Breeding of Seabuckthorn (*Hippophae rhamnoides* L.) in China

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ABSTRACT

The population structure and geographic variation of major traits have been studied for the "Chinese seabuckthorn (Hippophae rhamnoides ssp. sinensis Rousi) and various ecotypes and provenances were identified. Four nation wide plus tree selections were conducted, which form studies of population structure and genetic variation. 368 items of plus trees from 8 main seabuckthorn growing provinces (autonomous regions) were collected and preserved with a selection intensity of about 2.5-3.0%. Among these, there were 35 provenances and sub-thorny individuals and 20 exotic gene resources. Six ex-situ gene conservation plantations of provenances and plus tree were established in Dengkou, Fuxin, Yongshou, Xinin, Tianshui and Xifeng. A set of superior exotic cultivars of provenances was introduced to various ecological regions, largely enriching genetic diversity of the species in China. 14 superior cultivars of provenances were selected at different levels, from natural species or introduced exotic populations derived from seedlings. Some of these cultivars with high economic values, "Wu-lan-sha-lin", "Liao -Fu-1" and "Liao-fu-2" etc. are thornless types, with large fruits, high contents of oil and high fruit yields, which have been used in operational mass production. "Jifeng" and "Jida" are high yielding cultivars with a fruits yield of more than 20 kg per tree.

Key words: Genetic resources of seabuckthorn, selections, hybrids and fruit yield.

INTRODUCTION

Seabuckthorn (Hippophae rhamnoides L.) breeding in China started in 1985. A breeding program was initiated at the Chinese Academy of Forestry (CAF) and funded by the CAF together with financial aids from FAO and French government. This, under the leadership and coordination by the author of this paper, started systematic studies on genetic improvement of the seabuckthorn. A cooperative research network was established to connect various institutions of forestry and water resources. Breeding strategy, research methods, experimental design and technical measures were developed. Experiments on seabuckthorn breeding were carried out in various ecological regions. Later in 1986, seabuckthorn was included in the 8th "Five Year Priority Research Program" as one of the main tree species to be studied and a project on tree improvement and the State Science and Technology Commission funded silviculture of the seabuckthorn. Prof. Huo Shuhua of the Beijing Forestry University led the project and a cooperative was formed on seabuckthorn. The project lasted for 5 years.

In the 1990s, the breeding work of the seabuckthorn continued and studies on genetic improvement were conducted based on the previous studies. Analysis of previous studies were conducted, up to the middle 1990s, a series of important research results were obtained first ever in the history of our country. Nearly at the same time, when the Chinese Academy of Forestry started the program on seabuckthorn genetic improvement, Prof YU Zuode at Tianshui Water Conservation Experimental Station (The Yellow River Water Resources Commission, Ministry of Water Resources) started species trials of exotic species and subspecies of the seabuckthorn in 1986.

Later, the Northern Water Conservation Institute of the Chinese Academy of Sciences, Northern Forestry University, Shanxi Forestry Research Institute, Shanxi Biology Institute and some other provincial and research institutes also started selection of plus trees or surveys of different types of the species on smaller scales. In the early 1990s, Berry Institute of Heilongjing Academy of Agricultural Sciences started to introduce exotic seabuckthorn form abroad in order to select better cultivars. In 1993, Horticulture Institute of Qiqihar City, Heilongjiang Province, also introduced many superior seabuckthorn cultivars. In the following years, introductions of exotic seabuckthorn cultivars were conducted by different Provinces (Autonomous Regions) at various scales. A set of results was produced.

Up to the middle 1990s, seabuckthorn breeding received more attention from the authorities and many other organizations in the country. As a first step, the Administration of Upper and Lower Reaches of Yellow River (Water Resource Commission of Yellow River of the Ministry of Water Resource) formed a Task Force, conducting seabuckthorn breeding and research extension in 1994. Later the State Science and Technology Commission and the Ministry of Forestry funded a seabuckthorn-breeding project in the national priority research program. Research and development centers were established in various regions by the Water Resource Development inc, (Ministry of Water Resources). Presently, these projects are progressing very well.

