Utilization of winter-fallowed cotton fields in the Huang-Huai-Hai Plain[1]

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Abstract: *The Huang-Huai-Hai Plain is the largest agricultural farming region in China, covering about 22 million hectares of arable land and accounting for about 1/6 of the total cultivable land in China. In 2005, the total wheat and cotton production reached 43.43 million t and 1.82 million t, respectively. This paper investigates advantages and limitations of a new farming system for increasing land use efficiency by developing and adopting a series of new farming practices, that include double cropping of wheat and cotton, factory seedling nursing and mechanized transplanting of cotton. This new system has a great potential in optimizing resource use, reducing environmental impacts caused by using plastic films.,and high yielding, and is suitable for the Huang-Huai-Hai plain.*

Keywords: *cotton, transplanting, winter-fallow utilization, double cropping, Huang-Huai-Hai Plain.*

Introduction

China is a major cotton producing country with more than 2000 years of history of cotton production (Yu et al., 2003). The total land area cropped for cotton production increased from 2.77 million ha in 1949 to 5.75 million ha in 2008. The yield increased from 165 kg/ha in 1949 to 1302 kg/ha in 2008 (China Agricultural information network, 2008).

The Huang-Huai-Hai Plain, including 301 counties in Beijing, Tianjin, Hebei, Shandong, Henan, Jiangsu and Anhui provinces or municipalities, covers about 22 million ha of arable land, and makes up 1/6 of the total cultivated land area in China. This is the largest farming region in China (Shi et al., 1988). The climate in the Huang-huai-hai plain is warm-temperate continental monsoon type with an annual solar radiation of 4900 to 5900 MJ/m^2**.** The annual average cumulative temperature (≥10℃) (above 10□ thermo unit) is 4000~4800 □ (degree days), 180~230 days are frost-free, annual average rainfall 500~800 mm, of which 60~80% falls between June and September. The average temperature in the coldest month is higher than -8℃, a temperature that is suitable for winter wheat production. The average temperature reaches above 10℃ steadily in early April in most parts of the region, allowing early plantation of cotton and other spring crops.

In 2005, total wheat and cotton production reached 43.43 million t and 1.82 million t, respectively. This was equivalent to 44.57% and 31.86% of the total wheat and cotton production in China. The Huang-huai-hai plain is also an area of rapid economic growth, with large areas of agricultural land being used for infrastructure and industry. The plain is also a region with serious water shortage where the amount of available fresh water averages 501 m^3 per person, which is only 1/5 of China's average. Since the 1980s, the availability of water and environmental contamination have become serious issues undermining the long-term sustainability of the economic development in the region.

The area of grain production has been declining in the region, dropping from 23.47 million ha in 1999 to 19.87 million ha in 2004. Most of the potential arable land (90.6%) has already been used in the region. Therefore, the potential for increasing grain production by expanding the land areas of cultivation is limited. The only viable alternative is to increase the yield per unit area through innovation in production technologies.

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This research was to investigate a new and more environmentally friendly production system by modifying the sowing time, shortening the growth period in the field through transplanting seedlings produced in the glasshouse, and with a more efficient irrigation system. This new production system was designed to increase land and resource use efficiency, and to protect the soil from desertification and to avoid environmental pollution.

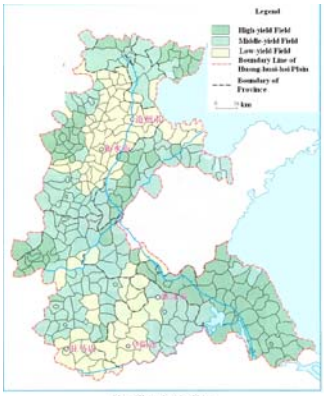

Figure 1. The map of Huang-Huai-Hai plain.

The current status and problems of spring-sowing cotton production system

Spring sowing cotton is the main cotton production system in the Huang-Huai-Hai plain. The crop is sown in late April and harvested in late October. There are some major problems with this production system.

Low utilization efficiency of land, light and heat due to long period fallowing: The five to six months fallow period reduced the efficiencies of land, solar radiation and thermo resource use.

Environmental pollution by the plastic films: According to a survey, the main crops were spring-sown cotton, winter wheat and maize, but cotton accounted for 83% of total arable land area in Disituan countryside, in Quzhou county of Hebei province. The field is covered by plastic films in spring. The usual amount of plastic film used is about 25.05 kg/ha, and the thickness of the films is about 0.006 mm. These plastic films persist in the field for a long period without being degraded.

