

Genetic resources of oilseed *Brassica* and related species in Gansu Province, China

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Abstract

Vavilov (1935) described China as the earliest and largest independent centre of origin of cultivated plants. Gansu Province occupies the geographic centre of China. With an area of 454,000 km², latitudes ranging from 32°3'N to 42°57'N and elevations varying from 500 to 6200 m, the province has an extremely diverse climate and topography. Stretching 1653 km along the ancient Silk Road, Gansu also has a long history of agriculture (6000 years) and for centuries was exposed to dynamic cultural exchanges between the East and the West. The unique combination of these conditions allowed rapeseed to be introduced from Europe and the Middle East, to evolve over a long time of cultivation and to diversify to adapt to many types of ecological conditions and cropping systems in Gansu. Currently, rich genetic resources exist in Gansu for *Brassica rapa*, *B. juncea*, *B. chinensis* and *Eruca sativa*. Eight landraces are described to demonstrate the diversity of rapeseed genetic resources in Gansu. It is generally recognized that *B. chinensis* originated in China. Information provided in this paper suggests that Gansu and its adjacent regions could also be a centre of diversity for *B. rapa* and *B. juncea*.

Keywords: *Brassica*; genetic diversity; genetic resources; oilseed crops

Introduction

Including both vegetable and oilseed crops, *Brassica* is one of the most important cultivated plant genera. *Brassica* oilseed crops, or rapeseeds, currently account for over 10% of the world's oilseed production and over 13% of vegetable oil production (Downey and Röbbelen, 1989; US Department of Agriculture, 2004). Because of their genetic and botanical closeness, vegetable and oilseed *Brassica* species can exchange genes relatively easily (Gómez-Campo, 1980; Mizushima, 1980; Liu, 1985). Consequently, germplasm research of oilseed *Brassica* species may benefit that of vegetable *Brassica* species and *vice versa*.

Vavilov identified eight independent centres of origin of cultivated plants, including China, which he described as the earliest and the largest (Vavilov, 1935). Gansu Province occupies the geographical centre of China. Many people know that Gansu is one of the native habitats for the Giant Panda. However, few people outside China are aware that Gansu, with a territory almost as large as Spain and an agricultural history of 6000 years, is also rich in plant genetic resources. Original research papers in Western languages on plant genetic resources in Gansu are rare. This paper summarizes some of the investigations on genetic resources of oilseed *Brassica* and related species in Gansu, China.

Modern crop cultivars often have a relatively narrow genetic base and conservation of genetic diversity is crucial to the future development of new cultivars (Frankel, 1970; Thompson *et al.*, 1992; Wilkes, 1989). Descriptive

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records from the time of original discovery of a genetic resource are important because once material is collected and transferred to a different environment, changes in phenotype and genotype may occur (Hyland, 1970). Wilkes (1989) grouped germplasm resources into seven levels of usefulness and management, with varieties in current use as the first level and organisms of no apparent immediate usefulness as level 7. The germplasm resources described in this paper are varieties still in current use by local people, and the characteristics described here are mostly from the time of original discovery.

Materials and methods

Information about the geography of Gansu has been gathered from various publications, including atlases, dictionaries, history books, etc. Information about specific varieties was mostly gathered either by examining the plants *in situ* or by talking to the local farmers where these materials are traditionally grown. Information from reports published in Chinese, which Western researchers seldom use as references mainly because of the language barrier, is also summarized and incorporated in this paper where appropriate. The purpose of this paper is to illustrate the genetic diversity in Gansu, rather than to provide information about individual germplasm resources *per se*. Therefore, systematic descriptors used for characterizing individual accessions have not been used to describe the plant cultivars mentioned in this paper.

Results

Geography of Gansu

Gansu Province, with an area of 454,000 km² and a population of 26.0 million, is in China's north-west (Fig. 1a).

