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Breeding Strategies of Russian Seabuckthorn *(Hippophae rhamnoides* ssp. *mongolica)* Varieties and their Global Introduction

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SUMMARY

In view of the findings of global research on seabuckthorn, the plant has emerged as an important crop for food, nutrition, health and cosmetic industries, besides being utilized in environmental conservation. Many genotypes of seabuckthorn were identified with high yield, and vitamins and anti-oxidants in countries like Russia, China, India, Germany, Mongolia, etc., as there was interest in local Seabuckthorn varieties due to their wide adaptation to local environmental conditions. But presence of thorns, small fruit size and high harvesting cost kept growers away from seabuckthorn for long in many countries, despite best efforts of research organizations of many countries. Soon it was realized that Russian seabuckthorn varieties (*Hippophae rhamnoides* ssp. *mongolica)* have advantage in characteristics of economic importance like few thorns or no thorns, large fruits (30-120 g/100), high yield (5-12 kg/plant) and high oil content (4-7 per cent) and carotenoids and easy harvesting. Russian varieties were introduced into the republics of former Soviet Union and then China decided to go ahead on large scale on introduction and cultivation of Russian seabuckthorn varieties, which proved very successful for their commercial cultivation to meet growing demands of industries. Russian varieties have also been introduced in Europe like Germany, Finland, Sweden and North America (USA and Canada). Lately, India has also started trials on introduction and evaluation of Russian varieties in Himalayan state of Himachal Pradesh. It is important to understand the breeding strategies of Russian experts and characteristics of Russian seabuckthorn varieties before their introduction in orchards.

Keywords: Russian seabuckthorn varieties (Hippophae rhamnoides ssp. mongolica), Breeding strategies, Features, Introduction, Evaluation, Russia, Europe, North America and Asia.

INTRODUCTION

Although, seabuckthorn has been quite popular in folk medicines in Siberia since centuries, it was the vitamin C discovery by Russians in early 1940s that led to its commercial utilization. As wild seabuckthorn is thorny and low yielding, therefore, there was a need for the improved varieties of seabuckthorn for commercial utilization. Seabuckthorn grows widely in Altai mountains, Buryatia, Tuva, central Asia, Kazakhstan, Caucasus, Baltic republics, Kaliningrad region, and south-western Ukraine, all republics of former Soviet Union. Siberia makes 57 per cent of the Russia geographical area and produces 16.4 per cent of Russia agricultural production. The region is characterized by extreme climatic conditions, low fertility of soil and humid to semi-humid conditions. In Russia, main institutes, *i.e.* the Lisavenko Research Institute of Horticulture for Siberia (LRIHS), Institute of Cytology and Genetics, Novosibirsk, Nizhny Novgorod State Agricultural Academy (NNSAA), Nizhny, Novgorod, Buryat Fruit and Berry Growing Experimental Station (BFBGES), Fruit and Berry Growing Experimental Station, Novosibirsk (NFBGES) took up research are working on seabuckthorn.

Large variations in morphological and biochemical characters in natural populations of seabuckthorn offer us an opportunity for the genetic improvement of this plant. The researchers at the Lisavenko Research Institute of Horticulture in Siberia were the first in the world to develop the thornless, large fruited and high yielding varieties of seabuckthorn, which helped the country to cultivate the improved forms in over 5000 ha orchards in 15 regions from Moscow to Krasnoyarsk. The institute tested the improved varieties in Baltic republics, Byelorussia, Ukraine, Azerbaijan, Armenia and other regions. Kalinina (1988) has reviewed the breeding work on seabuckthorn in the CIS states. The present papers aimed to analyze the useful economic characteristics of

Russian seabuckthorn varieties, breeding work carried out in Russian institutes, mainly at Lisavenko Institute and introduction of Russian seabuckthorn *(Hippophae rhamnoides* ssp. m*ongolica)* varieties in other countries like China, Europe and North America.

