Minimum tillage systems with winter-potato in Southern China

Andreas Oswald a.oswald@cgiar.org [1], Kaiyun Xie k.xie@cgiar.org [2], Fernando Ezeta f.ezeta@cgair.org [3]

[1]International Potato Center, Av. La Molina 1895, Lima 12, Peru
[2]International Potato Center, Zhong Guan Cun South Street 12, West Suburbs of Beijing, Beijing, People's Republic of China
[3]International Potato Center, Jl. Tangkuban Perahu no. 517, Lembang, Bandung 40391, Indonesia

Abstract

With the introduction of early maturing rice varieties in subtropical China, the later planting of the spring rice and the earlier planting and harvesting of summer rice resulted in a fallow period of 90–120 days during winter to spring. The mild cool temperatures of this season are suitable for vegetable or potato production, which opens the opportunity to increase food production and farmers' income without competing for arable land or clearing forests.

Heavily worked rice soils often have high clay content and are low in organic matter, and therefore difficult to plow. In China, some farmers have tackled this problem through minimum tillage and mulching. They basically place potato seeds on the ground and cover them with a thick mulch of rice straw. The crop then develops with irrigation or in rainfed conditions, producing yields of 15 to 30t/ha. A product of farmer innovation, the system has not been long in use.

Usually farmers use the straw from two to three hectares of rice to mulch a single hectare of potato. The rice straw is an important source of organic material that also benefits the subsequent rice crop. However, alternative uses of the straw (feed, fuel) might limit the application of this cropping system.

Since 2008 the International Potato Center is analyzing the potentials and constraints of this system via researcher and farmers surveys and the implementation of on-farm trials to improve management components and productivity. The system might have the potential to serve farmers in regions with similar agro-ecological conditions.

Keywords: rice straw, fertilizer management, mulch.

Introduction

In 1993 China became the world's leading producer of potatoes (Wang and Zhang, 1993). Since 1990, there has been a steady increase in cultivated area and total production (FAO, 2007) and it is expected that the proportion of arable land for potato cultivation will further grow (Janski et al, 2009). Reasons are an increased demand of potato from the processing industry, a growing population and the high profitability of the potato crop compared with other food crops in China. Although potato ranks fourth in importance following rice, maize and wheat, a large percentage of maize is used for animal feed while most of the potato yield is designated directly for human consumption.

In the future a further expansion of the area devoted to potato production will either be on the expense of other crops or pushing potato cultivation into the drier regions which actually account for 60% of China's arable land but probably have a low inherent productivity because of droughts and other biotic and abiotic constraints. A third option would be to gain arable land by an intensification of land use systems, making use of fallow periods between crops, introducing an additional crop, in this case potato, in an existing system without affecting its former productivity. The advantages would be that 1) no new land had to be developed, 2) experienced farmers would manage the new crop/cropping system, 3) the additional crop would generate an extra income, and 4) a more diversified cropping system could have beneficial effects on productivity and/or plant health, i.e. crop quality.

Such an opportunity, to increase food production without competing for arable land, arose with the introduction of early maturing rice varieties in the cropping systems of subtropical China. The earlier harvesting

of the summer rice crop and the later planting of the spring rice crop resulted in a fallow period of about 120 days of paddy rice soils in winter time. The mild cool temperatures of the season are suitable for vegetables and potato or sweet potato production. However, heavily worked rice soils often have high clay content and are low in organic matter, and are therefore difficult to plow. Preparing a fine textured seed bed as normally done for commercial potato production would be too time consuming and laborious. In the Southern provinces of China, some farmers have tackled this problem through minimum tillage and mulching. They basically place potato seeds on the ground and cover them with a thick layer of rice straw. The crop then develops with irrigation or in rainfed conditions, producing yields of 15 to 30 t/ha.

Usually farmers use the straw from two to three hectares of rice to mulch a single hectare of potato. The rice straw is an important source of organic material that also benefits the subsequent rice crop. However, alternative uses of the straw (feed, fuel) might limit the application of this cropping system.

As product of farmer innovation, the system has not been long in use, and neither has it been investigated thoroughly. Since 2008 the International Potato Center is analyzing the potentials and constraints of this system via researcher and farmers surveys and the implementation of on-farm trials to improve management components and productivity. A second objective of this study would be to evaluate the suitability of this system to serve farmers in regions with similar agro-ecological conditions in South or Southeast Asia making use of several million hectares of developed farm land for potato production.

In this paper we will present the results of a researcher and farmer survey conducted in 2008 and 2009 in order to give more insights in the driving factors, the constraints and opportunities of the winter-potato-mulch system. Based on these results on-station and on-farm trials will be developed and implemented during two growth seasons 2009/10 and 2010/11.

