PI—Xiying Zhang

1. EDUCATION

Bachelor, Agro-meteorological Department, China (Beijing) Agricultural University, 1985

Ph.D (Agronomy), Graduate School of Agriculture and Life Science, Tokyo University, 2006

2. PROFESSIONAL EXPERIENCE

July 1985 to Oct. 1990, Research Intern, Shijiazhuang Institute of Agricultural Modernization, The Chinese Academy of Sciences.

Oct. 1990 to Oct. 1994 Assistant Professor, Shijiazhuang Institute of Agricultural Modernization, The Chinese Academy of Sciences.

Oct. 1994 to Oct. 1999, Associate Professor, Shijiazhuang Institute of Agricultural Modernization, The Chinese Academy of Sciences.

Oct. 1999 to Oct. 2002, Professor, Shijiazhuang Institute of Agricultural Modernization, The Chinese Academy of Sciences.

Oct. 2002 to Present, Professor and Principal Investigator, The Center for the Agricultural Resources Research, Institute of Genetic and Developmental Biology, The Chinese Academy of Sciences (Former Shijiazhuang Institute of Agricultural Modernization, The Chinese Academy of Sciences)

May 1989 to May 1990, Visiting scholar at Rothamsted Experimental Station in UK

May 1996 to Dec 1996, Visiting scholar at CSIRO Land & Water, Australia

Apr. 2002 to Oct. 2002, Visiting scholar at University of California, Davis.

Oct 2007 to Dec 2007, Visiting scholar at Tokyo University, Japan

3. HONORS AND ACADEMIC AWARDS（2009-2013）

2009，Key technologies and integration demonstration for implementing precision agriculture to major crops in Hebei province， Hebei Science and Technology Progress Award，Second Prize.

2011, Improving farmland water use efficiency by reducing soil evaporation and increasing transpiration efficiency, Hebei Science and Technology Progress Award, First Prize.

2013, Water cycle and integrated modes of improved agricultural water use in Haihe river basin, Dayu Hydrological Science and Technology Progress Award, First Prize.

2011 Che Yuet Wah Outstanding Teacher Award from the Chinese Academy of Sciences.

4. MAJOR RESEARCH INTERESTS，SELECTED RESEARCH PROJECTS (research background, major research achievements, current research and future directions）

4.1 BACKGROUND

China is facing a water crisis that due to water shortages and water pollution. The increasing water scarcity and the competition from other sectors have put irrigation under great pressure. Grain production, a sector heavily dependent on irrigation, is facing unprecedented challenges. Further increase in grain production to meet the requirements of a growing population would further put pressures on water resources of China in future. Worsening water shortages threaten China's Food Security. Producing more food with less water by increasing Water Use efficiency (WUE) is an important measure to solve the water crisis both in China and around the world.

Water use efficiency (WUE) at yield level is defined as grain produced per unit water consumption. The recent average WUE of the three main grain crops in China has been 0.85 kg/m^3 for rice, 1.01 kg/m^3 for wheat and 1.51 kg/m^3 for maize. There should be tremendous opportunities to improve WUE for increasing grain production while using less irrigation water.

The improving in WUE for grain production in the North China Plain (NCP) is even urgent. NCP is one of the most important grain production areas in China. The rich soil and climate are favorable for growing winter wheat and summer maize as a double cropping system. The mean annual rainfall is about 450-600 mm. About 70% of the rainfall occurs from July to September, the growing season of maize. Rainfall during the winter wheat growing season, which is from October to May of the following year, ranges from about 60 mm to 180 mm. Supplemental irrigation is required to support wheat production, as the consumptive water use by winter wheat is about 430-500 mm. Farmers in this region generally irrigate winter wheat three or four times each season. They also irrigate maize once to three times per season. Farmers have pumped significant amounts of groundwater in recent years, contributing to a significant overdraft problem. The groundwater level has declined rapidly with a rate over 1m/yr in some part of NCP. “Science” gave a report on this water shortage problems titled “Water shortages loom as Northern China’s aquifers are sucked dry”(Science, 2010, Vol 328, 1462-1463)

The focus of our research group is to improve WUE in grain production in NCP so as to maintain or to increase grain production while reducing the use of irrigation water. Studies in crop water relationship and soil water storage and extraction have led to practical methods for farmers to save water and improve water use efficiency. Those studies included optimized irrigation and deficit irrigation scheduling, use of straw mulch to reduce soil evaporation, more efficient use of soil stored water, selection of better cultivars for high WUE and reduced irrigation water use by better field management. We established demonstration sites and successfully applied our results in practical farmland situations.