HISTORY OF BREEDING OF SEABUCKTHORN

On recommendation of I.V. Michurin, the first attempts on selection of promising forms of seabuckthorn in this regard were made by M.A. Lisavenko (1897-1967) in Russia, as early as 1933. Lisavenko started the pioneering work on selection of high yielding forms in 1934 in Altai mountains of Siberia, Russia. Later on J. Gatin and E.I. Panteleeva joined the work. Plant breeders started breeding work with selection of promising forms from wild forms of seabuckthorn from Katun (Gomy Altai) and produced a number of better forms Dar Katuni, Novost Altaya and Zolotoy Pochatok, the first 3 selections in former Soviet Union. This team did excellent work on breeding and produced a large pool of over 400 genotypes belonging to 10 ecotypes of seabuckthorn from different regions of CIS states. There was special emphasis on the selection of female forms possessing good characteristics like absence of thorns, dwarfness, compact crown, winter hardiness, large fruit (>0.3 g), strong fruit skin, solid pulp and long peduncle (5-10 mm), easily detachable from the branch, high oil content (>7 per cent), high vitamin C (>100 mg/100 g) and carotene (>6 mg/100 g). The male forms were selected for winter hardiness and their flowering synchronizes with flowers of female plants. As a first step, they collected 3,00,000 seeds from 148 selected forms from different regions and sowed them under similar conditions at the institute. After evaluation of fruits of 15,300 seedlings with free pollination, they made .selections as first improved forms by the names of Novost, Altaya, Dar Katuni, Zolotoi pochatok, Maslichnaya, Vitaminnaya and Chuyskaya (Kalinina, 1988).

During second phase of their work since 1959, J. Gatin and E.I. Panteleeva started work on hybridization of distant eco-geographical forms of seabuckthorn. The female forms were taken from the improved elite forms selected earlier and naturalized in the conditions of Altai area. The male forms were taken from the central Asia and European parts of former Soviet Union. For next 28 years, they artificially crossbred 350 combinations and obtained 2 million hybrid seeds, raised 145,000 seedlings and evaluated the fruiting of over 65,000 first generation hybrid plants under the orchard conditions. These days study is in progress on second and third generation hybrids, while making selections of plus trees for a number of desirable characters. Breeders have been doing saturation crossbreeding to intensify some of the characters, which provides for a multiple pairing of the obtained hybrids with one of the primary parental forms, therefore, they have succeeded in producing dozen varieties of intense type.

Later, they started work on hybridization of distant forms of seabuckthorn from "Katun" (Altai) and "Tunkin" (Trans-Baikal), producing better forms with higher adaptability, productivity and richer in oil and carotenoids (Goncharov, 1995). In next programmes, there was emphasis on developing forms with dwarfness, early maturing, large fruits, compact crown, thomlessness, firm fruit skin, large peduncle, easy fruit separation by machines, and resistance to pests and adaptation to mechanic harvesting. In Siberia, breeders could produce 20 improved varieties of seabuckthorn, among them 16 were produced by breeders in Altai. More than 20 varieties have been introduced in almost 20 regions of Russia and other CIS states. Experts have raised these improved varieties in 2000 ha in Altai, which is about third of total area under seabuckthorn in Russia. Therefore, people are raising orchards of seabuckthorn in different parts of Russia, mainly varieties from Altai province, because of better economic characteristics. After long period of research trials, the Lisavenko institute produced improved varieties of Dar Katuni, Novost Altaya and Maslichnaya, which were registered as early as 1965. During next stage, Oranzhevaya was released in 1974. Chuyskaya and Obilnaya were released in 1979. This institute released 2 more varieties Samorodok and Zolotistaya in 1985. The success of breeding programme of seabuckthorn has been because of clearly defined goals, use of promising parent materials, use of effective breeding methods and selection for economic properties of seabuckthorn.

It can be seen that for the production of 21 improved varieties, the parent materials of seabuckthorn were used from Gomy Altai, Trans-Baikal and Siberian selections. Among these varieties, 3 varieties were developed through selection and 8 varieties through mutagenesis. During these breeding programmes, irrespective of parent material and methods used in the breeding, selection for main economic and biological properties were applied during the final stage.

Despite the release of improved varieties, breeders continue their work on the genetic improvement of genotypes for important characteristics like winter hardiness, early ripeness, higher productivity, richer in oil, vitamin C, carotenoids and pectin. On the one hand, further survey of wild populations for selection of better forms continues. On the other hand, work on hybridization between different better forms continues including methods of mutagenesis and biotechnology. Efforts have also been made on breeding of sweet forms of seabuckthorn. The fruits should contain sugars more than 9 per cent and acid more than 1.3 per cent. The most promising forms are Tenga and forms like "45-15-13" and "91-81-3" (Zubarev, 1998).

