g)	Av. 2 years yield (tha^{-1})
Shatabdi	353	9.3	19.8	44.3	46.3	4.53
Bijoy	359	10.3	19.7	46.6	46.0	4.65
Prodip	319	9.1	18.3	44.6	47.6	4.02
BARIGom 25	335	10.0	18.6	44.0	46.3	4.37
BARIGom 26	348	10.3	18.9	44.3	50.3	4.71
BARIGom 27	357	10.6	20.3	47.3	43.6	4.31
SE	23.15	0.84	1.09	2.54	2.61	0.21
LSD (0.05)	73	2.65	3.44	8.00	2.22	0.51

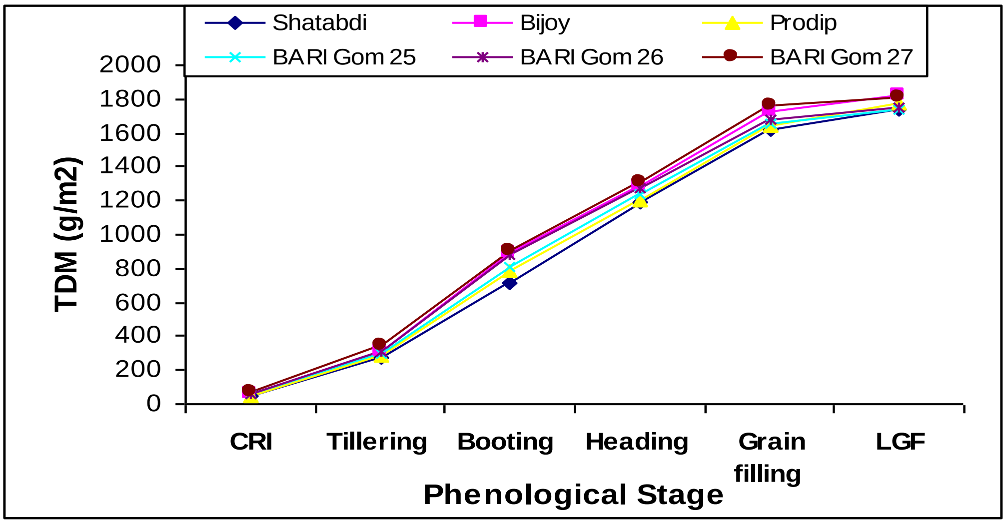

Figure 1. Total dry matter (TDM) of wheat varieties under raised bed

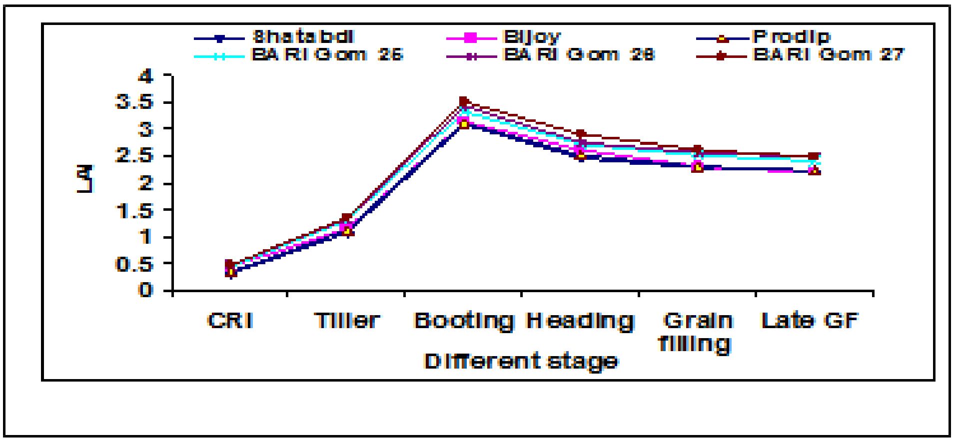

Figure 2. LAI of wheat varieties under raised beds

Effect of herbicides on weeds and crop performance of wheat in Northwest Bangladesh

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Introduction

Weed is one of the major yield-limiting constraints of wheat. Hand weeding is common method to control weed in Bangladesh. Although hand weeding is friendly to the environment but it is tedious, time intensive and expensive. The use of chemical weed control may be considered to be a viable alternative option to hand weeding *(Kamrozzaman et al.*, 2016). To minimize the cost and time, the usage of herbicides is becoming popular in rice field and to a limited extent in wheat field. Thus, there is a need to evaluate the herbicide performance for efficient weed control in wheat to increase crop yield.

Materials and Methods

The experiment was conducted at the Regional Agricultural Research Station, Ishurdi, Pabna during 2014-15 under Agro Ecological Zone-11. There were seven weed management treatments such as Affinity 1.5 kg/ha (Carfentazone-ethyl), U-46 D fluid 3 L/ha (2, 4-D), Glycel 3.7 L/ha (Glyphosate), Ronstar 1 L/ha (Oxadiazone), Panida 2.5 L ha^{-1} (Pendimethalin), hand weeding and untreated control. The experiment was laid out in a randomized complete block design with three replications. Herbicides were applied at three days before sowing (wheat). The wheat crop (cv BARI Wheat-26) was fertilized with 120-30-90-15-2.6-0.6 kg/ha of N-P-K-S-Zn and B. The seed was sown on 30 November 2014 and harvested on 22 March 2015. Weeding was done only in hand weeding treatment plots at 15 days after emergence (DAE) and no hand weeding on others treatment plots. Weed plant samples were collected from every plot from a fixed quadrat (1 m^2, middle of the plot) at 25 DAE and 50 DAE and converted to gm^{-2}. Weed control efficiency (Kabir *et al*. 2008) was calculated according to the following formulae:

$$WCE\ (\%) = \frac{\text{Dry weight in untreated control plot} - \text{dry weight in treated plot}}{\text{Dry weight in untreated control plot}} \times 100$$

The data were subjected to ANOVA and means were separated by LSD at 5% level of significance using MSTAT-C program (Russel, 1994).

Results and Discussions

Fresh weight and dry weight (g m^{-2}) of weeds varied with treatments (Table 1). The highest fresh weight (69.0 g) and dry weight (12.0 g) was obtained in untreated control while the lowest fresh weight (11.0 g) and dry weight (2.6 g) was recorded in hand weeding at 25 DAE. Hand weeding showed higher weed control efficiency (79% and 69% at 25 DAE and 50 DAE) but among the herbicides the highest weed control efficiency was found in Affinity (62%) followed by Panida (37%) and the lowest weed control efficiency was recorded in Glycel (20 %) at 25 DAE.

Table 1. Fresh and dry weight (g m^{-2}) of weed and weed control efficiency (%) at 25 DAE and 50 DAE as affected by treatments at RARS, Ishurdi, during rabi season 2014-15.

Treatment	Fresh weight (g m^{-2})		Dry weight (g m^{-2})		WCE (%)	
	25 DAE	50 DAE	25 DAE	50 DAE	25 DAE	50 DAE
Affinity®	22.6	87.0	4.7	13.5	62.4	53.0
U-46®	45.0	173.5	8.9	15.7	28.8	45.3
Glycel®	46.8	201.9	10.0	19.5	20.0	32.1
Ronstar®	41.5	104.0	8.4	16.7	32.8	41.8
Panida®	38.5	88.4	7.9	14.3	36.8	50.2
Hand weeding	11.0	53.2	2.6	8.8	79.2	69.3
Control	69.0	206	12.5	28.7	0.0	0
LSD $_{(0.05)}$	6.2	35.2	1.0	6.8	5.7	4.3
CV (%)	7.4	11.2	6.1	12.8	8.6	5.8

The effects of different treatments on yield and yield contributing characters are shown in Table 2. The maximum spike was counted in hand weeding (353 m^{-2}) while the minimum was recorded in the untreated control (320 m^{-2}). The highest 1000-grain weight was recorded from hand weeding (37.2 g) and the lowest in control (33.7 g). The weed control by hand weeding gave the highest yield (3.17 t ha^{-1}) and application of Affinity herbicide resulted in higher yield (3.15) and BCR (1.52) than others herbicides treatments. Although the grain yield was higher in hand weeding treatment, however on the basis of economic point of view Affinity could be affordable for controlling weed in wheat field.

Table 2. Yield, yield contributing characters and economic evaluation of wheat as affected by treatments at RARS, Ishurdi, during rabi season 2014-15.

Treatment	Spike m^{-2}	1000-grain wt. (g)	Grain yield (t ha^{-1})	Gross return (TK.)	Total variable cost(TK.)	Gross margin (TK.)	BCR
Affinity®	343	36.7	3.15	69290	45550	23740	1.52
U-46®	335	36.0	3.06	66930	45400	21530	1.47
Glycel®	341	36.8	2.67	58160	45960	12200	1.27
Ronstar®	338	36.5	3.01	64990	44000	20990	1.48
Panida®	337	36.3	3.13	67790	45500	22290	1.49
Hand weeding	353	37.2	3.17	70340	52000	18340	1.35
Control	320	33.7	2.29	50130	43000	7130	1.17
LSD $_{(0.05)}$	10.9	1.6	0.39	-	-	-	-
CV (%)	1.8	2.5	7.48	-	-	-	-

Price: Urea=TK. 16.00 kg^{-1}, TSP= TK. 22 kg^{-1}, MOP =TK. 15 kg^{-1}, Labour= TK. 300.00 per 8-hour $head^{-1}$, Wheat=TK. 20.00 kg^{-1} (Non-seed) and wheat seed= TK. 30.00 kg^{-1}

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Effect of strip tillage, residue mulching and weeding regimes on yield performance of T. *aman* rice

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Introduction

Development of efficient farm machinery and availability of effective herbicides have resulted the higher profitability in conservation agriculture (CA) that in turn has been identified as an effective tool for sustainability of agriculture (Farooq *et al.,* 2011). But weed species shifts and losses in crop yield caused from increased weed density have been cited as major hurdles of CA adoption (Dahal and Karki, 2014). Crop yields in CA can be similar to conventional systems if weeds are controlled (Chauhan *et al.*, 2012). The availability of pre-plant, pre-emergence and post-emergence herbicides provides an opportunity to control weeds in CA. But weed control strategies adopted must reduce the development of herbicide resistance by weeds. The presence of crop residues on the soil surface may reduce weed infestation by affecting weed seed germination and emergence patterns. Considering the above facts, this on-farm experiment was conducted to examine the performance of strip tillage, residue mulching and weeding regimes on crop yield and weeds.

Materials and methods

The on-farm experiment was conducted at the Durbacahra village under Gouripur upazila of Mymensingh district of Bangladesh from 04 July to 27 September 2014. Hybrid rice cv. *Hybrid Krishan2*, was transplanted with 6 tillage and weed control practices *viz*., Conventional tillage (CT) + 3 hand weeding (HW) (Control); glyphosate (Gly) + Strip tillage (ST)+1 HW; Gly+ ST + Pre-emergence herbicide (PE) (Pendimethalin); Gly+ ST + Post-emergence herbicide (PO) (Ethoxysulfuron); Gly+ ST + PE + PO; Gly+ ST + weed-free (6 HW), and 2 levels of crop residue *viz.*, farmers' practice (No residue) and increased retention (50% residue). The design was RCBD with four replications. Conventional tillage was done with 2-wheel power tiller (2WPT) and ST with Versatile Multi-crop Planter (VMP). Weed species number, total weed plant numbers and dry weight were recorded randomly from 1 m^2 area of each plot at 25, 45, 65 days after transplanting (DAT) and at crop harvest. The rice crop was harvested at maturity for grain yield. Data were subjected to ANOVA using *STATISTIX* program.

Result and discussion

Weed species identified in the T. aman rice field

The experimental plots were infested with 21 weed species belonging to 11 families (Table 1). Five species belonged to Cyperaceae, three to Poaceae, two to each of Amaranthaceae, Asteraceae, Pontederiaceae, Onagraceae and each one of rest of the five families. Broadleaves (62%) were dominant over sedges (24%) and grasses (14%) while annuals (71%) were outnumbered than perennials (21%).

Effect of tillage, residue mulching and weeding regimes on weed and crop

CT produced the highest weed biomass compared to ST at all times except at 25 DAT. Compared to glyphosate alone, PE reduced the weed biomass by 15-32% while the PO reduced 20-50% and combination of PE and PO reduced weed biomass by 52-70%. Retention

of 50% residue reduced weed biomass by about 20 -38% compared to no-residue level. CT+3HW yielded the lowest grain which was identical to ST with glyphosate and 1 HW (Table 2). ST kept weed free yielded the highest grain which was 25% higher compared to CT+1HW. ST with PE and PO yielded about 13% higher grain over CT+1HW and ST with glyphosate+ 1HW. ST with PE and ST with PO yielded the same grains but 3 and 6 % higher, respectively over CT. Among the treatment combinations, 50% residue resulted 4% higher grain over no-residue. The highest BCR was calculated from ST with PE and PO which was 19% higher than ST kept weed free but 160% higher than CT (Table 2). ST with PE and ST with PO had identical BCR which was about 90% higher than CT. ST with glyphosate and 1 HW earned 80% higher BCR over CT while CT earned lowest BCR. Among the treatment combinations 50% residue earned around 10% higher BCR over no-residue.

Acknowledgment
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Table 1. Weed species recorded from T. aman rice field (Weed morphology and life cycle in parenthesis- B= Broadleaf, G=Grass, S=Sedge, A=Annul, P=Perennial)

Scientific name	Family	Scientific name	Family
Sagittaria guyanensis (B, A)	Alismataceae	*Fimbristylis miliaceae* (S, A)	Cyperaceae
Alternanthera sessilis (B, P)	Amaranthaceae	*Echinochloa crussgalli* (G, A)	Poaceae
A. philoxeroides (B, P)	Amaranthaceae	*E. colonum* (G, A)	Poaceae
Pistia stratiotes (B, P)	Araceae	*Paspalum distichum* (G, P)	Poaceae
Eclipta alba (B, A)	Asteraceae	*Monochoria hastate* (B, A)	Pontederiaceae
Enhydra fluctuens (B, A)	Asteraceae	*M. vaginalis* (B, A)	Pontederiaceae
Cyanotis axillaris (B, A)	Commelinaceae	*Polygonum coccineum* (B, P)	Polygonaceae
Cyperus difformis (S, A)	Cyperaceae	*Jussiaea repens* (B, A)	Onagraceae
C. compressus (S, A)	Cyperaceae	*J. decurrens* (B, A)	Onagraceae
C. nemoralis (S, P)	Cyperaceae	*Oxalis europea* (B, A)	Oxalidaceae
Scirpus mucronatus (S, A)	Cyperaceae		

Table 2. Effect of tillage, residue mulching and weeding regimes on weed and rice yield and benefit cost ratio (BCR).

Tillage and Weeding regimes	Residue	Weed biomass ($g\ m^{-2}$) at				Yield ($t\ ha^{-1}$)	BCR
		25 DAT	45 DAT	65 DAT	Crop harvest		
CT+3 HW	No	52b	58a	35a	19	5.17gh	0.63g
	50%	46bc	50b	27b	10	5.20g	0.76g
Gly+ST+1 HW	No	77a	52b	29b	11	5.18g	1.15f
	50%	47bc	42c	19c	10	5.27f	1.33e
Gly+ST+PE	No	39cd	40cd	17cd	9	5.41e	1.24e
	50%	29de	37de	15cde	6	5.52d	1.36de
Gly+ST+PO	No	43bc	36de	13def	10	5.43e	1.25e
	50%	40cd	32e	11efg	6	5.56d	1.39de
Gly+ST+PE+PO	No	39cd	28f	10fg	5	5.47c	1.69b
	50%	30de	14g	7g	2	6.27b	1.90a
Gly+ST+WF (6 HW)	No	0	0	0	0	6.36b	1.42c
	50%	0	0	0	0	6.56a	1.61b
Significance		*	**	*	NS	**	**
$LSD_{0.05}$		13.6	4.7	4.4	7.6	0.32	0.18

Improving winter crop yield through no-till agronomy and summer weed management

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Introduction

Fleabane (*Conyza bonariensis*) emerges in spring to early summer and depletes soil moisture and nutrients from the soil profile and reduce the yield potential of the following winter crop. Fleabane is also becoming increasingly resistant to a broad number of herbicide modes of action in the Eastern States (Preston 2016). The study examined the efficacy of herbicides to control fleabane during summer, improve the following wheat crop yield and suppress spring emergence of fleabane through tactical agronomy including seeding rate, tillage techniques and row spacing in Western Australia.

Materials and methods

During 2016, a trial was conducted to control fleabane during summer at Geraldton, Western Australia (28° 78' 83.1" S and 114° 36' 46. 8" E) and the trial site was sown to wheat crop to examine the effect of seed rate, tillage and row spacing on winter weed (annual ryegrass, *Lolium rigidum)*, spring emergence of summer weeds (such as fleabane) and wheat yield.

Summer treatments:

Eight herbicide treatments were laid out in a completely randomised block design with four replications during the summer fallow (mid December 2015) to control fleabane at flowering stage (Table 1). Other summer weeds such as couch (*Cynodon dactylon*) and windmill grass *(Chloris truncata))* were also present on the site. The initial weed density before spraying and final density of summer weed plants surviving three weeks after spraying were counted from two quadrats (1m x 1m) per plot, and weed control was visually assessed in the whole plot.

Winter treatments:

During winter season, 18 combination of treatments including row spacing (22 and 44cm), different tillage (20mm narrow points, 180mm wide points and combined narrow and wide points) and seed rates (40, 80 and 120 kg/ha) were imposed in wheat (*Triticum aestivum)* cv Mace sown on the summer weed control site at Geraldton on 19 May 2016. The aims of winter treatments were to examine their in-crop effect on emergence and growth of annual ryegrass during winter, fleabane in late spring and the grain yield of wheat crop.

No in-crop herbicide was applied to control ryegrass in 2016 to measure the crop competitive effects. Biomass of ryegrass and wheat (at anthesis) were collected from a quadrat of 0.5m x 0.5m per plot (of selected four summer treatments) across the winter treatments (72 samples) on 1 September 2016. Ryegrass biomass was separated from wheat biomass and dry weight of each species was recorded.

Results and Discussions

Summer weed control

In 2016, herbicides applied alone, as a tank mix or in sequence to control fleabane at Geraldton showed that all treatments were very effective (100% control) on fleabane at flowering stage (Table 1). However, the double knockdown applications (glyphosate alone or

a mixture of glyphosate and phenoxy herbicides followed by paraquat based herbicide) provided 90-100% control of all emerging summer (including fleabane, couch and windmill grass). The 2016 summer weed results (treatment means data for couch and windmill grass not presented) were similar to those observed in 2015 season (Amjad and Hashem, 2016).

Table 1. List of different herbicides applied alone, as tank mixes or as double knockdowns on fleabane at Geraldton in 2016 (LSD=0.6, P<.001). '+' indicates tank mix and '/' indicates herbicides were applied in sequence.

Trt No.	Treatments	% Fleabane control
1	Control (no herbicide)	0
2	2,4-D E 1L / Spray.Seed® 2L	100
3	Glyphosate (Roundup UltraMax® 2L) + 2,4-D E 1L / Spray.Seed® 2L	100
4	Glufosinate (Basta® 3L) + 2,4-D E/ Spray.Seed® 2L	100
5	Glyphosate (Roundup UltraMax® 2L)	100
6	Glyphosate (Roundup UltraMax® 2L) + glufosinate (Basta® 3L)	100
7	Glufosinate (Basta® 3L)+ Saflufenacil (Sharpen® 34g)	99
8	Glyphosate (Roundup UltraMax® 2L) + Saflufenacil (Sharpen® 34g) / Spray.Seed® 2L	100

Agronomic tactics to enhance weed management and winter wheat crop yield

The summer herbicide treatments had no effect on ryegrass biomass across the winter treatments in 2016 at Geraldton. The interaction of wheat seed rate and tillage had significant effect on ryegrass biomass (LSD= 207, P= 0.031). The higher seed rate and tillage with wider points had greater reduction of ryegrass biomass than lower seed rate and tillage with narrow points (Fig. 1).