Materials and methods

The researcher survey was developed in 2008 and sent to research staff and extension officers of the nine provinces where the potato-mulch system is either in use to some extent or which have the (climatic) potential for the system to be introduced and diffused and therefore researcher are testing it in field trials. The provinces belong to three of the four major agroecological zones of China (Jansky et al, 2009), the Central double cropping zone (Anhui), the South winter cropping zone (Fujian, Guangdong, Gungxi) and the Southwest mixed-cropping zone (Chongqing, Guizhou, Hunan, Sichuan, Yunan). The questionnaire had about 15 mostly open questions. The objective of this survey was to get information about past or current research activities related to the potato-mulch system, a brief assessment of its major constraints and opportunities and a description of its implementation and management by farmers in the different provinces. Additionally to the survey, the researcher met for a two day workshop in Changsha, Hunan, to present information and to discuss further research activities on project and national level. Additionally field visits were organized for CIP researchers in Hunan, Chongqing and Guangxi provinces.

Based on the research survey and field visits a questionnaire for farmers was developed with 47 open and closed questions regarding crop management in general and the experience with the potato-mulch system specifically. In 2009 a total of 78 farmers were interviewed in the provinces of Fujian, Gungxi, Chongqing, and Hunan. In each province farmers from 1 to 3 villages per county and 1 to 5 counties per province were surveyed, with a total of 24 farmers per province, except for Hunan with 6 farmers only, because the potato-mulch system was not widely used in this province. In Fujian province few farmers had rented comparatively large areas of land, ranging between 6 and 80 ha. These areas were not considered if average land areas or areas under specific crops were calculated.

Data were analyzed using descriptive methods, correlations and linear regression models for results obtained from questionnaires.

Results and discussion

Potato-mulch system

Field visits showed that farmers used several types of minimum tillage potato-mulch systems (Photos 1). They either planted potato in double rows on ridges about 0.90 m wide covering them with a thick layer of straw, which then was covered with soil for better protection against low temperatures or prepared seed beds about 1.60 m wide for 4 rows of potato. The seed beds were sometimes slightly raised but often the seed tubers were placed directly among the rice stubble. Then the seed was covered with a thick layer of straw. Farmers principally used rice straw as mulch material and depending on the specific potato-mulch system and climatic conditions the straw of 1 to 3 ha of rice was required to mulch 1 ha of potato. Depending on the temperatures during sprouting and emergence the straw cover (of ridge or bed systems) could be further covered with plastic foil. The plastic serves the dual purpose of protecting against low temperatures and excessive moisture in regions with winter rains (Hunan).

In these systems potatoes were planted in high densities of 70,000 to 90,000 plants/ha. Depending on the region they were either irrigated or left to grow in rainfed conditions. For harvest the straw or straw soil cover was removed to collect the potato tubers, which resulted in a great reduction of labor compared with conventional systems. Farmers planted several potato varieties; either improved Chinese varieties or imported Dutch or German ones with a growth period of about 100 to 120 days. Reported yields averages ranged between 12 and 25 to 30 t/ha depending on the climatic conditions of the region and management skills of the farmers.

Photos 1: 1-seed bed with 4 rows of potato; 2-ridges with double rows; 3-straw mulch + plastic foil; 4-potato tuber under straw mulch; 5-tuber production in straw mulch; 6-harvest

Research information

First investigations of the potato-mulch system started in some regions about 8 years ago; meanwhile research programs have been implemented in all nine provinces. According to the researchers the winter potato crop has to compete with crops such as rape, winter wheat, vegetables, fruits or maize. The advantages of the potato-mulch system were described as generating relatively high yields, while production costs are reduced because the system is less labor-intensive, requires less pesticide inputs and conserves the soil against erosion and nutrient leaching. The potatoes are generally of good quality fetching a high price in the market. The increased land use intensity, by adding a commercial crop, gives the farmers an extra income. The main constraints are seen in the poor quality of seed resulting in lower yields, in the great straw quantities needed, in a high percentage of green tubers if potatoes are not thoroughly covered, in a slow and non-uniform emergence caused by low temperatures and a lack of early maturing varieties. As possible alternatives for rice straw the researchers mentioned straw from wheat and maize, sugar cane leaves or plastic foil.

Nevertheless, the area planted to the potato mulch system increased steadily in recent years indicating that farmers value the system and that the economic advantages are apparently greater than the prevailing constraints (Table 1).

According to the scientists there are three major factors which could hamper the expansion of the system. These are the availability of sufficient rice straw, the capacity of the extension service to train farmers and the necessity of a clear economic benefit for the farmers.