During the last 70 years, since 1933, more than 40 improved varieties have been developed at Lisavenko institute. Fruit yield varies from 7.5 to 18.0 t/ha, weight of 100 fruits varies from 62 to 120 g (maximum of 140 g), length of peduncle 3-6 mm, oil content 4-8 per cent, carotenoids 15-48 mg/100 g, sugar 5-10 per cent and acidity 1.0-1.9 per cent. The most of the varieties are thornless or mild thorny. The detail of characters of some of the Russian varieties are given below in Table 6.1 (Zubarev, 2005).

Table 6.1: Characteristics of Seabuckthorn Varieties Bred at Lisavenko Institute of Horticulture for Siberia, Barnaul, Russia

Variety	*Oil, %*	*Vit. C (mg/100 g)*	*Carotene (mg/100 g)*	*Sugar, %*	*Acid, %*	*Weight of 100 fruits, g*	*Fruit Yield* (t/ha)*
Novost	4.5	50	14.3	5.5	1.6	50	9.8
Maslichnaya	5.7	64	10.6	4.0	1.5	37	10.2
Dar Katuni	6.9	66	13.0	5.3	1.6	40	9.6
ZolotoyPochatok	7.1	68	12.8	4.8	1.5	40	10.2
Vitaminnaya	5.9	125	13.0	4.6	1.6	57	10.0
Zivko	6.3	53	48.2	6.2	1.2	56	13.0
Chuyskaya**	6.2	134	13.7	6.4	1.7	89	18.0
Chulishmanka**	6.2	169	23.3	8.0	1.4	62	12.5
Chechek**	7.8	157	24.7	7.8	1.3	77	15.1
Tenga**	4.9	110	21.0	7.0	1.3	67	13.0
Inya**	4.0	80	25.0	5.2	1.7	85	14.9
Elizaveta**	4.8	80	19.0	6.2	1.3	100	12.7
Altayskaya**	7.0	98	18.0	9.7	1.1	75	13
Avgustina**	6.7	82	20.0	9.6	1.6	120	7.5
Agurnaya**	6.2	112	12.7	8.3	1.9	110	7.5
Dgemovaya**	8.0	154	29.3	7.6	1.0	75	7.5

*** 1250 plants/ha, ** New varieties.** *Source: Zubarev, LIHS, Barnaul.*

Three methods were applied in the breeding of seabuckthorn, *i.e.* selection, hybridization and mutagenesis. After hybridization by over 100 crosses, about 50,000 hybrid seeds are obtained annually. Presently, there are 45,000 hybrid specimens of seabuckthorn at the institute.

In the breeding programme of seabuckthorn, it has been emphasized that the improved forms should adapt in the expected regions of introduction, must be superior in economic and biological characteristics to the existing forms of the that region, while meeting the local requirements, like early ripeness in the north and drought tolerance in the south and resistance to the attack of pests and diseases of introduction areas. The improved varieties released should be having wide genetic homeostatic.

CHARACTERISTICS OF SOME HIGH YIELDING SEABUCKTHORN VARIETIES AT LIHS, BARNAUL

There are many seabuckthorn varieties developed and adapted for the cultivation in Russia, features of some varieties, including new ones have been described below.

Avgustina

Cultivar was bred by selection of seedlings from open pollination of large-fruited forms ("Co-1 x Shcherbinka Katun" ecotype). It is a dwarf form without thorns, stem light brown, with a silvery gloss.

Fruits are large (weight of 100 fruit 110-140 g), egg-shaped, orange with a soft pulp, thin peel sweet and sour taste, and long peduncle (5.0-6.0 mm). It contains sugar-up to 9.6 per cent, acid-1.5 per cent, vitamin C- 111.6 mg/100 g, carotenoids - 20.0 mg per cent, and oil – 6.7 per cent. It is winter hardy. Fruit yields at 5 years of age is 5.2 kg per bush (6.0 t/ha). It is early ripening, the fruit ripens in mid-August. Fruit is multipurpose; the fruits are suitable as table fruit for fresh consumption and for processing of different types of products.

Elizaveta

Cultivar was bred by using the method of chemical mutagenesis. Seeds of varieties "Panteleevskaya" were treated in 1981 with a mutagen DES (0.05 per cent). Plant is bush type, oval crown with medium density and branches are dark brown. Fruits are large, weight of 100 fruits is 81.5-110.0 g, cylindrical, orange, and long peduncle (5.0-6.0 mm). Fruits have sweet and sour taste with a pleasant aroma. It contains 5.9-8.9 per cent sugar, acid 1.1-1.6 per cent, vitamin C 71.3-100.0 mg per cent, and oil 4.4-5.1 per cent. Winter hardiness is high. Yields in the 6 years of age is 14.7 and 18.01/ ha after 8 years. Bearing of fruit starts in the 4th year after planting. Fruits are of multipurpose, it is suitable as table fruit for fresh consumption and for different types of products processing.