RESULTS AND DISCUSSION

The seabuckthorn is a species not only good for ecology and environmental conservation, but also good for great economic benefits. China has rich genetic resources of seabuckthorn and studies on genetic improvement are still in its early stages. Contrastingly, out side China, there are already several improved cultivars available in operation. Under such situation, the seabuckthorn breeding was considered to be uniquely featured and a breeding strategy focused on "multipurpose breeding, multi-level selection, integration of selection, introduction and breeding, double mainstreams of breeding and use of both sexual and asexual reproduction". The experiments were allocated in multiple sites and run by a cooperative consisting of multiple institutions.

The multipurpose breeding was adopted in order to put the breeding program in line with the varying sites in China and the biological characteristics of the seabuckthorn. To select super cultivars of the species in China, a first consideration is environmental protection. However, it will be difficult if planting material used for environmental protection has no economic value at all. Therefore, the breeding purpose for the seabuckthorn in China should be finding eco-economic cultivars/provenances with both environmental and economic values. Since the seabuckthorn plants contains many precious nutrients, which are excellent material for health care, breeding for economic benefits must also be included in the breeding purpose. Many other aspects should be considered in the economic breeding purpose.

The purpose of multi-level selection is to make full use of the existing natural genetic variations. Most of the seabuckthorn populations occurring in China are wild and semi wild types. There are sophisticated variations in its characteristics. It has a typical polymorphic population structure. Substantial differences exist among different provenances, among different types with in provenances and among individuals within types. In order to utilize the natural variation to a maximal extent, the multi-level selection should be used in the selective breeding program. A first step is to conduct phenotypic surveys and provenance trials to study the provenance variation, following this, the variation among sub-populations within provenances should be investigated together with studies of ecological and environmental values for different types. Base on these, superior individuals can be selected from superior types of superior sub-populations from the selected provenances. A next step is a progeny test, selecting superior individuals from better families for operational use or for use as breeding material for next generation breeding. The overall objective of these is to obtain genetic gain as much as possible and improve the efficiency of selection.

Integration of selection, introduction and breeding was formulated in the breeding strategy to suit the specific situation of Chinese economy and forestry. On the one hand, native seabuckthorn is more adaptive to the local environment to meet the demands for improved planting material, nation-wide screening of native trees for high economic values and better adaptabilities was undertaken. Meanwhile, improved material from abroad was also introduced through as many as possible ways. The native and exotic materials were then bred for adaptation to the Chinese environments. The purpose for these is to develop planting materials with desirable economic values and good adaptability to the Chinese site conditions, and to provide a sound basis for further exploration of cross breeding.

Double mainstream breeding refers to the two mainstream populations of native and exotic genetic materials. The native and exotic resources of the seabuckthorn were treated as two mainstreams in the breeding strategy. Multi-generation breeding can be carried out in each of the two mainstreams. Genetic materials from the two mainstreams will be selected and intermated. Because the two types of the material have supplementary characteristics, it is possible to develop super cultivars with high economic values and adaptive potential.

Methods for reproduction depend on objectives of planting program. For programs, aimed at obtaining high yields of fruits or extracts from the fruits, it is desirable to use vegetative propagated planting material for establishment of plantations for industrial raw materials. In such a way, the uniformity of characteristics can be maintained. However, for programs aimed at improvement of ecological environment, although economic characters need to be considered, sexual reproduction may be preferred. For the former method, orchard from cuttings will be established with use of single or multiple clones, in order to produce superior cuttings in large quantity. For the later, clonal seed orchards utilizing several or many superior clones with high economic values and high adaptability can be set up to produce improved seeds. Nevertheless, the breeding strategy was designed to make use of both sexual and asexual reproduction methods, in order to meet the diversity requirements by different planting programs with various objectives.

Multi-site experiments and multi-institutional collaboration provide maximum working facilities for the breeding program in China. In order to shorten the time used for testing and production, trial were established at multiple sites. While obtaining certain amount of superior genetic material, their performance in different ecological conditions is also studied, therefore, speed up the progress of genetic material, their performance in different ecological conditions is also studied, therefore, speeding the progress of genetic improvement.