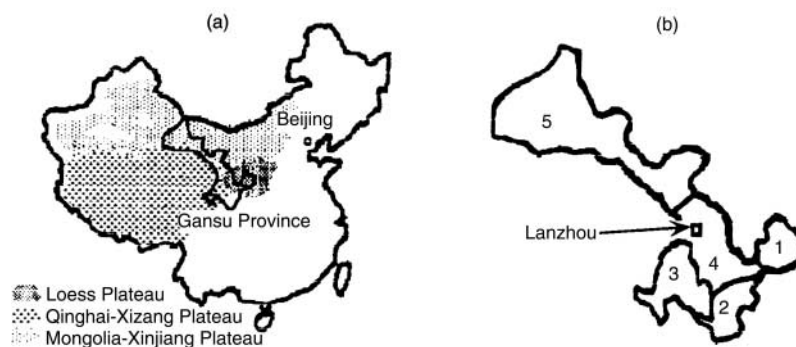


Fig. 1. (a) Gansu Province. (b) The five ecological regions for *Brassica* oil crops in Gansu: 1, eastern Gansu winter rapeseed region; 2, southern Gansu winter rapeseed region; 3, south-western Gansu spring rapeseed region; 4, central Gansu *Eruca sativa* region; 5, Hexi Corridor spring rapeseed region.

Brassica crops in Gansu are of special interest because the province has the following three characteristics described below: a diverse climate and topography, a long history of agriculture and a strategic location.

Diverse climate and topography

The province is at the juncture of the Qinghai-Xizang Plateau, Loess Plateau and the Mongolia-Xinjiang Plateau. High mountains, river valleys, plains, deserts, grasslands and forests combine to form an extremely varied landscape. The Yellow River flows through Gansu. With latitudes ranging from 32°3'N to 42°57'N and elevations varying from 500 to 6200 m, the province's climate varies from subtropical areas in the south, where the Giant Panda lives, to the permanently snow-covered Qilian Mountains in the north, where one of the world's largest glaciers lies. All these features result in a great variety of agricultural environments, which creates and preserves the diversity of *Brassica* crops.

A long history of agriculture (Wu, 1985)

There was human activity in this region 100,000 years ago. Many pre-history legends in Chinese culture are related to Gansu. The ancestors of the Zhou Dynasty (about 1100 BC to 256 BC) started their kingdom in Gansu. The Great Wall started in Gansu. Agriculture in this region can be traced back 6000 years. *Brassica* species are among the crops first cultivated by the ancient people in this region, and therefore they have had ample time to evolve under domestication.

A strategic location

Gansu was the north-west border of Chinese civilization for thousands of years. Extending 1653 km from the south-east to the north-west along the world famous 'Silk Road', the province served as a pathway for cultural exchanges between China and the Western world (Wu, 1985). In ancient times this region would have received

introduced *Brassica* species from the Western world before any other region in China.

This unique combination of environmental and socio-economic factors has resulted in unequalled diversity in the *Brassica* and *Brassica*-related oilseed crops in Gansu.

Oilseed Brassica and related crops in Gansu

China and India have the longest history of *Brassica* cultivation in the world, and Gansu has the longest history of *Brassica* cultivation in China (Liu, 1984, 1985). It is believed that *B. rapa*, as well as probably *B. juncea*, originated in Gansu and the surrounding areas. Records of *Brassica* being grown in the area can be found in *The Book of Songs*, a collection of poems written about 3000 years ago and edited by Confucius (551–479 BC). In his classic work *Compendium of Materia Medica*, Li Shizhen (1578), China's foremost expert on medicinal herbs and one of the world's notable pioneer botanists, pointed out that *Brassica* in China was first cultivated in Gansu.