Chuskaya

It is the most widely cultivated variety of seabuckthorn in Russia and many countries. It is sweet, fruits are bright orange in colour. Fruits are large in size (weight of 100 fruits is 70-90 g, oval in shape and bright orange in colour. It contains vitamin C-up to 134 mg/100 g of fresh fruit, carotenoids -13.7 mg per cent and oil-6.2 per cent. Yields in the age of 7 year is 12.5-14.7 t/ha. It is easy to harvest through hand picking and one can picking up to 100-150 kg in 8 hours.

Chechek

Cultivar was bred by selection of seedlings from open pollination in 1973 of selected forms "7-66-321 (1 x Shcherbinka Chulyshman ecotype) and Katun" ecotypes. It is bush type with a compact crown, without spines. Fruits are large, weight of 100 fruits is 77.0-95.6 g, broadly oval, orange, with large rosy spots at the base of the calyx and stem. Peel is thick. Peduncle length is 4.0-5.0 mm. Taste is sweet and sour. It contains sugar-up to 7.8 per cent, acid 1.3 per cent, vitamin C-up to 157.0 mg per cent, carotenoids-24.7 mg per cent and oil-up to 7.8 per cent. It ripens in late August-early September. The average yield after 4th year of fruiting is 16.8 t/ha.

Chulyshmanka

Cultivar was bred by using the geographically distant hybridization by crossing varieties in 1966 Shcherbinka-1 form of environmental Chulyshman and Gorny Altai. Variety was adopted in 1990. It is a dwarf form and has a strong and compact crown. Fruits are medium size (weight of 100 fruits of fruit 62.4-67.2), oval and bright orange. Taste is sweet and sour, with the aroma. Peduncle is long (5.0-6.0 mm). It matures during August 25-September 10. It contains sugar- up to 7.96 per cent, acid - 1.39 per cent, vitamin C-169.4 mg per cent, carotenoids-23.3 mg per cent and oil-up to 6.2 per cent. The average yields in the age of 7 years is 12.5 t/ha.

Dzhemovaya

The cultivar was bred by selection of seedlings from open pollination varieties. Fruits are oval, orange-red, with bright, large spot on the top and bottom of the fruit stalk. Weight of 100 fruits is 60.0-73.0 g. It is a late ripening variety. It contains sugar-up to 5.8 per cent, acid-1.3 per cent, vitamin C-154.0 mg per cent, carotenoids-29.3 mg per cent and oil up to 10.2 per cent. Yields in the 6 years of age is up to 6.0 t/ha and 7-year onward the yield is 16.0 t/ha. Plants come in bearing after 4 years of planting. Fruit is used for multi-purposes.

Tenga

Cultivar was bred in using the geographically distant hybridization by crossing the 1968 class, "Shcherbinka-1 and Aleem" ('Katun" ecotype). Fruits are medium size (average weight of 100 fruits 58.7 g, maximum 69.0 g), oval, bright orange, with medium-sized bright spots on the top and bottom of the fruit stalk. It is an early ripening variety. It contains sugar up to 5.8-9.8 per cent, acid 1.3-1.5 per cent, vitamin C 101.6-264.1 mg per cent and carotenoids 12.5-31.7 mg per cent. It is a high yielding variety; the yield after 6 year of planting is to the tune of 26.8 t/ha. It bears fruit every year, starting in the 4th year after planting.

Golden Siberia

Cultivar was bred by the method of geographically distant hybridization due to interbreeding in the 1961 class "Shcherbinka-1" with selective form of the "Katun" ecotype. Plant is bush with oval crown of medium density. Weight of 100 fruit is 80 g; peduncle length is 4-5 mm. Fruits ripens in early September. It contains up to 7.2 per cent sugars, titratable acids-1.76 per cent, oil-6.4 per cent, vitamin C-165.0 mg/100 g, 5.5 mg/100 g of carotene, vitamin E-5.2 mg/100 g and vitamin B-1.01 mg/100 g. Winter hardiness is high. Yields in the 6 years of age is 14.6 t/ha and after 7 years, it yields 25.6 t/ha.

