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Development strategies of small scale conservation farming practices on two wheeled tractor in Bangladesh

Khokan Kumer Sarker^{1,2}, Wang Xiaoyan^{1*}, Li Hongwen¹, Xu Chunlin³, Li wenyong, He Jin¹, Esdaile R. Jeff⁴, Rabi G. Rasaily^{1,5} and Qiao Xiaodong¹

¹Department of Agricultural Engineering, China Agricultural University, P.O. Box 46, Beijing, 100083, China.

²Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh.

³Harbin Agricultural Mechanization Institute, Harbin, China.

⁴Agricultural Consultant, Tamworth NSW 2340, Australia.

⁵Nepal Agricultural Research Council, Kathmundo.

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Conservation farming (CF) is an important profitable and competitive agriculture. It is essential for smallholder farming in South Asia. Small farmers use two wheeled tractor small seeders due to the fact that they are more cost effective. This review paper aims to assess the practices of small scale CF farm machinery for two-wheeled tractor and to develop strategies for small scale CF in Bangladesh. Research and development works on conservation farming has started and shown that it is possible to increase the soil fertility and crop productivity. Two-wheeled tractor operated small no-till seeders have increased in the last decade. Two wheeled power tiller operated seeders, zero till-seeders, strip till-seeders and bed planter had been tested in the farmer's field and crop yields were found more than farmer's conventional practice. The field performances of these small seeders were found satisfactory as compared to farmer's conventional practice. Considerable amount of planting cost could be saved by introducing CF. Crop residue controls weed growth and N uptake was found significantly higher under mulching as compared to conventional tillage practices. Increased sustainability of conservation farming systems can be established through implementation of development strategies for profitable production with concern of ecological and socioeconomic conditions in Bangladesh.

Key words: Conservation farming, minimum tillage, small-scale farming, two wheeled tractor.

INTRODUCTION

The two wheel tractors is commonly known as power tillers has been the part of farming system for many small farmers in developing countries due to small farm and scattered field size combined with an affordable price (Rabi et al. 2012). The common two-wheel tractors are available in Bangladesh. Bangladesh is a big delta plain formed by the three great rivers-Ganges, Brahmaputra and Meghna. The country is bordered on three sides by India and fronts by the Bay of Bengal. There is also a small strip of border with Myanmar. The country is situated between 20° and 26° North latitude and 88° and 92° East longitudes. The population of 160 million live in

the area of 147,570 km² making it the most densely populated country in the world (MoA, 2010). The country's population is increasing while the available agricultural land is decreasing. To keep up with projected increased food demand, farming efficiency must be increased. Improved farm mechanisation can be part of this program. This, along with other agronomic and crop variety developments can assist. The government has already signified the importance of agricultural mechanization in the National Agricultural Policy (MoA, 2009). Currently, 80% of the arable land is prepared by two-wheeled tractor using traditional implements. Conservation farming (CF) seeders, bed makers and other implements are currently limited in use (Islam, 2010). This trend needs to be extended further so that efficiency of production can be achieved with reduced cost and related resource, environmental and

*Corresponding author: E-mail: xywang@cau.edu.cn. Tel.: +86-10-6273 6482. Fax: +86-10-6273 7704.

economic benefits. Therefore, this paper reviews the recent literature concerning CF related small-scale two wheeled tractor farming practices and its future prospects in Bangladesh. The specific objectives of the study are (i) to assess the practices of small scale CF farm machinery for two-wheeled tractor, (ii) to develop strategies for small scale CF in Bangladesh. This study was undertaken to achieve its objective of identifying research priorities for the small-scale conservation farming systems in Bangladesh. Documents closely related to agriculture and conservation tillage have been studied to develop this paper. Information has been gathered from research priorities and were compiled, analysed and reported.