4.2 MAJOR RESEARCH ACHIEVEMENTS

4.2.1 Quantifying the contributions of different factors on WUE improvement

---Changes in crop water use, yield and WUE during the past three decades

Evapotranspiration (ET) is an important component of the water cycle on field, regional and global scales. It is affected by both atmospheric demands and surface conditions. A 30-year irrigation experiment on winter wheat and summer maize was used to analyze the impact of climatic factors and crop productivity on ET. The results showed that reference evapotranspiration (ET_0) was relatively constant. However, the actual seasonal ET of winter wheat and maize under well-watered condition gradually increased from the 1980s to the 2000s. The mean seasonal ET was 401.4 mm, 417.3 mm and 458.6 mm for winter wheat, and 375.7 mm, 381.1 mm and 396.2 mm for maize in 1980s, 1990s and 2000s, respectively. The crop coefficient (Kc) was not constant and changed with the productivity of the crops. The average Kc of winter wheat was 0.75 in the 1980s, 0.81 in the 1990s and 0.85 in the 2000s, and the corresponding average grain yield (GY) was 4790 kg/ha, 5501 kg/ha and 6685 kg/ha. The average Kc of maize was 0.88 in the 1980s, 0.88 in the 1990s and 0.94 in the 2000s, with a GY of 5054 kg/ha, 7041 kg/ha and 7874 kg/ha, respectively, for the three decades. The increase in ET was not in proportion to the increase in GY, with the former being smaller than the latter. The reasons for ET not increasing as rapidly as GY may be attributed to an increase in the harvest index and some water-saving measures, such as mulching to reduce soil evaporation for maize. An increase in soil fertility may also play a role in the enhanced GY with less water use. The results showed that with new cultivars and improved management practices it was possible to further increase grain production without much increase in water use. This is very important for mitigating global water scarcity and at the same time meeting the food demands for a growing population.

---Contributions of different factors to yield improvement

Yield results from a long-term field experiment (1979-2012) at Luancheng Experimental Station in the central part of the NCP was used to analyze the seasonal yield variation of winter wheat (*Triticum aestivum* L.) under the condition of sufficient water supply. The grain yield of winter wheat during the 1980s was relative stable. During the 1990s, the annual yield of this crop was continuously increased by 193 kg/ha/yr ($P<0.01$). While for the past 12 years, yield of winter wheat was maintained at relative higher level, but with larger seasonal yield variation than that back in 1980s. CERES-Wheat model was calibrated and was used to verify the effects of different managment practices on grain production. Seven scenarios were simulated with and without improvements in different management. The simulated results show that the yield of winter wheat was decreased by 5.3% during 1990s and by 9.2% during the recent 12 seasons, compared with that during 1980s, under the scenario that the yield of winter wheat was solely affected by weather. Seasonal yield variation caused by weather factors was around -39% to 20%, indicating the great effects of weather on yearly yield variation. Yield improvement by cultivars was around 24.7% during 1990s and 52.0% during the recent 12 seasons compared with that during 1980s. The yield improvement by the increase in soil fertility and chemical fertilizer input was 7.4% and 6.8% during the two periods, respectively. The initial higher soil fertility and chemical fertilizer input might be the reasons that the responses of crop production to the further increase in chemical fertilizer were small during the simulation period. Correlation analysis of the grain yield from the field measured data with weather factors showed that sunshine hours and diurnal temperature difference (DTR) were positively, and relative humidity (RH) was negatively related to grain yield of winter wheat. The climatic change trends in this area showed that the DTR and sunshine hours were declining. This type of climatic change trend might futher negatively affect winter wheat production in the future. The results also showed that cultivar renewing played the essential role in yield improvement of winter wheat.

---Yield and WUE improvement associated with cultivars

Renewing cultivars played an essential role in yield and WUE improvement in the NCP. Studies were carried out to understand the genetic gains in yield and WUE and their associated physiological and agronomic traits for winter wheat. Two groups of winter wheat cultivars were tested. Group 1 included 16 winter wheat cultivars that were released between 1998 and 2002, and Group 2 included 10 cultivars released between 1970 and 2000. Results showed that WUE increased substantially from 1.0-1.2 kg m^{-3} for cultivars from the early 1970s to 1.4-1.5 kg m^{-3} for recently released cultivars. Even in the more recently released Group 1 cultivars there was also a variation of about 20% in yield and WUE. Most of the cultivars in both groups had similar responses to water supply. WUE was greater for less irrigated treatments and maximum grain production was achieved with moderate water deficit.

The genetic gains in grain yield for cultivars released in different years were associated with increases in biomass, harvest index and kernel numbers per spike. Among the Group 1 cultivars, the ones with higher yield generally had higher WUE. No significant correlations were found between WUE and physiological traits such as ash content, chlorophyll content, or relative water content among the cultivars released recently. However a significant relationship was found between stomatal conductance or ash contents and WUE or grain yield among the Group 2 cultivars.

A relationship was apparent between WUE and date of anthesis and harvest index ($P<0.05$) in Group 1. Earlier flowering cultivars tended to have higher grain yield. In Group 2, flowering date was advancing by about 4 days over the 30 years of crop breeding. The positive relationship between grain yield and WUE for all the cultivars indicated that using a higher yielding cultivar has the potential to improve WUE.

Root length is an important trait in crop water use. The results from the Group 2 experiment showed that the seasonal ET of earlier released cultivars was similar to that of recently released cultivars under well-watered conditions. However, ET was slightly increased from earlier to recent released cultivars under water deficit conditions, indicating high soil water depletion by recently released cultivars. Total root length decreased from earlier to recent released cultivars and was significantly correlated with plant height. The breeding of winter wheat that reduced plant height not only increased harvest index, but also reduced root size, resulting in a smaller root : shoot ratio. The reduction in total root length from earlier to recent released cultivars mainly occurred in the top soil profile. The results indicate that total root length is not a factor that determines soil water use; rather, the distribution of root length density along the soil profile plays more important role in soil water utilization.