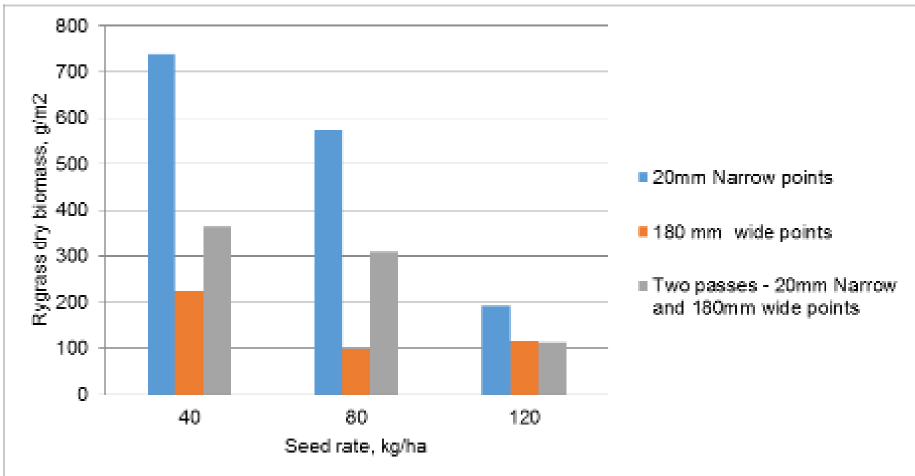

Figure 1. Seed rate and tillage effects on the annual ryegrass biomass in wheat crop in 2016 at Geraldton (LSD= 207, P= 0.031).

No emergence of summer weeds, particularly fleabane, was observed in the wheat crop in 2016 spring probably due to a drier spring than usual at Geraldton. In 2016, average wheat yield was 2.34 t/ha. However, the grain yield differed significantly among the winter treatments (Fig. 2). The interaction of row spacing, seed rate and tillage was significant for wheat yield (LSD= 0.339, P<.001). Increasing the row spacing from 22 to 44cm did not reduce wheat

yield when averaged over three tillage and seeding rate treatments. A combination of narrow row spacing (22cm) and tillage with 20mm narrow points consistently provided high wheat yield at all three seeding rates. In contrast, the combination of wide row spacing (44cm) and tillage with 180mm wide points provided a higher wheat yield with higher seed rate (Fig. 2).

Conclusions

Herbicides applied alone, as a tank mix or in sequence showed that all treatments were very effective to control summer weeds (100% control on fleabane at flowering stage) in 2016.

A combination of agronomy factors such as tillage, row spacing and seed rate had increased crop competition, suppressed ryegrass and enhanced the wheat yield across the summer herbicide treatments at Geraldton in 2016.

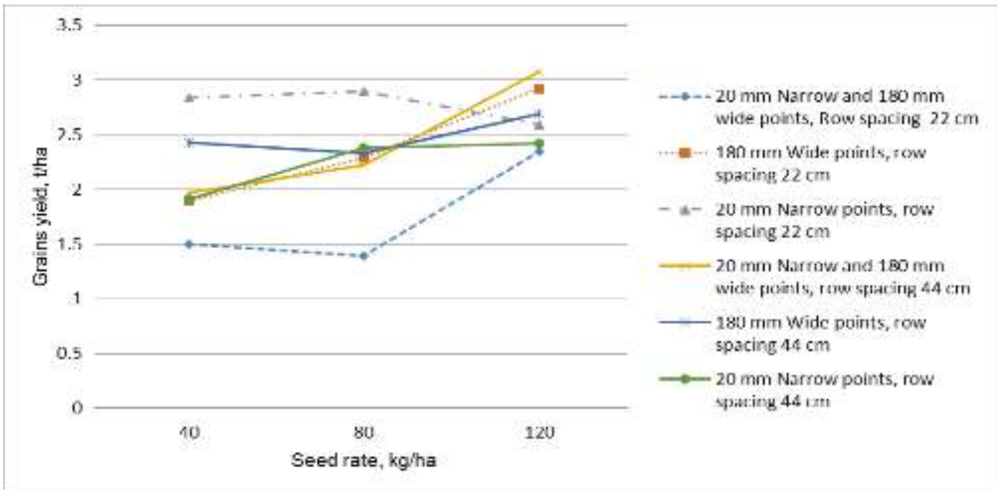

Figure 2. Effect of row spacing, tillage and seed rate on the wheat grain yield in 2016 at Geraldton (LSD = 0.339, P<.001).

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Changes in soil organic matter, plant nutrients and system productivity under conservation agricultural practices in the rice-jute cropping system

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Introduction

Soil organic matter (SOM) is central to soil quality and nutrient cycling. In Bangladesh, depletion of soil fertility is a serious threat to sustainability of agricultural production due to high cropping intensity and agriculture practices based on conventional tillage and residue removal (Rijpma and Jahiruddin, 2004). In this situation, CA practices (minimum tillage, crop residue retention and diverse crop rotations) could be a good option for the improvement of soil quality and crop productivity in Bangladesh. However, CA practices are poorly developed for intensive rice-based cropping system and their effect on SOM, plant nutrients and system productivity have not yet been properly addressed. Hence, the present study was undertaken to monitor the changes in SOM and other plant nutrients with system productivity under CA practices in the rice-jute cropping system in the Low Ganges River Floodplain of Bangladesh.

Materials and Methods

The experimental site is located at Baliakandi upazilla, Rajbari district, in a sub-tropical, wet and humid climate in the Low Ganges River Floodplain. The soils are *Chromic-calcaric gleysols* with sandy loam texture. The four types of soil disturbance practices for planting- zero tillage (ZT), strip planting (SP), 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- low residue (20% retention, comparable to farmer's residue retention practice where 20% residue was retained by height for rice and wheat straw or by weight for lentil straw, and high residue (50% retention), where 50% residue was retained by height for rice and wheat straw or by weight for lentil straw. For jute, all of the shed leaves were added to the soil during whole growing season were allocated to the sub-plots in a split-plot design with four replications under a rice-based cropping sequence. Zero tillage, SP and BP were accomplished by a Versatile Multi-crop Planter (VMP) whereas Power Tiller Operated Seeder (PTOS) is being used as CT at that locality. Soil samples were collected at the initiation of the experiment as well as at the end of each cropping cycle from 0-5, 5-10 and 10-15 cm and analyzed by standard methods for soil properties. Rice equivalent yield (REY) of lentil and jute crop 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

Minimum tillage practices (ST and ZT) increased SOM, total nitrogen (TN), extractable S and Zn content at the uppermost 0-5 cm soil layer and extractable P at the 0-10 cm soil layer after the 3rd crop cycle. The most remarkable changes occurred within the 0-5 cm soil depth where the soils were enriched with SOM and TN content by 24 & 23%, 23 & 18%, 17 & 15% and 11 & 9% under ZT, ST, BP and CT practices, respectively at 0-5 cm depth in contrast with the

initial values while the accumulation of extractable P, S and Zn followed the sequence as ZT>ST>BP>CT practice. But no significant differences were observed at 5-10 & 10-15 cm depths (data not shown). In the present study, the retention of higher amounts of crop residues increased SOM, TN, extractable P, S and Zn contents significantly after consecutive 3-crop cycles in the intensive rice–jute cropping sequence (Table 2).

Table 1. Effects of tillage on SOM, TN, extractable P and Zn contents after 3-crop cycles

Tillage practices	SOM	TN	Extractable P		Extractable S	Extractable Zn
	(t ha^{-1})		mg kg^{-1}			
	0-5 cm	*0-5 cm*	*0-5 cm*	*5-10 cm*	*0-5 cm*	*0-5 cm*
ZT	10.2 a	0.531 a	10.1 a	8.3 a	17.7 a	0.49 a
SP	10.1 ab	0.509 a	9.9 a	8.0 a	17.2 a	0.47 ab
BP	9.6 b	0.496 ab	9.3 b	7.7 ab	16.5 ab	0.44 b
CT	9.1 c	0.450 b	7.8 c	7.1 b	15.6 b	0.40 c
P	**	**	**	*	*	*
Initial value	8.2	0.430	6.1	5.5	14.6	0.32

Table 2. Effects of residues on SOM, TN, extractable P, S and Zn contents after 3-crop cycles

Residue levels	SOM			TN			Extractable K			Extractable P		Extractable S			Extractable Zn	
	(t ha^{-1})						cmol kg^{-1}			(mg kg^{-1})						
	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*	*0-5 cm*	*5-10 cm*	*0-5 cm*	*5-10 cm*	*10-15 cm*	*0-5 cm*	*5-10 cm*
Low	9.2 b	8.2 b	7.3 b	0.48 b	0.43 b	0.38b	0.21 b	0.17 b	0.153 b	8.4b	7.2b	15.8 b	14.9 b	14.2 b	0.4b	0.25 b
High	10.2 a	8.7 a	8.3 a	0.53 a	0.44 b	0.42a	0.24 a	0.20 a	0.173 a	10.2a	8.4a	17.6 a	17.3 a	16.5 a	0.5a	0.33 a
P	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Initial value	8.2	7.6	6.8	0.430	0.398	0.364	0.162	0.134	0.125	6.1	5.5	14.6	14.4	13.5	0.32	0.22

In the 1st cropping year, the maximum REY @ 19.7, 18.0 and 17.2 t ha^{-1} was recorded in SP, CT and ZT, whereas the minimum REY (15.2 t ha^{-1}) was obtained from BP practice. In the 2nd and 3rd cropping year, REY was significantly higher in SP compared to other tillage practices, whereas the lowest value was found in CT practice. Over the 3 years, the maximum mean REY (20.4 t ha^{-1}) was recorded in SP which was significantly higher that ZT (18.1 t ha^{-1}), BP (17.5 t ha^{-1}) and CT (16.9 t ha^{-1}) (Table 3). Increased residue retention gave higher REY over lower retention level in the 2nd and 3rd year.

Minimum soil disturbance practices (ZT & SP) and increased crop residue retention are showing promising results in terms of improvement of SOM and plant nutrients contents as well as cropping system productivity in the intensive rice –jute cropping system after 3-crop cycles.

Table 3. Effects of tillage and residues on REY (t ha^{-1})

Treatments	REY-1st year			REY- 2nd year			REY- 3rd year			Mean REY (3-years)		
	$R_{20\%}$	$R_{50\%}$	*Mean*	$R_{20\%}$	$R_{50\%}$	*Mean*	$R_{20\%}$	$R_{50\%}$	*Mean*	$R_{20\%}$	$R_{50\%}$	*Mean*
ZT	17.9	16.6	17.2 ab	18.8	20.1	19.4 b	16.9	18.2	17.6 b	17.8	18.3	18.1 b
SP	20.1	19.2	19.7 a	21.1	22.0	21.6 a	19.3	20.5	19.9 a	20.2	20.6	20.4 a
BP	15.0	15.4	15.2 b	19.1	20.5	19.8 b	16.5	18.4	17.5 b	16.9	18.1	17.5 b
CT	18.2	17.7	18.0 a	16.4	15.8	16.1 c	16.4	17.1	16.8 b	17.0	16.9	16.9 b
Mean	17.8	17.2	-	18.8 b	19.6 a	-	17.3 b	18.6 a	-	18.0 b	18.5 a	-
Probability level	Tillage (T) =*, Residue (R) =NS, and T × R = NS			Tillage (T) =**, Residue (R) =*, and T × R = NS			Tillage (T) =**, Residue (R) =**, and T × R = NS			Tillage (T) =**, Residue (R) =**, and T × R = NS		

Acknowledgment

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Adoption offline fertilizer recommendation among smallholder farmers through mobile apps

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Introduction

Mobile phone technology has grown significantly over the past decade and become an essential part of our everyday life and changing the way we live tremendously. Mobile is the most common form of communication to disseminate information and new technologies to different layers of a society smoothly and is increasingly available in remote areas. Farmers in developing countries struggle to get an information and new technologies about agricultural best practices including soil fertility and soil test basis fertilizer dose because poor communication infrastructure in isolated rural areas inhibit access to information source. Using mobile apps can bridge this information gap very effectively. In the preceding few years, the mobile users have migrated in masses from traditional phones to smart phones, and one of the key driving forces for the adoption of the smart phone is the mobile application popularly known as mobile apps.

Soil is the most important natural resources for crop production and storehouse of plant nutrients. Except carbon, hydrogen and oxygen, all the rest 13 elements are taken up by plants from soil. But the soil nutrient is not an inexhaustible resource and must be replenished according to the nutrient withdrawal. Soils of Bangladesh have lost its fertility to a great extent due to exhaustion of nutrients for continues cropping with imbalance use of chemical fertilizers. As a result, the productivity of the soil is trending to low and decline in crop yields has been reported in many areas in Bangladesh. Imbalanced use of fertilizers, unplanned cultivation and improper management of soil has already caused stagnation in crop production or reduction in yield of high yielding varieties. For restoring and improving the Soil health, it is need to special care for increasing crop production through dissemination of appropriate technology especially soil test based fertilizer recommendation among the farmers through mobile apps due to availability of mobile phones.

This mobile apps have become the first addition to the android phone market in Bangladesh that can provide Agro-information on location wise specific fertilizer dose and application method for almost all crops described as Fertilizer Recommendation Guide-2012. The farmers/users need not have any internet connection to operate this apps as it is devised to work in an offline mode. This android based apps are designed in a simple and easy way for farmers who have lacking mobile operating skills so that they can operate it smoothly by following the audio instruction and select expected crop to see the crop image content of the apps. The Entrepreneurs of Union Digital Centre and Extension worker, even the scientists of SRDI and other organizations can also use this apps for giving location specific fertilizer recommendation to the farmers and getting necessary information from this database. The fertilizer dose or other information (e.g. salinity management, soil acidity management etc.) that farmers will receive from this apps is based on latest research and information of Upazila land and soil Resources Utilization Guide (Popularly known as Upazila Nirdeshika) of SRDI and Fertilizer Recommendation Guide-2012 of BARC. The farmers/users with android phones

can download the apps as open source at free of cost and disseminate the apps by using ‘share it’ option easily. However, the objectives of this study are stated as-

(i) To provide location wise specific fertilizer dose smartly through mobile apps on an offline mode directly to

The farmers as well as beneficiaries’ i.e. agricultural extension worker, entrepreneurs of UDC, Scientists of SRDI and other Organization.

(ii)To reduce misuse of chemical fertilizers as well as improve soil health and increase sustainable crop production by using union wise soil test based balanced fertilizer through this mobile apps.

(iii) To develop and disseminate a union wise soil fertility and fertilizer use database that will lead to establish an integrated and effective soil, crop and fertilizer management in Bangladesh in the long run.

Materials and Methods

Primarily, different union of veramara upazilla of Kushtia district of Khulna division have selected to disseminate this location specific fertilizer mobile app. However, plan of Action for making location wise Fertilizer Recommendation Mobile App and disseminate to the farmers are given below-

i) Collecting soil έ land physiographic map along with Upazila Nirdeshika of the targeted upazilas (460 volumes).

ii) Classify the chemical data (soil test values) on the basis of land type, soil texture, soil group, and other characteristics of a union using soil έ land physiographic map.

iii) Calculate appropriate doses of fertilizer on the basis of average soil test value by interpreting the nutrient uptake by different crops along with varieties considering the fertility status (very low, low, medium, optimum etc.)

iv) Methods of fertilizer application based on fertilizer and crop will be added.

v) Preparation of mobile apps by making android mobile version of this location wise fertilizer recommendation in an offline mode so that the farmers/uses use it without any internet connection at free of cost.

vi) Turn the mobile apps more user friendly by adding audio option and crop image to use at ease by farmers who have lack in mobile operating skills.

vii) Turn the mobile apps more effective by adding specific soil management for specific location wise problematic soil such as salinity management for saline soil and lime management for acidic soil.

viii) Arrangement of awareness program to transfer and diffusion of this mobile apps including workshop, distribution of leaflets, poster, festoon, banner and using different social media i.e. Facebook, alapon (Govt. apps), e-mailing, imo etc.

ix) Finally supply this apps to 500 farmers of veramara upazilla by using `share it’ option of android phone.

Results and Discussions

The majority of smartphone users in Bangladesh use Android phones, so for any company or individual who wants to develop an app, the android market must be considered the key market. Most of our farmers were not familiar with mobile apps but most of their children were already familiar with mobile apps, having used them at least one year. This is evidence of the youth of Bangladesh being familiar with mobile apps and this allows developers to leverage that familiarity for social growth. In the recent years, older people also start using apps regularly as well, using them to augment the efficiency of their business (Ahmed et al, 2015). Thus, Bangladesh is a country with enormous potential for the mobile apps market (net market share, 2015).

The use of site specific fertilizer recommendations by farmers is negligible. Farmers apply fertilizer according to their financial resources, the types of fertilizer available and the expected financial returns (Ramapal et al.,2015). However, older farmers have accumulated years of experience in farming through observations and may find it is difficult to leave such experiences for new technologies. The maximum level of education within the farmers was found to have a positive relationship with the probability of adoption, educated members are more likely to adopt this mobile app including new technologies. However, the majority of our farmers is being motivated to make effective use of balanced doses of fertilizer and latest agricultural technology through mobile apps or from other sources. Most of respondent farmers said that soil test based location specific fertilizer recommendation become available to the grass root level in an offline mode (without any internet connection) that save their valuable time, labor & cost and they can collect crop wise fertilizer dose easily without any hassle and complexities. However, in Bangladesh, a little or less study work has been done on adoption of mobile apps. Therefore, it is still immature to make any concrete comments on adoption of Offline Fertilizer Recommendation Among Smallholders Farmers Through Mobile Apps and its socio-economic impact on farmers' acceptability due to very little study has been done in this aspect.

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Figure1. Feature image of the mobile app

Broadleaved weed management in wheat with post-emergence herbicides under strip tillage system

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Introduction

Conventionally wheat is grown in well prepared land followed by 3-4 full tillage which carry out degradation of natural resources and contribute to an increased cost of cultivation. Adopting strip tillage (single shallow pass) technology in wheat reduces the expenditure on field preparation and saves more than 30-60% fuel and time as well as advances the sowing time compared to conventional tillage practices (Mahal *et al*., 2009). But, early season weed control is critical for successful strip-till production (Mitchell *et al*., 2009). Moreover, weed can cause grain yield reduction in wheat by 50-80% (Montazeri *et al*., 2005). Both grass and broadleaved weeds infest wheat, but heavy broadleaved weed infestation causes significant wheat yield reduction (Zand *et al*., 2007), deteriorates the quality of wheat resulting low market value and also causes obstruction in harvesting. Broadleaved weed control in wheat could be easy and convenient if appropriate post-emergence herbicide can apply. Therefore, the study had taken to evaluate the efficacy of available post-emergence herbicides to control broadleaved weeds and to select a number of efficient post-emergence herbicides under strip tillage system.