Climate

Bangladesh has a tropical and sub-tropical monsoon climate. Though the country has six seasons – summer, rainy, sharat (early autumn), hemanta (late autumn), winter and spring, four seasons are quite distinct. The country on an average receives about 1145 mm rainfall annually. The winter starts in December and ends in February, and this are quite pleasant. The average minimum temperature ranges from 7 to 12°C and the maximum from 23 to 31°C (Roy et al., 2004). Climate change may have a range of positive and negative impacts on agriculture in Bangladesh. Climate variability is currently the dominant cause of short-term fluctuation in rain-fed agricultural production of sub-Saharan Africa and South Asia, and many other areas of the world. The most serious form is drought, when rainfall drops substantially below the long-term mean or fails at critical points in crop development. Such fluctuations can be countered by investment in irrigation or by food imports, but these options are not always open to low-income countries or remote regions (<http://www.fao.org>). CF systems can help to alleviate the effects of drought, erosion, and extremes of soil temperatures. Overall, CF systems have a higher adaptability to climate change because of the higher effective rainfall due to improved farming practice (Kassam et al., 2009).

Soil characteristics

The soils of Bangladesh were developed mainly by silt deposition from the major rivers. There are three broad categories: flood plain soils, hill soils and terrace soils. Flood plain soils comprises of 79% of the total land area. Generally, the soil erosion loss on these soils is much lower than for the hill soils, but is significant due to intensive tillage, high rainfall and windstorms. The soils of Bangladesh are low in organic matter content (<1 to 1.5%). Soils are acid-neutral in pH (BBS, 2002). Soil fertility is declining as a result of higher cropping intensity, improper cropping sequence, imbalance use of

fertilizer and faulty management practices. Crop residues can contribute organic carbon and nutrients to the soil (Malhi and Lemke, 2007). Cow dung is often used as fertiliser in Bangladesh. Other sources are crop residues. But due to scarcity of domestic fuel, insufficient quantities are returned to the soil (Miah et al., 2005).

Agriculture and cropping systems

Agriculture is the heart of Bangladesh economy, and is the dominant economic activity. Rice remains its lifeblood. The farm sector accounts for more than 60% of national employment. Sustainable self-sufficiency in rice has not yet been achieved, but there are clearly more gains to be had: average per hectare output of rice remains measurably lower than in India and about half that of China (Ziauddin and Ahmmed, 2010). The cropping intensity of Bangladesh is more than 197%. In many areas, two to three rice crops are produced per year from the same land; wheat or maize after rice is also a dominant cropping sequence. The sector contributes about 23.87% to GDP. Out of 9.09 Mha of arable land, 8.2 Mha is cropped. Major crops grown are rice, wheat, maize, jute, sugarcane, tea, pulses, oilseeds, potato, fruits, vegetables and spices (DAE, 2009). Rice, maize, and wheat are major cereals contributing to food security. These crops are grown either as a monoculture or in rotations in tropical and sub-tropical environments of South Asia. Rice-maize (R-M) systems are emerging all around South Asia but in particular, are developing quite rapidly in Bangladesh (Figure 1) (Timsina et al., 2010). There are mainly three cropping seasons in Bangladesh: summer or kharif or monsoon (or called kharif-II or aman) from June/July to September/October, rabi or winter from October/November to February/March, and spring or pre-kharif or pre-monsoon (or kharif-1) from March/April to May/June. All the three major double crop systems (rice-rice, rice-wheat, rice-maize) often include additional crops such as potato, lentil, chickpea and mustard in rabi, and jute, maize, rice, mungbean and cowpea etc during kharif-1 or spring season. The other two important systems, rice-rice and rice-wheat are practiced. The land productivity of all the major crops (except wheat and sugarcane) has increased significantly due to improved management practices (BBS, 2008; DAE, 2008). This indicates that the demand of agricultural equipment for tillage, sowing and others of these crops will certainly be increased in the near future due to decreasing agricultural labour force and cultivable land.

The current situation on farm mechanisation

Traditionally, the bullock drawn country plough has been used for tillage operations. The average farm size of Bangladesh is only 0.68 ha. Most of the farms are small.

