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WORLD CONGRESS6 on CONSERVATION AGRICULTURE

POSTER ABSTRACTS

Poster session 5: Impacts of Conservation Agriculture on Crop Production

Glyphosate Resistant Weeds - A Threat to Conservation Agriculture

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Background

Glyphosate-resistant weeds are now present throughout the Southeast. Hundreds of thousands of conservation tillage cotton acres, some currently under USDA Natural Resources Conservation Service (NRCS) conservation program contracts, are at risk of being converted to higher-intensity tillage systems (Price et al 2011). The shift to higher-intensity tillage facilitates burial of small weed seed as well as use of preplant incorporated herbicides for control of problematic weeds, especially in dry-land cotton production. NRCS defines conservation agriculture as cropping systems that maintain a minimum 30% residue on the soil surface.

Recent NRCS programs such as EQIP, the Conservation Security Program and the recently enacted 2008 Farm Bill Conservation Stewardship Program offer incentive contracts rewarding conservation. Cropping systems with higher resource conservation receive higher payments; in many states, use of high residue cover crops increase payments.

Since the mid 1980's, conservation tillage has been recognized as a beneficial alternative to conventional tillage practices. Despite definite advantages over traditional tillage practices, conservation tillage adoption remained sluggish through the 80's and mid 90's due, in large part, to unreliable weed control options in conservation tillage systems. Subsequently use of the broad-spectrum herbicide, glyphosate, in conjunction with glyphosate-resistant cultivars offered a successful alternative to conventional weed management that could be incorporated into conservation agriculture systems. Best management practices recommend rotating crops and chemicals to avoid the development of resistance in weeds, insects, and diseases. Unfortunately many producers have had little economic opportunity to grow different crops for a number of reasons. In addition, the system of glyphosate-resistant crops has become so prevalent that rotation of crops does not ensure that chemical weed control choice will change when crop are changed. It is not surprising that resistance to a single chemical would appear under these conditions. Glyphosate resistant Palmer amaranth is now present in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia in the Mid-South and Southeastern US.

Applications and Implications for Conservation Agriculture.

In conservation tillage systems, a heavy residue cover crop like rye can help reduce the emergence of glyphosate-resistant weeds by suppressing weed germination and growth. When the winter cover crop is planted early and managed for maximum growth, a dense mat is formed on the soil surface. In addition, conservation tillage systems that minimize soil disturbance (direct seeding or minimum tillage) can help reduce seed germination. Since weed emergence and growth are suppressed by the physical barrier and shading of the residue, more residue results in better weed control.

Maximizing residue along with minimizing soil disturbance can go a long way in controlling weeds. Price et al. (2012) also showed that higher amounts of rye residue decreased *Amaranth* spp. emergence and growth; while conservation systems with little or no winter cover had the highest *Amaranth* emergence and growth. A comparison of three tillage systems was conducted in Alabama, Georgia, South Carolina, and Tennessee. The experiment compared a high-residue cover, inversion tillage plus high-residue cover, and a farmer standard which consisted of winter fallow. When GR Palmer amaranth densities were relatively low, approximately 1,000 plants ha^{-1} or less, high-residue systems (with and without tillage) and winter fallow systems had similar GR Palmer amaranth densities or increased densities under high-residue conservation tillage, compared to high-residue inversion tillage and winter fallow treatments. However, where GR Palmer amaranth densities were ///relatively high, 18,000 plants ha^{-1} or greater, winter fallow systems had higher Palmer amaranth densities compared to either cover crop system.

To promote an integrated weed management approach, the University of Georgia released a publication with recommendations for controlling glyphosate–resistant pigweed (Culpepper et al. 2014) along with a YouTube video highlighting high-residue conservation tillage practices (http://www.youtube.com/watch?v=F0VTHsRO_0Q&feature=youtube.) The National Soil Dynamics Laboratory and Auburn University have also developed a publication "Controlling Glyphosate–Resistant Pigweed in Conservation Tillage Cotton Systems" that presents various control options and background information.

Discussion

Due to the threat of glyphosate-resistant weeds to conservation agriculture, much research has focused on controlling this problematic weed. The following is an abbreviated list of the solutions offered: (1) Crop rotation intensification (including pasture-based rotations, (2) Improve residual herbicide performance in dry-land conservation systems, (3) Weed management intensification (scouting, timely applications, etc.), (4) Integration of cultural solutions (high residue cover crops, delayed planting, etc.), (5) High residue cultivators Inversion tillage to bury seed bank followed by a continuous high residue conservation system, (6) Alternative herbicide chemistries, and (7) Use of fall residuals on harvested fallow fields to reduce weed seed bank additions

Depending on the severity of the glyphosate-resistant weed infestation, multiple strategies involving integration of cultural as well as chemical weed control will be needed to overcome this threat (Shaw et al. 2012). Integrating high-residue cover crop systems may help facilitate weed control in row middles; however, weeds emerging in the crop row remain a threat to crop performance, especially in dry land cotton. Much research is needed to solve this threat to conservation tillage production.

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Can Adoption of CA Rice-Wheat Systems Concurrently Increase Productivity and Stop the Groundwater Table Decline in North-West India?

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Background:

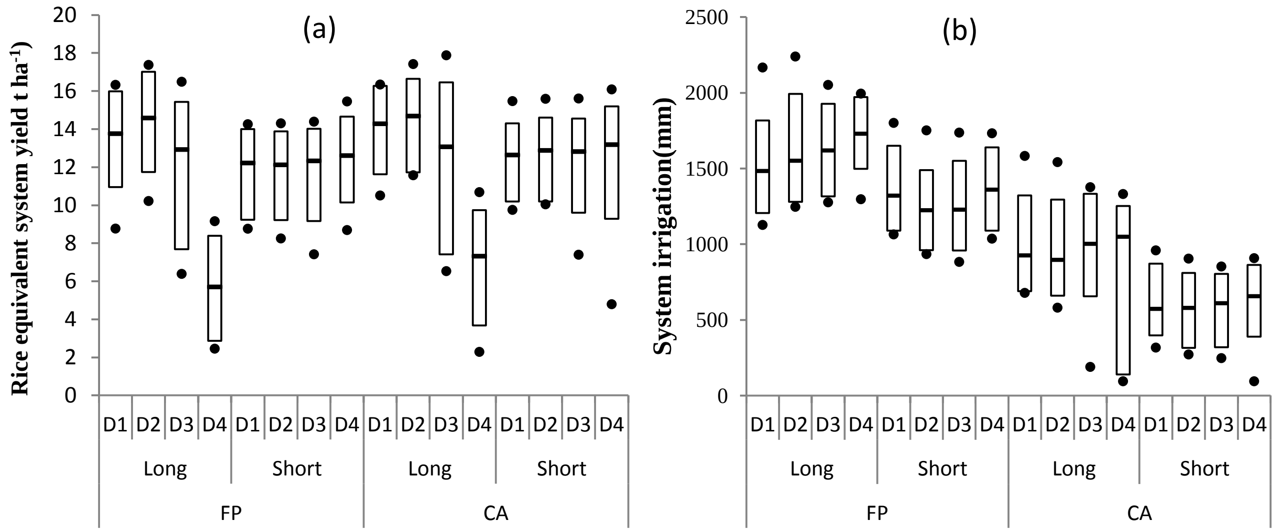
The irrigated rice-wheat system of north west India is not sustainable, as currently practised, due to over-exploitation of groundwater, soil degradation, labour scarcity, high fuel and labour costs, and air pollution from greenhouse gases and particulates from stubble burning (Ladha et al., 2007). Current farmer practice (FP) typically involves puddling and transplanting of long duration rice varieties in June, burning of rice residues, tillage for wheat, and removal or burning of wheat residues. Labour and water scarcity are driving farmers to change from puddling and manual transplanting of rice to mechanised dry seeding. The introduction of dry seeding to the rice-wheat system brings with it the potential of converting to conservation agriculture (CA), with reduced or zero tillage for all crops, and surface residue retention. This would further reduce fuel and labour costs for crop establishment, and atmospheric pollution. Avoidance of puddling and adoption of reduced tillage and residue retention would also be beneficial for soil structure and nutrient cycling. However, whether conversion to CA rice-wheat systems would help solve the problem of groundwater depletion is less well-understood. In this region, evapotranspiration (ET) must be reduced to reduce groundwater depletion (Humphreys et al., 2010).

Experimental approach:

We compared the performance RW systems using farmer practice (FP) and and conservation agriculture (CA) for a range of rice sowing dates (15 May, 5 June, 25 June, 15 July) and rice variety duration (long, medium, short). Farmer practice included puddle transplanted rice, 14 d of flooding after transplanting prior to implementation of safe alternate wetting and drying (AWD) water management, conventional tillage for wheat, and removal of all crop residues. In the CA systems, rice was dry seeded and grown with safe AWD, both rice and wheat were sown using zero till, and all the rice residues and 30% of the wheat residues were retained. The systems were compared using the APSIM model following parameterization and validation. Comparisons were made in terms of yield, components of the water balance, and water productivity for component crops and for the total system on an annual basis. Total system yield was calculated as rice equivalent yield (REY) based on the relative prices of rice and wheat.

Results and discussion:

Conversion of FP (average annual rice-equivalent yield 13.6 and 14.4 t/ha for 15 May and 5 June sowings, respectively, of the long duration variety) to a CA system resulted in only a very small system yield gain (means of 13.9 and 14.5 t/ha, respectively) (Fig. 1). The yield increase was due to higher yield of wheat because of more timely sowing and a longer vegetative phase. With CA there was a 40% decrease in irrigation input, but no effect on system ET (mean 1250 mm) with 15 May sowing (Fig.1). With 5 June sowing, there was a mean 55 mm decrease in ET to 1240 mm when changing from FP to CA (Fig.1). Thus, changing from current FP to CA, with no changes other than in tillage and rice residue management, will have little effect on the rate of groundwater table decline. However, the simulations showed that there is a range of management options which can significantly reduce ET (by 100-300 mm) compared with FP. Most of these involved changing to a short duration rice variety, with mean RW system rice equivalent yield of 11.9-12.3 t/ha, regardless of tillage and residue management and sowing date. Thus, there were tradeoffs between system yield, water depletion (ET), and irrigation requirement. Highest rice-equivalent system yield occurred with long duration rice sown on 5 June (mean FP 14.4 t/ha, CA 14.5 t/ha). Lowest system ET (mean 955 mm) occurred with short duration rice sown on 5 June in the CA system, however, mean system yield was reduced by 1.7 t/ha but with lowest irrigation input (560 mm). Intensification to three crops per year in a CA rice-wheat-mung system (with short duration rice varieties), had a yield potential slightly higher than that of the highest yielding rice-wheat systems, while providing a substantial decrease in ET. This triple cropping system also had considerable flexibility in rice sowing date, with similar yields for sowings from 5 June to 15 July. The results show that the only effective way to reduce groundwater depletion in RW systems is to change to short duration rice varieties, and therefore increasing yield potential of short duration rice should be of the highest priority.