Materials and Methods

The experiment was conducted at Bangladesh Agricultural University, Mymensingh during November 2013-March 2014. Eight treatments comprising combination of one pre-emergence herbicide, two early post-emergence and three late post-emergence herbicides were used in the experiment along with a weedy check (untreated control) in a randomized complete block design (RCBD) with three replications. Two weeks before of wheat sowing, non-selective herbicide Roundup® was applied @ 2.25 L ha^{-1}. Just before strip tillage, fertilizers were applied at recommended dose and then seeds of BARI Gom-26 @ 120 kg ha^{-1} were sown at 20 cm row spacing in a strip on 23 November 2013 with Versatile Multi-Crop Planter. Weed samples were randomly collected from three quadrates of 0.25 m^2 per plot and weed density and dry matter were recorded. The crop was harvested at maturity on 19 March 2014 from the central 3 m^2 areas (1.5m x 2.5m) and yield data were recorded. The collected data were statistically analyzed by following standard protocol.

Results and Discussions

The highest weed infestation was observed in weedy plots having 28.7 g grass, 7.6 g sedge and 68.1 g broadleaved weeds in m^{-2} area (Table 1). Study results indicated that broadleaved weed infestation was the highest under strip tillage system among the three types of weeds. Results also demonstrated that herbicides had significant effect on dry matter of grass, sedge and broadleaved weeds at 50 days after sowing and all herbicide treatments gave 100% control on broadleaved weeds compare to control except pendimethalin fb HW fb pendimethalin. This might be happened due to the less efficiency of pendimethalin to offer full control over broadleaved weeds those were escaped from hand weeding. Application of pendimethalin fb (carfentrazone-ethyl+isoproturon), pendimethalin fb pyrazosulfuron-ethyl fb 2,4-D amine and pendimethalin fb ethoxysulfuron fb carfentrazone-ethyl provided effective

control on all types of weeds and therefore these treatments produced 4.74-4.54 t ha^{-1} grain yield (Fig. 1a). On the other hand, pendimethalin fb ethoxysulfuron, pendimethalin fb 2,4-D amine and pendimethalin fb carfentrazone-ethyl provided full control on broadleaved weeds, but gave less control on grass and sedge weeds and as consequence these treatments produced 3.85-4.15 t ha^{-1} grain yield. The lowest grain yield (0.96 t ha^{-1}) was found from weedy plots. On the contrary, because of providing effective weed control, herbicide treated plots had 291-395% increased grain yield over weedy plots. The regression analysis result also expressed that grain yield of wheat was strongly negatively associated with weed dry matter (R^2 = 0.948) (Fig 1b). Therefore, the study results suggest application of pendimethalin fb carfentrazone-ethyl+isoproturon or application of pendimethalin with or without ethoxysulfuron/ pyrazosulfuron-ethyl followed by carfentrazone-ethyl/ 2,4-D amine could be effective for weed control under this system and optimum yield also can be achieved. However, it is strongly cautioned for repeated use of same herbicide or different herbicide with same mode of action to reduce the risks of herbicide resistance development in weeds.

Acknowledgment
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Table 1. Evaluation of herbicides against percentage of weed density reduction and weed dry matter (g m^{-2}) at 50 days after sowing in wheat under strip tillage system during 2013-14

Treatments	**Weed dry matter (g m^{-2})**		
	Grass	**Sedge**	**Broadleaf**
T_1=Weedy check	28.7 a	7.6 a	68.1 a
T_2=Pendimethalin fb HW fb pendimethalin	4.5 de	2.0 b	4.0 b
T_3=Pendimethalin fb ethoxysulfuron	11.5 b	0.0 d	0.0 c
T_4=Pendimethalin fb ethoxysulfuron fb carfentrazone-ethyl	6.1 cd	0.0 d	0.0 c
T_5=Pendimethalin fb carfentrazone-ethyl	7.8 c	1.6 bc	0.0 c
T_6=Pendimethalin fb pyrazosulfuron-ethyl fb 2,4-D amine	4.8 de	0.0 d	0.0 c
T_7=Pendimethalin fb 2,4-D amine	7.7 c	1.1 c	0.0 c
T_8=Pendimethalin fb (carfentrazone-ethyl + isopropturon)	2.1 e	0.7 cd	0.0 c
P value	<0.001	<0.001	<0.001
CV (%)	10.62	19.14	12.24

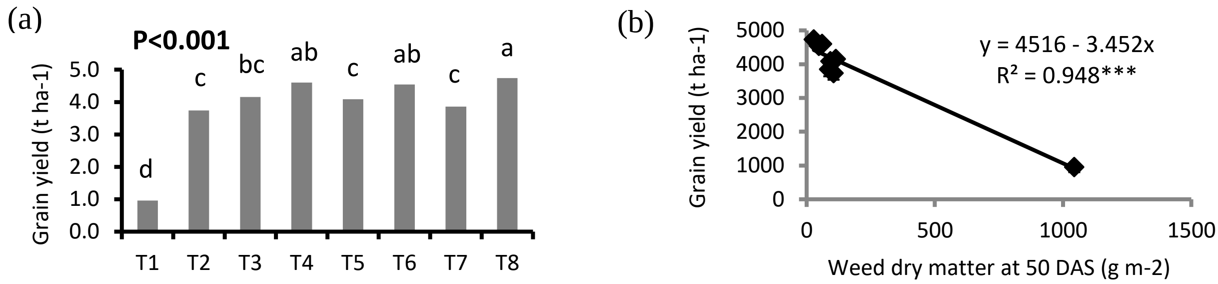

Figure 1. (a) Effect of herbicides on grain yield and (b) relationship between weed dry matter at 50 days after sowing and grain yield of wheat under strip tillage system during 2013-14

Mechanical weed control by Versatile Multi-Crop Planter in strip-planted wheat

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Introduction

Non-control of weeds will reduce wheat grain yield significantly (Sing et al., 2015). In Bangladesh, farmers use 2-6 tillage passes by 2-wheel tractor (2WT) to control pre-plant weeds and prepare the land to sow the seeds. Minimum soil disturbance is one of the key principles of conservation agriculture (CA). However, minimum soil disturbance planting systems could enhance weed infestation (Sing et al., 2015) if pre-plant weeds are not controlled properly. Although the use of herbicide is increasing quite rapidly in Bangladesh (Hossain, 2015), the use of non-selective herbicide (e.g., glyphosate) to control pre-plant weeds is limited due to higher price of glyphosate and non-availability at farmers' level. The Versatile Multi-crop Planter (VMP) (Haque et al., 2011) performs strip planting of various crop seeds and application of fertilizer in lines, and covering seeds simultaneously in a single pass operation. To manage pre-plant weeds in the field, the rotary shaft of VMP was redesigned with small blades attached between strips to cut the existing weeds while sowing seeds in the field. To evaluate the performance of the VMP for controlling pre-plant weeds in wheat crops, experiments were conducted at Rajbari, Rajshahi, and Thakurgaon districts of Bangladesh during 2015-16.

Materials and Methods

Experiments were established on three soil types and agro-ecological zones on 7 December 2015 at Rajbari (Baliakandi upazila), 9 December 2015 at Rajshahi (Durgapur upazila), and 25 November 2015 at Thakurgaon (Sadar upazila) during the rabi (November to February) season of 2015-16. The treatments in triplicate were (i) Conventional Tillage [CT] - four rotary tillage passes and two land leveling passes was done by locally hired 2-wheel tractor (2WT); (ii) Strip Planting with Glyphosate [SPG] - the non-selective herbicide, Roundup® (glyphosate 4 l ha^{-1}), was applied at 3.75 L ha^{-1} 24 hrs prior to strip planting of wheat by VMP; and (iii) Strip Planting with Small Blade [SPSB] - small blades attached between strips with the redesigned VMP shaft to cut weeds at ground level during planting. In SPG and SPSB, wheat cv. BARI Gom 26 was sown at 120 kg ha^{-1} and Di-amonium Phosphate fertilizer at 234 kg ha^{-1} was banded at planting time, and the other basal fertilizers (murate of potash 175 kg ha^{-1}, gypsum 175 kg ha^{-1}, zinc 11 kg ha^{-1}) were applied prior to sowing. In CT, the wheat and basal fertilizers were broadcasted prior to last tillage operation. To control broadleaf weeds, the early post emergence herbicide Affinity was applied 0.75 kg ha^{-1} at 25 days after sowing (DAS). Weed population, effective tiller number, grain yield and straw yield was recorded and analyzed by MSTAT-C.

Results and Discussion

Irrespective of treatments, the weed population m^2 was statistically similar in all three locations. The higher weed (majority *Cyprus rotundus (*L.*)*, *Brassica Eaculenta* (L.), *Alternanthera Sessilis* (L.), *Chenopodium Album (*L.*)* population at 25 days after sowing (DAS) and 15-day after Affinity application was reported in Thakurgaon followed by Rajbari, and the lowest in Rajshahi (Table 1). The highest number of effective tiller m^2 was found in SGP and

SPSB in Thakurgaon and the lowest number of effective tiller m^2 was recorded for CT in Rajshahi. Significantly higher wheat grain yield was reported in SPG in all locations. SPSB had the second highest grain yield of wheat, which was statistically similar to CT (Table 1). Similar trend was also found in straw yield.

Conclusions

The use of Roundup in strip-planted wheat provided highest grain yield. However, the use of VMP with small tines between strips to cut weeds (e.g., SPSB) could be advised as mechanical weed control where Roundup is not available. More trials are needed to confirm the benefit of as mechanical weed control by VMP before final recommendation of SPSB.

Acknowledgement

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Table 1. Effect of conventional tillage (CT), strip Planting with glyphosate (SPG), and strip planting with small blade (SPSB) on weed population effective tiller, grain and straw yield in Durgapur, Thakurgaon and Rajshahi, Thakurgaon, and Rajbari districts of Bangladesh, 2015-16

Location	Treatments	Weed plants m^2				Number of effective wheat tiller m^2	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
		Prior to wheat planting	Before Affinity spray (25 DAS)	15-day after Affinity spray (40 DAS)	After wheat harvest			
Rajshahi	CT	85	12d	1d	1d	5d	4.04b	3.49c
	SPG	52	10d	0.3d	1d	13ab	4.85a	4.46ab
	SPSB	84	10d	1d	0.6d	13ab	4.13b	4.28b
Thakurgaon	CT	86	45a	41ab	19b	7cd	4.08b	3.53c
	SPG	94	50a	41ab	27a	15a	4.89a	4.50ab
	SPSB	95	40ab	35bc	23ab	15a	4.17b	4.32ab
Rajbari	CT	91	20bc	2d	6cd	8c	4.15b	3.60c
	SPG	88	25bc	0d	8c	12b	4.96a	4.57a
	SPSB	51	16cd	0.3d	6cd	13b	4.24b	4.39ab
LS		NS	*	*	*	*	*	*

LS = Level of significance; * mean significant at 5 %.

Transplanting rice seedling in dry strip-tilled soil: A strategy to minimize soil disturbance during non-puddled transplanting

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Introduction

Continuation of soil puddling for rice transplanting will negate the benefits of conservation agriculture (CA) particularly minimum soil disturbing in other crops in the rotation as is reported for the rice–wheat system (Singh et al., 2011). Although, development of non-puddled transplanting of rice with minimum soil disturbance methods has created the opportunity to adopt CA in rice-based cropping systems (Haque et. al., 2016), critics suggest that during transplanting of rice seedling, significant soil disturbance has occurred in non-puddled field due to foot-steps or wheel traffic of the transplanter. To minimize the soil disturbance during transplanting rice seedling in non-puddled condition, two experiments were conducted at Durgapur and Godagari upazila of Rajshahi, Bangladesh during the boro rice season of 2016.

Materials and Methods

The treatments for land preparation and transplanting of rice seedlings were (i) Transplanted in Dry Strip (TDS) - in fallow dry land, 3-4 cm wide and 5-6 cm deep strips were made by Versatile Multi-crop Planter (VMP) (Haque et. al., 2011) in a single pass operation. Afterwards transplanting of seedlings was done manually in the tilled strip prior to irrigation. (ii) Transplanting in Wet Strip (TWS) - 3-4 cm wide and 5-6 cm deep strips were made by VMP in fallow dry land with a single pass operation, followed irrigation to inundate the field for 18 to 24 hours before transplanting. (iii) Conventional Transplanting (CT) - four rotary tillage passes followed by land leveling was done by 2-wheel tractor (2WT). Two-three seedlings were manually transplanted in rows with hill spacing of 20 x 20 cm for all treatments. Forty and fifty-five day old seedlings of *Jira Shail* boro rice variety was transplanted on 26 January 2016 at Godagari and 7 March 2016 at Durgapur, respectively. The experiments were laid out in a randomized complete block design with three replications. Data on grain yield and yield contributing characters, and economics were collected and analyzed by MSTAT-C program.

Results and Discussion

The highest number of dead hills/m^2 (4) at 15 days after transplanting (DAT) were found in TDS at Durgapur while no dead hills were recorded at Godagari. Although the number of effective tiller/hill were not affected by different crop establishment method at Durgapur, the effective tiller number/hill with CT was higher (18 tillers/m^2) than TDS (13 tillers/m^2) in Godagari. In Durgapur, the grain yield with TWS (5.36 t ha^{-1}) and CT (5.25 t ha^{-1}) were higher than TDS (4.65 t ha^{-1}). However, the grain yield was greater in TWS (5.98 t ha^{-1}) than CT (4.79 t ha^{-1}) and the lowest in TDS (4.19 t ha^{-1}) in Godagari site (Table 1). Although the straw yield was not significantly affected by crop establishment method, the highest straw yield was recorded in Durgapur site than Gogagari site. In Godagari site, the straw yield was higher in TWS (5.23 t ha^{-1}) followed by TDS (4.49 t ha^{-1}) and lowest in CT (4.01 t ha^{-1}). Benefit cost ratio (BCR) were maximum in TWS (1.02) and CT (1.03) treatments but was lower in TDS (0.90) in Durgapur site, while the highest BCR was recorded in TWS (1.93) followed by CT (1.41) and lowest in TDS (1.14) in Godagari site. In Durgapur, the higher air temperature (34 ^{o}C) and dehydration of seedlings exposed to the sun, low soil water content (<12%), delay of

application of first irrigation (at Durgapur), and low relative humidity during TDS might have contributed to higher rate of seedling mortality and poor crop establishment, which could be associated of depressed grain yield.

Conclusion

Although the first-year trials of dry transplanting of rice seedling reported the lowest grain yield, it was mostly due to inexperience with establishing rice seedlings in TDS condition. Further TDS trials in 2017 are planned to incorporate the learning and limitations from the first-year.

Acknowledgement

The research was conducted under the LWR-2010-080 project funded by Australian Centre for International Agricultural Research (ACIAR) with the strong collaboration of Conservation Agriculture Service Providers Association (CASPA) and the authors are highly acknowledging the contribution.

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Table 1. Effect of rice establishment method on yield performance and economic analysis of boro rice under different locations in North-west Bangladesh

Location	Method	Number of dead hills m^{-2} at 15 DAT	Number of effective tiller $hill^{-1}$	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	BCR
Durgapur	TDS	4a	16ab	4.65c	5.19a	0.90e
	TWS	0b	16ab	5.36b	5.07a	1.02d
	CT	0.3b	15ab	5.25b	5.14a	1.03d
Godagari	TDS	0b	13b	4.19d	4.49b	1.14c
	TWS	0b	16ab	5.98a	5.23a	1.93a
	CT	0b	18a	4.79c	4.01c	1.41b
LS		*	*	**	**	**

LS = Level of significance; ** and * mean significant at 1 and 5 %, respectively. TDS = Transplanted in Dry Strip; TWS = Transplanting in Wet Strip; CT = Conventional Transplanting; DAT = Days After Transplanting; and BCR = Benefit Cost Ratio. Mean values with the same letter within a column are not significantly different (at P < 0.05 [*] and <0.01 [**]).

Mulching and weed management effects on performance of non-puddled transplanted rice (*Oryza sativa* L.)

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Introduction

Farmers' in the tropics and subtropics of Asia traditionally transplant rice seedlings in puddled soil (Singh *et al*., 2014) for easy crop establishment and weed control. This traditional puddling method is labour and capital intensive and destructive to soil health and economic environment in various ways (Islam *et al.,* 2014). Adoption of non-puddled rice cultivation might be a very good alternative to puddled transplanting but is criticized for high weed pressure. Herbicides can control weeds but are threatened for resistance to weeds. Mulching may be used as an alternative to herbicides. Non-puddled rice transplanting technology based on mulch retention are being developed in Bangladesh but the optimum weed control for crops in the cropping sequence is yet to be developed. This present study was under taken to determine the effectiveness of mulch retention relative to herbicides and hand weeding on weed control and yield of non-puddled rice transplanted after mustard.

Materials and Methods

The on-farm experiment was conducted at Durbacahra village of Bangladesh (24.75^0 N and of 90.50^0 E) during 15 November-30 June in 2014 and 2015. *Boro* rice, cv. *BRRI dhan28*, was transplanted with a combination of six tillage and weed control practices *viz.,* (i) Conventional tillage (CT)+ 2 hand weeding (HW) (Control); (ii) Glyphosate (Gly)+strip tillage (ST)+1HW; (iii) Gly+ST+pre-emergence (PE) herbicide (pendimethalin); (iv) Gly+ST+post-emergence (PO) herbicide (ethoxysulfuron); (v) Gly+ST+PE+PO; (vi) Gly+ST+ weed-free (WF), and two levels of mustard mulch *viz.,* (M_0) no-mulch and (M_{50}) 50% mulch by height. In tillage practice, CT consisted of two passes primary tillage by 2WT and ST by Versatile Multi-crop Planter (VMP) in single pass operation. Three days before ST, glyphosate (Roundup®) was applied @ 75 mL/10 L water. PE was sprayed three DAT and PO at 25 DAT @ of 50 ml 10 L^{-1} of water and 1 g L^{-1} of water, respectively. Four hand weeding was done to keep the plots weed free. Weed densities were recorded from 0.25m × 0.25m randomly at four locations of each plot at 25, 45, 65 DAT and crop harvest. Weed biomass was assessed by oven drying at 70^{0}C for 72 hours. The crop was harvested at maturity on 7 May in 2014 and 2 May in 2015 from three quadrates measuring 3m × 3m each and then yield attributes and yield recorded at 14% moisture content. Data were subjected to ANOVA using STATISTIX and means separated by DMRT.

Results and Discussions

After two season rice cultivation in 2014 and 2015, 22 weed species were identified belonging to 10 families (Table 1). Seven weed species belonged Poaceae, five to Cyperaceae and two to each Amaranthaceae and Asteraceae and one of each Campanulaceae, Commelinaceae, Convolvulaceae, Onagraceae, Oxalidaceae, and Polygonaceae. Annuals were dominant over perennials and broadleaved over grasses and sedges.

CT produced the higher number of weed species compared to ST (Table 1). In CT, 15 weed species found in 2014 but 17 species with two new viz., *Ipomoea aquatica* and *Scirpus*

mucronatus in 2015. In ST, 12 weed species recorded in 2014 but 11 in 2015 with the absence of *Jussiaea decurrens*. Among 12 species found in ST, five species (*Mikania micrantha* Kunth., *Sphilanthes acmella*, *Cyperus nemoralis*, *Scirpus mucronatus* and *Jussiaea decurrens* were not found in CT.

Two years' data reveals among the treatment combinations, CT produced about 30% higher weed density and 40% higher weed biomass compared to ST. Spraying PE followed by PO reduced weed density by 40% in 2014 and 50% in 2015 and biomass by 70% in both the year. Mulch reduced weed density by 20% in 2014 and 16% in 2014 and biomass by 27% in 2014 and 34% in 2015 (Figure 1). The highest grain yield (30% higher over CT without mulch) was obtained from the interaction of Gly+ST+ WF with 50% mulch while the highest BCR (40% higher over CT without mulch) was obtained from the interaction of Gly+ST sprayed at PE followed by PO with 50% mulch (Figure 1).