4.2.2 Irrigation management for improving yield and WUE under limited water supply

---Optimized irrigation scheduling for winter wheat

Results of six years of field experiments with winter wheat using 6 irrigation treatments varying from rain-fed up to rain plus 5 irrigations showed that dry matter production, grain yield and WUE were not linearly related to ET, but were best described as quadratic curve. The maximum total dry matter production at maturity was achieved at 94% of the seasonal full ET and the highest grain yield was produced at 84% of the seasonal full ET. A positive relationship was found between harvest index and dry matter remobilization during grain filling. Moderate water deficit accelerated the remobilization and transfer of dry matter from vegetative tissues to the grain, resulting higher grain yield and WUE. The more rapid transfer of dry matter to the grain is of particular importance under the climatic conditions of the NCP where grain filling is only lasting one month because of the weather conditions.

Generally higher WUE occurred with relatively lower ET. The maximum WUE was achieved with a water supply of about half of potential ET but yield was much reduced. To optimize yield while achieving a higher WUE the seasonal water consumption for winter wheat was in the range of 250 mm to 420 mm (50%-84% of potential ET). With an average seasonal rainfall of 132 mm, irrigation requirement was around 120 mm to 300 mm.

Research also showed that maximizing yield and WUE of wheat also depended on the utilization of subsoil moisture. Due to the deep root system of winter wheat and the high water holding capacity of the soil profile about 100-150 mm of soil stored water is available during the wheat growing season. This is equivalent to an average of 35% of the ET required to support optimum yield and could be obtained by soil moisture depletion using water that accumulated during the previous maize crop. The optimum seasonal irrigation amount was then around 60 to 140 mm in a normal season. Practical guidelines for irrigation scheduling of winter wheat to optimize yield and WUE were developed as follows: in wet seasons one irrigation applied at jointing stage, in normal seasons two irrigations applied at jointing and during booting to anthesis, in dry seasons three irrigations applied at jointing, booting and early milk stages. When following the guidelines the number of irrigations that farmers would normally have been used was reduced by 1 or 2 and WUE was increased by 15% (from 1.3-1.5kg/m^3 increased to 1.6-1.7 kg/m^3). Threshold values of soil moisture at different stages of winter wheat were established to guide irrigation decision making.

---Minimum irrigation strategy for double cropping of wheat and summer maize

The double cropping of winter wheat and summer maize in the NCP is intensively irrigated and the practice contributes greatly to the rapid depletion of aquifers and threatens the sustainability of agricultural development in the region. Field studies were carried out to investigate the possibility of growing winter wheat and maize with minimum irrigation application (MI). The approach was to irrigate just before sowing to bring soil moisture in the upper root zone to field capacity with no further irrigation afterwards. Results over eight years showed that under MI grain yield of winter wheat was over 5000 kg ha^{-1} and maize was over 6000 kg ha^{-1} in most of the seasons. On average yield was decreased by 13.9% for winter wheat and 13.3% for maize, and WUE was increased around 10% to 20% under MI compared to the normal irrigation practice.

During the MI experiments the average seasonal ET for winter wheat was 334.7 mm, and for maize was 319.3 mm, respectively. The mean annual total ET of the double cropping system was 654 mm under MI and 850 mm under normal irrigation practice. Under MI irrigation water use could be reduced annually by 200 mm. An analysis of the long term impact of MI on yield based on rainfall data from 1960 to 2005 and using the established correlation between yield and seasonal rainfall, it was concluded that in 1 out of 2 years the yield reduction under MI would be less than 15%, 1 out of 3 years less than 10% and in 1 out of 5 years there was no significant yield decrease. Even when the seasonal rainfall was extremely low, soil moisture depletion by the deep winter wheat root system contributed over 200 mm to the seasonal ET. The dried soil profile was replenished gradually during the following summer rainy season. The results showed that in this serious water shortage area the MI irrigation strategy might be possible and the saved water could be used for other more profitable productions.

--- Optimizing the yield of winter wheat by regulating water consumption during vegetative and reproductive stages under limited water supply

A study lasted 6 seasons and comprised of four treatments: rain-fed, single irrigation applied at sowing to obtain a good level of soil moisture at the start of crop growth (I1s), single irrigation applied during recovery to jointing (I1r) and full irrigation supplied as three irrigations (control, I3), was carried out to optimize the grain production of winter wheat under limited water supply. The results showed that grain yield was significantly correlated with rainfall before heading and with evapotranspiration (ET) after heading ($P<0.01$) under rain-fed conditions. The average contribution of soil water stored before sowing to seasonal ET was 90 mm, 103 mm and 145 mm for rain-fed, I1s and I1r, respectively, during the six seasons. A smaller root length density (RLD), which restricted utilization of deep soil water by the crop, was one of the reasons for the lower yield with rain-fed and I1s treatments compared with the I1r treatment in dry seasons. The results also showed that the limited irrigation applied from recovery to jointing stage (Treatment I1r) significantly promoted vegetative growth and more efficient soil water use during the reproductive (post-heading) stage, resulting in a 21.6% yield increase compared with that of the I1s treatment. And although the average yield of the I1r treatment was 14% lower than that of the full irrigation treatment, seasonal irrigation was reduced by 120-140 mm. With smaller penalties in yield and a larger reduction in applied irrigation, I1r could be considered a feasible irrigation practice that could be used in the NCP for conservation of groundwater resources.

4.2.3 Managing root system for efficient soil water use

The monsoon climate in the NCP causes most rain to fall in the summer season, while during the winter wheat growing season (October-May), rainfall is far less than the water requirements for the crop. Therefore if the efficiency of soil water use by winter wheat can be improved then less irrigation would be needed. Field measurements were conducted to study soil water utilization, root growth and distribution, root water uptake by winter wheat under different irrigation treatments, and possible ways to improve soil water use efficiency.