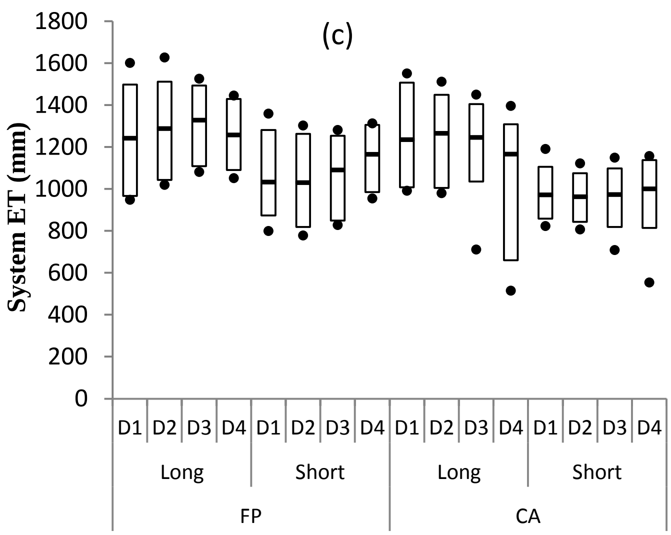


Fig 1. The effect of rice sowing date (D1-D4) and rice variety duration (long, short) on (a) rice equivalent system yield,(b) irrigation, (c) System ET in rice-wheat systems using farmers' practice (FP) or conservation agriculture (CA). Vertical shaded bars are 5-95 percentiles, black dots show the range over 40 years (1970-2010). Sowing dates are 15 May (D1), 5 June (D2), 20 June (D3), 15 July (D4).

Application and implications for conservation agriculture:

Conversion from conventional practice to CA in the rice-wheat system has considerable benefits, including reduced irrigation input, without compromising yield. However, there was only a small to negligible reduction in ET. Therefore, conversion to CA alone will not solve the problem of groundwater table decline in the rice-wheat regions of north west India.

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Conservation Agriculture Principles Applied For Brazilian Peanut Crop System

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Background

In Brazil the cultivated area with peanut is approximately 120.000 hectares and approximately 80% are concentrated in in Sao Paulo State, mainly as crop rotation to renew sugarcane crop. Recently, there has been increasing the adoption of green harvested sugarcane system, which represents almost 75% of 9,2 million hectares. After harvesting a great amount of straw (average 15 Mg of dry matter per hectare) is deposited over soil surface, thus the adoption of conservation agriculture principles (legume breaks, minimum tillage, trash retention and when it is possible to use controlled traffic) are desirable in order to reduce the costs, to diminish the soil erosion and to maintain the good stalk yields. Peanut farmers are resistant to adopt the no-till under sugarcane straw, although there are a lot of scientific results (that show many benefits in terms of yield, weed control, pest control, soil water availability and profitability). On the other hand, there are questions to answer in a commercial scale, such as digging and soil compaction.

Results

Although in Brazil no-tillage system is used for different crops in more than 32 million hectares, conservation agriculture for peanut are not widely used because there are many doubts about soil compaction, efficiency of digging and availability of herbicides. But in this condition, the relationship between sugarcane mills and peanut growers is in trouble because historically they have used the moldboard plow to prepare a smooth, uniform, and residue-free seedbed for planting. Bolonhezi et al. (2007) reported no statistical difference in peanut pod and kernel yield, number of pods and pegs, between the conservation and conventional tillage following green harvested sugarcane.

Applications and Implications for Conservation Agriculture

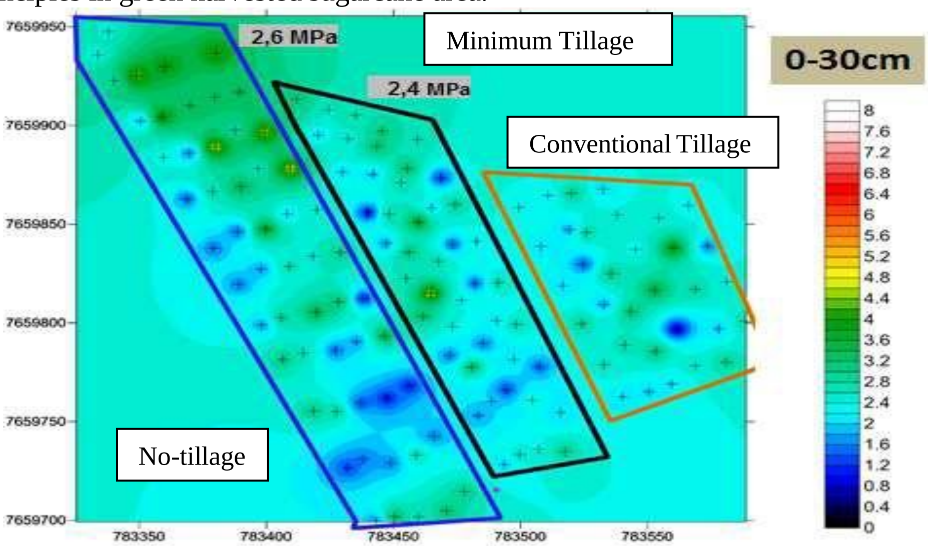
The partnership between peanut growers and sugarcane mills is traditional and it is a good example of food and energy crop system. But this relationship is in trouble if they continue to prepare soil before planting because the cost is increased approximately 30% due to the great amount of sugarcane straw. However, growers must be informed about the possibility to use CA knowledge. Furthermore, it is important to develop policies in terms of credit facilities and governmental support for smallholder farmers.

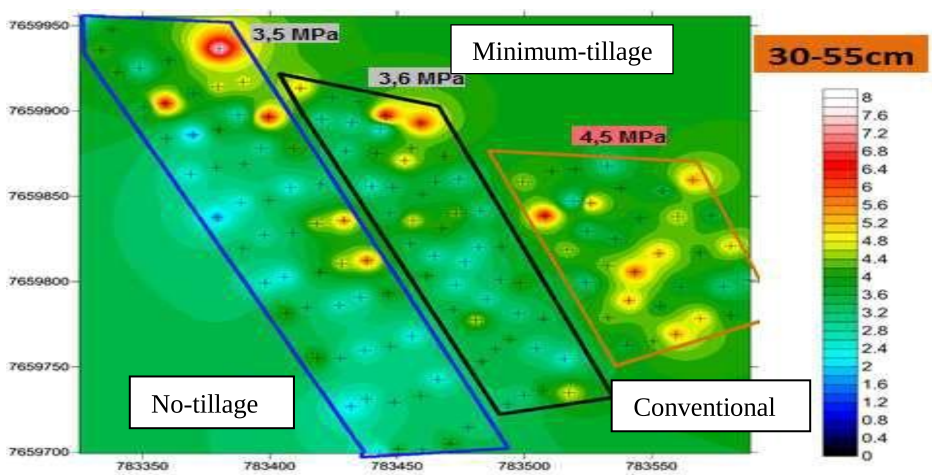
Experimental Approach

In this context, a trial was carried out in a commercial field located at Jaboticabal city, Sao Paulo State. The site was classified as a Red–Yellow Latosol (Brazilian Soil Taxonomy) and the area of sugarcane ratoon had approximately 4,5 hectares, in which three treatments were installed; conventional tillage (moldboard plowing followed by two applications of disk harrowing), minimum tillage (ratton mechanical breaker with three rows after spraying the area with 3.6 kg a.i. ha^{-1} of glyphosate), and no-tillage (crop residues on the soil surface after spraying of glyphosate). Peanut variety IAC-886 was sown on 1st November 2010 using a vacuum planter calibrated to establish 166.000 plants ha^{-1} in paired rows 90 cm apart with a large coulter followed by a double disc opener. The soil cone index was evaluated before installing the tillage and after harvesting of peanut using a digital penetrometer model PNT-2000® (DLG Company). Samples of pods were harvested in a grid of seven rows by seven columns, with distal points of its neighbour at intervals of 20 meters, in order to quantify the spatial variability of yield for each tillage system. After digging and mechanical harvesting, the same procedure was done to evaluate the pod loss in 2 m^2 of soil surface.

Results and Discussion

It were verified that the pod yield and pod loss in no-tillage was in average 500 and 125 kg ha^{-1} higher than conventional and minimum tillage, respectively. At first layer (from surface to 30 cm) the soil penetration resistance increased much more (2,7 MPa) in the no-tillage, but at the second layer (from 30 cm to 50 cm) this result was inverted and the highest value (4,7 MPa) was observed in the conventional and minimum tillage. In conclusion, it is possible to grow a commercial peanut field with conservation agriculture principles in green harvested sugarcane area.





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Long-Term Field Trial of No-Tillage and Crop Rotation for Grain Production System in Southeast Of Brazil

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Background

In Brazil the area with some kind of conservation agriculture system is estimated in 31,8 million hectares, which at least 3 million hectares is situated in the Southeast region, where is Sao Paulo State. Differently from the South region (most traditional, wet fall/winter and oldest users) and from West region (savanna, dry fall/winter and biggest farms), the Southeast is characterized by a transition weather, medium farms and great concentration of perennial (sugarcane, rubber tree, coffee, pastures, citrus) and vegetal crops, consequently the increase of conservation agriculture, specially no-tillage was not so huge in past decades. In general, the common sequence is soybean in the summer and corn as a second crop (called as “safrinha”) without cover crops because the rainfall is not enough during the winter. Regarding this context, research was installed in 2001, in order to study the effect of different crops rotation on the agronomic characteristics of corn, as well as to identify changes on the soil chemical properties.

Results

Conservation agriculture area in Brazil expanded impressively, going from 1 million hectares in1992 to 25 million hectares in 2007. This expansion was possible due to the availability of no-till planters in the national market that were appropriate to the range of soil types in Brazil (Bolliger et al., 2006). But in Sao Paulo State the adoption of CA is not so high in comparison with the other States. One reason maybe is due to the great area with perennial crops like citrus, eucalyptus and sugarcane. According to Franchini et al. (2012) concluded with data from long-term trials (23 years) that the stabilization phase of no-tillage in southern Brazil lasts 6 years and the soybean yield was around 23% higher than conventional tillage.