Conclusions

In non-puddled system, spraying a pre-emergence herbicide followed by a post-emergence with the 50% retention of previous crop mulch could control weeds more effectively over manual weeding and attributes the highest benefits.

Acknowledgment

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Table 1. Comparison of weed flora in conventional and strip tillage during 2014 and 2015

Weed type	Name of the weeds	Family	Life cycle	Conventional tillage		Strip tillage	
				2014	2015	2014	2015
Broad-leaved	*Alternanthera sessilis* L.	Amaranthaceae	Annual	+	+	+	+
	A. philoxeroides Griseb.	Amaranthaceae	Perennial	+	+	-	-
	Eclipta alba L.	Asteraceae	Annual	+	+	+	+
	Mikania micrantha Kunth.	Asteraceae	Perennial	-	-	+	+
	Spilanthes acmella A.	Campanulaceae	Annual	-	-	+	+
	Cyanotis axillaris L.	Commelinaceae	Annual	+	+	+	+
	Ipomoea aquatica Forssk.	Convolvulaceae	Annual	-	+	-	-
	Jussiaea decurrens Walter.	Onagraceae	Annual	-	-	+	-
	Oxalis europea Jord.	Oxalidaceae	Perennial	+	+	-	-
	Polygonum coccineum Muhl.	Polygonaceae	Annual	+	+	-	-
Sedges	*Cyperus difformis* L.	Cyperaceae	Annual	+	+	+	+
	C. compressus L.	Cyperaceae	Annual	+	+	+	+
	C. nemoralis Cherm.	Cyperaceae	Perennial	-	-	+	+
	Fimbristylis miliaceae L.	Cyperaceae	Annual	+	+	+	+
	Scirpus mucronatus L.	Cyperaceae	Perennial	-	+	+	+
Grass	*Echinochloa colona* (L.) Link	Poaceae	Annual	+	+		-
	E. crussgalli (L.) Beauv.	Poaceae	Annual	+	+	+	+
	Eleusine indica (L.) Gaertn.	Poaceae	Annual	-	-	-	-

Cynodon dactylon (L.) Pers.	Poaceae	Annual	+	+	-	-
Leersia hexandra Sw.	Poaceae	perennial	+	+	-	-
Parapholis strigosa Dumort.	Poaceae	Annual	+	+	-	-
Leptochloa chinensis L.	Poaceae	Annual	+	+	-	-
Total			**15**	**17**	**12**	**11**

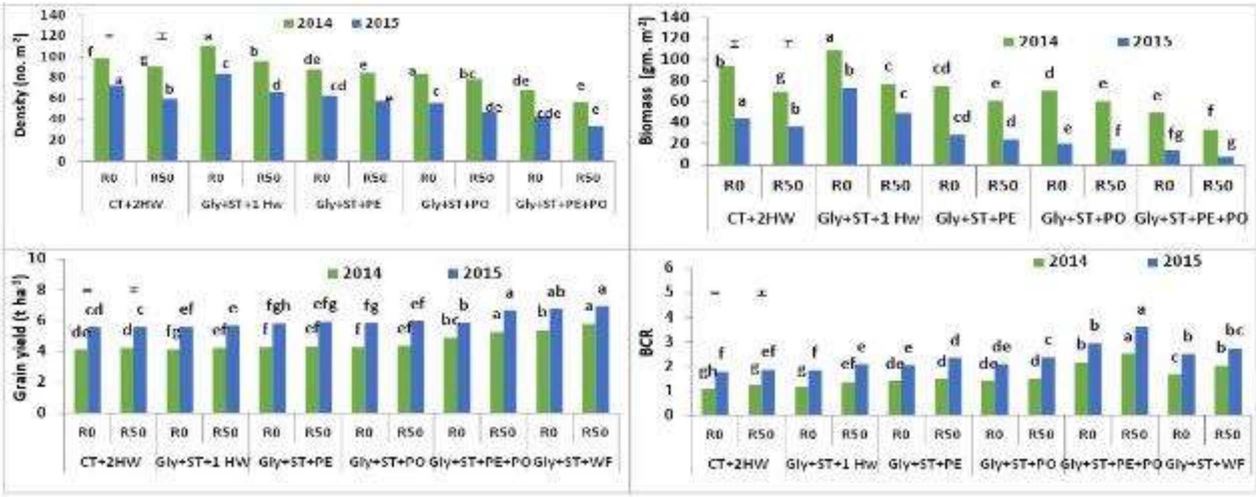

Figure 1. Mulching and weed management effect on weed density, weed biomass, grain yield and BCR of *Boro* rice during 2014 and 2015

Yield improvement of non-puddled transplanted *Aman* rice as influenced by effective weed control under conservation agricultural systems

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Introduction

Traditional puddled transplanting (PT) can successfully be replaced by strip-tilled non-puddled transplanting (STNT) because it saves energy, fuel, labour and cost of cultivation (Haque *et al*., 2016; Islam *et al*., 2012). Moreover, STNT provides better rice yield than the conventional PT (Haque *et al*., 2016). But heavy weed infestation can cause a significant yield loss in STNT (Zahan *et al*., 2014). While conservation agriculture (CA) systems highly relies on herbicide for controlling weeds (Muoni *et al*., 2014), this study was undertaken to find out the effective herbicidal weed control for strip-tilled non-puddled transplanted *aman* rice that can ensure the optimum grain yield.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from June to October, 2014. The study comprised of 15 weed control treatments using combinations of five herbicides (pyrazosulfuron-ethyl, butachlor, orthosulfamuron, butachlor + propanil and 2,4-D amine) along with weedy and weed-free check. Before setting up the experiment, previous crop mungbean was harvested by keeping 50% of biomass in the field as residue. Then pre-planting non-selective herbicide, Roundup® (glyphosate 41% SL- IPA salt), was applied @ 75 mL/ 10 L water (2.25 L ha^{-1}) one week before strip tillage (at 20 cm line spacing) by Versatile Multi-Crop Planter (VMP) (Haque *et al.*, 2016). Just before strip tillage, the land was fertilized at recommended rate and then the land was inundated to 3-5 cm depth of standing water for 48 hours. Twenty-five-day-old rice seedlings cv. Bina dhan-7 were transplanted on 20 July 2014 at 15 cm spacing between hills allocating three seedlings per hill. Weed samples were taken from randomly selected three locations of 0.25 m^2 each at 20, 35 and 50 days after transplanting (DAT). The crop was harvested at maturity on 25 October 2014 and data on yield and related attributes were recorded before harvesting rice. Data were subjected to 'ANOVA' and means were compared by Tukeys's HSD using 'STAR nebula' developed by IRRI (version 2.0.1, January 2014).

Results and Discussion

Herbicide treatments reduced weed biomass significantly ($p<0.001$) compared to the weedy check by 15, 36 and 19% at 20, 35 and 50 DAT, respectively (Table 1). Consistently, the highest weed biomass reduction was obtained from sequential application of pyrazosulfuron-ethyl, orthosulfamuron and butachlor + propanil. Earlier studies also found that sequential herbicide application was effective in controlling weeds under direct seeded rice (Awan *et al*., 2015; Ahmed and Chauhan, 2014). In strip-tilled non-puddled situation, weed competition for the entire growing season reduced *aman* rice yield by 54% compared with the weed-free control. In this experiment, sequential application of pre-, early post- and late post-emergence herbicides increased grain yield by 79-119%, application of pre- and late post-emergence herbicides increased 49-99%, application of early post- and late post-emergence herbicides increased 60-72% and sole pre-emergence or early post-emergence application provided 20-

44% increased yield over weedy control. However, sequential application of pyrazosulfuron-ethyl, orthosulfamuron and butachlor + propanil ensured about 1 % higher grain yield over weed-free control. Therefore, the study offered a wide range of herbicidal control, from which farmers can choose and rotate herbicide combinations for strip-tilled non-puddled transplanted *ama* rice within a cropping pattern to improve yield. But, application of same herbicide molecules with different trade names or different herbicide with same mode of action in the same field without rotation is strictly prohibited. Herbicides should be applied at the recommended rate only.

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Table 1. Effects of herbicide treatments on weed biomass at 20, 35 and 50 days after transplanting and change (%) in grain yield over the weedy control of transplanted *aman* rice in strip-tilled non-puddled field at Bangladesh Agricultural University, Mymensingh during 2014[1]

Treatments	Weed biomass ($g\ m^{-2}$)			YOC
	20	35	50	(%)
T_1=Weedy check	11.9 a	23.8 a	61.3 a	-
T_2=Weed-free check	-	-	-	117
T_3=Pyrazosulfuron-ethyl (pyrazosulfuron)	3.7 de	10.1 c	29.5 c	44
T_4=Butachlor	5.3 bcd	13.6 b	37.5 b	20
T_5=Orthosulfamuron	4.8 b-e	7.0 de	12.6 e	43
T_6=Pyrazosulfuron fb butachlor + propanil	3.8 cde	4.2 fg	5.4 ij	99
T_7=Butachlor fb butachlor + propanil	5.5 bc	6.1 def	19.2 d	60
T_8=Orthosulfamuron fb butachlor + propanil	4.4 cde	1.9 hi	7.9 f-i	104
T_9=Pyrazosulfuron fb 2,4-D amine	3.9 cde	6.4 def	10.9 ef	72
T_{10}=Butachlor fb 2,4-D amine	6.3 b	8.1 cd	12.5 e	49
T_{11}=Orthosulfamuron fb 2,4-D amine	4.4 cde	5.0 efg	9.5 efg	39
T_{12}=Pyrazosulfuron fb orthosulfamuron fb butachlor + propanil	1.1 g	1.2 i	2.6 j	119
T_{13}=Butachlor fb orthosulfamuron fb butachlor + propanil	3.5 ef	3.6 gh	6.2 hi	104
T_{14}=Pyrazosulfuron fb orthosulfamuron fb 2,4-D amine	1.9 fg	3.3 ghi	7.5 ghi	114
T_{15}=Butachlor fb orthosulfamuron fb 2,4-D amine	5.1 b-e	4.9 efg	9.2 fgh	79
S.E.D.	0.46	0.62	0.89	-
Level of significance	***	***	***	-
CV (%)	11.88	10.75	6.59	-

[1]fb = followed by, S.E.D. = standard error of the mean differences, CV = co-efficient of variance, *** = significant at 0.1 % level of significance [In a column, figures having same letter(s) are not significantly different at 5 % level as per HSD]

Chickpea emergence responses to compaction by 2-wheel tractor in two soils of Northwest Bangladesh

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Introduction

Field traffic has many beneficial effects of labour saving and timeliness, but little thought has been given to the potential deleterious consequences of soil compaction. The process of soil compaction reduces total porosity and increases bulk density, resulting in changes in soil physical properties. Excessive compaction in the seedbed may impede seedling emergence. Although greater soil compaction by heavier vehicle traffic has been reported worldwide, a lighter vehicle can cause soil compaction when used repeatedly. The spatial variability of soil physical properties from light farm machinery traffic with minimum tillage and or controlled traffic compared to conventional tillage are unknown. Hence, the objectives of the current study were: (i) to identify changes in soil physical properties as influenced by compaction during controlled traffic minimum tillage by a 2-wheel tractor and (ii) to determine the effect of soil physical properties on chickpea (*Cicer arietinum*) seedling emergence.

Materials and Methods

Field experiments were conducted in 2016 at two locations (Alipur and Digram) near Rajshahi, Bangladesh. The soils were sandy loam and silty clay loam, respectively. An existing plough pan was found at 8-13 cm depth at Alipur and 10-15 cm depth at Digram. The experimental design was split-plot with four replicate blocks. Tillage treatments (Strip tillage without loading (ST), Strip tillage with loading (STWL) or Conventional tillage (CT)) were arranged on the main plots, while number of tractor passes (1 and 4 passes on the same wheel tracks) was allocated in the sub-plots. The field test for wheel trafficking was carried using a Versatile multi-crop planter (VMP) mounted on a Chinese Saifeng 2-wheel tractor (2WT) of about 8.75 KW. Conventional tillage was done with a Saifeng 2WT by random trafficking. Ground pressure for CT, ST and STWL was 85 KPa, 121 KPa and 172 KPa, respectively. Bulk density soil samples were collected from wheel tracks for ST and STWL treatments and randomly from CT plots at 0-5 cm, 5-10 cm (8-13 cm for Alipur soil), and 10-15 cm depths. Chickpea (*Cicer arietinum*) seeds were sown by hand dibbing making a small hole on the wheel tracks for ST and STWL plots, and 15 cm row spacing for CT. Statistical analyses were performed utilizing the SPSS 16.0 program. An analysis of variance (ANOVA) was carried out on the data and means were analysed by least significant difference (LSD).

Results and Discussion

The tillage treatment effect on bulk density in the surface layer (0-5 cm) for both soils varied with the number of passes (P<0.001) (Fig. 1). At Alipur, single pass wheeling significantly increased bulk density (P<0.05) by 0.15 Mg m^{-3} and four pass wheeling by 0.30 Mg m^{-3} compared to CT. At Digram, a single passing significantly (P<0.05) reduced bulk density by 0.08 Mg m^{-3} compared to multiple passing in the traffic induced compaction plots. Bulk density increased with number of passes in the Digram soil at 5-10 cm depth (P<0.05). These results suggest that a greater number of passes, even with a lighter vehicle can cause compaction in the surface layers. The plough pan of both soils did not respond to the loading or number of passing of the light tractor, which suggests that surface compaction is related to the contact

pressure and deeper damage is related to total load. In terms of percent plant emergence, the interaction effect of tillage and passing was significant at Alipur ($P<0.05$), while the main effect of tillage ($P<0.001$) or passing ($P<0.05$) was significant at Digram (Fig. 2). At both locations, treatments receiving single pass of the wheel tracks had % higher plant establishment compared to treatment receiving four passes. The results suggest that increased traffic frequencies compacted topsoil and generated unsuitable soil physical conditions for optimum seedling emergence.

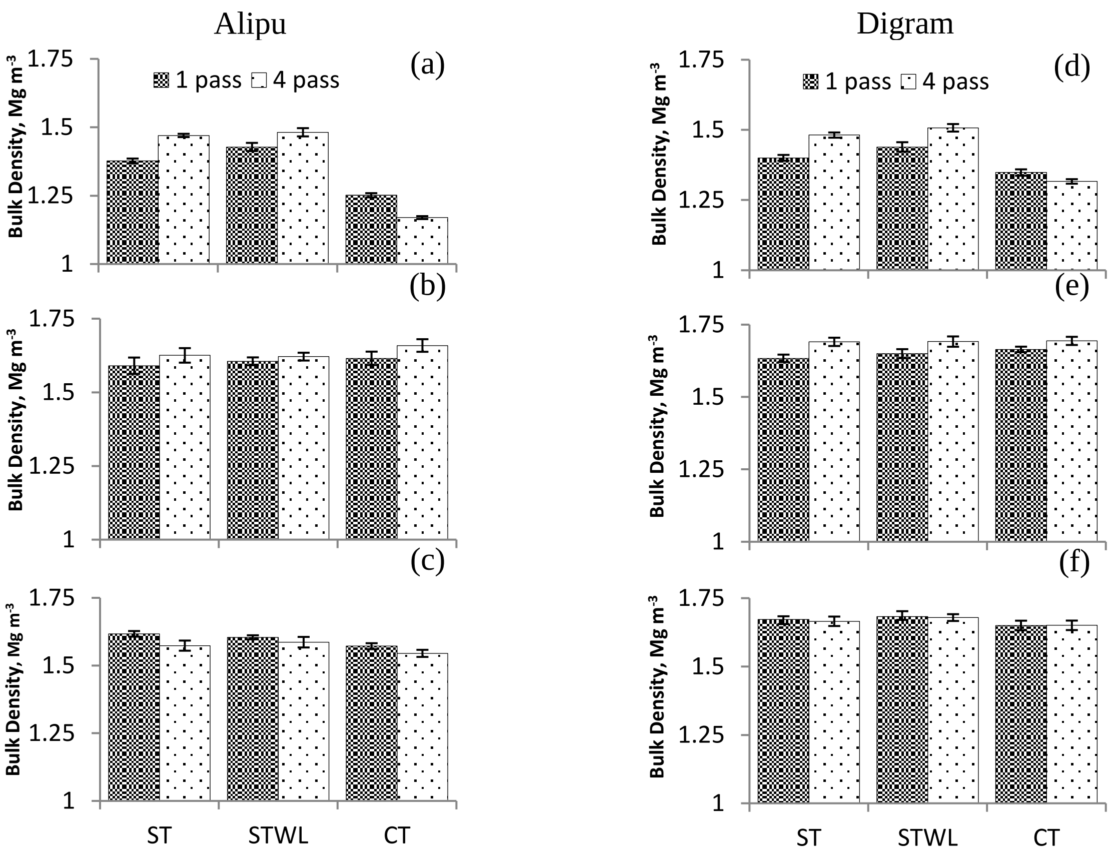

Figure 1. Wheel traffic effects on bulk density (Mg m^{-3}) at Alipur (a, b, c) and Digram (d, e, f) at three depths (a, d) 0-5 cm, (b) 8-13 cm for Alipur, (e) 5-10 cm for Digram, and (c, f) 10-15 cm. Error bars indicate the standard error of mean (n=16 for all treatments)

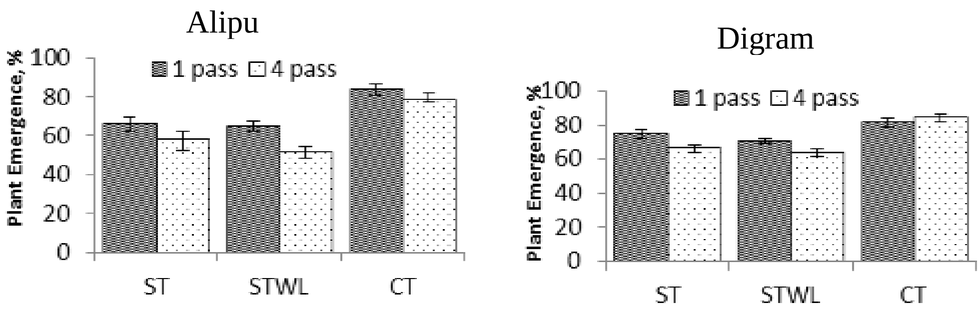

Figure 2. Wheel traffic effects on plant emergence (%) at two locations (percentage plant emergence was calculated from 710 seeds sown on each plot)

Non-puddling practice for rice-based cropping system increases carbon sequestration in soil

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Introduction

In Indo-Gangetic Plains, intensive rice-based cropping systems with conventional crop establishment practices has been followed for many years. Contradictory results are reported about the effect of rice monoculture or rice-upland crop rotations on soil properties. While CA practices may sequester C into the soil organic C pool and improve soil health, in most cases, the practice of CA in rice-upland rotations is only partial; conservation tillage and residues retention are followed for upland crops only but not for rice. So, whatever benefits may accrue from CA practices followed for upland crops are lost by several wet tillage operations followed by puddling. In the EGP, rice-upland crop growers are now adopting CA increasingly, namely non-puddling of rice, in the intensive triple cropping systems (Alam et al. 2016; Haque et al. 2016). The incorporation of minimum tillage and retention of more residues in these systems of the EGP will change the dynamics of C in soil but nature of these changes has not been explored yet. The study was, therefore, conducted to determine the C cycling in soils of rice-upland triple cropping systems under CA practices.

