Tropentag 2010
ETH Zurich, September 14 - 16, 2010
Conference on International Research on Food Security, Natural Resource Management and Rural Development

Performance of maize under conservation agriculture on salt-affected irrigated croplands of Uzbekistan, Central Asia

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1. Introduction

Maize is the third major staple crop after wheat and rice in Uzbekistan. It is cultivated annually on 35,000 ha and yields on average of 6.6 t ha^{-1} (FAOSTAT, 2010). Maize is grown after intensive tillage for land preparation, with poorly managed flood irrigation, and excessive use of chemical inputs. Previous findings confirmed that nitrogen (N) use efficiency in such conventional production systems is with 8.8% for cotton for instance, rather low (Kienzler, 2009). The high losses of N are not only a source of environmental pollution, but also increase production costs. In addition, excess use of irrigation water raises groundwater tables and in turn increases secondary soil salinization, deteriorates soil quality, and threatens the sustainability of the overall crop production system. During the vegetation period in the Khorezm region of Uzbekistan, 67% of the fields have groundwater levels above the threshold that induces secondary salinization (Ibrakhimov et al., 2007).

Conservation agriculture (CA) practices (i.e. reduced tillage, residue retention and proper crop rotation) offer the potential to increase wheat and maize productivity (Sayre and Hobbes, 2004), reduce production cost, increase soil organic carbon (Lal et al., 2007), and decrease soil salinity (Pang et al., 2009) compared to conventional production systems. Such advantages have been shown in a wide range of agro-ecological areas such as with wheat in Mediterranean conditions (Vita et al., 2007) or with maize in the sub-humid tropical highlands (Fisher et al., 2002). Yet, much skepticism prevails about the practicability and efficiency of CA based technologies under irrigated conditions. This is true also in the irrigated areas of Central Asia where the effects of CA, N, and residue management on the performance of major cereal crops are still poorly understood (Gupta et al., 2009). This study analyzed the performance of maize under CA-based technologies in the salt affected irrigated croplands of semi-arid Uzbekistan.

2. Material and Methods

In October 2007, a three factor, split-plot experiment with four replications was implemented in northwestern Uzbekistan for examining a cotton-wheat-maize rotation. The soil was an irrigated alluvial meadow, sandy loam to loamy soil, low in organic matter (0.3-0.6 %), saline (salinity ranged from 2-16 dS m^{-1}) and with a shallow groundwater table (0.5-2 m). The average precipitation of less than 100 mm $year^{-1}$ at the experimental site is by far lower than the potential evapotranspiration of about 1200-1600 mm. Two tillage methods (permanent bed, PB; and conventional tillage, CT) were analyzed as the main factor. Two residue levels (residue retained, RR; and residue harvested, RH), and three N levels were imposed as the sub-plot factors. In RR treatments, residues from the previous crop were retained whereas in RH treatments residues of the previous crop were completely removed. The officially recommended N rate for maize is 150 kg N ha^{-1}. In our experiment, three N fertilizer levels, i.e., no application (N-0), less than recommended (N-100 kg ha^{-1}), and more than recommended (N-200 kg ha^{-1}) were used. The sub-plot size was 550 m^2 (11m x 50m).

Short duration maize (*Zea mays* L., cv. Maldoshki) was planted at 40 kg seed ha^{-1} with 45 x 45 cm plant spacing on June 2009 and harvested as grain on September 2009. In CT, maize was planted after three cultivations followed by rough leveling, whereas in PB, no soil tillage occurred aside from drilling of seed and N fertilizer. N was top dressed as a band application 32 and 42 days after sowing (DAS). Phosphorus (P) and potash (K) were applied at 160 and 70 kg ha^{-1} as basal applications during seeding. Maize gain yield, total biomass and yield components were determined from three areas, each 4 m^2 in size, from each experimental plot. Grain yield was adjusted to 12% moisture. Six cobs from each plot were randomly selected to record the number of grains per cob, and thousand kernel weight (TKW).

Soil salinity was measured in PB+RR, PB+RH and CT. Soil samples were collected one day before irrigation. In PB, samples were collected from both the top of the bed and the center of the furrow, to get averaged salinity in bed, up to 30 cm soil depth. The collected soil samples were analyzed for electrical conductivity, EC_p, which is the EC of 1:1 water soil paste. The measured EC_p was converted to international standard EC value of the saturated soil extract, EC_e, derived from the equation $EC_e = (2.02*EC_p) + 0.14$.

