Short term agronomic gains from Conservation Agriculture in NW China

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Introduction

Increased water infiltration and reduction in water and wind erosion is achieved through reduced tillage and retention of ground cover (Ma *et al.* 2006). So there is more than 4,000,000ha in 14 provinces under conservation tillage in China (Hejin *et al.* 2007). The challenge for Chinese agricultural is to broadly embrace Conservation Agriculture (CA). Wheel compaction problems can be overcome and significant system benefits achieved by the use of CA and controlled traffic farming (CTF) (Tullberg *et al*. 2007). Permanent raised bed (PRB) cropping gives positive control of surface water, while also providing the physical guidance system needed for CTF. PRB cropping is highly compatible with CA, and its effectiveness is well documented (Bachmann and Friedrich 2003). Changing soil management practices from intensive tillage to PRB alters the partitioning of the water balance, decreasing soil evaporation and increasing transpiration, infiltration and deep percolation, leading to increased yields and WUE (Wang *et al.* 2004a and 2004b). PRB plus CA is a way to combine profitable agricultural production with improved sustainability, which has been effective in a variety of agro-ecological zones (McGarry 2006). Key constraints to implementation of CA in NW China are the lack of appropriate machinery, the "good farming" mindset of conventional tillage and competition for crop residues. However the impetus for CA is the increasing desertification and severe water restrictions imposed on farmers (Xie *et al.* 2005).

Materials and Methods

Research and demonstrations were conducted over 3 seasons near Zhangye, Shandan, and Jiuquan in the Black River Basin of Gansu Province PRC. Mean rainfall is less than 150mm/year on a Loess soil, which is frozen to 30cm deep from late November to mid April. Spring wheat is the dominant crop, grown from mid April until late July, although there are considerable areas of other grains and vegetable production.

The research area layout consisted of eight 400m^2 plots, in 2 replicates of 4 treatments; CA PRB, fresh raised bed (FRB), zero till - control traffic (ZT) and conventional tillage (CT). Larger comparative demonstration sites (3000m^2) of PRB, ZT and CT were located near the other cities. A five row zero-till planter was used in PRB, FRB and ZT, while CT was solidly planted with a conventional 8 row tine planter. Fertiliser was applied at planting at an average rate of 217kg/ha N and 205kg/ha P. ZT and CT treatments were flood irrigated, whereas PRB and FRB treatments were furrow irrigated. Irrigation volume was based on replacement of the soil moisture deficit (SMD) for PRB, FRB and ZT, while CT received up to 1.5ML/ha per irrigation event (farmer practice).

Results and Discussion

At the research site poor plant establishment had a considerable impact on treatment yields, but despite 20% less emergence in PRB, its yield at 5.6t/ha was not significantly different to that of other treatments in 2006. In 2007, despite a 10% lower establishment the grain yield of wheat under PRB was 7.1t/ha, compared to CT at 6.4t/ha (Table 1). Poor planter performance, low soil temperature and inadequate seed/fertiliser separation continued to restrict establishment and final

yields in 2009, however PRB was not significantly different from CT even with 20% of arable land given to furrows.
Water use by all treatments shown in Table 2, illustrated the substantial water-savings achieved by PRB compared with the other treatments. The lower volumes of irrigation water applied to PRB per irrigation are indicative of increased available water, plant root accessibility, lower soil wetted perimeter and soil water monitoring. Irrigation volumes were quite variable across treatments, but there was a 21% or 133mm saving in irrigation water in 2006 for PRB. In 2007, 39% less irrigation was required for PRB compared with that of CT. Increased competence in the farming system, close water monitoring, as well as improved soil structure maintained water savings (33%) in 2009. Consequently PRB water productivity, in all years, was better than CT, although the differences were small in 2006 (Figure 1) largely due to start up limitations. In 2007 and 2009, PRB WUE values (~15kg/ha/mm) were significantly different to CT at an average of 9.2kg/ha/mm for the 3 seasons.
Crop emergence, yield and applied irrigation water at the demonstration sites followed similar patterns to those found at the research site (data not shown). Total water savings for PRB in 2006 and 2007 at Shandan were 26% and 51%, respectively. Water savings in ZT were 23% and 26%, respectively. In Jiuquan water savings were also around 23%. Yields for all treatments were similar at Shandan, but were slightly lower (7%) than CT in Jiuquan.
During the establishment phase of the research and demonstration sites, crop emergence was poor. This appeared to be a result of the poor performance of prototype planting machinery, operating under difficult conditions of heavy residue, high soil moisture, frozen soil conditions, combined with poor depth control, inadequate seed-fertiliser separation and inexperience with CA techniques. Despite the adverse starting conditions, poor emergence and 20% loss of cropping area to wheel tracks in PRB and ZT, final yield was equivalent to CT in the first year, but considerable improvements were recorded in the following seasons. These yield and emergence results are an improvement on those achieved in a comparison of (non-PRB) conservation tillage with conventional practice in the same area by Ma *et al.* (2006), and consistent with the results of Hejin *et al.* (2006). Under PRB conditions less water was used to replace the SMD and coupled with continuous ground cover this reduced total water losses to evaporation and deep drainage.
Conversion from conventional (intensive tillage, basin-flood irrigation) to CA increased wheat yield by 10% in 2007 (2% over 3 seasons) while it provided 6.4ML/ha in total water savings over 3 years. CA can be implemented in the Chinese rural community without loss of yield and with considerable gains in natural resource conservation, provided that the operational capabilities of the prototype machinery continue to improve.