Materials and Methods

The implications of C cycling under novel and conventional rice production technologies on a long-term field experiment were studied at Alipur, Durgapur of north-west Bangladesh (Alam et al. 2016). The treatments comprise three crop establishment practices (conventional puddling-CT, non-puddling with strip planting-SP and non-puddling with bed planting-BP) in combination with low residue retention (LR- the current practice) or increased residue retention (HR). The soil of the experimental field was Calcareous Brown Flood plain with silt loam texture. Undisturbed surface soil samples (0-15 cm) from three locations per experimental plot were collected from field experiments in November-June 2014-15 by means of a push type auger (2.5cm dia). The complete procedures for collection of gas and measurement of heterotropic microbial respiration can be found in Alam et al. (2016). A simple model was used to predict the rate of C change in soil (Stevenson, 1982), $C_t = Co\ (1 - e^{-kt})$; where k is the decomposition constant, Co is the potentially mineralisable carbon (PMC), and C_t is the carbon mineralisation in time, t.

Results and Discussions

Non-puddled transplanting of rice following the strip planting approach (e.g. Haque et al. 2016) enhanced C sequestration in soil through decreasing decomposition rate of organic matter in soil during the rice growing season, and it reduced green-house gas emissions (Table 1 and Figure 1). Under rice soils, the highest cumulative CO_2 emission (346 kg C/ha) was recorded in CTHR during the rice growing period, closely followed by BPHR ($p > 0.05$). Cumulative C evolution under SPHR was similar to that of CTLR ($p>0.05$). The lowest C mineralization was recorded in SPLR treatment in rice field soils (Table 1; $p < 0.05$). The dynamics of other C pools also supported our results (Figure 1). Strip tillage followed by non-puddled transplanting produced the highest potentially mineralisable C (PMC), probably due to lower decay rate and

more organic matter deposited in soils under the treatment relative to other treatments ($p<0.05$). Bed planting followed by non-puddling had lower PMC ($p>0.05$) than those of SPHR while conventional tillage followed by traditional puddling (CT) had the lowest PMC value ($p<0.05$). The lower PMC in BPHR and CTHR may be attributed to high decay rate of PMC. Bed planting with increased residue retention had the highest decay rate of PMC (0.019 day^{-1}) in rice cultivated soils. The increase in soil C was associated with decreasing cumulative evolution of C as CO_2 and/or CH_4 under rice in rice based cropping systems (Figure 1). The cumulative C mineralisation in soils under SP and BP with HR were depressed compared to the current conventional soil disturbance with low residue retention. Conventional tillage practices ensure the constant exposure of the residues to air, moisture, soil and soil microbes, which accelerate the conversion of organic carbon to CO_2. Conversely, in SP and BP, residues retention or standing, and the roots are left intact which decreases the contact between soil microorganisms and the residue. Non-puddling of soils regardless of residue retention sequestered more C in soil of rice-based triple cropping system.

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Table 1. Cumulative CO_2 evolution and soil organic C in soil after five years at Alipur, Rajshahi

Treatments	Cumulative C evolution (at harvest; kg C/ha/season)	SOC (%)
BPHR	333	0.7
BPLR	268	0.51
CTHR	346	0.56
CTLR	263	0.44
SPHR	299	0.79
SPLR	251	0.62
$LSD_{0.05}$	55*	0.11*

*Significant

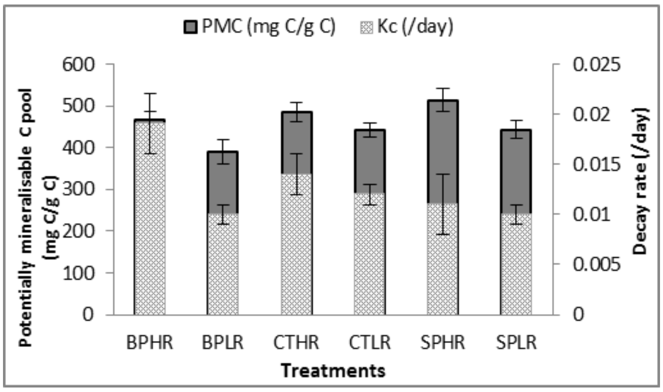

Figure 1. Potentially mineralisable C (PMC) and decay rate of PMC in Calcareous Brown Flood plain soil. Vertical bars represent standard error.

Non-puddled transplanting of rice reduces life cycle greenhouse gas emission

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Introduction

Wetland rice (*Oryza sativa* L.) production contributes 55% of agricultural greenhouse gas (GHG) emissions globally. Hence, any new technology with the potential to reduce the GHG emissions from wetland rice could make a significant contribution to total global warming mitigation by agriculture. Incorporation of conservation agriculture (CA) in the rice–based triple cropping system in the EGP remains a challenge. Measures to reduce CH_4 emissions from rice fields often lead to increased N_2O emissions, and this trade–off between CH_4 and N_2O is a major hurdle in reducing global warming potential (GWP) of wetland rice. Ideal strategies would reduce emissions of both CH_4 and N_2O simultaneously. A novel solution to these constraints for rice production is non-puddled transplanting of rice. The recent development of NP of rice together with residue retention is suitable for CA. A life cycle assessment (LCA) analysis of the new NP rice production technology can estimate its potential contribution to GWP. The present study was carried out to: assess the GHG emissions for conventional puddling and NP with different levels of crop residue retention; determine the hotspots contributing significantly to the GHG emissions within the system boundaries by a LCA study, and identify the causes for the predominant GHG emissions during the pre– and on–farm stages of rice production.

Materials and Methods

Greenhouse gas implications of rice crops were calculated for four establishment practices in the Eastern Gangetic Plains (Durgapur, Rajshahi, Bangladesh): i) conventional puddled transplanting (CT) with low residue retention (LR- current farmer practice for this region which involves keeping about 20% of the standing rice crop residue in the field during harvesting while for other crops like mustard, a complete removal of residues was followed); ii) conventional puddled transplanting (CT) with high residue retention (HR- retention of 50% of standing rice residue and all residues of other crops); iii) non-puddled transplanting (NP) with LR and iv) non-puddled transplanting (NP) with HR. A streamlined LCA approach was adopted, considering cradle-to-farm gate greenhouse gas emissions. A detailed description can be found in Alam et al. (2016).

Results and Discussion

The pre-farm stage in the current study contributed 7-11% of the total GHG emissions. The pre-farm stage produced significantly lower emissions compared to studies conducted in other climates. The lower pre-farm emissions in this study are due to the lower overall level of inputs in comparison with yields obtained, to the use of natural gas as a feed-stock for urea production and electricity generation and to light vehicles for transporting inputs. The contribution of on-farm processes varied between 89 and 93% (in the 100 years horizon) of total GHG emissions. The on-farm GHG emissions from CTLR and CTHR were 91 and 93% of the total emissions while the percentages were 89 and 90% in the case of NPLR and NPHR, respectively. The CTHR contributed the highest on-farm emissions resulting from lower productivity and higher methane emissions. The fuel consumption for irrigation and land

preparation and harvesting alone accounted for 14-19% of the total on-farm emissions. Total pre-farm and on-farm emissions from production of 1 tonne of rice in the EGP were 1.11, 1.19, 1.33 and 1.57 tonne CO_2-eq for NPLR, NPHR, CTLR and CTHR, respectively. Contributions to GHG emissions from CH_4 ranged from 60% for NPLR practice to 67% for CTHR practice. This was followed by farm machinery use (13-16%), CO_2 emissions from soil (9-10%), production of inputs (6-9%) and transport of inputs (2-3%). The N_2O emissions account for 2-3.5% of total direct GHG emission for rice production in the Eastern Gangetic Plain. The present study found 0.2 (NPLR) to 0.4% (CTHR) of the applied N fertilizer was emitted as N_2O which is lower than the IPCC default value (1%) of N_2O loss from applied mineral N fertilizer. Most of the produced N_2O might be reduced to N_2 in wetland rice condition. Overall, NP (NPLR and NPHR) offers greater GHG saving (29%, 24% over CTHR and 18%, 16% over CTLR) relative to the CT method. More specifically, NPLR had the highest reduction potential for on-farm emissions due to emission of least CH_4.

Conclusions

The novel minimum tillage establishment approach for rice involving strip tillage followed by non-puddled transplantation has potential to increase global warming mitigation of wetland rice in the EGP plains. We recommend conducting additional LCA for all the crops of the rice-based cropping system to assess the GWP of the CA practices in diversified rice growing areas.

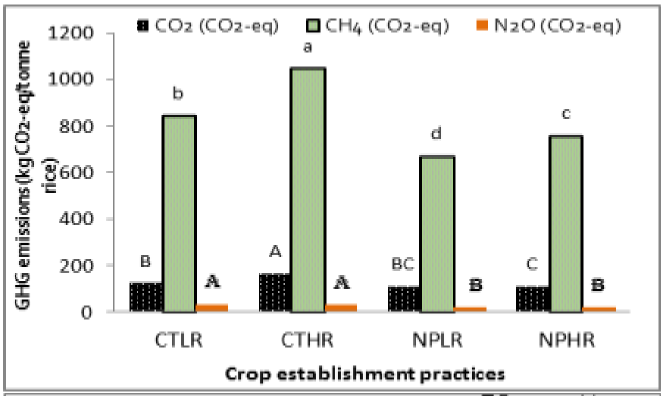

Figure 1. Effect of rice establishment techniques and residue retention on on-farm emission of GHG (CO_2 equivalent; $p < 0.05$). Bars with the same letter above are not significantly different at $p < 0.05$. SE (±) for CO_2 emission is 4.7; for CH_4 43.5 and for N_2O 0.2 over 100-year time horizons, respectively.

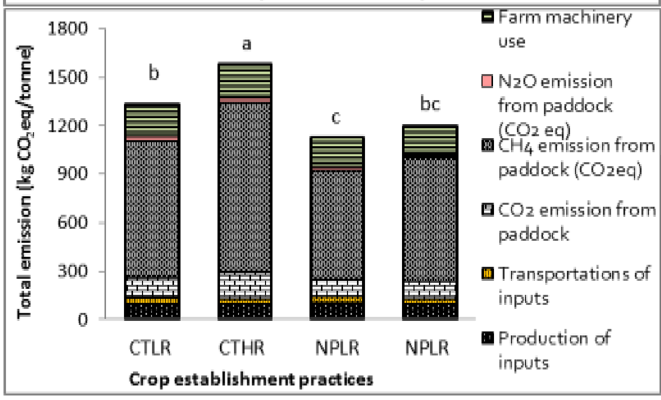

Figure 2. Total GHG emissions (CO_2 equivalents) in terms of inputs and outputs for one tonne of paddy production as influenced by crop establishment techniques and residue retention. [Legend: CT–puddled transplanting and NP–non-puddled transplanting; LR–low residue retention and HR–high residue retention]

References

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Performance of Boro rice to weeding regimes and crop residues under strip tillage system

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Introduction
One disadvantage of conservation tillage is increase in weed pressure (Hossain *et al,* 2014). Weed control in conservation tillage is dependent on the use of herbicides, but other cultural options may help in reducing weed infestations. There is limited knowledge about effective weed control under conservation tillage in intensive rice based cropping systems in Bangladesh. The objectives of this study were to examine the effect of herbicides and hand weeding with or without residues on weed control in rice

Materials and Methods
Boro (winter) rice cv. BRRI Dhan28 was transplanted on 14 February 2014 in Gouripur, Mymensingh, Bangladesh using the following treatments-

I. Tillage and weed control practices

C: Conventional tillage (CT) + three hand weeding (HW) (Control)

Gly+ST: Glyphosate +Strip tillage + one HW

Gly+ST+PE: Gly+ ST+ Pre-emergence (PE) herbicide (pendimethalin)

Gly+ST+PO: Gly+ST+ Post-emergence (PO) herbicide (ethoxysulfurun)

Gly+ST+PE+PO

Gly+ST+ weed-free (WF) (6 hand weeding)

II. Crop residues

R_0: No residue

R_{50}: High residue (50% by height).

The experiment was laid out in RCBD with 4 replications. Dry weed biomass was recorded at 40 days after transplanting (DAT) and grain yield at harvest. Benefit cost ratio (BCR) was calculated for each treatment.

Results and discussions
ST reduced weed biomass by 53% and increased rice yield by 9% and BCR by 16% compared to CT regardless of herbicides and residues. Higher residues significantly reduced weed biomass by 20% and increased rice yield by 4% and BCR by 9% (Table 1). Application of Glyphosate at pre-sowing in ST reduced weed biomass by 10% at 40 DAT compared to CT. Application of Glyphosate followed by a pre-emergence and a post-emergence herbicide with

residues in ST reduced weed biomass by 73% leading to 20% increase in grain yield and 48% in BCR compared to Roundup alone without residues (Table 1).

Conclusion

Strip tillage and residue retention reduced weed biomass and increased grain yield and BCR. Application of Roundup followed by one pre-emergence and one post-emergence herbicide with residues reduced weed biomass compared to Roundup alone and increase rice yield and BCR in strip tillage. Farmers are likely to increase productivity and profit from strip tillage and residue retention in rice crop, by suppressing weeds.

Acknowledgement

This study was a part of PhD research supported by Australian Centre for International Agricultural Research (ACIAR).

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Hossain MM, Begum M, Hashem A, Rahman MM, Bell RW and Haque ME (2014) Yield response of mustard as influenced by weed management practices under conservation agriculture system. Bangladesh Journal of Weed Science 4&5: 87-92

Table1. Effect of tillage and weed control practice and residues on weed dry matter, grain yield and BCR of *Boro* rice

Treatments	Weed biomass (gm^{-2}) at 40 DAT	Yield ($t\ ha^{-1}$)	BCR
CT+2 HW+R_0	58a	5.17gh	1.63g
CT+2 HW+R_{50}	50b	5.20g	1.76g
Gly+ST+1 HW+R_0	52b	5.18g	2.15f
Gly+ST+1 HW+R_{50}	42c	5.27f	2.42e
Gly+ST+PE+R_0	40cd	5.41e	2.44e
Gly+ST+PE+R_{50}	37de	5.52d	2.56de
Gly+ST+PO+R_0	36de	5.43e	2.65d
Gly+ST+PO+R_{50}	31e	5.56d	2.95c
Gly+ST+PE+PO+R_0	27f	5.47c	3.49b
Gly+ST+PE+PO+R_{50}	14g	6.27b	4.17a
Gly+ST+WF+R_0	0	6.36b	3.10c
Gly+ST+WF+R_{50}	0	6.56a	3.30b
LSD (0.05)	4.73	0.32	0.18

Short-term effects of tillage and water management on soil aggregate size distribution and stability in subtropical rice cultivation

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Introduction

Soil aggregate stability represents an important characteristic of the soil structure, which is closely connected with the soil water regime, soil erodibility, and soil nutrient availability. An enhanced aggregate stability decreases the losses of soil, C, N, and P (Kasper *et al.*, 2009), and increases the amount of macro-aggregates and the total and effective porosity (Shaver et al., 2007). Organic C acts as an important binding agent and reversely, the soil aggregation influences organic matter accumulation by providing physical protection to soil organic C by its incorporation into aggregates (Six *et al.,* 2004). Conventional tillage (CT) practices have recently appeared to be responsible for many air and water quality concerns. Reduced tillage (RT) practices reduce the adverse impacts of CT practice by increasing soil organic matter (SOM) and soil aggregation process (Lal *et al.,* 2004). Conservation agriculture (minimum soil disturbance, residue retention and suitable crop rotations) has gained global acceptance for its benefits to save fuel and improve soil health but its impact on rice production and soil health in subtropical environment warrants more investigations. Alternate wetting and drying irrigation is a promising method in irrigated rice cultivation with dual benefits of water saving and environmental security, while maintaining rice yields at least at the same level (Yang *et al.,* 2009). Better soil and water management is therefore required to maintain soil quality and to achieve the potential yield of rice for ensuring sustainable soil health. This research was undertaken to: -

1. assess the changes in the soil health indicators (aggregate mean weight diameter and stability and soil total N content) in three depths of soil under different tillage systems,
2. determine the effects of water regime on soil aggregate size distribution, aggregate stability,
3. assess the rice yield under different tillage methods and water regimes.

Materials and methods

The experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during the Boro season of 2016 (December 2015 to May 2016) located in a subtropical climate. Soil pH ranged 6.5 - 7.0, organic C content was 1.5% and texture is silt loam. The experiment was laid out in a split-plot design with tillage in the main plots and water regimes in the sub-plots with three replications. The tillage treatments were: i) minimum tillage-MT (one pass in 0-5 cm), ii) reduced tillage- RT (one pass in 0-10 cm) and iii) Conventional tillage- CT (four passes in 0-15 cm depth) and water treatments were: i) continuous flooding (CF) and ii) alternate wetting and drying (AWD). Soil was sampled at prior to transplanting and after harvest of rice from 0-5, 5-10 and 10-15 cm depth. Aggregate size fractionation of the soil was performed by using the wet sieving method to obtain water-stable aggregates (Clark et al., 2010). Aggregate MWD was calculated by using the following formula (van Bavel, 1949):

$$\text{MWD} = \sum_{i=1}^{n} (\text{d})i \ \text{wi}$$

Where, d is mean diameter of each fraction size i (mm), w is proportion of total sample weight (g) − sand and coarse fragments weight (g) occurring in the size fraction i and n is number of size fractions.

Total N content of soil was estimated following the Kjeldahl method. For determination of aggregate stability, soils were categorized into >2.00 mm, 2-0.85 mm, 0.85-0.30 mm, 0.30-0.15 mm 0.15-0.0.53 mm and <0.053 size fractions. A two-way analysis of variance (ANOVA) was performed using tillage as factor A and water regimes as factor B. To check the within treatment variations for tillage treatment, post-hoc test with 'Tukey' multiple comparison test was performed. All the statistical analyses were performed on SPSS version 20 (IBM SSPS Statistics 20).