Root sampling results showed that winter wheat had a prolific root system with an average depth of 2 m. Most of the root system was concentrated in the upper 40 cm of soil. Root length density in the top layer of soil (0-20 cm) was very high with values over 5 cm/cm^3. The distribution of water uptake from the soil profile under high soil moisture conditions was closely related to the distribution of root length density. When root length density was less than 0.8 cm/cm^3, the root was the main factor limiting the complete utilization of soil water by crops. At maturity, over 100 mm of available water remained in the root-zone for the rain-fed treatment, although the upper layers had already entered water deficit, since the scarcity of roots in the deep soil layers restricted the full utilization of soil water. For irrigated wheat, from 40% to 50% of crop water use was from the stored soil water, and for the rain-fed wheat up to 80% of the water use was from the stored soil water in a dry season. Available stored soil water played an important role in the higher production of wheat crops in North China Plain. Effective measures to increase the utilization of stored soil water could improve crop performance under conditions of limited water supply. Results showed that deep tillage to break the soil pan improved root growth in the deeper soil layers, and sowing the crop evenly also enhanced water uptake from the top soil layer to compete with soil evaporation. Recent measurements that we conducted in field showed that the bulky density was increased under the tillage layer and soil pan is becoming thick and moving upwards with the application of minimum tillage practices in NCP. This situation significantly affects root distribution along soil profile. Accurate descriptions of the root distribution are important in developing models to simulate the flux of water and nutrients in fields. The existence of a hard soil pan under the tillage layer greatly influenced the distribution curve of the root length density (RLD). We found that without bulk density modification, there was an apparent difference between measured and modeled RLD resulting in either overestimating or underestimating root length at certain soil depths. We developed a model to introduce bulk density into an RLD simulation model which significantly reduced the errors of simulated and measured RLD throughout the root zone profile.

4.2.4 Reducing soil evaporation by mulch

The double cropping system of winter wheat and maize in the NCP requires about 850 mm water annually, in which over 20%-30% is from soil evaporation that is generally thought non-effective to crop production. Straw mulching has been widely used to conserve soil moisture. The double-cropping system of winter wheat and maize produces a large quantity straw every year that is a good source for straw mulching. Experiments on straw mulching were carried out at Luancheng Station for over ten years to investigate the effects of straw mulching on soil evaporation, soil temperature and crop production as well as WUE.

Micro-lysimeters were used to measure daily soil evaporation with and without straw mulch. Results showed that the average soil evaporation rate for mulched treatment was smaller than that of non-mulched treatment, especially in the earlier growth stages of crops when leaf area index was low. Over the growing season the average soil evaporation rate was 0.52 mm d^{-1} and 1.17 mm d^{-1} for the mulched and non-mulched treatments of maize, respectively. The results over 12 years showed that straw mulch reduced soil evaporation in maize fields by 40-50 mm and improved WUE by 7-10%. For winter wheat under straw mulching, soil evaporation was reduced by 40%, averaged over five seasons. Straw mulching reduced soil evaporation about 80-100 mm annually. With the use of combines to harvest wheat, straw mulch could be readily applied to maize. A further benefit is the reduction in pollution from burning the straw as was commonly done by farmers before.

Straw mulch on the soil surface also affects soil temperature which in turn may influences crop growth, especially in winter crops. For maize, the summer crop, the mulch did not affect the crop development and yield. In contrast with winter wheat the presence of straw on the soil surface reduced soil temperature during the period of critical development period from February to early April when the plants re-greened and entered the jointing stage., During this time the average daily soil temperature (0-10 cm) was 0.42 ^{o}C and 0.65 ^{o}C lower under light and heavily mulched conditions compared to a non-mulched control. On average over five seasons the lower soil temperature under mulch in spring delayed the development of winter wheat up to several days and reduced the final grain yield by 5% and 7% for light and heavily mulched treatments compared to the control. After April with the increase in leaf area the effect of mulch on soil temperature gradually disappeared.

Although soil evaporation was reduced under mulch, yield of winter wheat was reduced. The overall WUE was not changed under straw mulching. It seems that under these experimental conditions the negative impact of delayed maturity was greater than any benefit of reduced evaporation from the soil surface. The negative effects of straw mulching to winter wheat need to be further studied and possibly combined with minimum irrigation or other treatments where water was a limiting factor in production.

Using different mulch materials to reduce soil evaporation was also carried out in orchards. Micro-lysimeter, sap flow method and water balance approach were used to decide daily soil evaporation and seasonal crop water consumption. Three different mulching practices were used and compared on their effects of reducing soil evaporation, i.e. plastic film mulching (FM), concrete mulching (CM), and straw mulching (SM). Results showed that seasonal water consumption (evapotranspiration, ET) of an adult jujube orchard was around 600 mm from budding to defoliation, in which soil evaporation took up 40%. Seasonal ET calculated by water balance approach was slightly higher than the sap flow plus micro-lysimeter method. The two methods were comparable. Crop coefficient for the jujube orchard varied from 0.32 (initial growth stage), 0.74 (mid-season growth stage) to 0.59 (late season growth stage). Mulch significantly reduced ET by 85.2 mm, 90.1 mm and 31.4 mm in 2010, and 80.3 mm, 87.7 mm and 32.4 mm in 2011 under CM, FM and SM, respectively, compared with that of CK. Water use efficiency was improved under FM and CM. No significant yield and quality difference were found among the four treatments. Results showed that mulching using any kind material in an orchard was efficient in reducing crop water use.