Applications and Implications for Conservation Agriculture

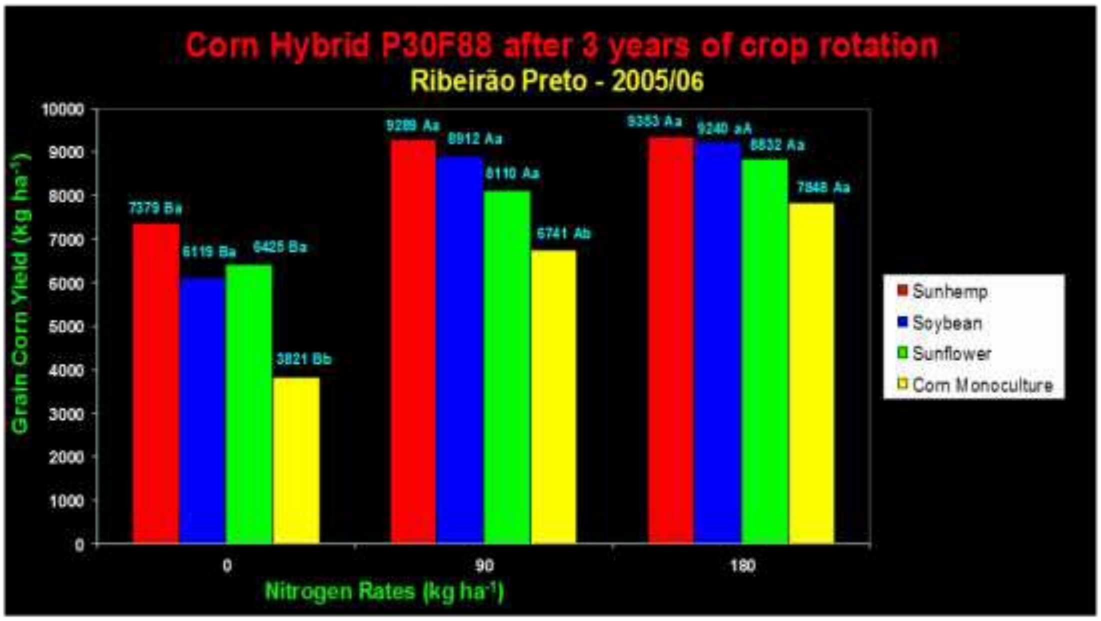
In general, the adoption of green manure in grain system is focused after main summer crop. Frequently, it is not possible to get good results of several species during dry season, consequently the possibility to increase the amount of dry biomass over the soil surface is reduced. On the other hand, when farmer grows some species during the summer the result in terms of straw is better. In addition, no-tillage reduces the time required between rainfall and the planting, then the sowing is done in good soil moisture. It’s important to emphasize that the *Crotalaria* spp. normally has the biomass yield reduced when is grown during the fall conditions. Furthermore, the association of leguminous crop and no-tillage increase the potential of biological nitrogen fixation in approximately 31 kg ha^{-1} $year^{-1}$ in comparison with conventional tillage (Zotarelli et al., 2012).

Experimental Approach

The trial was installed at Experimental Station of Agronomic Institute of Campinas (nowadays denominated APTA), situated in Ribeirao Preto city, Sao Paulo State, Brazil. The soil on site is classified as in a eutrophic clayed Rhodic Hapludox (Oxisol) and the no-tillage was initiated in 1995. The long-term trial was installed in 2001 with randomized complete blocks, four replications and four main treatments (corn in monoculture, soybean for three years, sunflower for three years and *Crotalaria juncea* in the summer + corn in the fall). After three years the corn was planted in all area, thus a second treatment was applied (0, 90 and 180 kg ha^{-1} of nitrogen by side-dressing application). In 2010 the sunflower were replaced by sweet sorghum. Each plot has at least 1.5 hectares and all the operations were mechanized. In 2005 the corn hybrid was P30F88 (conventional) and in 2010 was DKB 390 rr Bt (transgenic).

Results and Discussion

It was observed in 2005 that the corn yield after Sunhemp (*Crotalaria juncea*) + corn in the fall was 3540, 2520 and 1500 kg ha^{-1} higher, respectively with zero, 90 and 180 kg ha^{-1} of nitrogen by side-dressing, than corn in monoculture. The same trend of results were verified for DKB-390 rr Bt cultivated in 2009/10. It is important to emphasize that no significant difference was observed on corn yield, when was grown after green manure Sunhemp or soybean cash crop. On the other hand, the use of round-ready soybean® since 2007 selected weed plant (*Digitaria insularis*) resistant to glyphosate. It could be concluded that the strategy to use sunhemp in 25% of area, as green manure during the summer, improve the corn yield even with high nitrogen rates applied in side-dressing.



*Capital letters compare bars between nitrogen rates (Tukey test, 5%)

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Using Conservation Agriculture to Sustainably Intensify Maize Production and Increase Yields in the Maphusteng Valley, Lesotho

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Background
Agriculture has traditionally been the backbone of Lesotho's economy, providing the principal means of livelihoods for about 90 percent of the country's rural population and about 14 percent of Lesotho's GDP. The productivity of agriculture has been in serious decline for a number of years (from 60 percent of GDP in 1966, to 31 percent in 1970 and 21 percent in 1980). The declines in productivity can be attributed to declining soil fertility, soil erosion and land degradation, poor management and cultural practices, labor shortages (resulting from the HIV/AIDS pandemic) and a heavy reliance on tractors for plowing limit the ability of many resource-poor farmers to purchase inputs such as commercial fertilizers or improved seed. In recent years agricultural production has been impacted by recent droughts that reduced the estimated maize (*Zea mays*) harvest for 2007 to 0.43 tonnes / ha. The Lesotho Department of Agricultural Research of the Ministry of Agriculture consider soil degradation and irrigation to be the important research areas in the country. Major types of soil degradation in Lesotho include soil erosion and chemical degradation (depletion of organic matter, loss of nutrients and acidification). New approaches that integrate the management of mineral fertilizers and organic materials and alternative soil management strategies are key to tackling soil fertility and erosion issues in Lesotho.

In 2007, in collaboration with scientists from Tennessee a program of conservation agriculture (CA) research was initiated with the National University of Lesotho (NUL) and Growing Nations, a local NGO based in Maphutseng, near Mohale’s Hoek, Lesotho.

Results
Between 2009 and 2013, on-going field research at Maphusteng has demonstrated that yields of up to 8 tonnes / ha or more are achievable in conservation agriculture systems through sustainable intensification. Increases in yields have been achieved through reducing soil erosion losses with conservation agriculture, planting the crop early, increases in plant populations (from 15,000 to 45,000 plants / ha), effective weed control systems using cover crops and the judicious use of fertilizer. Optimum yields were achieved using 150 kg nitrogen per hectare. There were little or no significant responses to phosphorus or potassium fertilizer applications on the better soils at the research site, but it is recommended that 50 kg P_2O_5 per hectare and 30 kg K_2O per hectare be used to replace the nutrient removed with the grain.

Applications and Implications for Conservation Agriculture
After several seasons of work in Lesotho we have demonstrated that the implementation of conservation agriculture system for maize production is a more sustainable way of producing a harvestable maize crop. We have conducted experiments using mechanized (tractor and livestock) based no-till systems, as well as using a pothole or basin method with hand-hoes. By planting early, increasing plant populations, effectively managing weeds, and using NPK fertilizers we have been able to increase maize yields 20 to 30 fold (depending on the season and rainfall) compared to the national average in Lesotho.

In the absence of a local herbicide market, we have found that weed pressures can be effectively managed using cover crops.

Experimental Approach

The experimental research site at Maphutseng, Lesotho, southern Africa, is located at S 30°12’49.8” and E 27°29’41.3” at an elevation of 1455 meters. The soil series name for this research site is Phechela series. The soil is classified as a fine, montmorillonitic, mesic, Typic Pelludert.

The overall objective of this research was to find the optimum plant population density, nitrogen (N), phosphorus (P) and potassium (K) fertilizer application rates, and to obtain the greatest maize yield in relation to these parameters. The study was also performed to investigate the effects of planting date, tillage type, and weed control treatment applications on maize yields in order to find the optimum CA system for maize production in sub-Saharan Africa.

In our earlier studies no-till plots were planted using the “Likoti” or basin method; a common planting method where a small basin is dug that is approximately the width of the hoe and twice that size in length during the dry season. The conventional tillage plots were tilled using a mold board plow or an ox drawn planter. Variability in the plant populations achieved using the basin method, made it difficult to achieve our target plant populations for our fertility studies. Since 2011, all no-till plots were planted using a no-till planter.

Fertilizer was broadcasted immediately following planting and the treatments were laid out in randomized block design with four reps each. Nitorgen was applied as lime ammonium nitrate (LAN), phosphorus as single super phosphate and potassium as potassium chloride. The plots measured 4.5m by 10m and were planted as five 0.9m rows, seeded at rate to provide a plant density of 45,000 plants per hectare.

A weed control study conducted in 2009 to 2010 found that herbicides (glyphosate, flumetsulam and S-metolachlor) gave effective weed control weeds, and were much more cost effective than hand weeding. Due to the unavailability of herbicides in the local markets this system was abandoned in favor of cover crops. Oats (*Avena sativa*) and grazing vetch (*Vicia dasycarpa*) have been found to be not only effective at reducing weed pressures, but are a good permanent soil cover over the dry season months, reduce erosion and potentially be a valuable source of fodder for livestock. Both of these cover crops will re-seed and return the following season thus avoiding the need to re-seed.

Results and Discussion

Based on several seasons of on-farm research at Maphutseng, Lesotho we have found that:

1. There were no differences in yields between the ploughed and no-till treatments.
2. In 2013, maize yields were an average of 8.2 tonnes per ha at 150 kg N per hectare compared with 4.6 tonnes per ha with no nitrogen fertilizer on the black (Vertisol) soils and 5.4 tonnes per ha compared to 1.0 tonne per ha on the more eroded, red (Inceptisol) soils.
3. Maximum yields for maize were achieved at fertilizer rates of 150 kg N (as lime ammonium nitrate) and 60 kg P_2O_5 (as single super phosphate) per hectare.
4. Cover crops did not negatively impact yield on unfertilized maize and providing excellent weed control.

Effects of Planting Dates and Residue Mulch on *Phalaris minor* and Other Broadleaf Weeds in Zero-Till Wheat in a Rice-Wheat Rotation in North-West India

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Rice-wheat cropping system is the most important agricultural production system comprises 10.6 m ha in India. Unfortunately in North-west (NW) India, productivity of this cropping system is stagnant and total factor productivity is declining because of multiple factors, including (1) fatigued natural resource base, (2) rising scarcity of resources (labor and water), (3) rising cost of cultivation, and (4) increased weed infestation and evolution of herbicide resistance in *Phalaris minor* (little seed canary grass), a major weed of wheat (Kumar *et al*. 2013; Malik and Singh 1995).