Results and Discussions

Mean weight diameter (MWD) of soil at different depths was significantly influenced by tillage treatments (p<0.01). At 0-5 and 5-10 cm depth, MWD was significantly higher in MT and RT than the CT treatment (p<0.01). Unlike tillage treatments, water regimes did not affect soil MWD. Equally, soil aggregate stability index (SI) at different depths was significantly varied by tillage treatments (p<0.01). At 0-5 and 5-10 cm depth of soil SI was significantly higher in MT than RT and CT treatments (p<0.01) where the RT and CT treatments were statistically identical. This short-term experiment showed higher MWD in MT than the RT and CT. Considering differences between MT and CT, higher aggregate MWD in MT than CT were similar to the findings of Larry and Joe, (2006). Reduced tillage is more favorable to form soil aggregates than MT and CT, due to low disruption of larger aggregates (Mikha and Rice, 2004; Jahangir et al., 2011). Physical disturbance of soil structure through extensive tillage results in a direct breakdown of soil aggregates and an increased turnover of aggregates. No significant differences in soil TN content were observed between treatments. Total N of soil was found >50% in 0-5 cm depth of compared to other depth (Fig. 1). Grain yield was significantly higher in CT than RT and MT (p<0.01) where RT and CT were statistically identical

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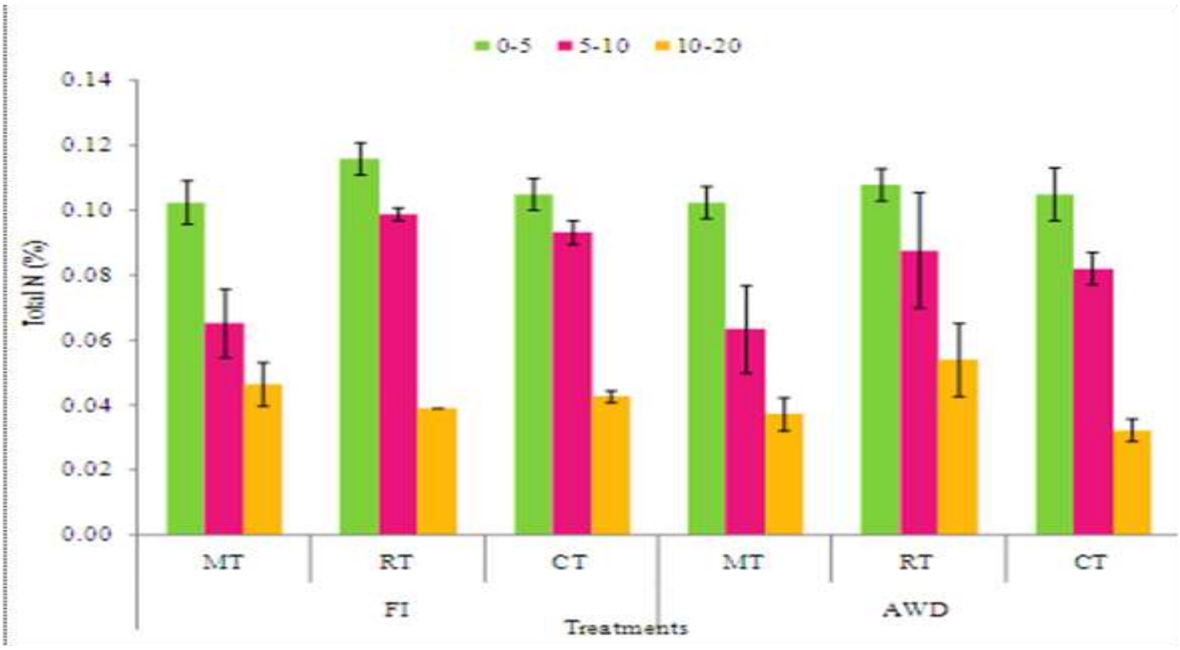

Figure 1. Total N content of soil at three different depths under different treatments

Performance of wheat varieties as relay crop in the transplanted aman rice field under rice-wheat system

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Introduction

Wheat is the second most important grain crop after rice in Bangladesh grown over an area of about 0.43 million hectares with an annual production of about 1.3 million metric tons (BBS, 2014) which is much less than country's need of 4.0 million metric tons (Parvez, 2014). To fulfill current and future demand it is essential to improve wheat productivity and production. Now-a-days, the scope of expansion of wheat in traditional area is very limited due to other competing crops, urbanization and industrialization (Rafiq *et al.*, 2005). A vast non-traditional area nearly 0.84 million hectares remains fallow with a problem of delayed harvest of transplanting aman rice along with having different level of excess soil moisture in winter of southern and some places of western Bangladesh (Karim *et al*. 1990). Whereas, wheat is mainly grown after the harvest of transplanting aman rice in the winter season (November-April) in Bangladesh but in most cases, wheat cultivation, after the transplanting aman rice harvesting is delayed specially in medium high-medium low lands due to excess soil moisture which is needed about one to two weeks more for fine tillable condition and land preparation, and further aggravated by higher infestation of diseases and insect pests and forced maturity, resulting in lower yields. It was also identified that global climatic changes lead to more frequent high temperature during the end of crop cycle. In this circumstance, wheat relay cropping as a resource conservation technology in the rice field has a great opportunity which ensures timely sowing and best use of residual soil moisture. For centuries, farmers in Bangladesh practice this planting method for cultivation of grasspea and pea in rice field (Ali *et al*., 2005). This system also reduces cost of production (45%) that is needed for land preparation (Ali and Khan, 2007). Now a day, farmers sporadically cultivate wheat with local cultivars as relay in transplanted aman rice resulting lower yield. But still now, there is no specific variety of wheat for relay cropping. Improved varieties of wheat appropriate for this system needed to be developed/selected for better adaptation and achieving higher yield of wheat through relay cropping.

Materials and Methods

A field experiment was carried out at Regional Agricultural Research Station of BARI, Jessore. Variety BRRI dhan 49 of T. aman rice was used as rice crop and five wheat varieties namely, BARI Gom 21, BARI Gom 25, BARI Gom 26, BARI Gom 27 and BARI Gom 28 were tested as relay crop. Unit plot size was 4m x 5m. This trial was laid out in a split- plot design with three replications where sowing method was placed in the main-plot and variety was placed in the sub-plot. In relay method (RM) wheat seeds were sown in the rice field just drained out of water through broadcasting method on 25 November before five days of rice harvest retaining 30 cm length of straw and in traditional method (TM) wheat seeds were sown through the broadcasting method after land preparation in the same field on 7 December, 2014. Wheat seeds were at the rate of 120 kg per hectare. Fertilizers were applied @ 100-27-50-20-1 kg ha^{-1} N-P-K-S-B in the form of urea, triple super phosphate, muriate of potash, gypsum and boric acid, respectively. Two third of urea and total amount of other fertilizers were applied as basal before two days of rice harvest. Basal application of fertilizers was done at the time of

final land preparation in TM. The rest amount of urea was top dressed at crown root initiation (CRI) stage followed by first irrigation in both methods. Intercultural operations were done accordingly required. Whole plot was harvested on 16 Mach, 2015. Data were collected on yield and yield attributes and data were analyzed using computer based MSTAT-C program.

Results and Discussion

A significant variation was found between relay and traditional method of late sowing in relation to all the characters studied (Table 1). Irrespective of varieties in relay sowing of wheat with rice produced the higher grain yield as well as yield contributing characters like- spike m^{-2}, 1000-grain weight, biomass and HI over traditional late sowing. It may be timely sowing of wheat under relay seeding increased the spike density and 1000-grain weight compared with traditional late seeding which lead to higher grain yield of wheat. Similar result was observed by Khan and Khaliq (2005), who reported that 69.4% higher grain yield was produced by relay planting of wheat by surface seeding compared with traditional seeding after cotton harvest. Among the wheat varieties the highest grain yield was found in BARI Gom 28 followed by BARI Gom 25 in both cases and the lowest yield was obtained from BARI Gom 26 in relay sowing and from BARI Gom 27 in traditional late sowing. This yield variation might be due to genetic capability of the varieties and the growth environment. The highest grain yield in BARI Gom 28 under relay cropping might be due to high adaptation and increased yield contributing characters like-spike $m^{-2}$and biomass (kg ha^{-1}). The results of this study showed that wheat may be grown as relay cropping with T. aman rice in rice-wheat system in southern and some places of western Bangladesh.

Table 1. Effect of relay with T. aman rice and traditional late sowing method on yield and yield attributes of wheat

Treatments	Spike m^{-2} (no.)	1000-grain wt.(g)	Grain yield (kg ha^{-1})	Biomass (kg ha^{-1})	HI (%)
R M x BARI Gom 21	345 bc	40.4 c	2933 c	8299 c	0.35 ab
RM x BARI Gom 25	292 de	43.6 a	3135 b	8989 b	0.34 b
RM x BARI Gom 26	295 d	41.3 bc	2833 c	8069 c	0.35 ab
RM x BARI Gom 27	354 ab	35.6 d	2879 c	8489 c	0.34 bc
RM x BARI Gom 28	359 a	42.2 ab	3586 a	9669 a	0.37 a
TM x BARI Gom 21	342 c	33.7 e	2404 de	8176 de	0.29 de
TM x BARI Gom 25	285 e	35.8 d	2540 d	8080 d	0.31 cd
TM x BARI Gom 26	283 e	34.7 de	2351 e	7963 e	0.29 de
TM x BARI Gom 27	350 abc	28.7 f	2308 e	8085 e	0.28 e
TM x BARI Gom 28	356 a	36.4 d	2917 c	8469 c	0.34 b
CV (%)	7.6	7.5	5.8	5.5	1.8

Legend: RM= Relay sowing of wheat with rice at optimum time, TM= Traditional method of late sowing

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Effect of row spacing, nitrogen and weed control on crop and weed in low rainfall zones of western Australia

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Introduction

Wide rows essentially ensure some temporal and spatial water availability in water-limiting crop environments, thus minimising the risk of water deficits at critical crop growth stages to ensure profitable yields (Whish et al., 2005). Presence of weeds will have a major impact on water availability to crops irrespective of planting geometries. Decreasing crop plant population and increasing row spacing decreases crop competitive ability against weeds, and generally wider row spacing will reduce crop competition for homogeneously distributed production factors, as postulated mathematically by Fischer and Miles, (1973). Hence 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. With a perceived decline in rainfall in central and eastern wheat belt of Western Australia (WA), wide row cropping practices may prove more productive if weeds can be managed by appropriate herbicides and depriving weeds from applied nitrogen (N). We examined the effect of nitrogen and herbicide on the crop performance and weed control under normal and wide row spacing in a wheat – lupin– canola rotation at Cunderdin and wheat – chickpea rotation at Merredin, WA.

Materials and Methods

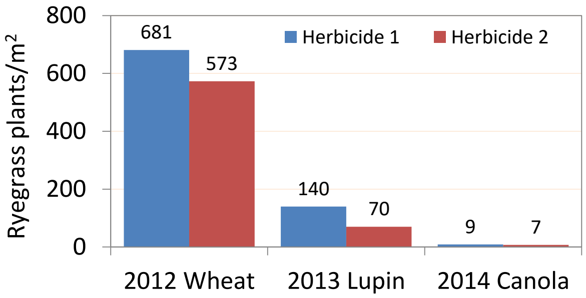
In 2012, rotation trials of three years' duration were initiated at Cunderdin (Rotation 1. Wheat – lupin– canola or Rotation 2. Lupin - wheat - canola) and at Merredin (Rotation 1. Wheat – chickpea or Rotation 2. Chickpea - wheat) in a randomised complete block design with four replications. For all crops row spacing treatments were 22 cm or 44 cm. In the wheat crop, there were two herbicide treatments (trifluralin 2 Lha^{-1} (trilfluralin 480 g L^{-1}) and Sakura® 118 g ha^{-1} (Pyrasulfotole 850 g Kg^{-1}) and three nitrogen treatments: N25 (25 kg N ha^{-1} drilled in front of tynes as urea), N50 (50 kg N ha^{-1} drilled in front of tynes as urea) and Flexi N50 (50 kg N/ha placed at about 7 to 8 cm depth as flexi N). In the lupin and chickpea crops there were two herbicide treatments (simazine 2 L ha^{-1} (simazine 500 g L^{-1}) and Outlook® (dimethenamid 720 g L^{-1}) 1 L ha^{-1})), with nitrogen for all plots. All crops were sown by a cone seeder, 1.54m wide.

At the Cunderdin site in 2014, annual ryegrass density was quite high and control of this weed was poor in wheat crop in 2012. To reduce the seed bank of ryegrass, stubble of all 2012 wheat plots and stubble of all 2013 wheat and lupin were burnt in April each year. In 2014, all plots at Cunderdin were sown to Roundup Ready® (RR) canola. The nitrogen treatments were the same as those for the wheat crop in 2012 or 2013. Roundup Attack® (Glyphosate 690 g/L) was applied at 900 g/ha each at the 2- and 5-leaf stage of the canola. At Merredin, about a ton of wheat and less than a ton of chickpea stubble were retained in each crop. The measurements taken across the trials were crop and weed emergence, weed control by visual assessments and by weed count, crop and weed biomass at anthesis.

Results and Discussions

Rainfall was extremely low at both sites in the 2012 season leading to very poor crop growth. Dimethenamid (Outlook®) herbicide was more effective on annual ryegrass than simazine in lupin and chickpea crops resulting in greater lupin grain yield at Cunderdin. Even though grain yields of crops were very low, yields of both crops at Merredin were greater at 44 cm row spacing than at 22 cm row spacing. These results showed the benefit of wide row spacing in a dry season like 2012 in low rainfall areas such as Merredin. However, under high weed competition at Cunderdin, narrow row spacing appeared more productive with Outlook® herbicide than wide row spacing.

At Cunderdin wide rows (44 cm) reduced crop establishment by 20-25% in all crops compared to 22 cm row spacing. Wide rows also reduced grain yield of wheat but grain yield of lupin and canola remained unaffected by row spacing. Alternative herbicides provided better level of weed control (68-80%) in wheat and lupin but weed control in canola was 99-100%. Flexi N banded below crop seed at sowing time of canola reduced canola establishment by 25% but increased crop vigor by 15% and grain yield by 12%. Management factors including rotation of crops and herbicides reduced annual ryegrass by 99.5% (Fig. 1). Once annual ryegrass burden has reduced to a low level, it is highly important that it should be maintained at a low level to sustain grain productivity.



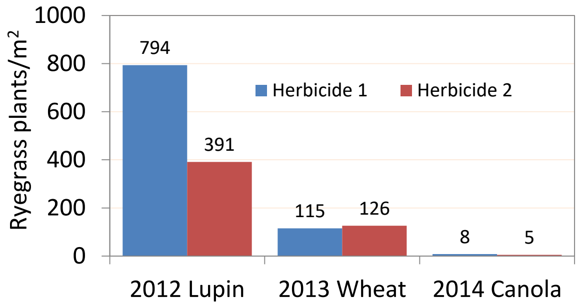


Figure 1. Effect of crop rotations and rotations of herbicides on the population dynamics of annual ryegrass from 2012 to 2014 in Rotation 1 (left graph) and Rotation 2 (right graph) at Cunderdin, Western Australia. Blue bar represents annual ryegrass number per m^2 in herbicide 1 and red bar in herbicide 2. Herbicide 1 was simazine for lupin and trifluralin in wheat while herbicide 2 was Outlook® for lupin and Sakura® for wheat crop. The only herbicide used in RR canola was Roundup Attack®.

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Screening of promising biofortified short duration lentil cultivars for conservation agriculture in North-west Bangladesh

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Introduction

In Bangladesh, lentil (*Lens culinaris* Medikus subsp.culinaris) production was 0.26 million tons from 0.20 million hectares (average yield 1.3 t ha^{-1}) which is 29 % of the total national pulse production (AIS, 2016). Globally, it is cultivated as a rainfed crop on 3.85 million hectares (m ha) with a yield of only 1.1 t ha^{-1} (Erskine *et al.,* 2011). In rice based cropping patterns, after harvesting of *t.aman* rice maximum land remains fallow for about 90 days until establishment of the *boro* rice. Presently, this rice land cannot be used to grow lentil since varieties have 110-115 days duration (AIS, 2017). Promising biofortified short duration (83-90 days) lentil varieties can play an important role to expand its cultivation through establishing lentil by relay sowing into *t.aman* rice and harvesting before *boro* rice. The relay cultivation method involves no tillage and residue retention, and establishes the lentil before *t.aman* rice is harvested. The selection of promising biofortified short duration lentil genotypes under relay cultivation method is therefore important to accommodate in fallow between *t.aman* and boro rice.

Materials and Methods

An experiment was conducted at Pulse Research Centre (PRC), BARI, Ishurdi, Pabna to investigate the selection of promising biofortified short duration lentil genotypes under relay and conventional establishment methods. The experiment included 28 lentil genotypes including BARI Masur 6 as the check variety but only the results for two promising short duration lines are presented. The experiment was laid out in a split-plot design with three replications. Lentil as a relay crop was sown on 25 October 2014 and harvested on 25 January, while lentil sown by the conventional method was sown on 8 November 2014 and harvested on 31 January 2015. The unit plot size was 4 x3 m. No fungicide and insecticide were used in this experiment. One hand weeding was used at 25-30 days after sowing. Statistical analysis was done by using MSTAT-C program.

Results and Discussions

Considering days to maturity, two promising short duration genotypes were compared to the long duration recommended cultivar, BARI Masur 6. Plant population, plant height, pods/plant and seed yield showed significant different due to different lines and establishment method (Table 1). In case of yield, there were significant different between short duration genotypes LRIL 22-15, LRIL 22-70 and BARI Masur 6. The yield of lentil under conventional establishment along with BARI Masur 6 were higher than under relay establishment or by advanced lines. However, conventional establishment and BARI Masur 6 while producing higher yield can't be harvested without delaying the planting of *boro* rice. However, LRIL 22-15 and LRIL 22-70 were promising short duration genotypes which can easily fit within the *t.aman-lentil-boro* rice cropping pattern under relay establishment. In addition to reducing turnaround time, relay method can save the cost of production and improved soil health over conventional method (data not shown). The above promising lines have been sent to

Saskatoon University, Canada to know the percentage of Zn and Fe in lentil seed. The experiment is continuing with 14 additional lines in this year (2016-17) for conformation.

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Table 1. Performance of promising short duration lentil lines under relay and conventional sowing methods.

Treatments	Advance line/ cultivar	Days to maturity (day)	Plant population (no.)	Plant height (cm)	Pods/plant (no.)	Seed yield (kg ha^{-1})
Relay method	LRIL 22-15	93	153	31	39	1054
	LRIL 22-70	93	198	39	31	1067
	BARI Masur 6	119	177	44	58	1790
Conventional method	LRIL 22-15	84	269	41	75	1293
	LRIL 22-70	85	271	43	91	1226
	BARI Masur 6	114	215	40	59	1486
LSD ($p \leq 0.05$)		1.5 **	52.4**	2.2**	18**	14.9**
CV (%)		0.8	7.4	1.9	17.9	0.4

LSD-Least significant difference, ** significant at 1 % level; CV - coefficient of variation

List of Invitees and Attendees for Inaugural and Technical Sessions

l No.	Name	Program	
		Inaugural	Technical
1.	Prof. Dr Richard W. Bell, School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch WA 6150 Australia	Inaugural	Technical
2.	Dr Enamul Haque Adjunct Associate Professor, Murdoch University, Australia and Coordinator, Conservation Agriculture Project2nd Floor, House 4/C, Road 7B Sector 9, Uttara, Dhaka, Tel. +88 01755520086	Inaugural	Technical
3.	Ms. Sally-Anne Vincent, Deputy High Commissioner, Australian High Commission, Dhaka, Bangladesh	Inaugural	---
4.	Mr. Minhaz Chowdhury, Country Manager, Australian High Commission, Dhaka, Bangladesh	Inaugural	---
5.	Ms. Priyanka Chowdhury, Economic Research Officer, Australian High Commission, Dhaka, Bangladesh	Inaugural	---
6.	Mr. M.I. Nahil, Australian High Commission, Dhaka Bangladesh	Inaugural	---
7.	Dr Evan W. Christen, Program Manager, Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia	Inaugural	Technical
8.	Ms. Chetali Chhabra, Assistant Manager, ACIAR, Australian High Commission, 1/50 G, Shantipath, Chanakyapuri, New Delhi-110021, Tel: 91 11 4149 4479	Inaugural	Technical
9.	Dr Abul Hashem, Principal Research Scientist, Department of Agriculture and Food Western Australia, 75 York Road Northam WA 6401 Australia	Inaugural	Technical
10.	Dr Ross Brennan, Department of Agriculture and Food Western Australia, 75 York Road Northam WA 6401 Australia	Inaugural	Technical
11.	Dr M.L. Jat, Principal Agronomist, International Maize and Wheat Improvement Center (CIMMYT), NASC Complex, New Delhi-110 012, India; M.Jat@cgiar.org; www.cimmyt.org	---	Technical
12.	Dr D.S. Rana, IRRI India	---	Technical
13.	Dr Akram H. Chowdhury, Chairman, BMDA, BMDA Head Office, Bahrampur, Rajshahi, Tel: 01777719345	Inaugural	Technical
14.	Executive Director, BMDA, Rajshahi	Inaugural	---
15.	Executive Engineer, BMDA, Region-01, Naogaon	Inaugural	---
16.	Executive Engineer, BMDA, Region-02, Naogaon	Inaugural	---
17.	Assistant Engineer, BMDA, Badolgaci	Inaugural	---
18.	Assistant Engineer, BMDA), Mohadebpur	Inaugural	---
19.	Prof. Dr Md. Ali Akbar, Vice-Chancellor, Bangladesh Agricultural University (BAU), Mymensingh-2202, Tel: 01715004752	Inaugural	---
20.	Prof. Dr Md. Jashimuddin Khan, Pro-Vice Chancellor, BAU, Mymensingh-2202, Tel: 01718151957	Inaugural	Technical
21.	Prof. Dr Md. Monjurul Alam, Director, BAURES, BAU, Mymensingh-2202, Tel: 01752929024	Inaugural	Technical
22.	Prof. Dr Lutful Hassan, Dept. Genetics and Plant Breeding, BAU, Mymensingh-2202, Tel: 01715091096	Inaugural	Technical
23.	Prof. Dr S.D. Chowdhury, Students Affair's Advisor, BAU, Mymensingh-2202, Tel: 01712541494	Inaugural	Technical
24.	Prof. Dr Monoranjan Das, Director, Planning and Development, BAU, Mymensingh-2202, Tel: 01711424587	Inaugural	Technical