4.2.5 Integrating water –saving measures and their application

Demonstration is an effective way to extend technologies to farmers in China. We established several demonstration sites in Hebei and Henan Province in the NCP to apply the water-saving technologies that we have developed. The demonstration sites include Luancheng county and Gaochen county in Hebei and Fengqiu County in Henan. The area of the core demonstration sites is around 1333 ha. In the demonstrations we applied deficit irrigation scheduling to winter wheat, straw mulch to maize, used improved cultivars and small border irrigation method to reduce irrigation water use and improve grain production. Yield was improved by 10% and irrigation application was reduced by 30%.

The methods that we adopted for technology extension included site demonstrations, technical manual, video and class training. We invited farmers to visit the demonstration site to show them the results of using water-saving measures. We wrote a practical manual to show farmers when and how to use the water-saving measures. A technique manual called “Using less water to produce higher yield of winter wheat and maize” was approved and published by Hebei Bureau of Measurement & Standard. A video was recorded showing application of the water-saving measures and later that was broadcasted by county TV stations. Training classes at village levels were carried out to raise the awareness of water saving for farmers as well as their skills in agricultural production. Now our water-saving technologies have been applied to more than 50,000 ha farmland with the help from local agricultural technology extension departments.

4.3 FUTURE WORK

With intensifying water shortage and the increase in food demand with population growth in China, further increase in water use efficiency and in grain production will become more important. Our future work will be focusing on further improvement in WUE as well as efficiently utilization of the available water resources such as precipitation and low-quality water (such as saline water, treated sewage etc.) to help mitigate the groundwater overdraft problem in the NCP. The results would also be relevant to agriculture in parts of northern China.

4.3.1 Further studies on mechanisms underlying crop responses to water stress

The mechanisms that underlay the responses of crops to water deficit involves many processes such as intercellular CO_2, oxidative stress, sugar signaling, membrane stability and root chemical signals (Chaves and Oliveira, 2004; Gloser et al., 2007; Gramer and Hawkins, 2009). In water-limited environments, photosynthetic carbon gain and loss of water by transpiration are in a permanent tradeoff as both are contrarily regulated by stomata conductance. Large unregulated fluxes of water are not essential to plant functioning and that water can be saved by manipulating stomatal aperture (Loveys et al., 2004; Dodd, 2009; Gong et al., 2010). Our future work will continue focusing on understanding of the factors that regulate the trade-off between carbon assimilation and water loss, and those that drive partitioning of assimilates between reproductive and non-reproductive structures in relation to soil water availability. Rhizosphere manipulation, especially partial root-zone drying, root hydraulic resistance in response to nitrate supply and other methods to alter root to shoot signaling to regulate crop growth and water loss, will also be one of our future research objectives.

4.3.2 Further extending deficit irrigation scheduling

Deficit irrigation strategies are likely to increasingly being adopted around the world due to the water shortage problems (Chaves and Oliverira 2004; Fereres and Soriano, 2007; Geerts S, Raes, 2009). The responses of crops to water stress are affected by crop type, cultivar type and phonological stage as well as the crop growing conditions. With the frequent change in cultivars and growing environments of grain crops, the opportunities for applying deficit irrigation practices and related strategies need to be continuously investigated and developed to fit different practical situations.

Our research results showed that winter wheat can successfully been grown with deficit irrigation in the NCP. However, winter irrigation is still widely practiced in this region. Winter irrigation is considered to compact the soil tillage layer for increasing the cold tolerances of winter wheat, particularly when straw from the previous crop is incorporated into the top soil. However, results from our study showed that the application of winter irrigation did not affect the growth and development of wheat in a normal season. Winter irrigation increased soil evaporation during the long winter dormancy period and also increased water and nutrient leaching from the root zone which poses environmental risks. So we aim to continue to study the impact of winter irrigation in order to provide management methods that farmers can adopt to replace this extremely wasteful use of water.

4.3.3 Supporting cultivation and management measures for new cultivars

Continuous breeding new cultivars have significantly improved grain production and WUE in China for the last three decades. Considering the vast population, limited arable land per farmer, the relative lower education background and weak economical situation in rural area, the extension of new cultivars is much easier than any other technologies in farming. Every year there are many new cultivars developed and sold on markets. However, farmers don't know which cultivar is more fitting to their conditions and what kinds of field management measures are required for a special cultivar. Our future studies will also focus on the traits of different cultivars that are beneficial to yield and WUE improvement, and corresponding field management practices in irrigation, fertilizing and cultivation to bring out the yield and WUE potentials of the new major cultivars of winter wheat and maize in NCP.

4.3.4 Integrated measures to increase crop productivity in rain-fed areas

The improvement in grain yield has a positive effect on WUE. China has a large area of arable land that is rain-fed and affected by the variation in rainfall. Crop yield is generally lower and varies greatly from year to year. Results have shown that integrated measures such as soil fertility improvement, ridge and furrow cultivation with plastic and straw mulching to harvest rainfall and conserve soil moisture, supplemental irrigation using small scale rainfall harvest system and so on would significantly improve grain yield and crop water productivity. This will make an important contribution to increasing food production in China, while at the same time not increasing agriculture water use. Our research group plan to extend our researches in rainfed areas, especially in the low plain surrounding Bohai in the North China Plain. This area has been designated as an important grain production area in Hebei for future yield increase planning. This area is shortage of fresh water, but has some shallow underground saline water that can be used for irrigation. Our future plan is to develop technologies that use rainfall more efficiently, and use some saline water for irrigation to mitigate drought effects on crops. We have obtained project support for saline irrigation in this area.