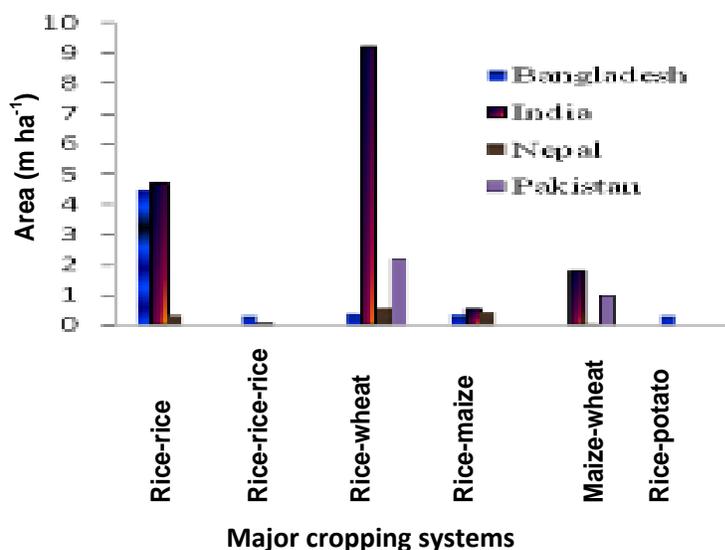


Figure 1. Area (mha) under major cropping systems in four South Asian countries.

Table 1. Current statistics on CF farm machinery in Bangladesh.

CF Machinery	Number of units
Power tiller (Two wheeled tractor)	>400,000
Tractor (Four wheeled tractor)	> 25000
High speed rotary tiller	30
Seed-cum-fertilizer distributor	60

Even this small size of farm is fragmented into many pieces making the individual farm plots very small (Ribeiro et al., 2007; Roy and Singh, 2008). In recent years with the increase of cropping intensity, power requirement for tillage has increased, since available bullock power was not sufficient. Due to shortage of draft power, land preparation was greatly hampered. Public sector effort to introduce four-wheeled tractors during 1970s did not succeed due to lack of spare parts and technicians, poor management, fragmented lands and various other reasons. The power shortage for tillage operation was aggravated tremendously. The Government then opened the market and waived taxes and duties on agricultural machinery. Price of Chinese power tillers became about US \$ 800.00 and were affordable to large and medium farmers. As a result, population of power tillers has increased rapidly in recent years and is still on the increase (Table 1) (Ahmed and Matin, 2008). Some small and landless farmers buy them to render services to other farmers. These tractors undertake a multitude of other activities such as, tillage and seeding, threshing, winnowing fans, milling and transport for people and goods.

THE POTENTIAL FOR CF AND ITS APPLICATION

CF and its benefits

CF is a set of agricultural practices that is seen to conserve the main basic factors in agriculture, namely soil, water, labour, capital and energy. Some applications of this include no-tillage and various reduced tillage seeding systems that leave much of the soil surface covered by crop residues (Baker et al., 2002; Hobbs et al., 2008; He et al., 2010). No-till (NT) is also an agricultural practice or technology whereby a crop is established without any prior tillage. NT is known by various names, including no tillage, zero-tillage and direct seeding. NT agriculture has received increasing interest worldwide from agricultural research and development workers, policy makers and mostly from farmers. Two main thrusts explain the increasing interest: first, its potential to conserve soil and water, and second, its potential to reduce input use, thereby, reducing production costs (<http://www.cultivationsudan.com>). In modern, mechanized agriculture, Faulkner (1943) first proposed no-tillage cultivation of crops in 1943, but it was