Treatment effects were compared through the analysis of variance, using GenStat Discovery Edition 3. Main and interaction effects were compared using Fisher's protected LSD (least significant difference; P=0.05).

3. Results

3.1 Grain yield and biomass

Tillage, N and crop residue levels had a significant ($p<0.05$) impact on grain yield and yield components of maize. Across the N and residue levels, grain yield in PB was 41% higher ($p<0.05$) than under CT (5520 vs. 3910 kg ha^{-1}). Irrespective of soil tillage and residue level, grain yield increased ($p<0.05$) by 127% under N-100 compared to N-0 (5295 vs. 2331 kg ha^{-1}). Doubling the N level from 100 to 200 kg N ha^{-1}, significantly increased grain yield by 23% (6519 vs. 5295 kg ha^{-1}). Averaged over tillage and N levels, grain yield in RR treatments were 10% higher ($p<0.05$) than under RH (4940 vs. 4490 kg ha^{-1}).

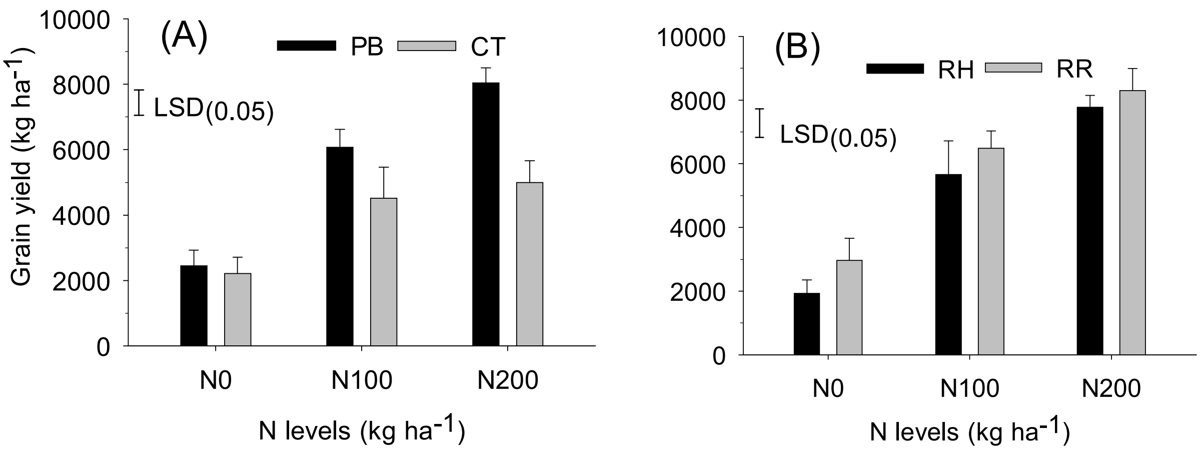

Figure 1. Interaction between (A) tillage (PB-permanent bed, CT- conventional tillage) and N rates (0, 100, 200 kg N ha^{-1}) (B) N and residue levels (RH-residue harvested, RR-residue retained) in PB, on grain yield of maize. LSD is estimated for the interaction between (A) tillage and N and (B) N and residue levels. Bars represent the standard error of the means.

A significant interaction between tillage and N, and tillage and residue levels was observed for the maize grain yield. The different tillage practices did not affect grain yield under N-0. In contrast, in N-100 treatments, grain yield in PB was 34% higher ($P<0.05$) than in CT. With N-200, grain yield in PB was 61% higher ($p<0.05$) than in CT. In PB, grain yield was 148% higher ($p<0.05$) with N-100 than under N-0. Similarly, when increasing the N level from N-100 to N-200, grain yield in PB increased ($p<0.05$) by 32%. Although grain yield in CT was 104% higher ($p<0.05$) with N-100 than N-0, no significant yield difference was observed with an additional application of 100 kg of N (N-200) (Fig. 1A). In PB with N-0 application, RR had 54% higher ($p<0.05$) grain yield than RH, while under N applied treatments, RR in PB had a positive although non-significant effect (Fig. 1B). In contrast, RR did not affect grain yield in CT. Treatment effects in aboveground biomass (AGB) production followed the same trend as for grain yield (Table 1).