25.	Prof. Dr A.K.M. Zakir Hossain, Dept. of Crop Botany and Proctor, BAU, Mymensingh-2202, Tel: 01713113559	Inaugural	Technical
26.	Prof. Dr Md. Alamgir Hossain-1, Dept. of Crop Botany & Associate Advisor, BAU, Mymensingh-2202, Tel: 01717054080	Inaugural	Technical
27.	Prof. Dr Md. Musharraf Hossain, Dept. of Farm Power & Machinery, BAU, Mymensingh-2202, Tel: 01712006283	Inaugural	Technical
28.	Prof. Dr M. Jahiruddin, Dept. of Soil Science, BAU, Mymensingh-2202, Tel: 01718813889	Inaugural	Technical
29.	Prof. Dr Md. Abul Hossain, Dept. of Seed Science & Technol., BAU, Tel: 01727276444	Inaugural	Technical
30.	Prof. Dr Md. Abul Hashem, Dept. of Soil Science, BAU, Tel: 01712196199	Inaugural	Technical
31.	Prof. Dr Masum Ahmad, Dept. of Entomology, BAU, Tel: 01716665704	Inaugural	Technical
32.	Prof. Dr Kazi Shahanara Ahmed, Dept. of Entomology, BAU, Tel: 01716626087	Inaugural	Technical
33.	Prof. Dr M. Ashrafuzzaman, Dept. of Crop Botany, BAU, Tel:01717388991	Inaugural	Technical
34.	Prof Dr A. K. M. Golam Sarwar, Dept. of Crop Botany, BAU, Tel: 01727432435	Inaugural	Technical
35.	Prof. Dr Md. Abdul Kader, Dept. of Agronomy, BAU, Tel: 01724828058	Inaugural	Technical
36.	Prof. Dr M. Anamul Hoque, Dept. of Soil Science, BAU, Tel:01741390715	Inaugural	Technical
37.	Prof. Dr Muhammad Mahir Uddin, Dept. of Entomology, BAU, Tel: 01747629072	Inaugural	Technical
38.	Prof. Dr Fakir Azmal Huda, Head, Department of Agril. Economics, Tel: 01711787456	Inaugural	Technical
39.	Prof. Dr Md. Amir Hossain, Dept. of Genetics and Pl. Breeding, BAU, Tel: 01743747508	Inaugural	Technical
40.	Prof Dr Md. Rafiqul Islam-2, Dept of Soil Science, Tel: 01711118761	Inaugural	Technical
41.	Prof Dr Mokter Hossain, Dept of Horticulture, Tel: 01748020966	Inaugural	Technical
42.	Prof Dr Md. Zakir Hossen, Dept of Agricultural Chemistry, Tel: 01733513640	Inaugural	Technical
43.	Dr Tamanna Haque, Department of Horticulture, Tel: 01712001654	Inaugural	Technical
44.	Prof Dr Gopal Das, Department of Entomology, Tel: 01749285388	Inaugural	Technical
45.	Prof. Dr Mahfuza Begum, Dept. of Agronomy, BAU, Mymensingh-2202, Tel: 01913513890	Inaugural	Technical
46.	Prof. Dr Md. Moshiur Rahman, Dept. of Agronomy, BAU, Mymensingh-2202, Tel: 01711072561	Inaugural	Technical
47.	Prof. Dr M. Mazibur Rahman, Dept. of Soil Science, BAU, Mymensingh-2202, Tel: 01712022109	Inaugural	Technical
48.	Prof. Dr M. Obaidul Islam, Dept. of Crop Botany, BAU, Mymensingh-2202, Tel: 01716334292	Inaugural	Technical
49.	Prof. Dr M. Harun-ur-Rashid, Dept. of Dairy Science, BAU, Mymensingh-2202 , Tel: 01720381581	Inaugural	Technical

50.	Prof. Dr M. Abdul Kader, Head, Dept. of Soil Science, BAU, Mymensingh-2202 Tel: 01714113892	Inaugural	Technical
51.	Prof. Dr Ashraful Haque, Dept. of Genetics & Plant Breeding, BAU, Mymensingh-2202, Tel: 01716022526	Inaugural	Technical
52.	Prof. Dr Md. Solaiman Ali Fakir, Dept. of Crop Botany, BAU, Mymensingh-2202, Tel: 01715523202	Inaugural	Technical
53.	Prof. Dr Md. Moklesur Rahman, Dept. Agricultural Chemistry, BAU, Mymensingh-2202, Tel: 01716383036	Inaugural	Technical
54.	Dr Md. Mahmudul Hassan Sikder, Dept. Surgery and Obstratics, BAU, Mymensingh-2202, Tel: 01766677178	Inaugural	Technical
55.	Prof. Dr Md. Romij Uddin, Dept. of Agronomy, BAU, Mymensingh-2202 Tel: 01780370135	Inaugural	Technical
56.	Prof. Dr Md. Ashik-E-Rabbani, Head, Dept. of Farm Power & Machinery, BAU, Mymensingh -2202, Tel: 01712634354	Inaugural	Technical
57.	Prof. Dr M.A. Awal, Dept. of Farm Power & Machinery, BAU, Mymensingh -2202	Inaugural	Technical
58.	Prof. Dr Md. Rafiqul Alam, Dept. of Surgery and Obstratics, BAU, Mymensingh, Tel: 01714073953	Inaugural	Technical
59.	Prof. Dr Md. Mozahar Ali, Director, GTI, BAU, Mymensingh, Tel: 01711391190	Inaugural	Technical
60.	Prof. Dr Md. Abdul Alim, Dept. of Food Technology & Rural Industries, Tel: 01732252229	Inaugural	Technical
61.	Prof. Dr M. Akteruzzaman, Dept. of Ag. Economics, BAU, Mymensingh, Tel: 01716539485	Inaugural	Technical
62.	Prof. Dr M. Serajul Islam, Dept. of Ag. Economics BAU, Mymensingh, Tel: 01715028792	Inaugural	Technical
63.	Prof. Dr Md Abul Hossain, Dept. of Seed Science & Technology, BAU, Tel: 01727276444	Inaugural	Technical
64.	Prof. Dr Md. Abdus Salam, Dept. of Agronomy, BAU, Tel: 01760178542	Inaugural	Technical
65.	Prof. Dr Khan Md. Saiful Islam, Director, Transport, BAU, Tel: 01715226510	Inaugural	Technical
66.	Mr. Md. Mohiuddin Howlader, Chief Security Officer, BAU Tel: 01711407198	Inaugural	Technical
67.	Prof. Dr Md. Alamgir Hossain-2, Dept. of Crop Botany, BAU Tel:01760178541	Inaugural	Technical
68.	Prof. Dr M. Rafiqul Islam, Dept. of Soil Science, BAU, Mymensingh, Tel: 01711985414	Inaugural	Technical
69.	Prof. Dr SK Paull, Dept. of Agronomy, BAU, Mymensingh	Inaugural	Technical
70.	Mr. Tariqul Islam, Lecturer, Department of Entomology, Tel: 01721204164	Inaugural	Technical
71.	Ms. Marium Zamila, Dept. of Languages, BAU, Mymensingh, Tel: 01712835944	Inaugural	Technical
72.	Prof. Md. Abdul Quddus, Dean, Faculty of Agriculture, BAU, Mymensingh	Inaugural	Technical

73.	Mr. Md. Mohiuddin Howlader, Chief Security Officer, BAU Mymensingh, Tel: 01711407198	Inaugural	Technical
74.	Mr. Md. Abdul Hannan Khan, Chief Farm Superintendent (Retd.), BAU, Mymensingh, Tel: 01754365765	Inaugural	Technical
75.	Director, BAUEC, BAU, Mymensingh	Inaugural	---
76.	Mr. Mozahar Hossin, PhD student, Dept. Agronomy, BAU, Mymensingh	Inaugural	Technical
77.	Mr. Shahjahan Sarker, PhD student, Dept. Agronomy, BAU, Mymensingh	Inaugural	Technical
78.	Ms. Fahmida Akter, MS student, Dept. Agronomy, BAU, Mymensingh	Inaugural	Technical
79.	Mr. Abdullah Al Mahmud, PhD student, Dept. Soil Science, BAU, Mymensingh	Inaugural	Technical
80.	Ms. Surya Ferdousy, MS student, Dept. Soil Science, BAU, Mymensingh	Inaugural	Technical
81.	Mr. Talash Mahmud, MS student, Dept. of FPM, BAU, Mymensingh	Inaugural	Technical
82.	Mrs. Anamika Nasrin, PhD Fellow, Dept. of Agirl. Economics, BAU, Mymensingh	Inaugural	---
83.	Prof. Dr Mahbub Mostofa, Dean, Faculty of Veterinary Science, BAU, Mymensingh	Inaugural	---
84.	Prof. Md. Abdur Rashid, Faculty of Agricultural Engineering and Technology, BAU, Mymensingh	Inaugural	---
85.	Prof. Dr Md. Abdul Quddus, Dean, Faculty of Agricultural Economics and Rural Sociology, BAU, Mymensingh	Inaugural	---
86.	Prof. Dr Subash Chandra Chakraborty, Dean, Faculty of Fisheries, BAU, Mymensingh	Inaugural	---
87.	Prof. Dr Ismail Hossain, Dept. of Plant Pathology, BAU, Mymensingh	Inaugural	---
88.	Prof. Dr Md. Abdur Rahman Sarker, Dept. of Agronomy & President, Democratic Teachers' Forum, BAU, Mymensingh	Inaugural	---
89.	Prof. Dr Md. Fazlul Awal Mollah, Dept. of Fisheries Biology and Genetics & President, BAU, Mymensingh	Inaugural	---
90.	Prof. Dr Md. Abul Hashem, Dept. of Animal Science & Secretary, BAU Teachers' Association	Inaugural	---
91.	Prof. Dr Md. Saidur Rahman, Dept. of Agricultural Economics & Secretary, Democratic Teachers' Forum, BAU, Mymensingh	Inaugural	---
92.	Prof. Dr Md. Shawkat Ali, Dept. of Poultry Science & Secretary, BAU, Mymensingh	Inaugural	---
93.	Prof. Dr Md. Sultan Uddin Bhuiya, Dept. of Agronomy, BAU, Mymensingh	Inaugural	---
94.	Prof. Dr Najrul Islam, Dept. of Agronomy, BAU, Mymensingh	Inaugural	---
95.	Prof. Dr Muhammad Salim, Dept. of Agronomy, BAU, Mymensingh	Inaugural	---
96.	Prof. Dr Md. Parvez Anwar, Dept. of Agronomy, BAU, Mymensingh	Inaugural	---
97.	Prof. Dr Ahmed Khairul Hasan, Dept. of Agronomy, BAU, Mymensingh	Inaugural	---
98.	Prof. Dr Md. Delwar Hossain, Dept. of Agronomy, BAU, Mymensingh	Inaugural	---
99.	Prof. Abul Hossain, Dept. of Soil Science, BAU, Mymensingh	Inaugural	---
100.	Prof. Dr M Abdul Matin, Dept. of Soil Science, BAU, Mymensingh	Inaugural	---
101.	Prof. Dr M Joinul Abedin Mian, Dept. of Soil Science, BAU	Inaugural	---
102.	Prof. Dr Abu Zofar Md. Moslehuddin, Dept. of Soil Science, BAU, Mymensingh	Inaugural	---
103.	Prof. Dr Md Anwarul Abedin, Dept. of Soil Science, BAU, Mymensingh	Inaugural	---

104.	Prof. Dr Murshed Alam, Dept. of Farm Power and Machinery, BAU, Mymensingh	Inaugural	---
105.	Prof. Dr Md. Ashraful Haque, Dept. of Farm Power and Machinery, BAU, Mymensingh	Inaugural	---
106.	Prof. Dr Chayan Kumar Saha, Dept. of Farm Power and Machinery, BAU, Mymensingh	Inaugural	---
107.	Prof. Dr Md. Rostom Ali, Dept. of Farm Power and Machinery, BAU, Mymensingh	Inaugural	---
108.	Prof. Dr Ehsanul Kabir, Dept. of Farm Power and Machinery, BAU, Mymensingh	Inaugural	---
109.	Mr. Md. Saiful Islam, Registrar, BAU, Mymensingh	Inaugural	---
110.	Prof Dr Md. Rakibul Islam Khan, Controller of Examinations, BAU, Mymensingh	Inaugural	---
111.	Prof. Dr M. Jiaul Hoque, Director, BAUEC, BAU, Mymensingh	Inaugural	---
112.	Mr. Md. Rakib Uddin, Treasurer, BAU, Mymensingh	Inaugural	---
113.	DR Faiz Ahmed, Chief Medical Officer, BAU, Mymensingh	Inaugural	---
114.	Engg. Md. Shahin Islam Khan, Chief Engineer, BAU, Mymensingh	Inaugural	---
115.	Dr Aminur Rahman Choudhury**,** Director, Public Relation & Publication, BAU, Mymensingh	Inaugural	---
116.	Mr. Din Mohammad Dinu**,** Assistant Director, Public Rel. & Pub, BAU, Mymensingh	Inaugural	---
117.	Mufti Moulana Mohammad Lutfar Rahman, Senior Imam, Central Mosque, BAU, Mymensingh	Inaugural	---
118.	Mr. Keshob Chandra Roy, Purohit, Central Mandir, BAU, Mymensingh	Inaugural	---
119.	Dr Kazi M. Kamaruddin, Executive Director, Krishi Gobeshona Faundation, BARC Complex, Farmgate, Dhaka-1215, Tel: 01979077207	Inaugural	---
120.	Dr M. A. Razzaque, Director (Crops), Krishi Gobeshona Faundation, BARC Complex, Farmgate, Dhaka-1215, Tel: 01715303893	Inaugural	Technical
121.	Dr Md. Abdus Satter, Chief Scientific Officer, Soil Unit, Krishi Gobeshona Faundation, BARC Complex, Farmgate, Dhaka-1215	Inaugural	Technical
122.	Dr Mohammad Jalal Uddin, Executive Chairman, Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215, Tel: 01720620621	Inaugural	---
123.	Dr Sultan Ahmmed, Member Director (NRM), Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215, Tel: 029228061	Inaugural	Technical
124.	Dr Paresh Chandra Golder, Member Director (Add. Charge), Administration and Finance Division and Member Director, Planning and Evaluation Division, Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215	Inaugural	---
125.	Dr Shah Md. Ziqrul Haq Chowdhury, Member Director (Routine Charge), Livestock Division, Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215	Inaugural	---
126.	Dr Md. Aziz Zillani Chowdhury, Member Director (Crops), Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215, Tel: 01552355393	Inaugural	Technical

127.	Dr Harunur Rashid, PSO, Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215	Inaugural	Technical
128.	Dr Md. Abul Kalam Azad, Director General, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur	Inaugural	---
129.	Dr Md. Lutfur Rahman, Director (Research), Bangladesh Agricultural Research Institute, Joydebpur, Gazipur	Inaugural	----
130.	Mr. Md. Shoheb Hassan, Director, Planning and Evaluation Wing, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur	Inaugural	--
131.	Dr Md. Nurul Islam, Head, Agronomy Division, Bangladesh Agricultural Research, Institute (BARI), Joydebpur, Gazipur	Inaugural	Technical
132.	Dr M. A. Matin, Head, Economics Division Bangladesh Agricultural Research, Institute (BARI), Joydebpur, Gazipur	Inaugural	Technical
133.	Dr ASMMR Khan, Head, OFRD Division, Bangladesh Agricultural Research, Institute (BARI), Joydebpur, Gazipur	Inaugural	Technical
134.	Dr M. Akkas Ali, Principal Scientific Officer, OFRD Division, BARI, Gazipur-1701	Inaugural	Technical
135.	Dr Israil Hossain, Head, FMPE Division, Bangladesh Agricultural Research, Institute (BARI), Joydebpur	Inaugural	Technical
136.	Dr M.A. Monayem Mia, Senior Scientific Officer Agricultural Economic Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur	Inaugural	Technical
137.	Dr M.A. Rashid, Principal Scientific Officer, Agricultural Economic Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur	Inaugural	Technical
138.	Dr Md. Omar Ali, Principal Scientific Officer, Pulses Research Center, Bangladesh Agricultural Research Institute Joydebpur, Gazipur	Inaugural	Technical
139.	Dr Noresh Chandra Deb Barma, Director, Wheat Research Center, Bangladesh Agricultural Research Institute Joydebpur, Gazipur	Inaugural	Technical
140.	Dr Md. Abdul Khaleque, CSO and Head WRC Bangladesh Agricultural Research Institute, Joydebpur, Gazipur	Inaugural	Technical
141.	Dr Muhammad Hossain, Director, Pulse Research Center, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur	Inaugural	Technical
142.	Dr Md. Ilias Hossain, Head, Regional Wheat Research Center, BARI, Shympur, Rajshahi	Inaugural	Technical
143.	Dr Bodruzzaman, CSO, RARS, BARI, Burirhat, Rangpur	Inaugural	Technical
144.	Mr. Nazmus Salahin, Scientific Officer, Soil Science Division, Bangladesh Agricultural Research Institute. Joydebpur, Gazipur	Inaugural	Technical
145.	Mrs. Taslima Zahan, Scientific Officer, OFRD Division Bangladesh Agricultural Research Institute, Joydebpur, Gazipur	Inaugural	Technical

146.	Md. Ariful Islam, Scientific Officer, Pulses Research Center, Bangladesh Agricultural Research Institute, Ishurdi, Pabna	Inaugural	Technical
147.	Mr. Md. Samsul Alam, SSO, PRC, Bangladesh Agricultural Research Institute, Pabna	Inaugural	Technical
148.	Mr. N.C. Shil, PSO, Soil Science, Division, Bangladesh Agricultural Research Institute, Gazipur	Inaugural	Technical
149.	Dr Md. Ayub Hossain, PSO, FMPE Division, Bangladesh Agricultural Research Institute, Gazipur		
150.	Mr. Muhammad Arshadul Hoque, SSO, FMPE Division, Bangladesh Agricultural Research Institute, Gazipur		
151.	Dr Bhagya Rani Banik, Director General, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
152.	Dr Md. Ansar Ali, Director (Research), Bangladesh Rice Research Institute, Joydebpur, Gazipur-1701, Tel: 01925053582	---	Technical
153.	Dr Shahjahan Kabir, Director (Admin.), Bangladesh Rice Research Institute, Joydebpur, Gazipur-1701, Tel: 01712280083	Inaugural	---
154.	Md Sirajul Islam, PSO, FM Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur-1701	Inaugural	Technical
155.	Dr Md Abdur Rahman, Head, FMPHT Division, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	Technical
156.	Md. Anwar Hossen, SSO, FMPHT Division, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	Technical
157.	Head, Agronomy Division, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	Technical
158.	Head, Agricultural Economics Division, Bangladesh Rice Research, Institute (BRRI), Joydebpur, Gazipur	Inaugural	Technical
159.	Mr. F.M. Moinuddin, CSO and Head, RFS Division, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	Technical
160.	Head, Plant Breeding, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
161.	Head, Hybrid Rice, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	--
162.	Head, Biotechnology, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
163.	Head, Genetic Resource & Seed, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
164.	Head, Grain Quality & Nutrition, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
165.	Head, Irrigation & Water Management, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
166.	Head, Plant Physiology, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
167.	Head, Rice Farming System, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---