not until the advent of modern herbicides that the technique was put into practice. Plowing for land preparation and planting is eliminated. The soil is not disturbed in between cropping sequences. Many have now found that the use of the plough has actually destroyed the productiveness of soils (Derpsch, 2004). In CF systems, the soil is not disturbed before planting, except for injecting fertilizer nutrients and opening narrow strips with an opener seed-furrow during planting. The entire residue from the previous crop remains on the surface of the soil is to protect it from erosion. Many producers use no-till in conjunction with crop rotations and measures such as contouring and terracing to meet soil conservation requirements on highly erodible soils (<http://www.ipm.iastate.edu>). CF offers numerous benefits that intensive tillage systems cannot match. These advantages have been summarized as; reduced labour requirements, time savings, reduced machinery investment, fuel savings, improved long-term productivity, improved surface water quality, reduced soil erosion, greater soil moisture retention, improved water infiltration, decreased soil compaction, improved soil tilth, improved root development and crop productivity, more wildlife, reduced release of carbon gases, reduced air pollution and improved habitat. It enhances the sustainability of food and fibre production by conserving soil, water and energy resources. Soil physical analysis and drainage characteristics are improved under CF compared to traditional tillage (Tullberg, 2007; <http://www.swcc.cn/waswc>; Roth et al., 1988; Wang et al., 2000). Using a local example, an experiment was conducted at the Wheat Research Centre (WRC), Bangladesh from 2008 to 2009 using various conservation farming treatments such as, zero tillage, one pass power tiller operated seeder (PTOS), bed planting and traditional farming practice under different irrigation levels. It was observed that the sowing cost of these machines was reasonably reduced than that of the farmer's traditional practice. Seasonal water use was less in all CF methods than farmer's conventional tillage methods. Grain yield was significantly affected by tillage methods. The higher grain yield was found from zero tillage, PTOS and bed planting than farmer's conventional practice, respectively (Sarker et al., 2009).

The challenge of crop residue retention and weed control

Lack of or even complete absence of crop residues, mulch and other biomass on the soil surface is perhaps the most important constraint limiting the adoption of CF in developing countries. Residue management is important in Rice-Wheat systems and crops are increasingly machined harvested (Timsina and Connor, 2001). Increased residue cover and reducing soil compaction can be effective methods for run-off and

erosion control. No-tillage combined with residue cover and minimum compaction can delay run-off and decrease run-off rates. These practices appear to be the best management options available to improve soil and water conditions (Hengx et al., 2008; Anning, 2004; Giller et al., 2009). Rice straw mulching has a significant effect on moisture conservation and weed growth suppression in no-till wheat fields. Nitrogen uptake can be significantly higher under mulching as compared to non-mulch conditions. Recent research was carried out in Bangladesh in a 3-year study to compare the effects of straw management and nitrogen levels in a permanent bed system. The cropping pattern was rice-wheat-maize + mungbean. The results obtained 31.6 and 19.3% more yield in maize and rice, respectively when 50% straw of previous crop was retained with 100% nitrogen application. Total system yield of third year was more than that of the first year (Talukder et al., 2004). A significant interaction of mulching and N levels was found for the grain yield of wheat (Rahman et al., 2005). However, weed control for small-size landholders of Bangladesh presents a greater challenge. Most do not have access to herbicides needed for an effective weed control. Products such as Paraquat, Glyphosate, atrazine and other chemicals are either expensive or not available. One of the most effective alternative management tools may be to ensure that crop canopies develop quickly by planting crops at relatively high density. Direct seeding systems in combination with rotational cropping principles combined with residue retention and crop health may assist (Harkerand, 2006). Increased sustainability of conservation farming systems can be accomplished through decreased reliance on herbicides and improved weed management strategies. Strategies may include: strategic tillage, improved residue management, cover crops and crop rotations, balancing of soil nutrients and soil micro-organisms, managing soil fertility around the seed zone resulting in greater seedling growth and faster plant shading (Bradford and Zibilske, 2001). Experience has shown that if farmers follow good weed management in CF systems, using the same herbicide as in traditional farming to prevent the weeds from setting seeds, herbicides will not be needed after 4 to 5 years of zero-tillage (Malik et al., 2004).