4.3.5 Extension of the water-saving technologies

Various water-saving measures used in grain production in China have significantly improved the water productivity of the crops. But there remains a great potential to further increase WUE for future food security and sustainable agricultural water use. Demonstration and extension of those technologies are critical. Further development in water-saving technologies that are suitable to the situations in agricultural production in China and can be widely applied in agricultural production are two important aspects for further improving WUE. Presently in rural areas in China, a lot of young farmers migrate to city, and in many place, older people and women stay home to take care of the land. In addition, the economic return from growing crops is not high. All those factors affect the willingness of the farmers to adopt new technologies. The development of water-saving techniques must include the goals of easy application and low cost. The combination of water-saving technologies with mechanization is also very important. Education to improve farmers' awareness of water shortages and the importance of adopting water-saving technologies is essential for sustainable agriculture development in China. New communication methods such as mobile phone, TV and internet are very popular in rural area and that can be implored as new ways to extend knowledge.

5. FUNDING AND LABORATORY PERSONNEL（2009-2013）

5.1 Funding from 2009-2013

Project name	Source of grant	Duration	Amount In RMB (10^4)
Technologies to reduce irrigation water use in farmland	National "863" sub-project	2006-2010	80
Integrating Biological – Agronomic – Engineering water-saving technologies and their application	Innovative project of CAS	2007-2010	120
Technology demonstration and extension for reducing crop water use for winter wheat and maize in the piedmont of Mt. Taihang	National Sci & Tec Supporting Scheme	2007-2010	132
Functions of hydraulic lift and bio-drilling of root system to improve crop drought resistance	National Natural Science Foundation of China	2008-2010	20
Integrating technologies and their demonstration for saline irrigation to different crops in the low plain of Northern China.	National Sci & Tec Supporting Scheme	2008-2011	276
Regulated deficit irrigation and improving soil water use efficiency	National "973" sub-project	2008-2013	40
The role of root in improving soil water and nutrient utilization efficiency	Innovative project of CAS	2010-2013	150

Mechanism in regulating leaf transpiration efficiency by coupling soil water and nutrients.	National Natural Science Foundation of China	2010-2013	26
Modern water-saving technology demonstration	Innovative project of CAS	2010-2013	60
Subsoil compaction related to the changes in tillage practices in the North China Plain	National Natural Science Foundation of China	2012-2015	60
Integrated measures to improve WUE of crops in Haihe river basin	Special Fund for Agro-scientific Research in the Public Interest	2012-2016	250
Assessment to the biological water-saving potentials in Hebei region	Special Fund for Agro-scientific Research in the Public Interest	2013-2017	126
Technologies to integrated utilization of different water resources in the low plain in the North China	National Sci & Tec Supporting Scheme	2013-2017	300

5.2 LABORATORY MEMBERS

Permanent staff

Ms. Suying Chen, Associate Professor, 2002-

Dr. Hongyong Sun, Associate Professor, 2002-

Dr. Shao Liwei, Assistant Professor, 2009-

Dr. Niu Junfang, Associate Professor, 2012-

Technical assistants

Mr. Xuchuan Nie, 1990-

Ms. Yuefen Liu, 2002-

Ms. Cailian Hao, 2007-

Graduate Students

Lina Gao, 2006-2009, Master degree

Liwei Shao, 2006-2009, Doctor degree

Xinxin Jin, 2007-2010, Master degree

Wang Feng, 2009-2012 Doctor degree

Miao Wenfang, 2009-2011 Master degree

Wang Yanzhe, 2010-2012 Doctor degree

Zhang Xiaoyu, 2011-2014 Master degree

Cui Xiaopeng, 2011-2014 master degree

Liu Xiuwei, 2010- Doctor degree

Lu Yang, 2013- Master degree

6. SELECTED PUBLICATIONS, PATENTS GRANTED，VARIETIES OBTAINED, major invited international conference talks）

6.1 Selected publications in international Journals

Zhang X.Y., Wang S.F., Sun H.Y., Chen S.Y., Shao L.W., Liu X.W. 2013. Contribution of cultivar, fertilizer and weather to yield variation of winter wheat over three decades: A case study in the North China Plain. Europ. J. Agronomy, 50:52– 59.

Zhang X.Y., Wang Y.Z., Sun H.Y., Chen S.Y., Shao L.W. 2013. Optimizing the yield of winter wheat by regulating water consumption during vegetative and reproductive stages under limited water supply. Irrigation Science. 31:1103–1112

Wang Y.Z., Zhang X.Y., Liu X.W., Shao LW., Sun HY., Chen S.Y. 2013. The effects of nitrogen supply and water regime on instantaneous WUE, time-integrated WUE and carbon isotope discrimination in winter wheat. Field Crops Research. 144: 236–244.

Liu X.W., Shao L., Sun H., Chen S., Zhang X.Y. 2013. Responses of yield and water use efficiency to irrigation amount decided by pan evaporation for winter wheat. Agricultural Water Management, 129:173– 180.