P. minor is the most common and predominant grass weed of wheat under rice-wheat cropping system of Indo-Gangetic Plains. In this system, the menace of *P. minor* has threatened the productivity of wheat crop. Yield losses especially from *P. minor* alone are estimated from 25 to 50 per cent and, under very severe infestations, the losses may go up to 80 per cent (Malik *et al*., 1995). In northwest India, weed control in wheat is solely dependent on herbicides. This sole reliance on herbicides resulted in development of resistance in *P. minor* against multiple herbicides, resulting in significant yield losses. In addition, zero-tillage (ZT) in wheat in the northwest India has been widely adopted in the rice-wheat systems and has shown positive effects on wheat productivity, profitability, and resource use efficiencies (Gupta and Seth 2007). Despite multiple benefits of ZT, weed control remains a major challenge to adoption, resulting in more dependence on herbicides for weed control. Therefore, there is need to develop alternative non-chemical weed control approaches as part of overall integrated weed management strategy in wheat (Kumar *et al*. 2013). This study aimed to (1) explore effects of wheat planting dates and rice residue mulch on weeds with emphasis on *P. minor* and crop productivity.

Experimental Approach

A field experiments were conducted at Cereal Systems Initiatives for South Asia (CSISA, CIMMYT) Experimental Research Platform, Central Soil Salinity Research Institute (CSSRI), Karnal, India during 2011-13 to evaluate the effect of date of sowing and residue load on emergence of *P. minor* and other broadleaf weeds. One experiment was carried out in a split-plot design with three planting dates (October 25, November 10 and November 25) as main plots and five residue mulch levels (0, 4, 6, 8, and 10 t/ha) as sub-plots. Second experiment was laid out in randomized complete block design (RCBD) with five residue mulch treatments (0, 4, 6, 8 and 10 t/ha) in which seeds of common wheat weed species viz. *P. minor*, *Chenopodium album* and *Melilotus indica* were sown. Weed count and biomass were taken in both experiments.

Results and Discussion

In the first experiment, results showed that both planting dates and residue mulch significantly reduced *P. minor* emergence (Figure 1). At 45 days after sowing (DAS), *P. minor* emergence was 68 and 80% lower in early-planted wheat (October 25) compared to normal (November 10) and delayed- planted (November 25) wheat. Similarly, *P. minor* emergence reduced with increase in residue mulch amount ranging from 45% at 6 t/ha residue mulch to 75% at $\geq$ 8 t/ha residue mulch compared to no mulch plots (Fig 1). Wheat emergence was not affected by residue mulch. When early seeding and rice mulch were combined, *P. minor* emergence was 83 to 98% lower compared with normal or delayed seeding without residue. Suppressive effects of rice residue mulch (6 to 7t/ha) on *P. minor* biomass have also been reported by Singh and Walia (2008).

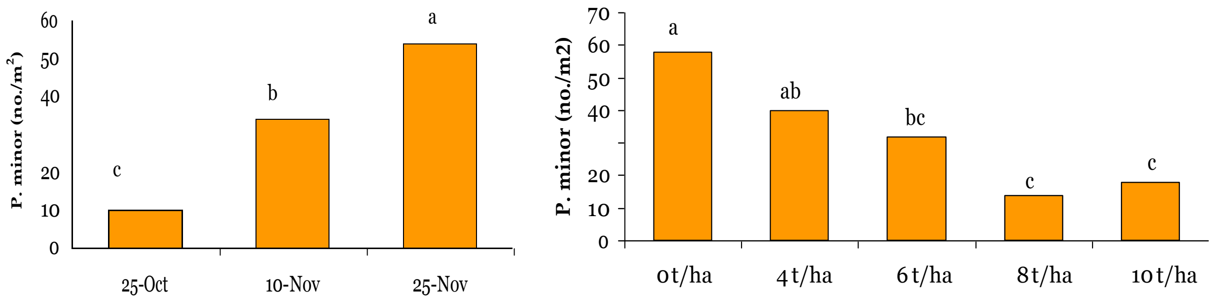

Fig. 1 Effect of wheat planting dates and rice residue load on *P. minor* emergence at 45 DAS in 2011-12. Vertical bars with same letters are not significantly different at 5% level of significance.

In the second experiment, it was observed that residue mulch reduced the emergence of *P. minor*, *C. album*, and *R. dentatus* in the range of 45-99% depending on species and residue mulch load (Figure 2). All the studied weed species except *P. minor* were almost unable to emerge with a residue load of 8 t/ha or more.

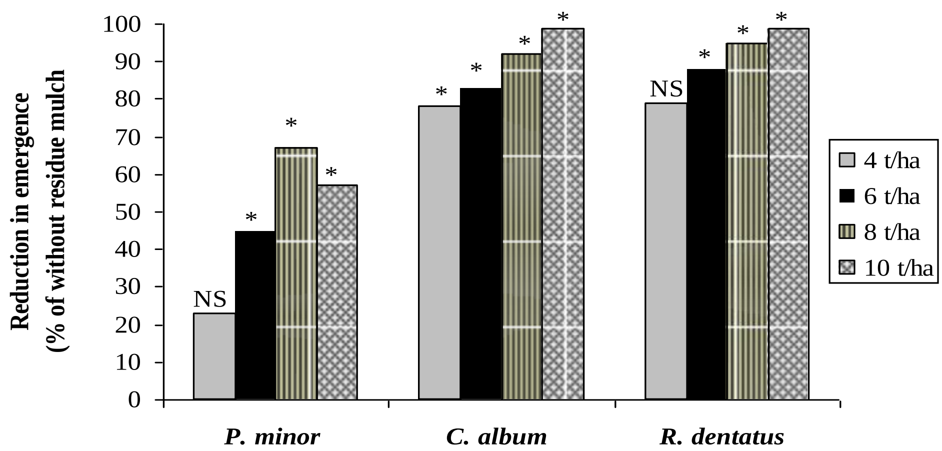

Figure 2: Reduction in emergence of three key weed species of wheat at different residue mulch levels compared with no residue mulch 45 DAS in 2011-12. Within a species, vertical bars with asterisk (*) are significantly different from no residue mulch (0t/ha) at 5% level of significance using Fischer's Protected LSD test.

Conclusion

Alternate non-chemical weed management practices are needed to delay herbicide resistance development and to reduce herbicide use for weed control in ZT wheat system. The results of these two studies suggest that weed problem in ZT wheat can be drastically reduced by planting wheat early (end of October) with retention of full previous rice crop residue on soil surface as mulch. Farmers in the region generally burn rice residues for ease of land preparation. This approach of keeping residue on soil surface as mulch not only helps in solving the problem of weeds but also reduce environmental pollution associated with residue burning

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Cassava Tuber Yield and Quality as Influenced by Different Combinations of Contrasting Nitrogen, Phosphorous, and Potassium Fertilizer Rates

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Background

Cassava (*Manihot esculenta* Crantz) is an important subsistence crop for many rural poor families in Africa. Cassava production is traditionally done by small scale, resource-poor farmers for both its edible leaves and tuber(s) using nutrient depleted soils either in association with other crops or as a sole crop and often without any fertilizer addition. Cassava tuber is consumed raw (fresh or dry) or processed into flour. During processing and/or upon tissue disruption, cassava tuber liberates cyanide (HCN) which is of physiological importance to the plant by providing protection against animal and insect predation, and to humans. Processing of cassava tuber(s) involves simple methods to lower cassava HCN such as blanching and fermentation. However, both of these methods result in high starch losses and may, therefore, lead to an underestimation of not only the actual cassava starch content (CSC) but the actual cassava HCN concentration present in the tubers as well. Studies have shown that continuous consumption of HCN rich or poorly processed cassava products with low intake of protein results in HCN poisoning. Konzo is an example of a common paralytic dietary disorder that impacts young women and children in eastern Africa that is caused by cassava HCN poisoning [2]. This study investigated the influence of different combinations of contrasting nitrogen (N), phosphorous (P), and potassium (K) fertilizer rates on both cassava tuber yield and quality as measured by starch content and cyanide concentration in the coastal semiarid Dondo District, Sofala, Mozambique.

Experimental Approach

A study consisting of twenty different combinations (treatments) of contrasting nitrogen (N), phosphorous (P), and potassium (K) fertilizer rates laid out in a completely randomized design (CRD) with four replicates was conducted at Milha-14, Dondo District, Mozambique aiming at investigating the influence of N, P, and K on both cassava tuber yield and quality over the 2013/2014 agricultural year. The plots were established using no-till where the planting material was just inserted into the soil without hilling in contrast to local practice. Cassava quality was assessed by both starch content and HCN concentration present in unprocessed tubers. CSC was estimated using a quick commercial cassava starch estimation procedure based on specific gravity (SG) [1]. SG was determined by measuring the weight lost by peeled tuber(s) submerged in water [4]. Commercial CSC estimation procedures were assessed using the Megazyme total starch procedure [5] to verify whether these quick procedures could be used as an alternative means to determine CSC in remote areas that lack lab facilities. HCN concentration was determined using alkaline picrate method [3].

Results and Discussion

Significant differences in tuber yield were observed with fertilizer addition. The fertilizer combination of 60 kg N/ha-60 kg P/ha-0 kg K/ha outperformed all other fertilizer combinations with an average of 27.68 tons per ha compared to 14.67 tons per ha in the unfertilized control. The CSC (%) obtained using the quick commercial CSC estimation procedures did not differ statistically. Significant differences were observed between CSC for fertilizer combinations and CSC estimates from 3kg and 5kg samples, and between CSC determined from Megazyme Total Starch procedure and CSC estimates from 3kg and 5kg samples. Adding 60 kg of N per ha (60-0-0) not only yielded less tuber(s) than all other fertilizer combinations but also less CSC (%). This, therefore, confirms that plant available carbohydrates are, indeed, seized by higher biomass over tuber production stimulated by addition of N fertilizer [3]. No statistical differences were detected between tuber HCN concentrations due to fertilizer application, thus, conflicting with the idea that addition of N and K leads to high (and bittiness of the tuber) and low cassava HCN concentration, respectively [6].

Applications and Implications

From our analysis/results, it has been found that: a) K is not a limiting nutrient to cassava production at Milha-14 site; b) quick commercial CSC estimation procedures can be used interchangeably; c) CSC is or can be influenced by addition of fertilizer; d) sample size can lead to an over or underestimation of CSC based on SG; e) 5kg sample size and quick commercial CSC estimation procedures can underestimate the actual CSC; and f) the concentration of HCN present in the tubers is not influenced by fertilizer addition. It is, therefore, hypothesized that the tuber HCN concentration is more related to the physiology of the crop itself rather than the environment or conditions under which the crop is grown.

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Short Term Effects after Introduction of Conservation Agriculture Practices on Yield and Quality of Wheat and Canola in the Swartland Sub-Region of the Western Cape Province of South Africa

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Introduction

Tillage practice and crop rotation together with stubble retention are regarded as important management strategies that will determine the success of conservation agriculture (CA). The positive effects of CA on crop performance are however not instantaneous but may take several years to develop. The aim of this study was to quantify the effect of tillage practice and crop rotation on wheat and canola productivity during the wheat and canola phases after completion of the first cropping cycle of four years.

Applications and implications for conservation agriculture

The major long-term aim of this project is to quantify the effects of tillage practice and crop sequence on soil physical and chemical properties, and soil biological activity towards a gaining better understanding of soil parameters that will promote sustainability in crop production systems on the shale derived soils of the Western Cape. This presentation however will concentrate on the short-term effects to demonstrate the effects of tillage practice and crop rotation on crop production and quality. The outcome and importance of this presentation will show that adopting CA will not instantaneously result in increased yields of better quality.

Experimental approach

Three crop rotations, continuous wheat (WWWW), wheat/medic/wheat/medic (WMcWMc) and wheat/canola/wheat/lupin (WCWL) were allocated to main plots and replicated four times at the Langgewens (Moorreesburg) Research Farm (33^0 16'42.33" S; $18^0$42'11.62" E; 191m). Each main plot was subdivided into four sub-plots allocated to four tillage treatments, namely: zero-till – soil left undisturbed, no-till – soil left undisturbed until planting and then planted with a tined, no-till planter, minimum till – soil scarified March/April and then planted with a no-till planter and conventional tillage – soil scarified late March/early April, then ploughed and planted with a no-till planter. Yield and quality data recorded during 2011 will be discussed in this presentation.

Results and discussion

No-till resulted in the highest wheat grain yields in all cropping sequences, although not always significantly (P=0.05), in all systems tested (Table 1).

TABLE 1 Wheat grain yield (kg ha^{-1}) as influenced by tillage practice and crop rotation during the 2011 production season at Langgewens.

Tillage treatment	Cropping system				Mean
	WWWW	McWMcW	LWCW	CWLW	
Zero-till	1178.3 c	1670.3 c	1290.0 b	2475.3 a	**1653.4 c**
No-till	2662.8 a	3535.8 a	3076.0 a	3561.8 a	**3209.1 a**
Minimum-till	1905.8 b	2868.8 b	2779.3 a	3059.8 a	**2653.4 b**
Conventional-till	2557.3 a	2877.0 b	2807.8 a	2660.0 a	**2725.5 b**
Mean	**2076.0 b**	**2737.9 a**	**2488.3 ab**	**2939.2 a**	

The highest microbial activity was recorded in the no-till system. Residue cover on the no-till plots was higher than the 30% set as minimum to qualify as CA. Soil organic carbon and active carbon content tended to be higher for the no- and minimum-till treatments compared to the other treatments tested. Except for wheat after canola (LWCW), treatment combinations did not influence the hectoliter mass of wheat grain produced. Differences (P=0.05) in protein content were recorded with a tendency of lower protein content in the WWWW and zero-till treatments. Falling numbers were not influenced by the treatment combinations tested. The highest canola seed yield (1923.5kg ha^{-1}) was recorded for the no-till treatment, although not significantly higher than the zero- (1629.5 kg ha^{-1}) and conventional-till (1878.8 kg ha^{-1}) treatments.

TABLE 2 Canola seed production (kg ha^{-1}) and quality as influenced by tillage practice at Langgewens (2011).

Tillage treatment	Seed yield (kg ha^{-1})	Oil (%)
Zero-till	1629.5 ab	39.99 a
No-till	1923.5 a	39.17 a
Minimum-till	1416.8 b	38.55 a
Conventional-till	1878.8 a	39.48 a

Canola oil content was not influenced by the treatment combinations tested.

Conclusions
Results showed that, although differences in selected soil quality parameters were recorded, the effect of introducing CA will not yield instant positive results. In the relatively low C soils and hot dry summers of the Swartland this study showed limited positive effects in the 5th season after introducing the treatments.

Keywords: canola, grain quality, nitrogen, oil content, wheat

Environmental Footprints of Agri-Food Commodities: An Alberta Experience

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Background

The retail sector and supply chain participants are considering footprints of food. Primary production plays a key role in the agri-food market and producers are facing an increasing demand for transparent and accountable environmental sustainability. The early versions of carbon footprints are evolving into more comprehensive environmental footprints. Environmental footprinting information contributes to sustainable agri-food management decisions and is helping producers realize both economic and environmental benefits.

Alberta Agriculture and Rural Development (AARD) is committed to assisting Alberta agricultural producers to remain competitive, adaptive, and responsive to the changing global marketplace. This project was undertaken to better understand and quantify the environmental impacts of four major Alberta agri-food commodities: canola, chicken, egg, and potato using a life cycle assessment (LCA) approach.

Applications and Implications for Conservation Agriculture

Environmental footprinting provides agricultural producers with credible information and assesses the environmental impacts of their production in terms of carbon, water, resources, and land use. This project informs and encourages producers as to the potential economic benefits and competitive market access associated with sustainable agriculture practices. The results of this project provide Alberta's primary producers with detailed information on the impacts associated with each life cycle step for multiple environmental indicators. Impact "hotspots" were identified and corresponding beneficial management practices (BMPs) were recommended for each commodity. Commodity specific BMPs derived from comprehensive environmental footprinting data will enable primary producers to efficiently implement management strategies conducive to conservation agriculture.

As the global agri-food industry continues to evolve and strive for continuous improvement, it is crucial that Alberta's primary producers have access to information that enables them to remain competitive both locally and internationally. This research serves the dual purpose of positioning sustainable production practices while supporting Alberta's producers in maintaining economically efficient operations.

Experimental Approach

In collaboration with the commodity associations, the project completed environmental assessments of the 2012 practices within the industry using LCA, a framework defined by the International Organization for Standardization (ISO) 14040-14044 standards (ISO 2006a; ISO 2006b). Similar studies have been conducted by AARD analyzing the production of beef and pork. However, this project provides a more comprehensive analysis of environmental impacts by including five impact categories as opposed to only carbon impacts.

Life cycle assessment data was collected primarily from farmers through online and paper surveys. Secondly, marketing boards and commissions provided internal data and thirdly, data from literature and databases were used to complete the needed information. The environmental indicators analyzed were carbon, water, ecosystem quality, resources, and human health. A cradle to farm gate boundary was used in the evaluation of the environmental footprint of the four commodities.

Table 1. Environmental footprint results and BMP recommendations by commodity

Commodity	*Life cycle stage with largest footprint (descending order)*	*General BMP recommendations*
Canola	1. Crop inputs**,** mainly due to the associated fertilizer production and application. 2. Farm utilities and infrastructure and field operations, generating impacts primarily from energy consumption.	Adoption of 4R Nutrient Stewardship manage nutrient sources can enhance nutrient use and reduce the carbon footprint. • Soil carbon sequestration from conservation tillage can reduce GHG emissions.
Chicken	1. Farm operations resulting from on farm energy use and methane (CH_4) emissions from manure management. 2. Feed production due to fertilizer production and use, field-related activities, and land use.	• Phasing out coal barn heating for natural gas or biomass heated barns could lower the carbon footprint. • The industry's efficient feed conversion ratio can minimize feed contribution to overall footprint.
Egg	1. Feed production due to fertilizer production, subsequent nitrous oxide (N_2O) emissions after field application, and field-related activities. 2. Farm operations resulting from energy consumed at the farm and methane (CH_4) emissions from manure management.	• Carbon footprint can be reduced by implementing on farm energy efficiency measures such as well-designed ventilation systems. • Soil carbon sequestration from conservation tillage reduces the carbon footprint of feed production.
Potato	1. Crop inputs**,** mainly the result of fertilizer production and application. 2. Farm utilities and infrastructure, irrigation and field operations, generating impacts mainly from energy consumption.	• Adoption of 4R Nutrient Stewardship to manage nutrient sources can enhance nutrient use and reduce the carbon footprint. • Ongoing improvement of irrigation infrastructure and delivery equipment, such as a variable rate irrigation system, could lower the water and carbon footprint.

The use of LCA enables members throughout the agri-food supply chain to increase the transparency and reporting of the environmental performance of commodities. This project establishes a foundation for sustainability quantification of agri-food production in Alberta. It provides a solid framework for measurement, innovation and improvement, and communication and collaboration of environmental footprinting in agriculture.

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Crop Response to Nitrogen Fertilizer under Strip Tillage and Two Residue Retention Levels in a Rice-Wheat-Mungbean Sequence

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Introduction

Minimum tillage is an emerging approach in Bangladesh agriculture for optimizing crop yields, with economic and environmental benefits. This practice can slow the breakdown of plant residues and reduce the release of mineralized inorganic forms of plant nutrients in soil (Hobbs et al., 2008; Kassam et al., 2009). Under minimum tillage, nitrogen (N) mineralization rate tends to be lower since the soil is not as greatly disturbed and the organic residues remain on the surface. Hence, N in the system might be less available under minimum tillage, at least in the initial years after conversion from full tillage. However, no data are available to assess the requirement for N fertilizer under the minimum tillage systems in Bangladesh. Moreover, most studies on the effect of minimum tillage on N requirements were performed with rainfed and irrigated crops on aerobic soils with very little data for the minimum tillage under rice based cropping system. A novel unpuddled transplanting system has been recently developed in Bangladesh for rice (Islam et al., 2010). It involves strip tillage, irrigation of soil to soften the soil in the strips and then transplanting. It avoids the full puddling of soil as occurs in conventional transplanting. The present study was undertaken to examine whether strip tillage system with residue retention altered nitrogen requirement for crops in a rice-wheat-mungbean sequence.

Methods

The experiment was conducted at the BAU Research Farm, Mymensingh during 2012-13. Two tillage systems (strip tillage and conventional full tillage) and five N rates (60, 80, 100, 120 & 140% of recommended N rate; 70 kg N ha^{-1} for rice, 100 kg N ha^{-1} for wheat and 20 kg N ha^{-1} for mungbean) were tested. Herbicide 'Glyphosate' was applied before transplanting of rice seedlings and sowing of wheat and mungbean seed. In addition, for rice another herbicide, 'Prepilachlor' was used three days after transplanting. At maturity the crop was harvested and the rice or wheat straw was retained in split plots at 20 and 60 % of plant height. Thus for the second and third crops, the residue retention was another factor affecting the crops and N requirement.