Almost all the world's *Brassica* and *Brassica*-related crop species can be found in Gansu. Of the three major *Brassica* oilseed species (*B. napus*, *B. rapa* and *B. juncea*), only one generally dominates in a specific region. However, all three species are equally important in Gansu. In certain mountain areas only spring types can be grown on the slopes, while 5 km away in the valley winter types are grown. *B. rapa*, *B. nigra* and the related species *Eruca sativa* and *Sinapis alba* are minor oilseed crops in the world whose production is often confined to certain regions. Yet they all exist in Gansu (Li, 1981; Wang *et al.*, 1982). There are numerous landraces of these *Brassica* and *Brassica*-related oil crops. Gansu is therefore a prime *in situ* genebank for *Brassica* and *Brassica*-related oil crops.

Five ecological regions can be identified where ecotypes of *Brassica* oil crops are grown (Fig. 1b; Table 1) (Li, 1981):

- (i) Eastern Gansu winter rapeseed region: this region occupies the central zone of the Loess Plateau and

has a typical temperate continental climate. Winter-type *B. rapa* is the major oilseed crop. Varieties have strong winter hardiness.

- (ii) Southern Gansu winter rapeseed region: the region is hilly and mountainous and has very complicated topography. The southern part of the region has a subtropical climate. Both *B. rapa* and *B. napus* are grown. Varieties have medium or poor winter hardiness.
- (iii) South-western Gansu spring rapeseed region: this is the most important rapeseed production region in Gansu. It is a mountainous area on the eastern edge of the Qinghai-Xizang Plateau and has a very varied topography. Most areas in this region are high, cool and humid. In some counties there are vast grasslands with animal husbandry as the major industry. *B. juncea* is the major oil crop species. *B. napus* and *B. rapa* are also grown. *B. napus* varieties have been very successful in the last 10 years in the areas above 1800–3100 m above sea level (asl). Varieties are usually early maturing and cold tolerant. This region is a likely secondary centre of diversity for *B. juncea* and *B. rapa* and numerous landraces of both species have been found.
- (iv) Central Gansu 'Yunjie' (*Eruca sativa*) region: this region lies on the western side of the Loess Plateau. The dry climate and lack of irrigation make this region unsuitable for most *Brassica* species which require a plentiful supply of water. 'Yunjie' (*E. sativa*) is a traditional oilseed crop in this region (details below). Early maturing *B. rapa* is grown in the moister parts of the region. *B. napus* can be found in irrigated fields.
- (v) Hexi Corridor spring rapeseed region: this region is connected to the north-east corner of the Qinghai-Xizang Plateau. Most of this region lies within the Mongolia-Xinjiang Plateau. There are high mountains in the west and deserts in the east. Precipitation is very low and all the farmland is irrigated with the melt water from the snow-covered mountains. Rapeseed is grown at the foot and on the slope of the mountains. Early maturing and winter

Table 1. Elevation and major climatic parameters of five *Brassica* oilseed crop regions of Gansu Province, China

Region	Elevation (m asl) ^a	Annual average temperature (°C)	Annual precipitation (mm)	Frost-free days
Eastern	1000–1500	7–10	400–650	140–190
Southern	500–3000	7–15	430–950	160–285
South-western	1800–3100	≤7	500–600	80–150
Central	1400–2400	3.4–10	300–500	120–210
Hexi Corridor	1000–3000	5–9.3	40–250	80–150

^a Cropped land only.

hardy *B. rapa* varieties are dominant in areas of 2500 m asl or higher. *B. napus* is dominant in areas in the range 1800–2500 m asl. *B. juncea* is also grown in some areas.