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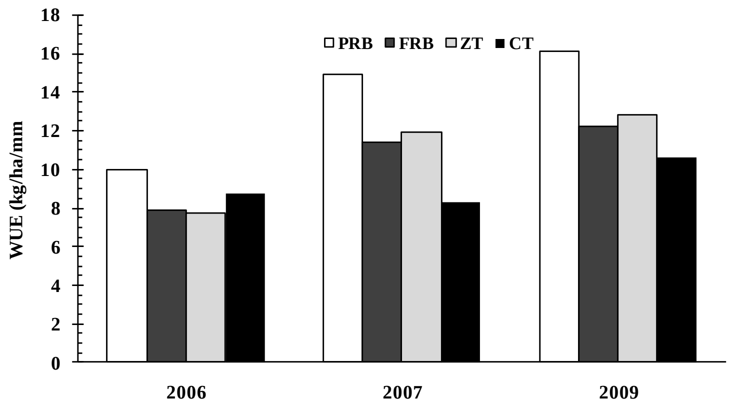

Figure 1. Water Use Efficiency (kg/ha/mm) for wheat in each treatment PRB, FRB, ZT and CT at the Zhangye Research Station for 2006, 2007 and 2009 seasons.

Table 1. Crop yield from the 2006-2009 at the Zhangye for the four treatments PRB, FRB, ZT and CT.

Treatment	Yield(kg/ha)		
	2006	2007	2009
PRB	5575^{ab}	7132^{a}	6680^{a}
FRB	5306^{b}	6651^{b}	5542^{b}
ZT	5420^{b}	6356^{b}	6200^{ab}
CT	6088^{a}	6458^{b}	6520^{a}

Note: Yields followed by the same letter are not significantly different within years at P<0.05

Table 2. Irrigation volumes (mm) by date and effective rainfall for 2006 (a), 2007 (b) and 2009 (b) at Zhangye Research Station.

a Irrigation Date	21/11/05	22/04/06	1/05/06	16/05/06	23/05/06	6/06/06	22/06/06	2/07/06	Eff Rain	Total
PRB	174*	79		53		78	113		64	560
FRB	131*	73	88		78	105	132		64	670
ZT	153*	96		77		95	144	69	64	693
CT	145*	89		94		107	140	53	64	698

b Irrigation Date	18/10/06	9/11/06	4/05/07	16/05/07	30/05/07	2/06/07	5/06/07	23/06/07	Eff Rain	Total
PRB		180*		55		73		95	76	479
FRB	110**	131*	36		111			117	76	581
ZT		185*		106			81	85	76	533
CT	95**	177*	150		143			137	76	777

c Irrigation Date	31/10/08	3/05/09	5/06/09	26/06/09	Eff Rain	Total
PRB	90*	99	105	82	37	414
FRB	122*	98	109	86	37	452
ZT	109*	131	104	102	37	484
CT	180*	148	114	134	37	614

Note: Irrigation values followed by ** indicate tillage irrigations and values followed by * indicate winter irrigations. Both irrigations are post-harvest irrigations in preparation for winter and the following production season.