Since the mid 1990s, significant progress has been made in seabuckthorn breeding, which is attributed to the breeding strategy adopted and suited to the Chinese reality and large scale collaboration by number of participating institutions. For instance, only the cooperative led by the Chinese Academy of Forestry has involved with 26 institutions and more than 70 persons. Following is the main institutions, involved in implementing the program: Institute of Forestry and Center for Desert Forestry Research of the Chinese Academy of Forestry, Fuxin Municipal Water Resource Bureau of Liaolin Province; Institute of Water and Soil Conservation, Survey and Planning of Shaanxi Province; Institute of Forestry of Qinghai Provincial Academy of Agricultural and Forestry Sciences; Tianshui Water and Soil Conservation Experiment station of the Yellow River Water Resource Commission; Institute of Water and Soil Conservation of Yikeshao Prefecture, Inner Mongolia; Forestry Research Institute of Fenglin Man Autonomous County, Ganshu Province; Forestry Institute of Linfen Prefeture, Shanxi Province; Seabuckthorn Research Institute of Youyu County, Shanxi Procince. Lately Xifeng Water and Soil Conservation Experiment Station of Yellow River Water Resource Commission and other institutions have also joined it. A series of useful research results were obtained during a relatively short period due to the effective collaboration by participating institutions and researchers.

Major achievements of the seabuckthorn breeding obtained in China during the last 10 years can be summarized as the followings:

1. The population structure and geographic variation of major traits have been studied for the “Chinese seabuckthorn (Hippophae rhamnoides ssp. sinensis Rousi), and various ecotypes and provenances were identified. These provided basic information for genetic improvement of the Chinese seabuckthorn. For any breeding program or development of new cultivars of any tree species, the first step is to get basic genetic information on populations of the species, which provides useful information for the development of correct breeding strategy and implementing plan. For this purpose, we studied the population biology of the species by establishing a set of sample plots. The polymorphic population structure and gradient variation form southwest to north east for the Chinese seabuckthorn has been found. This finding was proved by provenance trials and experiments of sub-population trials. Based on these results, eco-types of the Chinese seabuckthorn were identified and demarcation plan for seed transfer was formulated, all these paved the way for further genetic improvement of the species. Meanwhile, some research institutes have also conducted similar studies in these own areas.

2. Four nationwide plus tree selections were conducted which form studies of population structure and genetic variation. 368 items of plus trees from 8 main seabuckthorn growing provinces (autonomous regions) were collected and preserved with a selection intensity of about 2.5-3.0%. Among these, there were 35 provenances and sub-thorny individuals and 20 exotic gene resources. Six ex- situ gene conservation plantations of provenance and plus tree were established in Dengkou, Fuxin, Yongshou, Xinin, Tianshui and Xifeng. A set of superior exotic cultivars of provenances was introduced to various ecological regions, largely enriching genetic diversity of the species in China. In addition, the exotic cultivars introduced by Qiqihar Horticulture Institute of Heilongjiang Province, have also made great contribution to enrich genetic diversity. Other institutions, having made great contribution and worthy of mention are the Northwest Water and Soil Conservation Institute of the Chinese Academy of Sciences, the Northwest Forestry College and some provincial research institutes.

3. Through studies of biological systematic of the species and field trials of sub-populations, areas with trees having high adaptability and high economic values suited for seed collections were identified for major planting in the province (regions). For example, Fenglin, Zhuolu of Hebei Province; Luofugou in Jianping Country of Lianlin Province; Huanglong County of Shaanxi Province; and Datong County of Quinghai Province etc. In the zoning process, attention has been given to those with exotic origin, but have similar ecological conditions. Meanwhile, principles and methods for establishment of seed stands were formulated, providing scientific information for establishment of ecological forest eco-economic forest in large areas.

4. A set of superior seabuckthorn cultivars or origins was identified. This work was conducted in various experiment sites of the CAF cooperative, particularly the Dengkou Experiment Center. 14 superior cultivars of provenances were selected at different levels, from natural species or introduced exotic populations derived from seedlings. Some of these cultivars with high economic values, “Wu-lan-sha-lin", “Liao -Fu-1” and “Liao-fu-2” etc. are thornless types, with large fruits, high contents of oil and high fruit yields, which have been used in operational mass production. “Jifeng” and “Jida" are high yielding cultivars with a fruit yield of more than 20 kg per tree. In addition, some other clones for grazing and ornamental purposes were also identified. By multi-level selection, asset of male and female clones used for cross breeding was selected for the establishment of second-generation seed orchard. This combination of clones for cross breeding was called “Senshui”. They were clones with less-thom, high-yielding and high adaptive potential, their fruit yields were more than 10 kg per tree. Fruit production can increases as much as 3.67 times and number of thorns can reduce by 30%-40%. They are the ideal planting material for ecological and economic forests in the northern and the northwestern China. These clones have been used in operational mass production. Currently they are being used for the establishment of second-generation seed orchard, this has not been reported in the world. The Qiqihar Horticulture Institute of Heilongjiang Province has developed a clone “Xiangyang”, which produces large fruit,

no thorn, high yield and was adaptive to local environment, by selection form the introduced exotic genetic resources.