Panteleevskaya

Cultivar was bred by crossing in 1968, ("Shcherbinka 1 x Katun" ecotype) with selective form of the "Katun" ecotype. Fruits are large, weight 100 g fruit is 80.5-110.8, oblong-oval, red-orange, sweet and sour. Peduncle length 3.0-4.0 mm. Flesh is firm and it contains: sugar - up to 5.8 per cent, acid -1.9 per cent, vitamin C - 87.5

mg per cent, carotenoids - up to 17.2 mg per cent, oil-5.7 per cent, vitamin E-to 10.5 mg per cent. Fruit ripen from 5th to 25th September. Yields in the 6 years of age 10.9t/ha and after 7 years, it yields 22.91 / ha. The fruits are suitable for various kinds of processing.

Rosinka

Cultivar was bred by selection of seedlings from open pollination of selected forms of "30-61-1363" ("Shcherbinka 1 x Katun"). It is a dwarf type with oval crown and sparse foliage. Fruit are large (up to 0.8 g /berry), wide-oval, orange, firm flesh with a sweet-sour taste. Peduncle length is 4.0-6.0 mm. It contains sugar 5.6-8.0 per cent, acid 1.3-2.0 per cent, vitamin C 40.2-92.0 mg per cent, carotenoids-up to 17.3 mg per cent, and oil 4.1-7.0 per cent. Fruit yield in 6-7* year after planting is 15.7 t/ha.

Besides above varieties, the most recent varieties are Klavdia and Essel, which are high in carotene content, have large fruits and are high yielding.

SEABUCKTHORN BREEDING STRATEGIES AT LIHS, BARNAUL

Scientists working at the Lisavenko Institute of Horticulture for Siberia (LIHS), Barnaul adopted the strategies for the development of seabuckthorn varieties, which are high yielding with large fruits and high oil, carotenoids and adaptable in varied environmental conditions, and resistant to cold and diseases and pests. Some of the aspects of breeding strategies are as follows:

Thorns

LIHS has evaluated over 1,000 seedlings of seabuckthorn obtained from various crosses, with varying degree of thorniness and observed that after crossing thornless varieties with those with few thorns produced a generation (up to 74 per cent of total numbers) with lesser thorns. For example, when experts crossed thornless female "Novost Altaya" with mild thorny male "Dar Katuni", they also got thornless plants, numbering 0.9-1.9 per cent. Consequently, these workers could obtain 5 thornless varieties, *i.e.* "Novost Altaya, Vitaminaya, Velikan, Prevoskhodnaya and Alei" and 13 mild thorny varieties (Kalinina, 1988).

Fruit Peduncle Length

Pedicle length and abscission affect the efficiency of mechanical harvesting. Therefore, fruits with long peduncle with easy separation are desirable for selection. Fruit skin toughness is an important trait, which affects the suitability for mechanical harvesting in seabuckthorn. Skin damage during fruit harvesting invites the growth of microbes, therefore, affecting the quality of raw materials and also causing crop losses. Forms were selected with not only larger fruit size, but also easily detachable by mechanical means. On crossing the "Chuyskaya" and "Kuddyrga-1" and other varieties with "Katun" ecotype, experts could produce promising hybrids. Improvement of length of peduncle helps in easy separation of fruits. The length of peduncle may vary from 1 mm to 10 mm. Some varieties with large peduncles (6-10 mm) are "Orangevaya, Luchezamaya, Chiulishmanka and Ulala", which makes it easier to pick up the fruits (Panteleeva, 1998).

Fruit Weight

Large fruits are considered easy to harvest. Breeders in order to increase yield, looked for large fruit size, especially large fruit pulp size. As a result of breeding work, they could produce the fruits with weight of 100 fruits from 37 to 120 g/100 (Zubarev, 2005). The "Maslichnaya" had smallest fruits (37 g/100 g), whereas it was as high as 100 g/100 in "Elizaveta" and 110 g in "Agurnaya" and "Avgustina" has largest fruits (110-140 g/100). There are varieties with large fruits with high oil content.