SOME ALTERNATIVE CF PRACTICES WITH SMALL SCALE EQUIPMENTS

Minimum tillage

Minimum tillage is also referred to as Resource Conserving Technology (RCT). It is a new technology that is more cost effective for farmer use as compared to conventional tillage. Work on RCT started with power tiller operated seeders (PTOS), imported from China, for



Figure 2. Two Wheeled Tractor Operated seeder (PTOS) in Bangladesh; planting six rows in no-tilled field in full-width tillage mode (a), No-till tined drill planting rabi crop (b), strip-till planting crop (c), forming raised bed and planting simultaneously in no-tilled field (d).

sowing wheat in a one-pass operation immediately after harvesting the monsoon rice. Demonstrations of this technology to farmers of different areas have proved very cost effective and farmers are adopting the technology. All these resource conserving technologies have been proved appropriate in many areas of the country and extension work need to be undertaken to popularise these technologies to more farmers due to less input costs and environmental friendliness. As a result, farmers, nowadays, are changing to these new farming systems (ISTRO, 1997). In traditional tillage, land preparation takes about two weeks. Therefore, the yield of wheat in most of the areas is lower after monsoon rice. To overcome this late sowing, CIMMYT has introduced the PTOS technology in 1995. Three main components of this seeders (Figure 2a) are; i) A 48-blade, 120 cm wide high-speed shallow tillage (maximum of 10 cm deep) rotavator ii) six row fluted roller seed meter (11 and 17 flutes available) and seed bin, and iii) A 120-cm roller for planking, compaction and depth control. A Chinese-designed PTOS has consistently produced higher yields for the following reasons; 1) it was able to drill wheat, lentils, and other winter crops into very wet soils (up to 30% moisture content) immediately following the rice harvest, avoiding late planting; 2) it provided a very fine soil tilth that ensures germination; 3) it placed seeds at a uniform depth, and 4) it reduced weed problems associated with the previous rice crop. With this seeder, timely sowing of wheat is possible, and yield can be

increased. Every year, adoption of PTOS is increasing as farmers note the advantages of this system (Hossain et al., 2010). At present, PTOS can alleviate the shortage of labour and has the potential in Bangladesh for profitable crop production and yet addressing environmental concerns and sustainability.

Zero tillage systems

As an alternative to PTOS, low cost and robust no-till seeders to suit two-wheeled tractor (12 HP) has been developed at the WRC, Dinajpur, Bangladesh with the support of the Australian Centre for International Agricultural Research (ACIAR). Work on the research and development of a two-wheeled tractor operated zero-till drill started very recently. The main functional parts of the drill are toolbar frame, seed metering device, seed and fertilizer boxes, and inverted "T" furrow opener and press wheel attachment (Haque et al., 2004). This follows initial research and development work assisted by CIMMYT and Bangladesh Agricultural Research Institute (BARI) from 1995 to 2004. This drill is structurally improved, lighter and more versatile than the original prototype. A fertilizer attachment has now been fitted, residue clearance is improved, and the seed drill is easily adjustable for time layout, row spacing, and depth of seeding. Seed and fertilizer rates are easily adjusted and the machine can conveniently meter all seed sizes from

maize to mustard. Press wheels have also been fitted. Attachment hitches for both Chinese made, as well as, Thai made two wheeled tractors are available. The tined drill has been extensively tested over two seasons in Bangladesh. This seed drill was tested in the field and for wheat, maize, chickpea and lentil and compared with farmer's conventional practice and indicated that these crops can be established immediately after rice using this drill. The tined seed drill generally has excellent penetration when used for rabi planting in Bangladesh (Figure 2b) and performance was excellent (Hossain et al., 2009). Zero-tillage is possible just after rice harvest and residual moisture is available. Seasonal water use was less in zero tillage than bed planting and grain yield of wheat was found more in zero-tillage than other planting methods. The planter was capable of applying seed and fertilizer in a narrow (3 to 3.5 cm) opening slit in a single operation wheat, mungbean and maize were planted by the zero till drill in rice-wheat cropping system. Wheat yield was 14% higher than that of conventional method. Zero till wheat had less lodging when compared to the conventional planted wheat. Considerable amount of planting cost can be saved by introducing zero till drill and minimizing 8 to 12 days turns around time between two crops. The effective field capacity of the planter was 0.14 ha h⁻¹. This drill enables farmers to sow seeds when soil moisture and optimum planting time are critical (Sarker et al., 2009).