Unique genetic resources of oilseed Brassica and related species in Gansu

'Dongmanjing' (*B. rapa*)

This crop is mainly found in Minxian County and Zhangxian County in south-west Gansu. The plant branches profusely and has 150–450 pods per plant with 22–24 seeds per pod. Oil content of the seed is 43–45%. The oil has 44% erucic acid and is much preferred for cooking by the local people. It is grown on the mountain slopes at elevations of 2500–3100 m asl, where few other crops can be grown due to the long cold winter, very short frost-free period and low annual average temperature (Table 1). This crop is unusual in several respects. It is planted in July and harvested from June to August the following year. The time from planting to harvesting is 340–380 days in its native region—probably the longest among all the winter-type *Brassica* oil crops in the world. Interestingly, some summer *B. juncea* and *B. rapa* landraces mature in 70–90 days in the same area. These two types have adapted to the environment by contrasting strategies: one matures early and the other survives the cold winter. In the traditional 'Dongmanjing' production area in Minxian County the annual average temperature is 3.9°C and the average January temperature is -9.2°C. These temperatures are significantly lower than those typical of winter rapeseed areas in China, which have an annual average temperature of 10–15°C and an average January temperature of -5°C. Uniquely, the most high-yielding 'Dongmanjing' is grown on newly opened perennial grassland. The grassland is ploughed two or three times in the summer to ensure soil fertility and favourable soil structure, and the crop is planted the following summer. No other management is applied before harvesting. 'Dongmanjing' is used mainly as an oilseed crop, but the leaves are frequently used as a vegetable. The roots are swollen and provide a carbohydrate reserve for over-wintering. In times of famine, to which the region is prone, the roots are cooked and eaten like potatoes (Pan, 1987).

Recently rapeseed breeders in Gansu have successfully introduced 'Dongmanjing' from Minxian County (34°26'N) to Jingyuan County (36°34'N). Jingyuan is located on the edge of the Tenggel Desert. Between the time when the major crop was harvested in the autumn to the time the next crop starts to cover the ground in the spring and winter, the farmland used to

be exposed to severe erosion by strong winds from the desert. Because of its outstanding winter hardiness, 'Dongmanjing' is now used as a cover crop to cover the fields from the autumn to the spring to reduce the soil erosion.

'Yunjie' (*E. sativa*)

'Yunjie' is not a single landrace, but a local name farmers have given to a type of oil crop traditionally grown in central Gansu where precipitation is unpredictable, and drought is a constant threat. The plant has a well-developed tap root and hairy leaves, stem and pods. It matures in about 100 days. The seed contains 30–38% protein and 23–38% oil with 34–37% erucic acid. 'Yunjie' has excellent tolerance to drought and poor soil fertility, with few pests, and a high level of cold tolerance (seedlings can tolerate -5°C). As a food, the oil is considered to be low quality because of its pungent taste. For centuries it has been maintained in the local agricultural system because it can be grown on marginal land with little input. It will return some yield when other crops fail due to drought and/or poor soil fertility. A common cropping practice is to plant 'Yunjie' in a mixture with flax, the other major oilseed crop in the province. The 'Yunjie'–flax mixture is better adapted than pure stands to environmental instability. 'Yunjie' in Gansu has drawn much attention from rapeseed researchers in recent years. There are active studies on its cytology, taxonomy and genetics. Fifty landraces of the crop have been collected by Gansu Agricultural University and Gansu Academy of Agricultural Sciences (GAAS) (Lu, 1979; An, 1990).

'Lintao Caizi' (*B. chinensis*)

B. chinensis is well known as a vegetable, but in Lintao County, it is used both as an oilseed crop (cooking oil) and a vegetable. The vegetable is 'Baicai' and the seed is 'Caizi'. Most regions in north-western China can grow 'Baicai', but only some places can produce the seed. The Tao River valley in Lintao County has fertile land and a well-developed irrigation system, making it ideal for 'Caizi' production. Though grown in the spring rapeseed region, 'Caizi' is a winter crop. To produce the seed the crop is planted in late August. In late October the whole plant is dug up and the leaves 2–4 cm above the crown are removed for use as a vegetable. The root (2–4 cm in diameter at the collar) is then either stored dry or buried at a depth of 30 cm. It is transplanted in early to mid-March of the following year. The seed is harvested a week earlier than wheat, which is desirable for double cropping. 'Caizi' can yield 3500 kg per ha where wheat can produce 4500 kg per ha. 'Lintao Caizi' may represent a stage in the evolution of oilseed *Brassica* species.