Ongoing and past research has been directed towards the development of adapted crop management technologies such as planting densities, planting and harvesting times, the use of different straw quantities and testing of distinct cover materials, the screening of varieties for earliness, drought and frost tolerance as well as late blight and fertilizer management. However, research efforts have been on a relatively small scale and need to be intensified to generate improvements and innovations to further increase productivity of the potato-mulch systems. Hence, research needs for further scientific investigations were identified as 1) the development and screening of adequate varieties (earliness, drought tolerant and adapted to low temperatures), 2) improvement of the fertilizer use efficiency and 3) the development of (integrated) crop management technologies to improve yields.The national research community has recognized the value of the winter-mulch system in generating more food and economic benefits without investing considerable resources or cultivating new land. Past and ongoing research has identified and described constraints and opportunities of the system. Further research needs have been clearly articulated but would probably need a more coordinated (interdisciplinary and interprovincial) effort to generate outputs in the near future. However, the vast areas in China and neighboring countries, which have adequate climatic conditions and appropriate cropping systems to accommodate an additional winter cropping season might convince decision makers to provide the required resources for the further expansion of the potato-mulch system.

Table 1. Development of land area under potato-mulch cultivation in 9 provinces of China and potential land for further expansion

Province	Potato-mulch area in ha			Areas for potential expansion
	1997	2002	2007	
Guangdong	1,300	3,700	6,400	in double cropping areas of southern China with winter cropping regions - potential up 1.2 million ha
Sichuan	25,000	35,000	46,000	in surroundings of bigger cities
Chongqing	none	3,700	20,000	in medium elevation areas <800m asl only 15% of the 135,000 ha rice area are planted with fall potato
Gungxi	none	None	93,000	30,000 to 60,000 ha in rice and sugarcane fields; especially south of the tropic of cancer:
Guizhou	none	None	83,000	in southern regions with paddy rice fields
Anhui	None	None	14	in the rice planting area between Yangtze and Huaihe River
Yunan	no data			no estimates
Hunan	no data			about 2 million ha of potential farmland in the South which could be used for winter potato
Fujian	no data			some potential in less developed regions with abundant rice straw

Farmer information

Farmers interviewed had an age average of about 50 years with more than 30 years working on their farm. About 50% were part time farmers looking for additional income with jobs in cities or as traders. The average farm size was with 0.27 ha rather small, but 42% of the farmers rented more land for crop production, increasing the average cultivated land per farmer to 0.38 ha. Usually land is cropped thrice per year.

The spring crop is planted in March/April, the summer crop follows in July/August and in November/December the third season starts. However in Chongqing, because of low temperatures, farmer plant often only twice and leaving the fields fallow in winter (Figure 1). Rice was mentioned by 96% of all farmers as the most important subsistence crop, while for 79% of the farmers potato was of specific commercial importance.

Potato was grown on 0.10 to 0.15 ha of land on average, except for Fujian province where the potato area was larger with about 0.33 ha (about 25% of the farmers in Fujian rented large areas increasing the mean potato area for that province to 6.8 ha). In Fujian farmers stated that they were growing potatoes with straw mulch for about 9 years, while in the other provinces farmers had only 2 to 3 years of experience with the system. The average yields achieved ranged between 11-14 t/ha for Chongqing and Hunan up to 25-30 t/ha in Fujian and Gungxi. Most farmers used their own rice straw for potato planting or could obtain it for none or little costs, however, transport seemed to be a more crucial cost factor. 25% of all farmers used some insecticides and about 50% fungicides to control late blight. Labor input amounted to about 21 man-days for field preparation, and 30 man-days each for planting and harvesting. The major cost factor was probably potato seed, as there are no seed storage facilities in the South and farmers have to renew their seed annually. About a third of the farmers was not content with seed quality and complained about low emergence, different varieties mixed together, virus infections and rotten tubers. Another crucial input was inorganic fertilizer, which farmers apply in high quantities to rice and potato. A significant difference in fertilizer management between the two crops is that potato receives often a more balanced N-P-K application and organic manure while rice is cultivated with a nitrogen based fertilization and little manure applications (Figure 2). A crude balance of applied and removed nutrients shows that fertilizer is not used efficiently and might therefore cause environmental damage but at least constitutes a cost factor, which reduces farmers' income.