Strip tillage system

The PTOS seeder can be converted to strip tillage seeders by removing 50% or more of the blades from the rotary tillers (Figure 2c). In this system, the rotavator only tills narrow strips and the seeds planted into these strips. The researcher compared the performance of strip tillage planting with PTOS and conventional method for wheat cultivation. The yield in strip tillage was better than the conventional method and was equal to PTOS. Field capacity of the seeder was increased by 25%, fuel consumption was reduced by 20% and planting cost was reduced also by 8% as compared to PTOS. Field efficiency was improved by 15 to 20% with less fuel and time consumption (Hossain et al., 2009).

Bed planting system

BARI also developed two-wheeled tractor operated bed former-cum-seeder. It can form beds both in tilled and no-tilled soils (Figure 2d). This machine can be used to form beds and sow seeds in conventional and conservation farming systems. For planting maize, wheat, and vegetable seeds in beds, the machine can fairly be used. Scientists conducted trials on the performance of rice, wheat, maize, mungbean lentil and potato in different locations of the country. Total area covered by the bed

former in different locations was 21.74 ha. Potato yield increased about 16% by bed planting method over that of conventional method. Crop performances on beds were found better than farmers' practice (Wohab et al., 2004). The bed planting system has considerable potentials for crop production in parts of the country that regularly experience waterlogging and poor drainage.

CHALLENGES ASSOCIATED WITH CF USING TWO-WHEELED TRACTORS

The two-wheeled tractor toolbar design is largely based on modifications of four-wheeled tractors tool bars. The toolbar is bolted to the rear of the transmission of a two-wheeled tractor. Such a rigid mounting system in uneven fields may be a problem compared with more flexible three-point-hitch systems. Some small-scale soil opener designs are restricted by power, down force and symmetry requirements. Seed and fertilizer metering devices most commonly resemble adaptations of those used in larger machines. Also a low standard infrastructure, including local manufacturers and extension systems, together with low literacy, slows interest or adoption of any technology. Many farmers focus on low cost machinery investment and forego quality for price. There is limited research and development on conservation farming attachments for two-wheeled tractors compared with four-wheeled models. Affordable equipment is not readily available in the marketplace. The limited number of rows influences several functions, including opener design. Some of these influences are beneficial, whilst others are not. For example, many of the more advanced soil opener design require 8 to 10 hp per opener, which restricts their use on two-wheeled tractors (Ribeiro et al., 2007). Also, non-symmetrical openers such as, angled discs is difficult to adapt as they must be mounted in pairs to neutralise side forces. Small planter operation requires more intimate operator involvement than larger machines. Precision multi-crop seed delivery is the major constraint of using permanent raised beds in Bangladesh. Lack of machinery remains a limitation to the expansion of permanent beds using two-wheeled tractor bed formers (Meisner et al., 2005). A conventional seed drill used on ploughed land cannot be used in a CF field with heavy residues (Lal, 2007). Limited research results and equipment availability deter the best conservation practices for tillage, planting, residue management and distribution, nitrogen application, and proper operation and maintenance of farm productivity.