To collect samples of plastic film residue, cotton fields using plastic film for 2, 4, 6 years respectively were selected as sampling fields. 3 samples in the size of 50 cm×50 cm×25 cm were taken from 3 fields of each field type. The sampled plastic films were brought to the laboratory, washed with water, dried and weighed.

Results of the investigation reveal that: (1) The amount of plastic film remaining in the soil increased with the time period of their use. The amount of film residue is 29.0 kg/ha after 2 years filming, 59.8 kg/ha after 4 years and 83.5 kg/ha after 6 years. (2) Most of the film residues were of middle size (4~25 cm^2), followed by large ones (≥25 cm^2), and small sized ones (≤4 cm^2) were the least. The longer the film residue stayed in the soil, the more serious it was shattered.

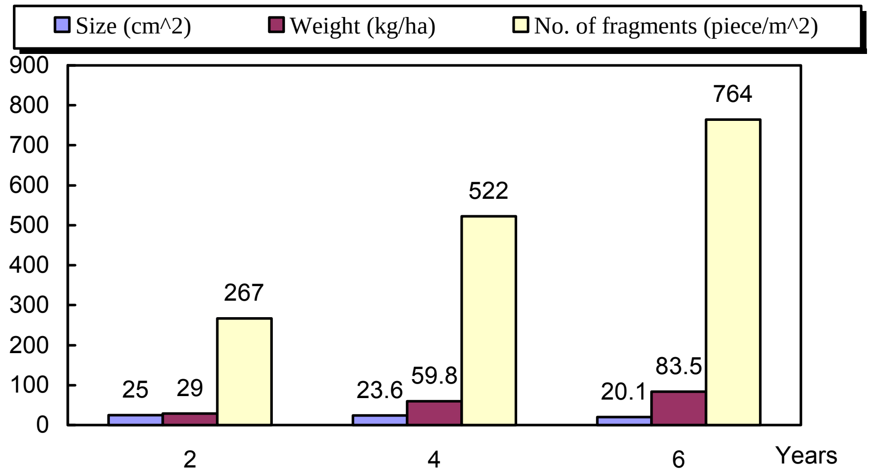

Figure2. Size, weigh and fragment amount of plastic film residues after 2, 4 and 6 years remaining in the soil.

Sandstorms: The windy season spans from November to May in Huang-Huai-Hai plain. For example, in the northwest region of Shandong province (Gao et al., 1996), Average occurrence frequency of winds stronger than force seven are 20 days in Yucheng, 27.3 days in Liaocheng, and 13.8 days in Dezhou. There are 161 days in Dezhou with winds reaching a speed of 4 m s^{-1} that is capable of blowing soil particles into the air. There are 141 such windy days in Liaocheng and 71 days in Heze. That makes sand storm a serious problem in the region.

It can be seen in Table 1 (Gao et al., 1996) that the quantity of soil lost in wind erosion in the wheat field was 3.92 less than that in the fallowed field, demonstrating the vulnerability of winter fallowing to wind erosion. In order to decrease wind erosion, winter-fallowing should be replaced by winter crops as winter wheat, etc.

Design of the wheat-cotton double cropping system

The winter wheat-cotton double cropping system was designed aiming at increasing the efficiency of land use, reducing sand storm and avoiding use of plastic film in cotton production.

Adopting wheat and cotton varieties with short growing seasons. The success adoption of double cropping system of wheat and cotton requires an accumulative temperature exceeding 5300 (≥0 ℃) degree days, while the value is

Table 1. The quantity of sandy soil loss in wind erosion in Shahe area of Yucheng County (Gao et al., 1996).

Wind speed (m/s)	Sampling Height (cm)	Dust deposit (g cm^2•min)		Percentage in total dust deposit (%)	
		Fallow field	Wheat field	Fallow field	Wheat field
6.8	2	13.8	2.4	23.46	16.00
	4	11.4	1.2	19.38	8.00
	6	7.2	1.2	12.24	8.00
	8	6.6	1.2	11.22	8.00
	10	4.2	1.8	7.14	12.00
	12	4.2	1.8	7.14	12.00
	14	3.6	1.2	6.12	8.00
	16	2.4	1.2	4.08	8.00
	18	1.8	1.2	3.06	8.00
	20	3.6	1.8	6.12	12.00
Add up		58.8	15.0	100	100

4880 to 5000 degree days or even less in Handan (Zhang, et al., 2001). The inadequate quantity of thermo resource could be a big problem for double cropped cotton which may suffer from frost damage in late growing season and thus yield loss. Early mature type of wheat variety is required to give some thermo resource to cotton. Han 6172 has been identified to be suitable for this purpose.

According to the analysis of available experimental and meteorological data, 300~400 sunshine hours during the 50 days after blossoming would be necessary to have highly yielding good quality cotton crops. 10 overcast or rainy days would have a significant negative impact on yield and quality. Handan, with 1 200~1 300 sunshine hours, i.e. 7~9 hours daily, during the period that safe for cotton growth and development （when temperature is above 15 ℃）, is suitable for the growth and development of cotton crop (Zhang, et al., 2001). This study proved that transplanting of greenhouse cultured cotton seedlings could add 322~414 sunshine hours to the double cropped cotton, and this solved the problem of inadequate thermo and sunshine hours effectively.

Early maturing cotton variety needs 3 000~3 300 above 10℃ degree days in the whole growing season. The healthy development of cotton fiber requires a temperature higher than 15℃. In Handan, the temperature drops below 15℃ after October 10. There are 3 380 above 10℃ degree days, with a probability of 90%, during the period between May 21, the date when the seeds for culturing transplanting seedlings are sown, and October 10 when the fiber stops developing. Therefore, cultivars adapted for transplanting should be early maturing requiring less than 3 400 above 10℃ degree days of accumulative temperature.

Table 2. Effects of climatic factors on yield and quality of cotton (Zhang, et al., 2001).

Growing stage	Time period during a year	Climatic factor	Effects on yield and quality of cotton
Entire growing season	May 21～ Oct. 10	≥10 ℃ thermo resource	＞3400 degreed days is good for high yield and good quality
		Rainfall	＞500 mm would cause yield loss and quality decrease
Boll setting	Aug.1～ Sept. 20	Drought	Beneficial for yield formation
		Sunshine hours	Beneficial for maturity and strength of fiber
		≥20 ℃thermo resource	Beneficial for fiber maturity
		Drought	Beneficial for fiber quality
		Sunshine hours	Beneficial for appearance and quality of fiber
Boll opening	Sept.21～ Oct. 10	≥15 ℃thermo resource	The minimum temperature allowing fiber to mature

The cotton cultivar Hanza 429 was selected for the experiment. The Bt-gene transferred hybrid cultivar, with a growing period of 121 days, was sown in middle April for seedling nurse and transplanted to the open production field by machine in late June. A yield of 3 540 kg/ha could be expected in moderately fertile soil under a population density of 45 000~52 500 plants/ha.

Factory seedling nursing: Transplanting of nursed seedlings is one of the approaches solving the problem of inadequate thermo resources. The nursed seedlings should be healthy, strong and suitable for large scale mechanized transplanting. A mixture of peat, vermiculite, and nutrient solution was selected as the medium for cotton seedling nurse, which contains organic matter not lower than 30% and N + P + K not lower than 4%. The suitable seeding time is during late April and Early May. After emergence, hulls were removed manually. Growth regulators such as paclobutrazol were used to control the height of the seedlings to a maximum of 30 cm in greenhouse. Pesticides were used to control diseases and pests.

Mechanized transplantation of cotton seedlings: Early June, when solar radiation and temperature are the best during a year, is the most suitable time for cotton growth in the Huang-Hai-Hai plain. In order to use the climate resources efficiently, cotton seedlings should be transplanted as early as possible after wheat harvesting. Mechanization is an essential technique for the successful extension of the new wheat-cotton system.

Figure 3. Factory seedling nursing and mechanized transplanting.

Timely Irrigation: As a drought-tolerant crop, cotton needs 557~587 mm water in the total growth period, while during this period the average rainfall is 501.6 mm in Handan. Furthermore, the inadequate rainfall varies greatly both in annual quantity and in seasonal distribution. In the Huang-Huai-Hai plain, the average daily temperature in early June is usually above 25 ºC that causes strong soil evaporation. Therefore, an immediate irrigation after transplanting is a must to ensure the survival of the seedlings.

Other field management **practices required**: The seedlings need a period of time to re-vigour and to re-establish after being transplanted, which is known as the so called transplanting shock. It is important to shorten the time period of transplanting shock by applying adequate basal fertilization, earlier application of top-dressing fertilizers at blossoming and boll-forming, and applying adequate potassium and phosphorus in order to promote the seedlings to establish quickly. Application of chemical growth regulators timely at early stages and reduce the use of mepiquat chloride at late stages are also key important. Since the decrease of pest population (the second generation of the boll worm needs no control), pesticide use on transplanted cotton should be reduced.

Preliminary results of field test of the new system

The new design was tested in the year of 2009, and some data had been observed or measured. The major findings are discussed bellow.

Reduction of pesticide use: Wheat crop is usually harvested in early June. Cotton was transplanted on the experimental plots in June 9. Since the seedlings being transplanted were 25~30 cm high with well developed root systems that gave the crop better resistance to diseases, use of bactericide reduced by 3 000 ml/ha.

Rapid growth of transplanted cotton seedlings: After 40 days growing in open field, the transplanted seedlings reached the same height of the directly seeded ones. As it is shown in figure 4, plant height of the directly seeded was 36.1 cm while that of the transplanted was 25.4 cm on June 22, 2009, leaving a difference of 10.7 cm 13 days after transplanting. On July 1, plant heights of the directly seeded and the transplanted were 41.4 cm and 28.1 cm, and the growth rates of two types of seedlings were 0.59 cm and 0.30 cm per day respectively. On July 9, both of the two types of seedlings reached the same growth rate of 0.58 cm per day, assuming the end of the 'transplanting shock' of the transplanted seedlings after one month in the open field. T On July 16, growth rates of the two types of seedlings were, showing a 'compensation growth' of the transplanted seedlings. After July 28, growth rates of the two types of seedlings were almost the same, 2.14 cm and 2.13 cm per day respectively.

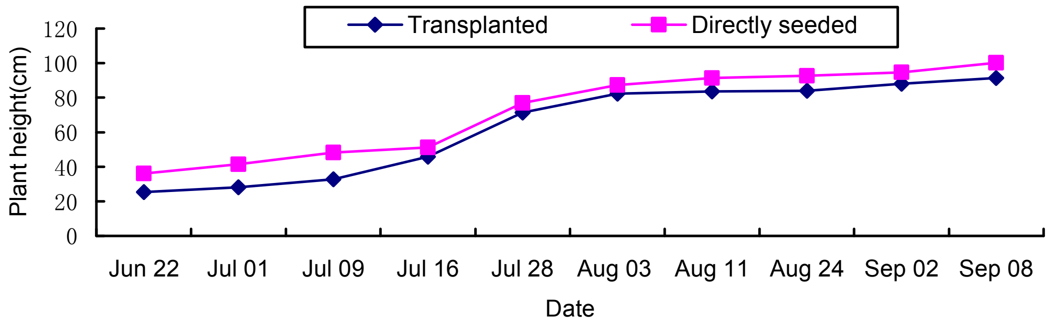

Figure 4. Comparison of transplanted and directly seeded seedlings' growth.

Effect of transplanting on cotton bud development: Fig. 5 shows that the first bud of the transplanted cotton appeared on June 22, 13 days after transplanting, when bud number of the directly seeded cotton was 6.1. On July 9, bud number of the directly seeded cotton was 8.4 while that of the transplanted was 5.7 one month after transplanting. On August 3, 54 days after transplanting, bud number of the transplanted cotton reached 12.2, exceeding that of the directly seeded of 11.9. This proves the yield potential of the transplanted cotton.

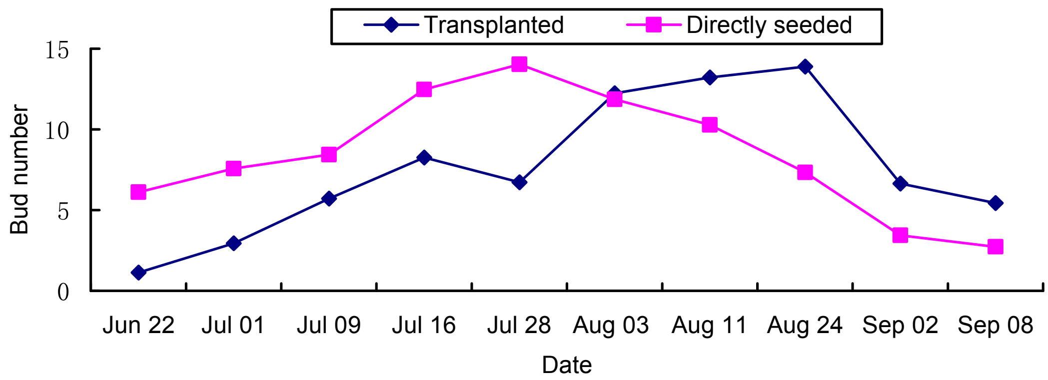

Figure 5. Comparison of bud numbers of transplanted and directly seeded cotton.

Summary

The new wheat-cotton system characterised with factory nursing and transplanting of cotton seedlings has a great potential in increasing land use efficiency and annual crop productivity as well as in reducing pollution of plastic film and agrichemicals in Huang-Huai-Hai plain. However, better integration of various technologies to obtain stronger seedlings, to shorten the period of 'transplanting shock' of the transplanted seedlings, and to reduce the proportion of bud numbers after frost, etc., need to be further addressed before extension.

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