Yield

Breeders also focused on the fruit yield. Fruits are produced on the branches, buds of which are borne a year earlier. The fruit yield depends on the size of fruits, their density on the branches, number and length of fruit bearing branches. The Lisavenko Institute has the distinction of producing all high yielding varieties of seabuckthorn. For example, "Novost Altaya and Dar Katuni" varieties produced 11.3 tonnes and 12.7 tonnes per ha, respectively, for over 10 years of period at 4 m x 2 m spacing, while peaking at 23.1 and 27.6 tonnes per ha respectively, without any irrigation. Effect of reduced spacing was better, as "Chuyskaya" variety produced higher yield of fruits varying from 28.7 tonnes at 4 m x 2 m to 33.0 tonnes at 4 m x 1 m and even higher (49.2 tonnes) on being irrigated. The institute has recommended the following high yielding female improved varieties for orchard raising, "Vitaminnaya, Dar Katuni, Shcherbinki-1, Chuskaya, Oranzhevaya and Obilnaya" and following male varieties, "Katun and Sayan" (Kalinina, 1988). Their Evaluation studies on introduction in introduction areas found that seabuckthorn varieties have produced an average of 12.9 tonnes of fruits per ha in 5 ш year after plantation under orchard conditions at the experimental farm, Bamaulskoye, Altai, 16.0 tonnes in the Chistoozerny State Farm, Novosibirsk region and 13.1 tonnes in Magnitogorsky state farm in Chelyabink region. After 6 years of plantation, 3 varieties, "Samorodok, Chuyskaya and

Oranzhevaya" produced 11.1-16.0 tonnes per ha on an average and a maximum to 21.1-26.5 tonnes per ha in Gorky region. A 3-year old variety produced 6.7-9.4 tonnes fruits per ha in Yaroslavl region (Kalinina, 1988,). Most successful in Russia and China and promising in fruit yield has been "Chuskaya" with maximum fruit yield of 18 tonnes/ha. However, "Avgustina" with largest fruit of 120 g/100, had 7.5 tonnes of fruits per ha (Zubarev, 2005).

Breeding Strategies of Russian Seabuckthorn (Hippophae rhamnoides ssp. mongolica) Varieties

Winter Hardiness

Seabuckthorn, which belongs to temperate zone, may or may not tolerate winter frost. Seabuckthorn forms of Altai region, where Lisavenko institute is situated do not have significant winter damage due to extreme harsh conditions (-40 °C). However, in some regions of Siberia, floral buds of male plants of seabuckthorn are often frostbitten, sharply decreasing the number and viability of pollen, causing reduction of fruit yield in female plants. After evaluation of floral buds of 10 hybrid forms of male seabuckthorn, the breeders could select "Katun and Alei male" varieties (Kalinina, 1988).

Fruit Quality

Quality of fruit is an important parameter in seabuckthorn breeding programme. Seabuckthorn fruit is known mainly by presence of high contents of vitamin C, oil and carotenoids. Russian varieties are considered very rich in oil content (4.5-8 per cent) and carotenoids, they are generally not that rich in vitamin C (50-170 mg/100 g) (Zubarev, 2005), as compared to Chinese and Indian seabuckthorn. Variations in vitamin C contents have been widely found in geographical regions (Korovina and Fefelov, 2006). A low vitamin C correlation with fruit size has been reported (Karhu and Ulvinen, 1999). In hybrids, vitamin C content has been found related to the genotype of a male population. Other compounds of interests for a breeder may be vitamin E, riboflavin, niacin, folic acid, carotenoids and unsaturated fatty acids.

Bioactive compounds may be related to the characteristics of a fruit. In seabuckthorn, pigments and aromatic compounds occurs in fruit skin and hypanthium. Therefore, in case we want to extract mainly these compounds, then fruit skin characteristics and colour (red or reddish orange), etc. may be useful parameters for selection. For oil extract from the seeds, oil content and seed size are important criteria. Seed shape has not been studied to have any influence on oil content.

Initially, breeders believed that small fruits are richer in oil than large fruits. Soon, they discovered that even large fruits are richer in oil content than small fruits, as there was a positive correlation between fruit size and oil content. Consequently, breeders could produce improved forms with high oil content of 4.7-6.9 per cent, 50-330 mg/100 g vitamin C and 2.8-7.6 mg/100 g carotene. Vitamin C rich varieties are "Oranzhevaya, Sibirskaya and Yantamaya, Zolotistaya Sibiri". Carotene rich forms are "Luchezamaya, Panteleevskaya, Yantarnaya and Zolotistaya Sibiri" (Kalinina, 1988). "Zivko" has 48.2 mg/100 g carotenoid content and "Dgemovaya" has about 29.3 mg/100 g carotenoids in the fruits. "Chechek" and "Dgemovaya" have 7.8 per cent and 8 per cent oil, respectively. Varieties with medium oil content, but with high fruit productivity or yield like "Chuyskaya" (6.2 per cent oil and yield 18 t/ha) have been considered useful for raising orchards, as total oil production will be higher than from oil-rich forms with lower fruit yield. However, consideration of high contents of carotenoids and tocopherols are important priority.