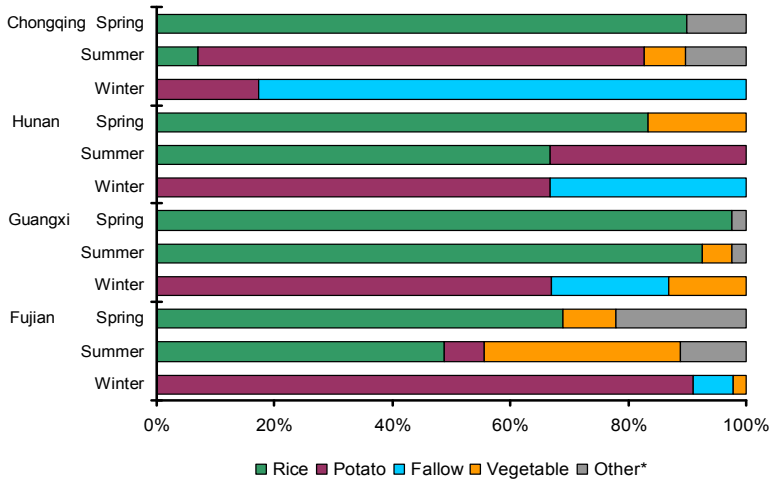

Figure 1. Frequency of crops in farmers fields during an entire cropping cycle in 4 provinces of China, 2008/09. (*other crops are peanuts, sweetpotato, green soybean, maize)

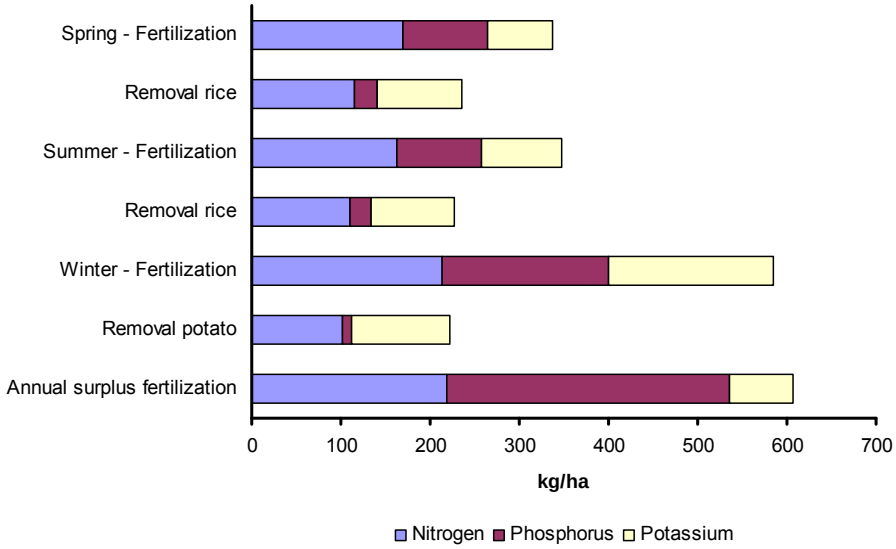

Figure 2. Nutrient applications and nutrient removal by crops during one year

Although farmers appreciate the extra income and the reduced effort in labor, they are also aware about further improvements of their present cropping systems. They specifically stress the importance of a better fertilizer management, the more efficient use of straw, to reduce transport costs and enable the cultivation of larger areas, the improvement of management techniques (planting dates and densities, furrow depth, mechanization etc.) and the provision of a higher seed quality.

Conclusions

The potato-mulch system allows farmers to crop their land up to three times a year. It provides the households with an extra crop and a substantial extra income. The potatoes are cultivated on medium to heavy, formerly inundated, rice soils, which have the advantage of a relatively constant water supply by residual soil moisture and quasi eliminates soil borne diseases or insects. Labor requirements are limited due to the minimum tillage approach and the fact that tubers can be harvested almost from the soil surface.

Hence the system requires few resources for pesticides and labor but needs great amounts of rice straw, seed tubers (provided from the Northern provinces) and fertilizer. Other constraints are often of abiotic nature such as low temperatures in some provinces retarding emergence and affecting plant growth or too little or too abundant rainfall, requiring extra drainage or irrigation.

The system was developed by farmers and operates with a sound profitability; however, raising costs for agro-chemicals, seed and labor affect these margins and require an improvement in productivity and resource use efficiency. That is why farmers claim support in the development of adequate fertilizer management and more efficient cropping management technologies such as plant densities, planting dates, straw application etc. Furthermore, the selection or breeding of early-maturing varieties, adapted to low temperatures would facilitate the expansion of the system to the more temperate zones.

In a second phase the project in collaboration with Chinese NARS will test crop management options in on-station and participatory on-farm trials with the objective to increase yields and improve input-use-efficiency and evaluate the options of expanding the technology to other potential winter cropping zones.

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References

Jansky, S. H.; Jin, L. P.; Xie, K. Y.; Xie, C. H., Spooner, D. M. 2009. Potato Production and Breeding in China. Potato Res 52, 57-65.

Wang, Q.; Zhang, W. 2004. China's potato industry and potential impacts on the global market. Am J Potato Res 81, 101–109.

FAOSTAT. Trends in total potato production, yield, and production area in China since 1990 (http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor).