# Chapter 13

# A Study of the Process of Replacement of Old Crops and Land Races by New Crops in Sichuan, China

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## Introduction

Sichuan is located in southwest China. Most of the area of 0.57 million sq. km. is covered by hills and mountains, except for the Chengdu plain. The altitude of the populated area ranges from 300 to 4,000m. Affected by the mountains and plateaus, the natural environment and agricultural resources are complex and diverse. As the Sichuan valley is surrounded by high mountains, its climate is much warmer than that of other areas located at the same latitude.

This paper describes the rate of genetic erosion of wheat and rice that has taken place in Sichuan during the process of agricultural development from 1950-1995 and highlights the problems associated with the introduction of new varieties. The case studies of wheat and rice are presented as examples to show the magnitude of changes.

Traditional land races of rice and wheat were the main basis of food production in Sichuan before 1950. The genetic diversity was substantial. Of 10,000 crop germplasm accessions collected by the Sichuan Academy of Agricultural Sciences (SAAS), Chengdu, 70 per cent were land races from Sichuan. A number of these land races may have evolved through both natural selection and selection by farmers. These land races were maintained by local farmers to meet various qualitative preferences and environmental requirements. Since 1950, China has introduced a number of exotic crops and varieties after systematic yield trials, and this has initiated a process of genetic erosion of land races and crops. After

1950, local land races of rice and wheat were gradually replaced by three to five major varieties.

In the late 1970s, hybrid maize and rice varieties were introduced and rapidly replaced officially registered high-yielding varieties. It is a matter of concern that among the released hybrid varieties, 80 per cent of them used the same male fertility restoration line, Minghui 63. From 1988 to 1995, SAAS developed 122 hybrid lines, 25 of which used the same male sterile line. In some cases the same sterile line was repeated 30 times (Zeng 1995). The extensive use of core parents in hybrid production has also reduced the genetic diversity in this major crop. Similarly, there are many such examples of wheat varieties showing the same problem. Since 1980, a total of 30 wheat varieties was released in Sichuan, but resistant genes for yellow rust were all taken directly or indirectly from the 'Fan-6' variety. This variety was grown extensively in Sichuan in the 1970s. In recent years (1991-1995), 22 new wheat varieties were developed by SAAS, but eight of them still shared the same parent (77 Zhong/2882). This case is not unique to Sichuan. The same process is probably taking place in the Consultative Group on International Agricultural Research (CGIAR) centres and other NARC (National Agricultural Research Centres) breeding programmes as well. The principal threats to yield stability from the use of such hybrids or high yielding varieties (HYV) are the increasing uniformity and continuous cropping. Because of such uniformity, regional diseases, such as maize leaf blight (*Helminthosporium maydis*) and rice blast (*Pyricularia oryzae*), began to spread widely and have become epidemic diseases in China. The issue raised here is whether research policy to develop hybrids or HYVs with the same genetic background is a sensible strategy or not. What are the principal drawbacks to widening the genetic background in introgression processes faced by breeders? Issues related to institution and government policy need to be analysed in order to rectify such problems.

## The Status of Wheat Cultivars in Sichuan

About 150 land races and 22 varieties of wheat were used in Sichuan during the 1940s. These land races were divided into three types, normal, round and *floriferous*, of *Triticum aestivum* and *T. turgidum*. Most of them adapt well to stress environments and farming conditions and have a tolerance to local diseases. They are generally adapted to niches and their coverage was usually small. Only a few of them, such as Chengdu Guangtou, were planted widely.

During the 1950s most land races were replaced by the four excellent varieties, *Mentana, Villa Glory, Ailiduo* and *Chengdu Guangtou*. In the late 1950s, the annual planting area of *Mentana*, which was introduced from Italy, was about 700,000 hectares, half the total area under wheat at that time. This was the first big replacement of wheat cultivars on a large scale. As a result, the average wheat yield in Sichuan increased to 1,185 kg/ha from 850kg/ha in 1949. On the genetic resources' side, more than 70 useful land races were completely replaced by new cultivars in the high potential valley areas (Table 13.1).

Table 13 1: **Changes in wheat cultivars (cv) and their planting area**

| Years | Area covered by released cv | % area covered by modern cultivars | Land races replaced | Dominant cultivar 'HYV' |
|---|---|---|---|---|
| 1940-50 | 233,000 | 4 | 125 | Jinda 2905 |
| 1951-59 | 1,020,000 | 7 | 58 | Mentana |
| 1960-65 | 933,000 | 7 | 56 | Shannong 205 |
| 1966-70 | 1,200,000 | 29 | 41 | Abbondanza |
| 1971-80 | 2,130,000 | 37 | 57 | Fan 6 |
| 1981-90 | 2,000,000 | 34 | 50 | Minanyang 11 |

After 1960 another four varieties replaced the previously well adapted cultivars in Sichuan. During this period, the number of introduced cultivars increased and the land races became fewer (Table 13.1). By this time land races were confined to remote mountain areas with special climates, niches, and disease problems; land where the modern cultivars could not be established.

By 1965, only four to five cultivars were used widely in production but their phenotypes and genetic background were significantly different. One came from Australia, *Chuanfumai*, and two from Italy, *Mentana* and *Villa Glory*. A few were developed from local land races, for example, Jinda 2905, original name *Nanxuzhou*. The cultivars released after 1965 were all progenies of the above-mentioned parents. The released cultivars and advance lines were hybridized again to breed new cultivars of new generations. In this manner, most advantageous traits of different old cultivars and land races were joined together year after year. As a result the genetic basis of new cultivars became narrower and narrower like an upside-down pyramid.

After release of the new cultivars, the wheat planting area increased to 2.2 million hectares in 1950. The number of land races replaced by new cultivars also increased accordingly. No efforts were made to improve the yield level of land races and, as a result land races could never compete with improved cultivars.

Institutions failing to produce new widely-adapted cultivars had to give up their breeding programmes. Because of this popular fear, breeding institutions always tried to use the most popular core parent. Because breeders in the same institute usually use similar breeding methods and parent populations, different cultivars developed in the same institute generally showed similar characteristics and shared the same core parents. The genetic diversity among cultivars decreased because of this process, despite the increased number of varieties released. In recent years, the genetic diversity of new cultivars produced by breeding programmes has definitely become much smaller.

Further to orders to release new cultivars as soon as possible, many breeders adopted a so-called 'amending breeding method', which aimed to improve one or two of the unsatisfactory characteristics of newly released and widely adopted cultivars. The frequent use of core parents has accelerated the erosion of genetic diversity in wheat cultivars. For example, the 12 cultivars used in the third replacement were developed at seven breeding institutes. Five of them shared the same parent, *Mentana*. Similarly, the 21 cultivars used in the fourth replacement came from 10 breeding institutes; six of them shared the same parent, *Flora;* another six shared *Abbondanza;* and another four shared the parent *Mara*. The 17 cultivars used in the fifth replacement were from only four institutes and 13 of them had the same parent, *Fan 6*.

## Rice Genetic Diversity and the Erosion Process

Rice (*Oryza sativa L.*) is the most important food crop in Sichuan. It has been cultivated in this area for millennia. Therefore, a great diversity of land races is found here. In the 1940s, more than 85 land races were in use, but their yield levels were poor.

Between 1949 and 1995 about 324 rice cultivars were registered in Sichuan. Among them, 141 cultivars had a great impact on rice production, the largest area, covered by one of them, exceeded 3,500 hectares. In the 1950s, 11 excellent cultivars, including five local land races, three introduced cultivars, and three improved cultivars, were grown extensively (Table 13.2).

The first big replacement of rice land races took place in Sichuan between 1950 and 1956. Several elite local cultivars, pure line cultivars, and hybrids from

Table 13.2: **Process of Genetic Erosion in Rice: Replacement of Land Races by Cultivars in Sichuan from 1936 to 1995**

| Years | No of cultivars developed | % of rice area planted with released cultivars | % of rice area planted with landraces | % of rice area planted with hybrids |
|---|---|---|---|---|
| 1936-39 | 85 | 0 | 100 | 0 |
| 1947-49 | 46 | 0 | 100 | 0 |
| 1950-59 | 11 | 27.2 | 72.8 | 0 |
| 1960-69 | 41 | 14.6 | 21.8 | 63.6 |
| 1970-79 | 71 | 23.9 | 0 | 59.2 |
| 1980-83 | 18 | 16.7 | 0 | 83.3 |
| 1987-95 | 52 | NA | 0 | 100 |

the breeding programme were developed and they slowly replaced the traditional cultivars (Table 13.2). Rice output in Sichuan steadily increased year after year to reach a record of 13.17 billion kilogrammes in 1956, 41.9 per cent higher than in 1949. The average rice yield increased to 3.7 t/ha in 1956 from 3.2 t/ha in 1949.

After 1970, there was a second big replacement by new cultivars. During this period, the number of cultivars released in the rice production system increased, but at the cost of replacement of land races. The third replacement of cultivars started in 1977. From that time on, only hybrid rice sustained the production (Table 14.2). Only a few semi-dwarf traditional land races with good adaptability and preference survived in remote villages.

Compared with the 1950s, the rate of cultivars released for rice was remarkably high in the 1970s (Table 13.2). As hybridisation between similar parents was carried out in different breeding institutions, many cultivars shared the same core parents and the biodiversity among cultivars did not enlarge with the increasing number of cultivars. Pedigree analysis showed that of the 112 cultivars released between 1960 and 1979, 82.2 per cent were related to one of six core parents: *Guanchangai, Aijiao Nante, 29ai, Chengai 8, Lushuang 1011, Zhulianai.*

In the late 1970s, hybrid rices began to be used in production. It is interesting to note that all land races of rice were completely replaced by hybrid rice from 1970 onwards when hybrid seeds were made available. Even new varieties developed by conventional breeding could not compete with hybrid rice. The registered number of traditional cultivars declined. Uniformity of rice fields became very serious (Table 13.2). Most rice planting areas were covered by a few hybrids. In addition, with the exchange of excellent parents and advances in breeding, the genetic background of different hybrids became more or less similar (reported in the Sichuan Regional Hybrid Rice Yield Trail in 1988). Eighty per cent of combinations were produced using the identical male fertility restoration line *'Minghui 63'*; only 25 male sterile lines were used in total. In the 122 new combinations of hybrid rice accepted in the Sichuan Regional Yield Trial from 1988 to 1995, some sterile lines were used repeatedly — over 30 times (Zeng 1995). The extensive use of core parents will certainly have added to the decrease in genetic diversity, increasing the vulnerability of the crop.

## Reduction in Diversity and Increasing Epidemics

The extensive use of new improved cultivars on a large scale increased the crop yield, but the genetic diversity among cultivars decreased. As a result some regional diseases, such as maize leaf blight (*Helminthosporium maydis Nisik et Miyake*) and rice blast (*Pjricularia oryzae*), spread, finally reaching epidemic proportions. In the past, rice blast was controlled effectively by using genes of many land races. Before 1960, rice blast mainly occurred in the mountainous districts surrounding the Chengdu plain. But later it gradually started spreading. In 1984, 366,000 hectares of rice fields were blasted and there was a yield loss of about 300 million kg of rice. The area affected by rice strip (*Xanthomonas oryaze*) was only 7,300 hectares in 1971. Now it has became a major disease covering an area of 67,000 hectares. This affected area is still growing, with even more severity in new areas. This is the outcome of narrowing down the genetic diversity of crops in diverse mountain environments.

Strip rust in wheat was originally a disease of the marginal areas of the mountainous districts surrounding Chengdu. After the spread of Mentana in the 1950s, the physiological races of yellow rust also evolved. The appearance of a new race of yellow rust 'Tiaozhong-13' made Mentana susceptible to yellow rust. As a result, yellow rust began to spread throughout the whole province. The second dominant cultivar 'Shannong-205' showed good resistance to 'Tiao Zhong-13' which helped control the epidemic of yellow rust. Unfortunately, Shannong-205 lost its resistance to yellow rust after five years. During this period, the physiological races of yellow rust kept on evolving. With the appearance of new yellow rust races, Tiaozhong 18 and 19, the new cultivar Abbondanza also lost its resistance to yellow rust in 1972. The release of Fan 6 and its offspring maintained resistance to yellow rust for 20 years until the appearance of Tiaozhong 30 and 31 in 1992. Analysis of this 'hide and seek' process between cultivars and diseases indicates that the cycles between disease epidemics and cultivar replacement must be the result of genetic diversity reduction in cultivars.

## Effects of Genetic Diversity on Yield Steadiness and Cultivar Improvement

The replacement of the genetic diversity of land races not only supplied opportunities for epidemics of crop diseases, it also decreased the adaptability of new varieties to other environmental stresses. During the wheat growth period in 1966, the temperature in winter was higher than in a normal year, which accelerated the development of the wheat, but much lower in April when the pollen was developing. Most of the wheat cultivars showed sterility caused by the low temperature during the pollen formation period. The yield loss from cold stress was about 10 per cent. Therefore, the value of local genetic diversity may be gauged from the advantages it provides in the adaptability of crops to environmental conditions.

The genetic advance of new varieties has apparently decreased in recent years. One of the important limiting factors is the lack of sufficient genetic diversity among parent populations. The similar genetic background makes it very difficult to use the accumulative effects of different alleles and epistasis among genes.

There is hardly any chance of selecting genetic variants markedly better than the parents (Jing 1983). This analysis of wheat and rice crops in Sichuan highlights a common process of breeding and land race replacement and reflects its potential danger to the sustainability of mountain agriculture.

## References

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