Results Snd Discussion

The highest grain yield was always recorded from 100 or 120 % N application and the lowest yield with 60 % N addition. The grain yield generally did not vary significantly between two tillage systems except in mungbean, where strip tillage performed better. Difference between 60 and 20% residue retention was not significant; however the 60 % residue retention showed an increasing tendency towards increased yield with later crops in the sequence. When the grain yield data were fitted to the crop response equation ($y = a + bx + cx^2$), the optimum N rate ($Ny = -b/2c$) was estimated for rice as 82 kg N ha^{-1} for conventional tillage and 76 kg N ha^{-1} for strip tillage. For wheat, optimum N rate was 106 kg N ha^{-1} for conventional tillage and 119 kg N ha^{-1} for strip tillage. Similarly the optimum N rate for mungbean was calculated as 24 kg N ha^{-1} for conventional tillage and 28 kg N ha^{-1} for strip tillage. The N requirement of wheat was higher for strip tillage compared to conventional tillage which was due to immobilization of N under minimum tillage system, coupled with residue retention. Greater weed infestation under strip tillage may also contribute to higher fertilizer N requirement which points to the need for more effective use of herbicides.

Table 1. Influence of different tillage, residue retention and N rates (as a % of recommended fertilizer dose- RFD) on the grain yield (t ha^{-1}) of rice, wheat and mungbean

Factor	Rice	Wheat	Mungbean	Factor	Rice	Wheat	Mungbean
N rates				**Tillage**			
60% RFD	3.87 c	2.34 c	0.611 c	Conventional	4.68	3.22	0.642 b
80% RFD	4.60 b	3.00 b	0.80 b	Strip	4.47	3.22	1.038 a
100% RFD	4.90 a	3.56 a	0.90 a	**Residue retention**			
120% RFD	4.86 ab	3.67 a	1.01 a	60% retention	-	3.32	0.86
140% RFD	4.64 ab	3.52 a	0.89 a	20% retention	-	3.12	0.8

N effect = ** for all, Tillage and residue effects = ** for mungbean only
Values having same letters in a column do not differ significantly at 5% level by DMRT.

CONCLUSION

The N requirement of wheat was higher for strip tillage compared to conventional tillage which may be due to immobilization of N under minimum tillage system, coupled with residue retention. Greater weed infestation under strip tillage may also cause the higher N fertilizer requirement; however it is possible to minimize weed infestation by using efficient herbicides. There was no evidence of a higher N fertilizer N requirement for rice established by unpuddled transplanting in strip tilled plot. Moreover, tillage method had no effect on the N fertilizer requirements for mung bean, presumably because crop N fixation compensated for any effects of tillage on N mineralization.

Acknowledgement

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Interactive Extension Techniques Effectively Engage Audiences Regarding Agriculture and Environmental Stewardship in Manitoba

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Phosphorus **(P)** is an essential nutrient for life, both plants and animals, on land and in water: it is a component of bone, teeth, leaves and seeds. At the same time it is a potential pollutant in surface water; at very low concentrations P can trigger blooms of cyanobacteria commonly referred to as blue-green algae, a nuisance and potentially harmful organism. Agriculture has received much attention as a source of P to surface water. Inherent conditions of climate, landscape and soil on the Canadian Prairies influence the nature and magnitude of the risk of P transfer from agricultural land to surface water. So too does farmer practice.

Through a Memorandum of Understanding signed at Ag Days 2013 in Brandon, a formal partnership between the Province of Manitoba, The Canadian Fertilizer Institute (CFI) and Keystone Agricultural Producers has reinvigorated extension efforts addressing sustainable fertilizer use in crop production. The chief intent is to raise awareness about the issue of surface water quality, improve understanding of water and phosphorus movement and explain the role of agriculture. It is critical to link the concern with agronomic practice to demonstrate relevance to farmers and agronomists, and to instill a sense that actions can be undertaken to address the problem without undue economic penalty. In fact, profitability can be improved by following the principles of *4R Nutrient Stewardship* that favour efficiency in fertilizer use: the Right Source at the Right Rate, Right Time and Right Place.

Extension messages regarding nutrient management and environmental stewardship are delivered in an informative, interactive and inventive fashion through the use of props, illustrations, demonstrations and simulations. Frequently a learning station is developed to feature a particular subject. The design of the learning station fosters a flow of information from one aspect of the topic to the next, leading to a "what can be done" conclusion.

One of the most elaborate and effective learning stations, deployed in both table-top form and a larger-scale field version, is the subject of this poster presentation. This learning station consists of a combination of rainfall and snowmelt simulators used to explain water movement on agricultural landscapes of the Canadian Prairies. Mechanisms of runoff (growing season rainfall onto unfrozen soil vs. snowmelt from frozen fields) are linked to inherent conditions in this region as well as land management practices employed by farmers. Ultimately, implications for surface water quality are addressed along with the extent to which farmers can mitigate the risk of phosphorus reaching surface water. One of the means of mitigation available to farmers is the set of principles and practices that together constitute *4R Nutrient Stewardship* the 4Rs of nutrient management.

More than a thousand people received this message about agriculture and water quality in 2013. The learning station explaining water movement and P runoff in much of the Northern Great Plains region continues to be an effective and in-demand extension tool. Steps are being taken to document the level of outreach achieved in the 4R campaign, including the deployment of the learning station. Table 1 illustrates the kind of rudimentary tracking that can be done to depict the success of this extension effort. This represents the starting point to recording, semi-formally at least, the outcomes of this work, such as the audiences reached and the nature of the extension message.

Table 1. Excerpt from summary of MAFRD contribution to the 4R campaign.

Activity	Results	Content	Applicable Rs	Environmental Component (Air, Water, Soil)
Oral presentation at St. Jean Farm Days	**100 participants**	Rotational fertilization for P management	Time Place	Water
Oral presentation at soybean grower event in Morris	**200 participants**	Rotational fertilization for P management	Time Place	Water
In-field lessons delivered at the **Crop Diagnostic School** in Carman	**417 participants** **$12.9x10^6$ ac** (evaluations from 61% of attendance)	Water movement as well as sediment and P loss on the Manitoba landscape	Time Place	Water, Soil
		Nitrogen management in corn – the 4R approach	Source Time Place	Air, Water
Soil and Water Field Clinics ...in PlaP	**~25 participants (3-5 CCAs)**	Water movement as well as sediment and P loss	Time Place	Water, Soil
		Practices in the Lake Erie watershed and in MB	Time Place	Water
...in Carberry	**~25 participants (3-5 CCAs and growers)**	Practices in the Lake Erie watershed and in MB	Time Place	Water
...in Winkler	**~25 participants (3-5 CCAs and growers)**	Water movement as well as sediment and P loss	Time Place	Water, Soil
		Practices in the Lake Erie watershed and in MB	Time Place	Water
Articles in the Agri-Environment Knowledge Centre e-newsletter	Distribution to Conservation Districts, producer groups and departmental staff (>100 recipients)	Signing of the MOU and proposed activities	all four	Air, Water
		Rotational fertilization for agronomic and environmental sustainability	Time Place	Water
		Description of the water movement learning station deployment at the Crop Diag. School in Carman	Time Place	Water, Soil
Agro-Ecology Day at the UofM Res. Stn in Carman	**87 Grade 10 students** Conservation and education staff	Water movement as well as sediment and P loss	Time Place	Water, Soil
U of Manitoba field trip	**200 first-year students**	Water movement as well as sediment and P loss	Time Place	Water, Soil
Intermountain Conservation District **Water Festival**	**>100 primary students** CD staff plus farmers	Water movement as well as sediment and P loss	Time Place	Water, Soil

Affects of Tillage and Mulching on the Growth, Yield and Water Productivity of a Dry Seeded Rice-Wheat Cropping System in North-West India

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Background:
The rice-wheat systems of north-west India are of critical importance to the food security of India. However, their sustainability is threatened by groundwater depletion, labour scarcity, soil degradation and atmospheric pollution. Therefore, some farmers are moving from puddling and transplanting to dry seeding of rice (DSR) because of its greatly reduced labour and irrigation water requirements. After harvest, the rice straw is normally burnt, the soil is intensively tilled prior to sowing wheat, and the wheat residues are removed for fodder or burnt. However, further reduction in fuel, labour and irrigation water requirement, and atmospheric pollution, can be achieved by changing to zero tillage (ZT) and surface retention of the rice residues. While there is already some adoption of ZT wheat in north-west India, this is usually done after burning of the rice residues. There is evidence from maize-wheat systems that changing to zero tillage without residue retention will have adverse effects on cropping system performance over time (Govaerts et al., 2008). Furthermore, it has not been established whether the rice residues remaining on the soil surface after wheat harvest will be beneficial for establishment of DSR in terms of conservation of soil moisture and weed suppression. Therefore, an experiment was initiated in 2011 to evaluate the effects of tillage (ZT or conventional dry tillage (CT)) and rice residue retention, and their interactions, on the performance of a dry seeded rice-wheat system.

Experimental Approach:
A replicated experiment was conducted on a sandy loam soil at Ludhiana, Punjab, India. A uniform puddled, transplanted rice crop was grown prior to the imposition of the treatments, which started with wheat sown in November 2011. There were two tillage treatments for both wheat and rice (CT, ZT), and two rice residue management treatments - removed (-M), retained as a surface mulch (+M) - in a split plot design. Thus there were a total of 8 treatment combinations. Wheat was sown into bare soil or rice residues at 20 cm row spacing and 112 kg seed/ha using a "Turbo Happy Seeder" (Sidhu et al., 2007). Rice was sown at 20 cm row spacing and 30 kg/ha in 2012 and 40 kg/ha in 2013 using a seed-fertilizer drill with an inverted T furrow opener and a cup seed metering system. All treatments were irrigated according to soil water tension, with a threshold of 35 kPa at 30 cm for wheat, and 15 kPa at 15 cm for rice. Water was added to each plot until the water depth reached 5 cm. Grain yield of individual wheat and rice crops is presented at 12 and 14 %, respectively, and of the total system as rice equivalent yield based on the relative prices of rice and wheat.

Results and Discussion:
There were no significant effects of tillage or mulching treatments or their interactions on crop growth or yield of the first 2 wheat crops (7.3 and 6.3 t/ha in 2012 and 2013, respectively), and of the first rice crop (5.9 t/ha). However, in 2013, grain yield of ZTDSR (3.1 t/ha) was significantly lower than yield of CTDSR (3.8 t/ha). Rice yield was low in all treatments in 2013, partly due to heavy sheath blight and leaf folder attack which commenced mid-way through grain filling and which could not be controlled by spraying. This was reflected in much lower average grain weight (by 25%) in 2013, which accounted for about 70 and 50% of the yield decline in CTDSR and ZTDSR, respectively, in comparison with 2012. Furthermore, growth of DSR was relatively poor throughout the season in 2013. For example, 32 DAS, biomass production of CTDSR in 2013 (0.4 t/ha) was less than half that in 2012. At anthesis (99 DAS), biomass production of CTDSR was 11.0 and 8.0 t/ha, in 2012 and 2013, respectively (Fig. 1). The lower biomass production and grain yield in 2013 was associated with lower solar radiation

during grain filling (16% lower) compared with 2012. Potential yield simulations using ORYZA2000 suggest a reduction in yield of 23% in 2013 compared to 2012 due to differences in weather conditions. There was also much higher weed infestation in 2013, particularly of *Cyperus rotundus*, which probably also contributed to the lower yield in 2013. The lower biomass of ZTDSR than CTDSR in 2013 during the vegetative stage was also associated with higher weed infestation in ZTDSR.

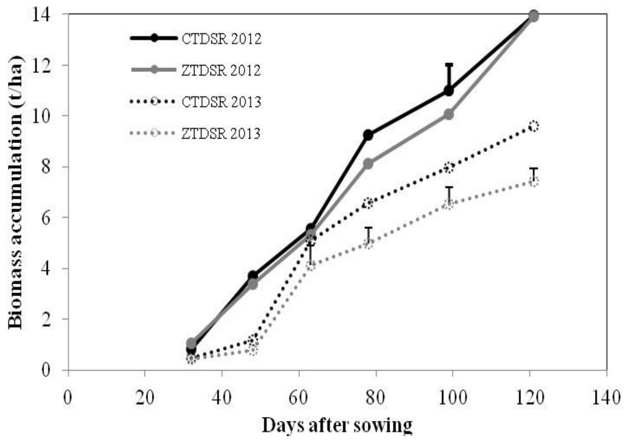

Fig 1: Biomass accumulation (t/ha) in 2012 and 2013 (vertical bars are $lsd_{P=0.05}$ for comparing CT and ZT in 2012 and 2013)

Total system rice equivalent yield was not affected by tillage or residue treatments in 2012 (mean 13.3 t/ha), but was significantly lower in systems with ZTDSR (9.4 t/ha) than CTDSR (10.0 t/ha) in 2013, due to lower rice yield. Each year, total irrigation input to the ZTDSR systems was significantly higher than to the CTDSR systems, but the differences were very small (16 and 43 mm or 1 and 2.5% of the total irrigation input in 2012 and 2013, respectively). The net result was no treatment effects on total cropping system irrigation water productivity (WPi) in 2012 (mean 0.89 kg/m^3), and significantly higher system WPi in 2013 with CTDSR (0.73 kg/m^3) than ZTDSR (0.66 kg/m^3).

Applications and Implications for Conservation Agriculture:

The different performance of both wheat and rice in the second year highlight the need for long term field evaluation, together with the use of crop models, to evaluate the effects of tillage for rice and wheat and rice residue retention. Weed pressure, especially from *Cyperus rotundus*, increased in the second year of implementation of the DSR-wheat system, regardless of tillage or rice residue management treatment. However, the problem was worse in the systems with ZTDSR.

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Seven Years of Conservation Agriculture in a Rice-Wheat Rotation of Eastern Gangetic Plains of South Asia: Yield Trends, Economic Profitability and Carbon Use Efficiency

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Introduction

Rice-wheat (RW) cropping system occupies 13.5 million hectares in the Indo-Gangetic Plains (IGP) of India, Bangladesh, Nepal and Pakistan and is fundamental to employment, income and livelihood for millions of people in the region. In India alone, RW rotation occupies about 10.5 m ha and contributes about 40% of the country's total food grain basket (Saharawat et al., 2010). In eastern IGP, typically, the rice planting time with conventional tillage based system is uncertain due to erratic rainfall behavior leading to many a times delayed harvest of rice and resultantly late planting of wheat. In eastern IGP, the shorter wheat cycle coupled with delayed planting coincides with high temperature at grain filling stage leading to large yield penalty due to terminal heat stress. Labour, water and energy scarcity and increasing cost of production are major challenges faced by the farmers under tillage based intensive rice-wheat production system of Indo-Gangetic Plain. This production system is also a significant contributor of anthropogenic greenhouse gas emission. To address these challenges conservation agriculture (CA) based tillage and crop establishment methods are being developed and promoted in the region. We evaluated agronomic productivity, economic profitability and C use efficiency of various combinations of tillage and crop establishment techniques in rice-wheat rotation from a long-term trial started in 2006.

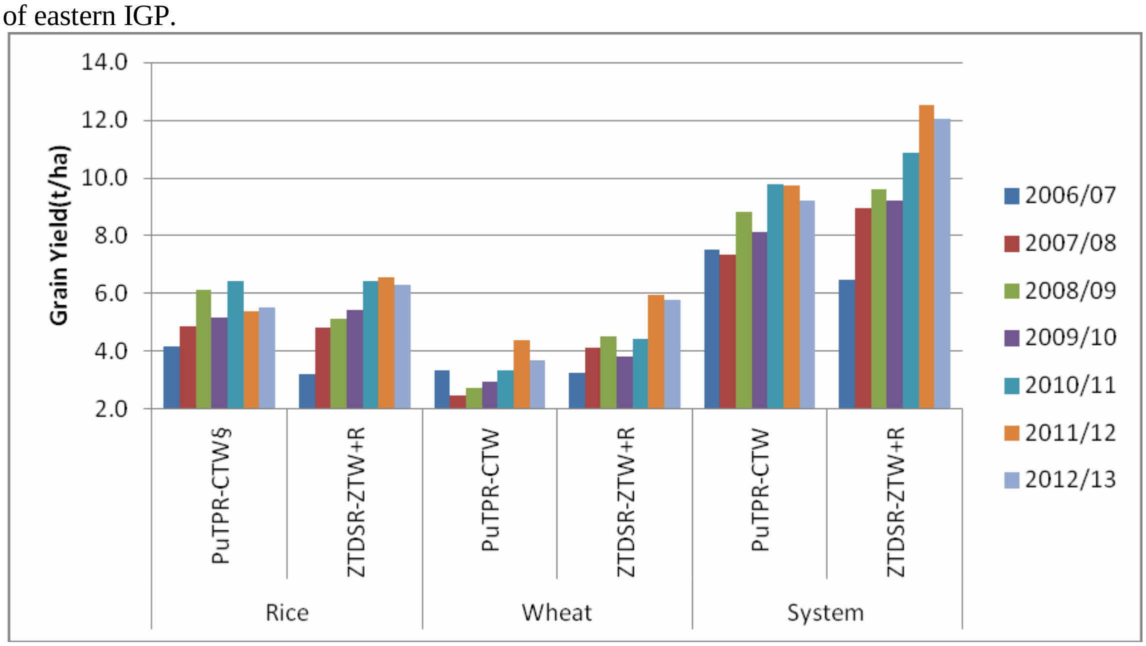
Methods

Experimental field is located at research farm of Rajendra Agricultural University, Samastipur, Bihar, India (25.58510 N, 85.40313 E). Long-term trial was established during monsoon 2006 involving various combinations of tillage, crop establishment and residue management practices in a rice-wheat rotation. The soil of the experimental site is clay loam with medium organic matter content (0.68 %). Soil properties of the experimental field at the beginning of experiment are presented in table 1. The climate of the site is characterized by hot and humid summers and cold winters with average rainfall of 1344 mm, 70 % of which is received between July to September .

Seven combinations of tillage, crop establishment and residue management in rice-wheat rotation were puddled transplanted rice followed by conventional tilled wheat (PuTPR-CTW); PuTPR followed by zero tilled wheat (PuTPR-ZTW); zero tilled direct seeded rice followed by zero till wheat both on permanent beds (PBDSR-PBW); zero-tilled direct seeded rice followed by CTW (ZTDSR-CTW); ZTDSR followed by ZTW without previous crop residue (ZTDSR-ZTW); ZTDSR followed by ZTW with previous crop residue (ZTDSR-ZTW+R) and unpuddled transplanted rice followed by ZTW (UpTPR-ZTW). All these treatments were completely randomized within a block and were replicated thrice. For PuTPR, 23 days old seedlings were transplanted after 3 passes of dry tillage followed by 2 passes of wet tillage & planking. In CTW, 3 passes of dry tillage (harrow & cultivator), broadcasting of 150 kg seed/ha followed by 1 pass of tillage and planking was practiced. For ZTDSR, 25 kg seed ha^{-1} was drilled using a multi-crop Zero till seed-cum-fertilizer planter without any tillage. Same was used for direct drilling of wheat (ZTW) using 100 kg seed ha^{-1}. On permanent beds (67cm centre of furrow to furrow) both rice and wheat were planted using a raised bed planter keeping two rows on each beds and seed rate for rice and wheat were used @ 20 and 75 kg ha^{-1}, respectively. In UPTR, the 23 days rice seedlings were transplanted after dry tillage but eliminating wet tillage (puddling). The WDSR was established using broadcasting of sprouted seeds of rice after both dry and wet tillage (puddling). All the treatments received similar fertilizer nutrients @ N-150 kg, P_2O_5 60 kg and K_2O 60 kg both for rice and wheat. The yields were recorded using the standard protocols. The profitability (net returns) was calculated as the values of the inputs and outputs over the years in Indian rupees and were expressed into US$ as the value of US$ over the years.

Results and Discussion

We recorded higher rice grain yield in CT based systems (i.e. PuTPR-CTW and PuTPR -ZTW) than in CA based systems (i.e. ZTDSR-ZTW, UpTPR -ZTW) for initial three years, comparable yield between CT based and CA based systems during fourth and fifth year and higher yield in CA based system than in CT based systems during last two years. Wheat yield were higher in CA based system right from second year onward. We observed lowest wheat yield in the system where preceding rice crop was grown with intensive tillage operations. System productivity was higher in almost all CA based systems than in CT based and mixture of CT and CA based systems from second year onward.Net returns were always higher in CA based systems than in CT based system although the differences were obvious only fourth year onward in rice and second year onward in wheat and at system level. The yield and economic advantage of CA after initial 2-3 years was as the adaptation of CA based component technologies evolved with time. Yield and economic efficiency of carbon (i.e. grain yield and net return per unit of carbon input) was also higher in CA based tillage and crop establishment techniques (i.e. ZTDSR-ZTW both with and without residue retention and PBDSR-PBW) followed by partial CA based systems (PuTPR-ZTW, ZTDSR-CTW and UpTPR-ZTW) whereas conventional tillage based production system (PuTPR-CTW) had lowest carbon efficiency. In medium term, we found CA based systems to be agronomically, economically and environmentally superior than CT based systems for rice-wheat rotation of eastern IGP.