Sun H., Shao L., Chen S., Wang Y., Zhang X. 2013. Effects of sowing time and rate on crop growth and radiation use efficiency. International Journal of Plant Production. 7(1):117-138.

Niu J.F., Zhang W.F., Ru S.H., Chen X.P., Xiao K., Zhang X.Y., Assara M., Imas P., Hille M., Zhang F.S. 2013. Effects of potassium fertilization on winter wheat under different production practices in the North China Plain. Field Crops Research. 140: 69–76.

Zhang X.Y., Shao L.W., Sun H.Y., Chen S.Y., Wang Y.Z. 2012.Incorporation of Soil Bulk Density in Simulating Root Distribution of Winter Wheat and Maize in Two Contrasting Soils. Soil Science Society American Journal. 76: 638-647.

Sun H.Y., Shao L.W., Liu X.W., Miao W.F., Chen S.Y., Zhang X. Y. 2012. Determination of water consumption and the water-saving potential of three mulching methods in a jujube orchard. European Journal of Agronomy. 43:87-95.

Wang F., Zhang X., Zhang K., Bai L. 2012.Simulation of intensive swine wastewater irrigation of wheat-maize with RZWQM in North China Plain. Journal of Food, Agriculture & Environment. 10:1020-1024.

Shao L.W., Zhang X.Y., Chen S.Y., Sun H.Y., Wang Y.M. 2011. Yield and water use response of winter wheat to winter irrigation in the North China Plain. Journal of Soil and Water Conservation, 66: 104-113

Zhang X.Y., Chen S.Y., Sun H.Y., Shao L.W., Wang Y.Z. 2011. Changes in evapotranspiration over irrigated winter wheat and maize in North China Plain over three decades，Agricultural Water Management, 98: 1097-1104.

Chen S.Y., Zhang X.Y., Sun H.Y., Ren T.S., Wang Y.M. 2010. Effects of winter wheat row spacing on evapotranpsiration, grain yield and water use efficiency. Agricultural Water Management, 97 :1126–1132.

Sun H.Y., Shen Y.J.,Yu Q., Flerchinger G.N., Zhang Y.Q., Liu C. M., Zhang X.Y., 2010. Effect of precipitation change on water balance and WUE of the winter wheat–summer maize rotation in the North China Plain. Agricultural Water Management, 97:1139-1145.

Shao L.W., Zhang X.Y., Hideki A., Tsuji A, Chen S.Y. 2010. Effects of Defoliation on Grain Yield and Water Use of Winter Wheat. Journal of Agricultural Science, Cambridge, 148:191-204.

Zhang X.Y., Chen S.Y., Sun H.Y., Wang Y.M., Shao L.W. 2010. Water use efficiency and associated traits in winter wheat cultivars in the North China Plain. Agricultural Water Management, 97:1117–1125.

Zhang X.Y, Chen S.Y., Sun H.Y., Wang Y.M., Shao L.W. 2009. Root size, distribution and soil water depletion as affected by cultivars and environmental factors. Field Crops Research, 114: 75–83

Wang Y.M., Chen S.Y., Sun H.Y., Zhang X.Y. 2009. Effects of different cultivation practices on soil temperature and wheat spike differentiation. Cereal Research Communication, 37(4): 587-596

Shao L.W., Zhang X.Y., Chen S.Y., Sun H.Y., Wang Z.H. 2009. Effects of irrigation frequency under limited irrigation on root water uptake, yield and water use efficiency of winter wheat. Irrigation & Drainage, 58:393-405.