Strategy developments for small scale CF systems

Future challenges for small scale CF

Future challenges for small scale CF are as follows:

1. CF systems are a critical component of a sound conservation plan. Achieving soil erosion control and minimizing surface run-off when livestock are incorporated into the farming system is also a challenge. Manure applications, residue reduction by grazing and soil compaction are constraints (<http://www.ipm.iastate.edu>).
2. The cropping system brings together conflicting and complementary practices. Much of the system operates at low yield because of inadequate nutrients and inappropriate water management. The challenge to research is to understand crop responses so that the required combination of practices can be implemented and management systems can be devised for high and sustainable combined yield.
3. Many technological innovations and policy changes have taken place in agriculture in recent years, but farmers still rely on the soil, water, nature, and lots of hard work to grow the nation's food supply and to make a living. If agriculture is to remain the principal industry in the country, then we have to confront its challenges in order to produce adequate food more efficiently to help feed our population, find a way to keep our good farmland down on the farm, preserve the economic incentives, and guarantee the survival of the family farm (Gerald, 1979). Environmental changes (including climate change) and health and safety considerations may also have an impact.
4. Weed management is a challenge in conservation tillage. This is partly due to the dearth of pesticide available and the low standard of the application equipment.

Strategic research

There is a strong need to conduct further research on the response of soil, environment, and crop production for small scale conservation farming systems. Some of the specific research needs are:

1. An identified priority research plan from 2010 to 2015 needs to be developed by research organizations on conservation farming (Ziauddin and Ahmmed, 2010).
2. Development projects may need to be established to identify the area and the topic of research in the field of CF systems.
3. A research program to develop double or triple cropping system using two wheeled tractor needs to be undertaken.
4. A comprehensive analysis is needed to assess the role of residue for maintaining soil productivity, reducing risks of pollution of surface water, and sustaining agricultural productivity.
5. Initiate specific studies on the assets and limitations of a range of crop residue types.
6. Develop a robust database on the degree in which soil

properties, soil organic matter, and crop grain and biomass yields change over short (<3 year), medium (3 to 5 years), and long-term (5 to 10 years) following complete and partial residue removal across a range of soils, tillage and cropping systems, and climatic conditions (Canqui and Lal, 2009). Well designed and long-term experiments at variable indicators on soils managed under small scale conservation tillage and cropping system are required.

Encouraging innovation for two wheeled tractors

1. Continued development of suitable affordable planters for two wheeled tractor is essential for sowing seed into fields prepared by CF systems. This will allow these systems to be successfully adopted by farmers is a prerequisite for success.
2. A comparison of hoe/tine openers to disc and rotary tillage openers with two wheeled tractors in CF systems must be continued. Also press wheel set-ups for different soil and residue conditions need further work. The potential of the tined seed drill as an inter-row cultivator needs investigation (Esdaile et al., 2009).
3. Strip-tillage and bed planting systems based on two-wheeled tractors involve comparatively lightweight machines that allow seeding into wetter soils. This is important in conservation tillage systems in South Asia with both flat and low-bedded applications. Innovative methods of handling these wetter conditions must be developed.
4. The potentials for future extension to hilly areas including agro-ecologically disadvantaged regions must be explored.
5. Providing straw chopping and fertilizer seed row placement at seeding time may be important to enhance early crop availability and reduced weed growth.

Imperatives for CF systems

- i. The Bangladesh government needs to actively encourage the implementation of conservation farming practices, which contribute to the conservation of soil and water, with tillage as one component of these practices. The ministry of agriculture needs to be responsible for evaluating and assessing of extension activity, providing practical solutions for on-farm problems, strengthening research collaborations, standardizing and developing conservation farming management program.
- ii. The Bangladesh government should establish an organization body for conservation tillage systems under the ministry of Agriculture, and include experts groups to lead the programs. Other members of the group should come from the different National agricultural organizations/institutions, extension stations, and the national universities.
- iii. The national agriculture policy may include the

standardization and quality control measures for conservation farming systems. The government should speed up the process of CF mechanization for both producers and users of machines by providing the necessary credit supports.

iv. The government should also encourage the production and manufacture of agricultural machinery that suits our socio-economic context. Manufacturing workshops and industries engaged in CF mechanization activities should be provided with appropriate support.

v. Bangladesh may elect to pursue complementary CF mechanization, not from the imported and supply side, but from the demand side and developing strategic services that enable manufacturers to respond appropriately.

vi. Bangladesh should conserve the land base for production of agricultural crops by stopping the conversion of prime agricultural lands to other uses by reducing the erosion of soil and unplanned construction infrastructures.