3.2 Yield components

The interaction between tillage and N levels was significant ($p<0.05$) for the number of ears m^{-2} (ear density), grains ear^{-1}, and TKW. In PB, ear density was 21% higher ($p<0.05$) with N-100 than under N-0. Doubling N level from N-100 to N-200 increased ear density ($p>0.05$) by 15%. In contrast, a N application did not effect ear density in CT. In N applied treatment, grains per ear increased significantly ($p<0.05$) in both tillage modes, as evidenced by the 76% in PB and 33% in CT with N-100 compared to N-0. Doubling N level from N-100 to N-200 increased the number of grains per ear by 8% in PB and 7% in CT. The difference in TKW in both tillage systems was insignificant regardless the amount of N applied. But TKW was 12% higher ($p<0.05$) in CT than in PB with N-0. TKW increased ($p<0.05$) by 21% in PB and 8% in CT with N-100 compared to N-0. When Doubling N levels from N-100 to N-200, TKW increased ($p<0.05$) by 9% in PB and 8% in CT. Tasseling in CT was delayed by 5 days than under PB.

Table 1. Interaction between N and tillage on aboveground biomass (AGB), ears m^{-2}, grains ear^{-1}, thousand kernel weight (TKW), and tasseling days of maize

Tillage	N levels kg ha^{-1}	AGB kg ha^{-1}	Ears m^{-2}	Grains ear^{-1}	TKW g	Tasseling days
Permanent bed	0	4469 d	5.1 b	254 e	170 d	42 a
(PB)	100	10373 b	6.2 a	418 b	206 b	35 c
	200	13810 a	7.1 a	453 a	225 a	35.4 c
Conventional	0	3853 d	4.7 b	274 e	191 c	42 a
tillage (CT)	100	7412 c	4.9 b	366 d	206 b	39 b
	200	8267 c	5.2 b	390 c	222 a	39 b
LSD (0.05)		1513	0.98	22.7	10.5	1.12

Figures within each column followed by the same letter are not significantly different, p=0.05

3.3 Soil salinity

The decrease in soil salinity (ECe) of 26% under PB (averaged of bed and furrow) compared to CT in the 30cm topsoil was significant. Soil salinity in PB was further decreased by 22% due to retention of crop residues (2.2 under RR vs. 2.8 dS m^{-1} under RH).

4. Discussion

The increase in grain yield under PB was caused by an increase in grains ear^{-1} and ears m^{-2}, which have previously indeed been identified as the prime components determining yield (Fischer et al., 2002). The greater response of N applied in PB compared to CT on grain yield of maize can be associated with various factors such as an earlier seedling emergence and stand establishment, faster growth, earlier days to tasseling, and longer grain filling periods.

The retention of crop residues, which significantly increased grain yield in PB with N-0 treatments compared to RH, could have been caused by a higher rate of mineralizable N in the top soil layer as postulated previously (Campbell et al., 1993). The surface mulch of wheat residues was a crucial source of mineral N since its release is known to be fast in environments with extreme (high and low) temperature and low soil fertility as prevailing in Central Asia. On the other hand, the absence of a residue retention effect on grain yields with N applications may have been due to an immobilization of the applied N due to the surface mulch as has been postulated previously (Cochran, 1991).

The observed significant decrease in soil salinity under PB is likely to be associated with the type of irrigation applied in PB. Furrow irrigation may have leached salts from the furrows during irrigation (Bakker et al., 2010). But also the retention of crop residue decreased soil salinity in PB compared to RH, which is often monitored and attributed to decreased soil water evaporation. A reduction in soil water and salt movement by surface residues had been also reported by Huang et al. (2001).

5. Conclusions and Outlook

Despite that the results stem from a single season experiment, the outstanding performance of maize in PB with 200 kg N ha^{-1} suggests that this could be the best-bet maize cultivation practices for the salt-affected irrigated regions of Uzbekistan. Residue retention in combination with PB showed the potential to reduce the increase in soil salinity in the salt affected irrigated drylands of Uzbekistan. Further experiments are under way to corroborate these findings.

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