'Jingyuan 60-Days' (*B. rapa*)

'Jingyuan 60-Days' was originally identified as a unique landrace in Jingyuan County in central Gansu and now it is grown in eastern Gansu. It is the earliest maturing rapeseed cultivar in our rapeseed germplasm collection. It can mature in 60–70 days, hence its name. Because of its early maturity, local farmers plant it in the summer as a second crop which can be harvested in the autumn. As it can be planted in both spring and autumn, it is insensitive to photoperiod. It also has outstanding tolerance to drought and low soil fertility, and good resistance to diseases and insect pests. When planted in spring, it matures 20 days earlier than spring wheat under local conditions. Early maturity of the spring crops is crucial for success of the second crop (buckwheat, millet, etc.) in the local double-cropping system. The frost-free days in Jingyuan and surrounding areas are more than enough to grow one crop but insufficient to guarantee a successful harvest of the second crop. Because of its early maturity, 'Jingyuan 60-Days' plays an important role in the local cropping system whether it is planted in the spring or in the summer.

'Wuwei Xiaoyoucai' (*B. rapa*)

'Wuwei Xiaoyouca' was originally identified as a unique landrace in Wuwei County in the province's Hexi Corridor. It has wide adaptation and has been introduced to other provinces including Heilongjiang and Liaoning in north-east China. 'Xiao' in its name means 'small' or 'early maturity' ('youcai' means 'rapeseed'). It is early maturing (80–90 days under local conditions). As with 'Jingyuan 60-Days', the early maturity of this cultivar is utilized in the local double-cropping systems. Generally speaking, early maturity in rapeseed is usually linked to low seed yield. This cultivar, however, adapts well to the high-fertility, irrigated soil conditions and has relatively good seed yield. Yield is very stable in comparison to other rapeseeds. For rapeseed breeders, an unusual characteristic is the presence of variable self-compatibility. It is, however, relatively easy to isolate completely self-compatible plants from this material, and it may be possible to transfer this character to self-incompatible rapeseed varieties.

'Dahuangjie' (*B. juncea*)

'Da-huang-jie' means 'big yellow mustard', which describes well the major characteristics of this rapeseed. The plants are very tall (220 cm in height), its seeds are yellow and it is widely used to make a pungent mustard. To local farmers, it is primarily used as an oilseed crop. It is grown in Linxia as well as in other regions of central and south-western Gansu. Different regions probably have distinct landraces of 'Dahuangjie'. It matures in 140–150 days, and therefore cannot be used in

double-cropping systems. Its seed yields are higher than most other rapeseeds. Although 'Dahuangjie' is very tall, it seldom has lodging problems under normal conditions because its stems are very strong. Local farmers sometimes use 'Dahuangjie' stems to build fences. In addition, the plants are compact, with a branching angle of usually less than 30 degrees, and a branching height of more than 40 cm above the ground. As a result local farmers often intercrop 'Dahuangjie' with wheat, faba bean, flax, vegetables and potato. In these intercropping systems the plant canopy is of two layers, with the canopy of 'Dahuangjie' forming the upper layer and that of the other crop the lower layer. As a result overall light utilization by the plants per unit area of the land is improved.

'Longxi Reman' (*B. juncea*)

This landrace is grown in south-western Gansu including Longxi County. 'Longxi Reman' is early maturing, with a growth period of 80–90 days and with a brown seed coat. Because of its early maturity, it is often used in a double-cropping system. 'Longxi Reman' adapts well to poor soil conditions. Pea is an important crop in the 'Longxi Reman'-growing area and wilt is a severe disease locally, but farmers have noted that wilt is significantly reduced where the previous crop was 'Longxi Reman'.