168.	Head, Workshop Machinery and Maintenance, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
169.	Head, Agricultural Statistics, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
170.	Head, Farm Management, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
171.	Head, Adaptive Research, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur	Inaugural	---
172.	Head, Training, Bangladesh Rice Research Institute (BRRI); Joydebpur, Gazipur	Inaugural	---
173.	Dr Md. Rafiqul Islam, CSO & Head, Regional Station, BRRI, Shympur, Rajshahi	Inaugural	---
174.	Mr. Md Nasiruzzaman, Chairman, Bangladesh Agricultural Development Corporation, Agriculture Building, 49-51, Dilkosha C/A, Motijhil, Dhaka	Inaugural	---
175.	Joint Director (Fertilizer), Bangladesh Agricultural Development Corporation, Bolashpur, Mymensingh	Inaugural	----
176.	Dr Md. Monjural Alam, Director General, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka 1207	Inaugural	----
177.	Dr Rahima Khatun, Director (Agriculture), Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka 1207, Tel: 01937399699	Inaugural	---
178.	Prof. Dr GKM Mustafizur Rahman, Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur – 1706, Phone: +8801718186642 Email: mustafiz@bsmrau.edu.bd	Inaugural	---
179.	Head, Dept. of Agronomy, Sher-E-Bangla Agricultural University, Sher-E-Bangla Nagar, Dhaka	Inaugural	---
180.	Prof. Dr Abul Kashem, Dept. of Soil science Sylhet Agricultural University, Sylhet	Inaugural	Technical
181.	Prof.Dr Mrittyonjoy Biswas, Dept. of Agronomy and Haor Agriculture, Sylhet Agricultural University, Sylhet	Inaugural	Technical
182.	Prof. Dr Nazrul Islam, Professor, Dept. of Agronomy and Haor Agriculture, Sylhet Agricultural University, Sylhet	Inaugural	Technical
183.	Head, Dept. of Agronomy, Dept. of Agronomy and Haor Agriculture, Sylhet Agricultural University, Sylhet	Inaugural	---
184.	Head, Dept. of Soil Science, Sylhet Agricultural University, Sylhet	Inaugural	---
185.	Head, Dept. of Agricultural Economics, Sylhet Agricultural University, Sylhet	Inaugural	---
186.	Prof. Dr Asadul Haque, Dept. of Soil Science, Patuakhali Science and Technology University, Patuakhali	Inaugural	Technical

187.	Dr Shahidullah Mian, Director, Agricultural Science International University of Business Agriculture and Technology, Embankment Road Sector 10, Uttara, Dhaka	Inaugural	--
188.	Dr Syedur Rhaman, Faculty, Agricultural Science International University of Business Agriculture and, Technology, Embankment Road Sector 10, Uttara, Dhaka	Inaugural	---
189.	CSO, Bangladesh Sugar Crop Research Institute Ishwardi, Pabna	Inaugural	--
190.	Director General, Bangladesh Institute of Nuclear Agriculture, BAU campus, Mymensingh-2202	Inaugural	---
191.	Director(Research), Bangladesh Institute of Nuclear Agriculture, BAU campus, Mymensingh-2202	Inaugural	Technical
192.	Director General, Bangladesh Fisheries Research Institute, BAU campus, Mymensingh-2202	Inaugural	---
193.	Director (Research), Bangladesh Fisheries Research Institute, BAU campus, Mymensingh-2202	Inaugural	---
194.	Director General, Bangladesh Soil Resource Development Institute, Krishi Khamar Sharak, Dhaka-1215	Inaugural	---
195.	Md. Abul Kalam Azad, Chief Scientific Officer, Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202	Inaugural	Technical
196.	Dr M. Ataur Rahman, Regional Wheat Research Centre, Bangladesh Agricultural Research Institute, Gazipur	Inaugural	Technical
197.	Mr. M. N. H. Mahmud, School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch WA 6150 Australia	Inaugural	Technical
198.	Technician 1 Technician 2 Bangladesh Rice Research Institute, Gazipur	Inaugural	---
199.	Mr. S. M. Shamsuzzaman, Soil Resource Development Institute, Krishi Khamar Sarak, Dhaka-1215	Inaugural	Technical
200.	Mr. M. S. Islam, Agronomy Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202	Inaugural	Technical
201.	Mr. M.H. Rashid, Bangladesh Rice Research Institute Regional station, Rajshahi	Inaugural	Technical
202.	Mr. M. H. Ali, Agricultural Engineering Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh	Inaugural	Technical
203.	Mr. Jamil Hossain, Pulses Research Centre, Bangladesh Agricultural Research Institute, Ishurdi, Pabna 6620.	Inaugural	Technical
204.	Mr. M.A.K. Mian, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur 1701	Inaugural	Technical
205.	Ms. Masuda Akter, Department of Soil Management, Ghent University, Coupure Links 653, 9000 Gent, Belgium	Inaugural	Technical
206.	Mr. Md. Safiqul Moula, Scientific Officer, Soil Resource Development Institute, Kushtia	Inaugural	Technical

207.	Ms. Rafeza Begum, SO, Soil Resource Development Institute, Jamalpur	Inaugural	Technical
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209.	Mr. Mohammad Mobarak Hossain, Ph.D. Fellow, Agronomy Division, BAU, Mymensingh-2202	Inaugural	Technical
210.	Mr. M. A. Matin, Director General, Rural Development Academy, Bogra-5842	Inaugural	Technical
211.	Director, Mechanization Project, Rural Development Academy, Bogra-5842	Inaugural	---
212.	Mr. Muhammad Maududur Rashid Safdar Director General Bangladesh Academy for Rural Development (BARD) Kotbari, Comilla, Bangladesh	Inaugural	---
213.	Agriculturist Md. Manzurul Hannan, Director General Department of Agricultural Extension (DAE) Khamar Bari, Dhaka	Inaugural	---
214.	Mr. Sree Chaitanya Kumar Das, Additional Director, Field Service Wing (Monitoring), Department of Agricultural Extension, Khamar Bari, Dhaka, Tel: 01718456164	Inaugural	---
215.	Mr. Nazimuddin Ahmed, Department of Agricultural Extension, Khamar Bari, Dhaka	Inaugural	---
216.	Mr. Ashok Kumar Biswas, Monitoring and Evaluation Officer, Mechanization Project, Department of Agricultural Extension Khamar Bari, Dhaka	Inaugural	Technical
217.	Mr. Amitava Das, Additional Director, Department of Agricultural Extension, Bolashpur, Mymensingh	Inaugural	---
218.	Deputy Director, Department of Agricultural Extension Khamar Bari, Moharaja Road, Mymensingh	Inaugural	---
219.	Deputy Director, Department of Agricultural Extension Khamar Bari, Rail gate, Rajshahi	Inaugural	--
220.	Deputy Director, Department of Agricultural Extension, Khamar Bari, Dinajpur	Inaugural	---
221.	Deputy Director, Department of Agricultural Extension Khamar Bari, Panchagahr	Inaugural	---
222.	Deputy Director, Department of Agricultural Extension Khamar Bari, Thakorgaon	Inaugural	---
223.	Deputy Director, Department of Agricultural Extension Khamar Bari, Natore	Inaugural	---
224.	Deputy Director, Department of Agricultural Extension Khamar Bari, Rajbari	Inaugural	---
225.	Deputy Director, Department of Agricultural Extension Khamar Bari, Bogora	Inaugural	---
226.	Deputy Director, Department of Agricultural Extension Khamar Bari, Naoga	Inaugural	---
227.	Deputy Director, Department of Agricultural Extension Khamar Bari, Rangpur	Inaugural	---

228.	Additional Director Additional Director, Department of Agricultural Extension, Bogora Region, Bogora	Inaugural	---
229.	Additional Director Additional Director, Department of Agricultural Extension, Rajshahi Region, Boalia, Rajshahi	Inaugural	---
230.	Additional Director Additional Director, Department of Agricultural Extension, Bogora Ranpur, Rangpur	Inaugural	---
231.	Additional Director Additional Director, Department of Agricultural Extension, Faridpur Region, Faridpur	Inaugural	---
232.	Additional Director, Department of Agricultural Extension, Dinajpur Region, Dinajpur	Inaugural	---
233.	Upazilla Agriculture Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Sadar, Panchagahr	Inaugural	--
234.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Sadar, Dinajpur	Inaugural	---
235.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Sadar, Thakorgaon	Inaugural	----
236.	Upazilla Agricultural Officer Department of Agricultural Extension, Sadar, Rangpur	Inaugural	---
237.	Upazilla Agricultural Officer; Department of Agricultural Extension, Sadar, Natore	Inaugural	Technical
238.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Sonatola, Bogora	Inaugural	---
239.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Durgapur, Rajshahi	Inaugural	Technical
240.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Godagri, Rajshahi	Inaugural	---
241.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Paba, Rajshahi	Inaugural	---
242.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Balikandi, Rajbari	Inaugural	---
243.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Sadar, Mymensingh	Inaugural	---
244.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Gouripur, Mymensingh	Inaugural	Technical
245.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Muktagacha, Mymensingh	Inaugural	Technical
246.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Dhanbari, Tangail	Inaugural	Technical
247.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Badalgacchi, Noagaon	Inaugural	---
248.	Upazilla Agricultural Officer, Upazilla Agricultural Officer, Department of Agricultural Extension, Mohadevpur, Noagaon	Inaugural	---
249.	Ms. Sue Lautze, Country Representative, FAO-Bangladesh, House # 37; Road #08, Dhanmondi R/A, P.O. Box 5039 (New Market), Dhaka-1205, Bangladesh. Tel: +88 02 9126673	Inaugural	---

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252.	Dr T. P. Tiwari, Country Representative, CIMMYT-Bangladesh, House 10/B, Road No. 53, Banani, Dhaka 1212, Tel: 01730426384	Inaugural	---
253.	Dr Tim Krupnik, Systems Agronomist, CIMMYT House 10/B, Road No. 53, Banani, Dhaka 1212, Bangladesh	Inaugural	---
254.	Mr. Jack McHugh, CIMMYT	Inaugural	Technical
255.	Mr. Danniel Auchettl, CIMMYT	Inaugural	Technical
256.	Mr. Bredon Fallon, CIMMYT	Inaugural	Technical
257.	Mr. Iqbal sidkki, Manager, CIMMYT	Inaugural	Technical
258.	Dr M.G. Neogi, World Bank	Inaugural	Technical
259.	Ms. Aklima Haque, Project Management Coordinator, USAID	Inaugural	---
260.	Mr. Anar Khalilov, Senior Food Security Advisor, USAID	Inaugural	---
261.	Ms. Shameem Ara Sheuli, Knowledge Management Officer Room 14:23 (14th Floor), IDB Bhaban, Sher-e-Bangla Nagar, 1000 Dhaka, Bangladesh	Inaugural	---
262.	Dr Yam Gaihre, Soil Scientist- EurAsia Division International Fertilizer Development Center (IFDC)-Bangladesh	Inaugural	----
263.	Ms. Ishrat Jahan, Resident Representative, IFDC- Bangladesh	Inaugural	---
264.	Mr. S.M. Monowar Hossain, Advisor, Vegetables Sud-sector, AFC-Bangladesh	Inaugural	---
265.	Ms. Rita Lohani, Associate Operation Officer, International Finance Corporation-Bangladesh	Inaugural	----
266.	Dr Chris August, Team Leader, BFPB	Inaugural	---
267.	Mr. Kazi Mustafa, Deputy Credit Guarantee Fund Manager, BFPB	Inaugural	---
268.	Mr. Abu M. Musa, Executive Director PROVA, Upashahar, Rajshahi	Inaugural	Technical
269.	Dr Salima Rahman, Executive Director, RDRS Bangladesh House 43, Road 10, Sector 6, Uttara, Dhaka-1230	Inaugural	---
270.	Managing Director, Center for Natural Resource Studies (CNRS) House-13 (4th-6th Floor), Road-17, Block-D, Banani, Dhaka-1213, Bangladesh	Inaugural	---
271.	Country Representative, CARE Bangladesh, RAOWA Complex (Level 7-8), VIP Road, Mohakhali, Dhaka -1206, Bangladesh	Inaugural	----
272.	Mr. Abdur Rahman Minto, Managing Director, USEKA, Sesh Moor, BAU, Mymensingh	Inaugural	---
273.	Mr. Md. Liakot Ali Khan, Chairman, Bangladesh Conservation Agriculture Service Providers' Association, Rajabari, Gudagari, Rajshahi	Inaugural	----
274.	Managing Director, Christian Commission for Development in Bangladesh (CCDB), 8, Senpara Parbatta, Mirpur 10, Dhaka	Inaugural	---

275.	Managing Director, Friends in Village Development Bangladesh (FIVDB), Khadimnagar, Sylhet	Inaugural	---
276.	Mr. Moazzem Hossain, Executive Director, Gram Biksah Kendra, Parbotipur, Dinajpur	Inaugural	----
277.	Mr. Md. Abdul Hakim, Executive Director, RDS, Sirajgong	Inaugural	---
278.	Country Director, Syngenta Foundation, House 2/1/A (3rd Floor), Block G, Lalmatia Dhaka 1207	Inaugural	---
279.	Mr. Md. Mizanul Hoque, Managing Director, Hoque Corporation, Dhaka, Tel: 01772984331	Inaugural	---
280.	Mr. Engr. Humayun Kabir, Managing Director, The Metal (Pvt) Limited, PBL Tower (9th & 14th Floor), 17, North C/A, Gulshan Circle-2, Dhaka-1212, Mobile: 01713164201, Email: humayun.kabir@metalbd.biz	Inaugural	----
281.	Mr. Ashfaq Ahmed, Manager Operation, RFL Agri. Business, Middle Badda, Holland Venture, Level-8, Dhaka, Mobile: 01678714749, Email: rfl.op3@rflgroupbd.com,	Inaugural	---
282.	Mr. Md. Murad Hossain, Assistant General Manager, Alim Industries Ltd., BSCIC Industrial Estate, Gotatikor, Kodomtoli, Sylhet, Mobile: 01733200133	Inaugural	---
283.	Mr. Md. Oleullah, Managing Director, Janata Engineering, Sorojgonj Bazar, Chuadanga, Mobile: 01711960861	Inaugural	----
284.	Mr. Md Shah Alom, Managing Director, Alom Engineering Workshop, 25 Vogohori Saha Street, Wari, Dhaka 1000	Inaugural	---
285.	Mr. Mizanur Rahman, ACI Agribusiness, ACI Centre 245, Tejgaon Industrial Area, Dhaka-1208, Bangladesh	Inaugural	---
286.	Auto Crop Care, Abedin Equipment Ltd., House # 69, Road # 04, Block # C, Banani, Dhaka-1213, Bangladesh	Inaugural	---
287.	Syngenta Bangladesh Limited, House No-2/6, Block -E, Lalmatia, Mohammadpur, Dhaka-1207	Inaugural	---
288.	Mr. Afzal Hossain, Hossain Enterprise C.C. Limited Road # 30, House # 423 (2nd Floor), Flat-D New DOHS, Mohakhali	Inaugural	---
289.	Manager, Bangladesh Krishi Bank, BAU Branch, Mymensingh	Inaugural	---
290.	Regional Manager, National Bank Ltd., Rajshahi	Inaugural	---
291.	National Bank Ltd. Director and HR, Rajshahi	Inaugural	---
292.	Manager, South Bangla Agricultural Bank Ltd.	Inaugural	---
293.	Manager, Social Islami Bank Ltd.	Inaugural	---
294.	Manager, Lonka Bangal Finance	Inaugural	---
295.	Manager, Exim bank, Uttara, Dhaka	Inaugural	---
296.	Manager, Rajshahi Krishi Unnayan Bank	Inaugural	---
297.	Manager, Basic Bank, Uttara, Dhaka	Inaugural	---
298.	Mr. Younus Ali, FT, CA Project, Durgapur, Rajshahi	Inaugural	---
299.	Mr. Md. Masud Rana, LSP, CA Project, Durgapur, Rajshahi	Inaugural	---
300.	Mr. Abul Kalam, Farmer, CA Project, Durgapur, Rajshahi	Inaugural	---
301.	Mr. A.B. Siddique, Farmer, CA Project, Durgapur, Rajshahi	Inaugural	---

302.	Mr. Mokhlesur Rahman, SAAO, Durgapur, Rajshahi	Inaugural	---
303.	Mr. Shoheel, BBBF, Naogaon	Inaugural	---
304.	Mr. Shohag, BMDA, Naogaon	Inaugural	---
305.	Dr Md Sohrab Ali, Director Department of Environment, Ministry of Environment and Forest, Paribesh Bhaban, E-16, Agargaon, Sher-E-Bangla Nagar, Dhaka 1207	Inaugural	---
306.	Dr Md. Abdul Wohab, Chief Scientific Officer, RARS, BARI, Rahamatpur, Barisal, Email: m.wohab@yahoo.com	Inaugural	Technical
307.	Mr. Riaz Uddin, Manager, BFA	Inaugural	---
308.	Mr. Kamal Hossain, Proprietor, M/S. Kamal Machine Tools, Salimpur, Bogra	Inaugural	---
309.	Mr. Mostafa Kamal, Region Sales Manager Monsanto, Bangladesh, Sel-chandra Mollika,4-d, 458, Senpara, Parbata, Kafrul, Mirpur, Dhaka, Bangladesh	Inaugural	---
310.	Mr. Shahinur Rahman, Manager, Syngenta Foundation, Dhaka, Bangladesh	Inaugural	---
311.	Mr Arful Islam, BRAC Agricultural Research and Development Center, CERDI Road, Joydevpur, Gazipur 1701	Inaugural	---
312.	Mr. Shitesh Chandra, BRAC Agricultural Research and Development Center, CERDI Road, Joydevpur, Gazipur 1701	Inaugural	---
313.	Mr. Mojibur Rahman, ED, PEP, Dhaka, Bangladesh	Inaugural	---
314.	Media Mix, Event Management, Dhaka, Bangladesh	Inaugural	Technical
315.	Mr. Rashed Khan Menon, PIO-MU, Dhaka, Bangladesh	Inaugural	Technical
316.	Mr. Kamrul Hasan, PIO-MU, Dhaka, Bangladesh	Inaugural	Technical
317.	Mr. Ruhul Amin, PIO-MU, Dhaka, Bangladesh	Inaugural	Technical
318.	Mr. Asman Foragi, PIO-MU, Dhaka, Bangladesh	Inaugural	Technical
319.	Mr. Babul Hossain, PIO-MU, Dhaka, Bangladesh	Inaugural	Technical
320.	Mrs. Rubina Akther, PIO-MU, Dhaka, Bangladesh	Inaugural	Technical
	Total	**320**	**132**