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Assessing the Performance of Various Resource Conservation Technologies for Sustainable Management of Rice-Wheat Cropping System in Punjab, Pakistan

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Pakistan has total area of 79.61 mha with a population exceeding the figure of 180 million. 25% of the land is engaged for agriculture. The agriculture sector holds the prime importance in the economy of Pakistan contributing 21% to its GDP and employing 45% of the country's manpower. Rice-Wheat is major cropping system occupying about 1.7 million ha in Pakistan out of the total 13.5 million ha in South Asia (Hobbs and Morris, 1996). The importance of Rice-wheat (RW) system cannot be overlooked in IGP plains as it provides food and livelihood to mass of population. The use of conventional methods of crop cultivation with an increasing population seems to be one of the factors for stagnant yield. The horizontal increase in cultivation area is not possible so attention should be given on better alternative and modified cultivation practices. With growing population, there is a need to mutate the practices with maximum yield using least of the resources. The farmers should be introduced with new improved practices that could ascertain the yield improvement not only of the crop of one season but also for other crops that are being practiced in sequence. Conservation Agriculture Technologies (CATs) such as zero-tillage (ZT) and bed planting have been shown to be beneficial in terms of improving soil health, water use, crop productivity and farmers' income (Gupta and Sayre, 2007; Gupta and Seth, 2007).Keeping in view, certain conservation agriculture (CA) practices were evaluated in Pakistan in Rice-wheat (RW) system under Lower Bari Doab Canal Improvement Project (LBDCIP) implemented by the Directorate of On-Farm Water Management (DOFWM) in 53 demonstration centers (DCs) in Okara, Sahiwal, Khanewal and Kasur to observe the crop production, water conservation and resulting increase in farmers' income.

Table 1:Effect of Conservation Agriculture Technologies on wheat growth and yield

Treatments	Plants/ m^2	Tiller/m^2	Plant height (cm)	Weed density/m^2	Avg. grain weight (mg)	Grain yield (t/ha)
2008-09						
CT-BCW	93a	415b	90b	42a	38.2d	2.87c
ZT-DSW	82b	454ab	98a	31c	40.2c	3.29b
BED-DSW	73c	461a	98a	35b	43.1a	3.45a
30CR-W	81b	458ab	96a	26d	41.5b	3.21b
50CR-W	85b	461a	93ab	18e	38.1d	3.34a
2009-10						
CT-BCW	94a	395c	92b	43a	38.5d	2.90c
ZT-DSW	84b	459ab	98a	33c	40.2c	3.32b
BED-DSW	77c	463a	98a	36b	43.1a	3.58a
30CR-W	85b	461ab	96a	26d	41.5b	3.31b
50CR-W	86b	463a	93ab	18e	38.4d	3.52a
2010-11						
CT-BCW	94a	395b	92b	39a	38.2d	2.91c
ZT-DSW	89ab	489a	99a	34b	40.9c	3.42b
BED-DSW	81b	472b	102a	37ab	43.7a	3.61a
30CR-W	85b	461ab	96a	26d	41.8b	3.45b
50CR-W	86b	463a	93ab	18e	38.4d	3.53a

The values are average of 53 DCs of 4 districts. LSD values were calculated at $P \leq 0.05$

The average results of the experiments revealed that the practices significantly improved the yield of wheat crop and treatment where wheat was sown on bed (BED-DSW) resulted the highest grain yield in 2008-09, 2009-10 and 2010-11 with 3.45, 3.58 and 3.61 t ha^{-1} respectively. In terms of income, the highest earning was recorded through wheat grown in zero tillage during 2008-09 and 2009-10 while in 2010-11 wheat sown in 50% residue resulted in highest income.

Table 2.Effect of Conservation Agriculture Technologies on rice growth and yield

Treatments	Plants/ m^2	Tiller/m^2	Plant height (cm)	Weed density/m^2	Avg. grain weight (mg)	Grain yield (t/ha)
2009						
CT-TPR	51a	335a	130a	8a	24.1b	4.10a
ZT-TPR	39b	265b	127ab	3bc	24.3a	3.35b
BED-TPR	32c	235c	124b	2c	23.6c	3.25bc
30CR-TPR	41d	291d	124b	4b	23.9bc	3.24bc
50CR-TPR	39d	277e	111c	3bc	22.8d	3.15c
2010						
CT-TPR	53a	349a	130a	8a	25.3a	4.12a
ZT-TPR	41b	273b	127ab	3bc	24.3b	3.37bc
BED-TPR	34c	241c	124b	3bc	23.6c	3.27b
30CR-TPR	40d	285d	124b	4b	23.9bc	3.25bc
50CR-TPR	37d	271e	112c	3bc	23.1c	3.18c
2011						
CT-TPR	53a	353a	134a	8a	25.1a	4.12a
ZT-TPR	43b	278b	127ab	3bc	24.3ab	3.43b
BED-TPR	39c	251c	124b	2c	23.6c	3.27bc
30CR-TPR	41d	294d	124b	3bc	23.4bc	3.24c
50CR-TPR	40d	275e	113c	3bc	22.9d	3.21c

The values are average of 53 DCs. LSD values were calculated at $P \leq 0.05$

In rice, during the first year (i.e. 2009) there was poor response of rice in every tested practice however, the response improved in following years slightly. The rice sown with zero tillage (ZT-TPR) and bed planting (BED-TPR) showed much better results in 2011 with average grain yield of 3.43 and 3.27 t ha^{-1} respectively, as compared to CT-TPR (4.12 t ha^{-1}). In rice, the yield was lower in CA practices as compared to conventional method. The best results were obtained in conventionally sown rice (CT-TPR) and highest grain yield was obtained during three years study. The water conservation was recorded to be highest in zero tillage as observed in both wheat and rice during all years under study. The study suggests that the interventions in wheat are promising and have the potential to introduce such tillage practices throughout the country to enhance the yield of wheat. While in rice, there is lot of need to work extensively for better options of rice yield improvement without any negative impact on the soil structure which it currently poses for the next crop due to overuse of water causing compaction and creating difficulties for the next crop. There is a need to explore site specific interventions more extensively regarding the RW system for better package to farmers with quality of improving both water conservation and income. The introduction of such conservation agriculture practices has positive impacts on the water conservation and income of farmer of Okara, Sahiwal, Khanewal and Kasur. Such experiments must be conducted widely throughout the country to increase the yield of these crops to satisfy the food demand in the highly populated region of world.

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Keywords: RW system, crop production, water conservation, income

LIFE+ Agricarbon. Sustainable Agriculture in Carbon Arithmetics

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Background

LIFE+ Agricarbon (LIFE08 ENV/E/000129) is an European Union funded project in partnership with the Spanish Association for Conservation Agriculture & Living Soils (AEAC SV), ECAF, the Andalusian Institute of Agricultural and Fisheries Research and Training (IFAPA) and the University of Córdoba (UCO). This project aims to encourage the progressive establishment of sustainable agriculture, such as Conservation Agriculture and Precision Agriculture (CA&PA), contributing to GHG emission decreases and the adaptation of the agricultural system to the new climate conditions found in global warming. Also, making available to European and National authorities sufficient knowledge about these practices could serve to set up environment policies in the agricultural domain, with the two-fold goal of mitigating and adapting to climate change.

The project has two main strands. One has been the fieldwork, managing 90 hectares in 3 demo farms in the South of Spain, which have served to obtain data that have supported many publications. Secondly, the technology transfer activities are at the heart of the project. Through field days and courses, partners expect to train over 2,500 farmers and technicians in sustainable agriculture.

Experimental Approach

Farms in the study are located in the South of Spain. Córdoba, 37 º 55 '50.4" N 4 ° 43' 07.7" W; Carmona, Seville, 37 º 25 '31.0 N 5 º 38' 01.2" W and Las Cabezas de San Juan, Seville, 36 º 56 '37.8" N 5 º 55' 13, 6" O. All fields are in the Mediterranean area, which corresponds to a xeric moisture regime, according to the standards set by the Soil Taxonomy (USDA, 1998). The climate is characterized by a cool, wet period, which coincides with the autumn and winter and which account for 80% of rainfall, and a very warm and dry, which corresponds to the spring and summer, in which a significant water deficit. The temperature regime is thermic. There is great variability both intra as annual rainfall, relatively wet periods alternating with cycles of drought for several years. On each farm were installed 6 experimental fields of 5 ha; 3 under CA&PA, and 3 handled with conventional tillage, which makes a total of 30 ha per farm and 90 ha in the joint project. Trials in both management systems maintain the typical rotation of the Andalusian countryside, wheat-sunflower-legume, and follow the guidelines of the owners, in order to obtain real results in each season.

Results

The joint use of CA&PA, captured up to 35% more Carbon compared to conventional tillage farming. Moreover, the absence of tillage made CA&PA reduce soil's emissions between 56% -218%. Regarding energy use, CA&PA, resulted in cuts by 13.8% in wheat, 21.6% in sunflower and 24.4% in the legume when compared to tillage farming. These savings caused lower CO_2 emissions, corresponding to 199.1 kg ha^{-1} for wheat, 63.6 kg ha^{-1} for sunflower and 107.1 kg ha^{-1} for legume. In terms of yield, the seasons have been very erratic, but results show that in the rotation wheat-sunflower-legume, there are no major differences between Conservation Agriculture and tillage systems. Due to lower costs, economic results per hectare have always been better for CA&PA compared to conventional tillage: +€77 in chickpea, +€59 in wheat, +€48 in sunflower and +€25 in beans.

LIFE+ Agricarbon has also been prolific in publications. To date, these include 3 papers in peer reviewed journals, 3 more being reviewed currently; 18 communications at international conferences; 10 communications at national conferences; 16 numbers of the Agricultura de Conservación journal; 5 technical reports and one booklet. Available in the website, an internet platform has been created to help farmers and technicians choose agricultural Carbon-friendly management.

Applications and Implications for Conservation Agriculture

It is expected a greater support to Conservation Agriculture in the region thanks to the implementation of LIFE+Agricarbon. Institutions and organisations have recognized the effort made by the project partners. The United Nations Environment Programme highlighted this LIFE project as good example of Green Economy in 2011. In 2012, the Government of Andalucía awarded Agricarbon as Best Project on Climate Change in the XVII Environmental Award. The project was also granted for the Best Communication at the VII Iberian Conference of the Agro-Engineering Spanish Society, 2013.

Acknowledgements

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