5. Breeding technologies for the seabuckthorn were developed for the Chinese environments. Research and extension network was established in the major seabuckthorn planting regions. These provided solid technical and institutional foundations for the extension of use of improved seabuckthorn materials.

During the period of "7-th Five-Year Research Plan", Prof. Shuhua at the Beijing Forestry University and his colleagues have conducted a through study on cutting propagation technology of the seabuckthorn and have successfully developed cutting propagation technology for the Chinese environments. Following this, Prof. Xu Yongxu and his research team at the Qinghai Provincial Agriculture and Forestry Academy have developed various cutting propagation techniques for a variety of site conditions. With the development of seabuckthorn production, we have conducted further explorations with consideration of specific features of different regions. It can be generally regarded, that we have solved the cutting propagation problem. Traditional nursery techniques for raising planting stock are already available. Wang Zhanmeng at the Xifeng Water and Soil Conservation Experimental Station of Yellow River Water Resources Commission, developed techniques for planting stock raising in the arid areas, which had significant impacts on mass production of the seabuckthorn. As the Chinese government attaches great importance to the improvements of environment, the cultivation of seabuckthorn is rapidly developing. Research network of the seabuckthorn is being set up. Presently, production based of improved seabuckthorn planting material in the major planting regions have been established on a visible scale and the selected superior planting material is being used in the operational production.

The seabuckthorn breeding in China has made significant progress during the last one decade, however, there is still a large gap between the availability of improved planting material and the requirements by large scale ecological forest plantations and land resource management. In the upper and middle reaches of the Yellow River, where the improved seabuckthorn planting material is mostly needed, lack of superior planting materials, which should produce large fruits and high yields, no thorns and sufficiently adaptive to the harsh environment, is a burning problem. Although some preliminary results have been obtained by cross breeding, it is still away the operational applications.

More over the new cultivars developed by the breeding programs, particularly those introduced form areas with high latitudes, has not been fully tested for their suitable planting ranges and potential of yields. Therefore, completing trials of regional planting experiments and large scale planting experiments are the immediate tasks to be taken. Otherwise, simple extension of the planting material without proving trials would lead to a overall failure of seabuckthorn production.

As a carrier of many nutrients for health care, the seabuckthorn has great potential to be explored for the economic utilizations. For the establishment of plantations for industry raw materials, planting material should be specified for this purpose, so that economic efficiency of cultivation of the seabuckthorn can be improved. However, this has not been realized in operation yet. At present, some foresters and seabuckthorn breeders is still not using correct planting material in their plantation programs. In fact, concerns with the seabuckthorn planting were raised, but the requirements for environment improvements, not purely for economic benefits. However, from the point of view of the whole country's development, ecological development contains substantial economic connection. It is unpredictable that how much economic benefits can be obtained from ecological and environmental development. The seabuckthorn cultivation and breeding in China should face these realities. The seabuckthorn breeding and tree improvement should be pushed forward from the perspective of both ecology and economy. Planting material required by the ecosystem and environment construction should be highly adaptive and rich in genetic diversity at first, and then high economic benefits on this basis. However, this has not received sufficient attention, immediate measures must be taken to strengthen this aspect. Therefore, future seabuckthorn breeding in China is till a difficult task and need to be continued for a long time, then the cultivation of seabuckthorn can progress at large scale.

CONCLUSION

Finally, we should say that in such a relatively short period of last one decade, the seabuckthorn breeding in China has made great progress and achievements, which is encouraging. However, it should be noted that there are still a few problems which need immediate solutions. With the strong support from the government to ecology and environmental conservation and increasing economic demands by the society, the seabuckthorn breeding in China is undoubtedly will have significant progress in the future.