Pollen

The number of pollens and duration of their release, compatible with the development of female flower, directly affect the fruit yield. Therefore, it is an important parameter for selection that male plants produce optimum quantity of pollen at the time of female plants is in flowering stage with receptive stigma (Buglova, 1981). Russian breeders have developed a number of male varieties with promising characteristics "Dar Katuni, Katun, Sayan and Aley"".

Varieties for Handpicking

Presently, seabuckthorn varieties are provided to the growers, which collect fruit by handpicking. Varieties of seabuckthorn have been developed which are easy for hand-picking for fruits, *i.e.*

"Chuyskaya, Inya and Avgustina ", etc., in which a person can collect 100-150 kg fruits in 8 hours by handpicking method. Some high yielding cultivars have been developed, which are suitable for handpicking of their fruits and a person can collect as high as 200-250 kg in 8 hours.

Varieties for Mechanical Harvesting

Handpicking of seabuckthorn is very expensive and time consuming in Russia, therefore, the Lisavenko institute has developed a mechanical harvester, which can harvest 10 tonnes of fruits per 8 hours. However,

most of the varieties are not suitable for mechanical harvesting; therefore, breeders have been working on varieties rich in economic and biological characters and also suitable for mechanical harvesting of fruits. The main characters for mechanical harvesting of seabuckthorn are easy and dry separation of fruits, long peduncles, compact crown, moderate growth and strong branches.

Harvesting Period

In order to expand harvesting period, breeders have produced early and late harvesting varieties of seabuckthorn. Consequently, they could extend the harvesting to 2.5-3.0 months of fruiting period, *i.e.* from second half of July to the middle of October. Further, varieties are also being developed, which can be mature and develop fruits during winter, while maintain their biochemical quality.

Pest and Diseases Resistant

For the higher yield and better acceptability in market, breeders have given special attention to the development of varieties, which are resistant to pests and diseases like *Fusarium*, which infect plants even in nursery stage.

Taste

Taste of seabuckthorn fruits is an important parameter for utilization in various products development. However, the sugar-acid index (SAI) can be used to decide the taste of seabuckthorn fruits. The sugar-acid index of seabuckthorn fruits under the Altai conditions is on the higher side. On the basis of the studies, the experts at this institute have made a table to decide the taste of the fruit on the basis of sugar-acid index (Table 6.2).

Table 6.2: Sugar-Acid Index and Taste Relationship in Seabuckthorn Fruits

Sl. No.	*SAI*	*Taste*
1	<4	Sour
2	4-6	Sweet sour
3	6-8	Sour sweet
4	>8	Sweet

Source: **Zubarev (2005).**

Dissert Varieties

Seabuckthorn has high demand in fresh juice, juices without addition of sugar, beverages, jams, etc., therefore, considering requirement of health food products, dissert varieties are being developed under the breeding programme. For health food production, vitamin C rich varieties are given preference. However, for cosmetic and medicines production, seabuckthorn varieties having oil with high content of oil, carotenoids and tocopherols are preferred.

BREEDING OF SEABUCKTHORN AT OTHER INSTITUTES IN RUSSIA

Nizhny Novgorod State Agricultural Academy (NNSAA), Nizhny, Novgorod

Like the Lisavenko Institute, NNSAA, earlier known as Gorky Agricultural Institute, has also been in front of research work on breeding of seabuckthorn in Russia. Work on selection and introduction was started in 1949 by I.P. Eliseev. The first cultivars "Scherbinky-l and Scherbinky-2" were selected from Sayan and Irkut rivers region. Scherbinky-l was used for many hybrid varieties development. Five varieties were developed by mutagenesis methods. These varieties have large fruits, few thorns and dwarf type. The institute developed hybrids from crosses between "T-50 x Katun and T-50 x Sayan". The pollinator was obtained from seeds of "Katun 24" irradiated with by gamma rays (50 cR) (Fefelov, 1998). The institute has selected hybrid cultivars and elite forms of seabuckthorn with high content of carotenoids like "Zarevo (259 ppm), Nadezhda (316 ppm), Plamennaya (224 ppm) and Ryabinka" (333 ppm). The forms with red colour and high contents were developed like "Gomelskaya, T-50, Karatal 8" and a male form "K-24 and Otradnaya" (Fefelov and Selekhov, 2009).