6.2 Selected publications in Chinese Journals (With English abstract)

邵立威，张喜英，陈素英，孙宏勇，高丽娜，花后脱叶对冬小麦产量形成和水分利用效率的

影响，农业工程学报，2009，25（1）：21-26

陈素英， 张喜英， 毛任钊， 王彦梅，孙宏勇，播期和播量对冬小麦冠层光合有效辐射和产量的影响，中国生态农业学报，2009，17（4）：681-685

孙宏勇，陈素英，张喜英，王彦梅，一种可移动式农田小定额灌溉装置，农机化研究，2009，4：95-97

金欣欣，张喜英，陈素英，孙宏勇，王彦梅，邵立威，高丽娜，不同灌溉次数和灌溉量对冬小麦氮素吸收转移的影响，华北农学报，2009，24（4）：112-118

孙宏勇，张喜英，陈素英，王彦梅，邵立威，高丽娜，气象因子变化对华北平原夏玉米产量的影响，中国农业气象，2009，30（2）：215-218,

高丽娜，陈素英，张喜英，孙宏勇，王彦梅，邵立威，华北平原冬小麦麦田覆盖对土壤温度和生育进程的影响，干旱地区农业研究，2009, 27（1）：107-113

孙宏勇，张喜英，邵立威，调亏灌溉在果树上应用的研究进展，中国生态农业学报，2009,17(6):1288-1291

邵立威，张喜英，陈素英，孙宏勇，裴冬，降水、灌溉和品种对玉米产量和水分利用效率的影响，灌溉排水学报，2009，28（1）48-51

陈素英、张喜英、邵立威、孙宏勇、刘秀位，微咸水非充分灌溉对冬小麦生长发育及夏玉米产量的影响，中国生态农业学报，2011，19(3): 579-585

苗文芳、陈素英、邵立威、孙宏勇、张喜英，不同灌溉处理对夏玉米氮素吸收及转移的影响，中国生态农业学报，2011，19(2): 293-299,

陈素英 张喜英 邵立威 孙宏勇，农业技术和气候变化对农作物产量和蒸散量的影响，中国生态农业学报，2011，19(5): 1039−1047

张喜英，中国科学院栾城农业生态系统试验站农田节水研究过去、现在和未来，中国生态农业学报，2011，19（5）：987-996

孙宏勇，张喜英，陈素英，邵立威，王艳哲，董博飞，农田耗水构成、规律及影响因素分析，中国生态农业学报，2011,19（5）：1032-1038

孙宏勇，张喜英，陈素英，邵立威，王艳哲，刘克桐，亏缺灌溉对冬小麦生理生态指标的及应用，中国生态农业学报，2011,19（5）：1086-1090

邵立威，孙宏勇，张喜英，陈素英，根土系统中的根系水力提升研究综述，中国生态农业学报，2011，19（5）：1080-1085

刘秀位，苗文芳，王艳哲， 孙宏勇，邵立威，陈素英，张喜英，冬前不同管理措施对土壤温度和冬小麦早期生长的影响，中国生态农业学报，2012, 20(9): 1135−1141

张喜英，提高农田水分利用效率的调控机制，中国生态农业学报，2013, 21(1): 80− 87

陈素英，张喜英，孙宏勇，邵立威，华北平原秸秆覆盖冬小麦减产原因分析，中国生态农业学报，2013, 21(5): 519-525

刘秀位，王艳哲，陈素英，张喜英，孙宏勇，邵立威，不同种植方式对棉田土壤温度、棉花耗水和生长的影响，干旱地区农业研究，2013,1:14-20

王艳哲，刘秀位，孙宏勇， 张喜英， 张连蕊，水氮调控对冬小麦根冠比和水分利用效率的影响研究，中国生态农业学报，2013, 21(3): 282-289

张小雨，孙宏勇，王艳哲，张喜英，应用基于红外热画像技术的 CWSI 简化算法判断作物水分状态，中国农业气象，2013，3（5）：569-575

苗文芳 刘秀位 邵立威 孙宏勇 张喜英，金丝小枣蒸散和作物系数变化规律研究，灌溉排水学报，2013，1:77-82

王艳哲，邵立威，刘秀位，张小雨， 张喜英，小麦和玉米根系取样位置优化确定及根系分布模拟，植物生态学报，2013，37 (4): 365–372

崔晓朋， 郭家选， 刘秀位， 张喜英， 孙宏勇，不同种植模式对夏玉米光能利用率和产量的影响，华北农学报，2013,28(5)：231-238

6.3 Book chapters

Xiying Zhang and Hu Chunsheng，2013. Root Growth and Distribution in Relation to Different Water Levels. In: Dennis Timlin and Laj R. Ahuja (ed.), Enhancing Understanding and Quantification of Soil–Root Growth Interactions. Advances in Agricultural Systems

Modeling Series 4. ASA, CSSA, SSSA, 5585 Guilford Rd., Madison, WI 53711-5801, USA. Pp45-65.

Mingsheng Fan, Xiying Zhang, Lixing Yuan, Weifeng Zhang, Fusuo Zhang，2013， Current Status and Future Perspectives to Increase Nutrient- and Water-Use Efficiency in Food Production Systems in China. In: Zed Rengel (ed.) Improving Water and Nutrient-Use Efficiency in Food Production Systems, March 2013, Wiley-Blackwell

6.4 MAJOR INVITED INTERNATIONAL CONFERENCE TALKS

Water Use in the Irrigated Farmland on the North China Plain - Past, Present and Future, Hebei-The Netherlands Cooperation in Hydrological Engineering, Oct 2009, Shijiazhuang.

Long-term Monitoring of the Crop Water Use and the Potential for Water-saving, International Symposium on New Approaches to Agricultural Water Management in a Changing Climate. 2011, Shijiazhuang

Managing limited irrigation for maximizing grain production in the North China Plain. 6th Annual International Symposium on Agriculture, Greece, 2013.

6.5 PATENTS GRANTED FROM 2009 TO 2013

A method for furrow planting cotton with plastic mulch on saline soils , Chen Suying et al., ZL200910076901.8, 2013

Special equipment for irrigating maize using small amount of water per irrigation, Chen Suying et al, ZL201210001990.1 2013

A preparation enhancing crop photosynthesis, Sun Hongyong et al., ZL201010262812.5 2013

A device for field crop irrigation using small quota of water, Zhang Xiying et al., ZL200810055462.8, 2010.

Manufacturing method and application of a multi-functional self-degradation liquid film. Sun Hongyong, Zhang Xiying et al., ZL200810079787.X. 2010.

A device for indicating the amount of irrigation water applied. Sun Hongyong et al., ZL200820076805.4. 2010

A sprinkler irrigation device for irrigating field crops using small quota of water. Zhang Xiying et al., ZL200820078008.X 2009

A combined rotary tiller with straw chopper. Zhang Xiying et al., 2009

A combined machine that integrating subsoiling, fertilizing and sowing together. Zhang Xiying et al., ZL201020139976.4. 2009.

A narrow row and close planting sowing machine. Chen Suying, Zhang Xiying et al., ZL200920102012.X. 2009

7. Editorial duties

Member of Editorial Board of “Agricultural Water Management”, 2013-

Member of Editorial Board of “European Journal of Agronomy”, 2013-

Member of Editorial Board of “Journal of China Eco-Agriculture”, 2006-

8．国际组织任职（conference organization）