'Longxi Reman', 'Dongmanjing' and 'Dahuangjie' are very different from one another with respect to plant morphology and adaptation. However, they can co-exist in the same region. Farmers grow 'Longxi Reman' on the mountain slopes of elevations of 1600–2400 m asl, 'Dongmanjing' on the mountain-top grassland of elevations of 2500–3100 m asl and 'Dahuangjie' on irrigated valley fields of elevations of 1600–2000 m asl.

'Gangu Xiaoyoucai' (*B. juncea*)

This landrace was originally identified in Gangu County, located at the transition zone of central Gansu and southern Gansu (Fig. 1b). As noted above, 'Xiaoyoucai' means 'early maturing rapeseed'. This cultivar matures early, with a growth period of only 75–85 days. In contrast to the tall 'Dahuangjie' *B. juncea* landrace, this landrace consists of short plants (50–80 cm). The crop is typically interplanted with potato. Potato is a full-season crop and cannot be planted until late spring because the plants cannot tolerate frost. It is also a thinly planted crop, with 40–60 cm between plants. Farmers plant 'Gangu Xiaoyoucai' in early spring. One to two months later, potato is inter-planted in the rapeseed field. Before the potato plants reach their fast-growing stage the rapeseed is ready to be harvested. The potato yield is hardly affected and the rapeseed represents an extra harvest from the same field. Compared to 'Longxi Reman', 'Gangu Xiaoyoucai' is grown in warmer (lower-elevation) environments, where problems

of plant disease and insect pests are severe for most crops. However, it shows good levels of resistance to diseases and insect pests.

Discussion

In this paper, we have described the physical and socio-economic environment of Gansu, given an overview of rapeseed resources in Gansu, and described some local landraces. Gansu has the conditions to generate genetic diversity of rapeseed and genetic diversity of oilseed *Brassica* and related species does indeed exist in Gansu. The area's unique geographical location, land topography and cultural history can explain its wealth of genetic resources.

The landraces described in this paper belong to the *Brassicaceae* species *B. juncea*, *B. rapa*, *B. chinensis* and *E. sativa*. Many rapeseed authorities believe that mentions of *B. campestris* in earlier literature are better categorized as *B. rapa*, although there is no agreement as to whether *B. rapa* should replace *B. campestris*. In this paper we have used *B. rapa* to refer to materials previously labelled as either *B. rapa* or *B. campestris*.

Gansu, and the adjacent Qinghai and Xinjiang, have been suggested as a centre of origin for *B. campestris*, *B. juncea* and *B. nigra* (Hemingway, 1976; Liu, 1984, 1985). However, Prakash and Hinata (1980) proposed that *B. juncea* originated in the Middle East, and McNaughton (1976) believed that the Mediterranean littoral and Afghanistan were the two primary centres of origin for *B. campestris*, with Asia Minor as a secondary centre. These different hypotheses on how different rapeseed species originated may not be mutually exclusive because, as Harlan (1970) pointed out, 'a crop as we know it today did not originate in one nuclear area'. The Chinese landraces described here can contribute to an understanding of how *B. juncea*, *B. rapa* and *E. sativa* have evolved as crops. We suggest that Gansu and adjacent regions form a centre of diversity for *B. juncea* and *B. rapa*, and possibly for *E. sativa* as well.

Evolutionary changes are of two types, phyletic and episodic (Frankel and Soulé, 1981). Both types are evident in rapeseed species in Gansu. The contrasting characteristics between the two *B. juncea* cultivars, 'Dahuangjie' and 'Longxi Reman', suggest an episodic evolution, while the dramatic characteristics of 'Dongmanjing' are typical of phyletic evolution. It is these evolutionary changes that have brought about the genetic diversity of rapeseed in Gansu.

Over the past several decades, modern *Brassica* cultivars have been introduced in all the rapeseed regions in Gansu. Some landraces, such as those described here, have surprisingly survived competition from these

new cultivars. It is likely that there exist other landraces in Gansu, but without detailed information, it is impossible to predict their ultimate value. Even for the materials described here, our knowledge is still rudimentary.

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