Adoption and extension

National and international research organizations, agriculture extension departments, universities, non-government organizations, private company, farmers, farm groups, banks and financiers, high level bureaucrats, engineers, publicity people, all kinds of agribusiness and machinery manufacturers should have established linkages and must all be 'singing from the same song sheet' for CF to go ahead (Sims et al., 2009).

The following key components are essential for the successful adoption of CF programs and the strengthening of program management (He et al., 2010):

- i. Key implementation points of CF technology.
- ii. Executing program of CF projects.
- iii. Field monitoring regulation of CF effect in demonstration sites.
- iv. CF technology books and training materials (including questions and answers of CF knowledge).
- v. Videos and other photographic material on CF.
- vi. Recommended list of CF machines and implements.
- vii. Promotional materials (Brochures, Books, Booklet and Electronic videos) can be produced for instructional use and marketing. Some local manufacturers are making affordable two wheeled tractor seeders from local components in their workshops. Some locally made seeders are currently used in Northwest region of Bangladesh. These two wheeled tractor seeders can be easily set up and adjusted.
- viii. Organizations/institutions should address the key requirements of technology adoption of awareness, information sharing and encouragement of farmers, motivation for change and positive experience, quality control of CF machinery, establishment of a National

Centre for CF Machinery, a special fund for machinery research, reactivation of National Standardization Committee, and formulation of an agricultural mechanization policy.

ix. CF needs to be extended throughout the country as a labour saving measure. However, other labour intensive agricultural activities such as crop drying, irrigation and water saving technology are equally demanding areas of mechanization. Some of the areas of research need to be short-listed for immediate intervention for research.

x. Modern technological know-how is available for dissemination. However, some farmers need a lot of basic instruction for operation of the CF equipment.

xi. Extension services need to be empowered to capture the farmer's knowledge on how they fine tune different elements of CF to cope with location specificity. Farmer to farmer exchange visits between sites would be synergistic in this respect. Farmer to farmer extension systems also need to be promoted since farmers are less wary of and more willing to listen to other farmers when adopting new technology (Resler, 1979).

xii. Providing adequate financial incentives to the farmers to strengthen the financial base of support for research and the extension activities and improve production capability.

xiii. Improving public understanding of national dependence on the production of crops using CF farming systems and the need to support sound CF practices

xiv. The farmers who have adopted the conservation farming technologies are very happy with this system and majority would never consider going back to their old tillage practices. It can be concluded that mindset is the main reason why people do not change. We need to remember, "No-tillage is not a farming practice; it is a concept of the mind. If we do not believe in it, we will fail" (Bieber, 2000).

xv. Overcoming traditional mindsets about tillage by promoting farmer experimentation with this technology in a participatory way will help accelerate adoption. Encouraging donors to support this long-term applied research with sustainable funding is also an urgent requirement (Baker et al., 2008).

CONCLUSIONS

The following conclusions are hereby drawn in the course of the study:

- i. CF is suited for smallholder farming in Bangladesh and also south part of south Asia.
- ii. The farmers who are adopting the various CF technologies now have more profitable production with better environmental sustainability.
- iii. The government and non-governmental organizations should be encouraged to support conservation farming related activities.

- iv. Research and development works on CF showed that it is possible to arrest soil fertility decline and increase crop productivity. Strengthening systems to increase crop intensity through double or triple cropping system can be achieved.
- v. CF machinery like minimum tillage seeder, strip till seeder, bed planter, and zero till seeders have been developed locally and the field performance of these seeders have been satisfactory.
- vi. Increased sustainability of conservation farming systems can be accomplished with decreased reliance on herbicides and improved alternative weed management strategies.
- vii. Critical assessment is essential for CF with concern of ecological and socio-economic conditions.
- viii. The strategy development action is essential at government level to promote CF for environmental protection, improve the quality and supply of CF machinery and encourage farmer adoption of CF.

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