The Buryat Fruit and Berry Experiment Station (BFBES), Ulan Ude

The focused work on seabuckthorn breeding started since 1976 at BFBES, Ulan-Ude. More than 80 forms were tested from various regions like Temnik, Selenga, Irkut rivers, etc. 7 varieties like Atsula, Ajayganga, Stepnaya, Sayana, Bajyan-gol, Baykal Ruby and Naran have been finalized and introduced. Zarya Dabat was

developed by mutagenesis (Myahanova, 1998). The oil content in fruits was quite high in "Sayana (7 per cent) and Naran" (9 per cent). The best results of fruit production were at spacing of 4 m x 1.5 m (Shripnimbueva and Myakhanova, 2009). The cultivars "Novost Altaya, Maslichnaya and Prevoshodnaya" were high wilt resistant (Fefelov and Selekhov, 2009).

Institute of Cytology and Genetics, Novosibirsk

The institute developed a number of varieties of seabuckthorn in collaboration with Novosibirsk Zonal Fruit and Berry Experimental Station. The main focus was to develop hybrid varieties with large fruits and few or no thorns. Some of the varieties are- "Rumyanets" with red fruit and high carotene content, maturing in mid August; "Druzhina" is an early ripening (mid August), dwarf plants and large fruits; "Kapriz", early ripening with high sugar content (up to 10 per cent) and pleasant aroma; "Podruga" with very large fruits (0.9-1.1 g); and "Zamitsa" late ripening, orange-red colour fruit with high carotene content (28.8 mg per cent) and oil (4.5 per cent), etc. (Kreymer *et ah,* 2009).

"Triumf", a hybrid form was developed by Shchapov (2009). Fruits are large (0.7-0.8 g) with red colour, large pedicle (5-8 mm), vitamin C 93 mg/100 g, carotene 3.4 mg/100 g and oil 4.3 per cent. It is late ripening (mid September). The fruit yield is 11 kg per plant. As a results of mutagenesis, a number of seabuckthorn varieties were produced in Russia, among them "Zyrianka" being prominent, which has been introduced in Russia and other countries. The weight of 100 fruits was 61-64 g, vitamin C-110 mg/100 g, carotenoids-19.7 mg/100 g and fruit yield-13.9 kg/plant (Privalov, 1986).

Minusinskaya ESHM, Naberezhnaya

U.G. Leonova selected the first 2 varieties "Skorospelka and "Kukuruzka", were early selections from Baikal ecotype, but planted in limited area due to many thorns and small fruit size. Varieties like "Obilnaya, Prevoskhodnaya and Chyuiskaya", and pollinator "Aley" collected from LIHS, Barnaul were introduced in southern area of Krasnoyarskiy region. But, there were problems like attack by seabuckthorn fly. Many varieties with high economic characters were introduced with promising results. New varieties like "Minusa and Solnechnaya" were developed and introduced in middle Siberia. They achieved as high as 25 tonnes/ha yield (Smykova, 2009).

Michurin Zonal Fruit and Berry Growing Experimental Farm, Novosibirsk

Research work on selection and breeding was started with the purpose of development of varieties, with high economic characters and high contents of biologically active compounds. The institute developed collaboration with Institute of Cytology and Genetics, Novosibirsk. Work started in 1995 with new varieties "Podruga and Zolotoi Kaskad" and 5 other commercial varieties. The maximum vitamin C content was found in "Krasny Fakel (148 mg per cent) and Ivushka" (115 mg per cent). A high content of carotenoids (46 mg per cent) was estimated in red fruits of "Sibirsky Rumya-nets". A high content of fruit oil (6.3 per cent) was found in "Krasny Fakel" (Karpova, 1998).

Moscow State University, Moscow

Work started on introduction of seabuckthorn at Botanical Garden of Moscow State University, Moscow in 1952. The main focus was to introduce high yielding seabuckthorn varieties able to grow in stress conditions. Out of the 32 seabuckthorn varieties, 7 have been brought under cultivation in orchards, which are "Trophimovskaya, Botanicheskaya, Botanicheskaya Aromatnaya, Botanicheskaya Lubitelskaya, Moskvichka, Ortradnaya and Perchik" (Aksenova and Dolgacheva, 1998).

INTRODUCTION OFRUSSIAN SEABUCKTHORN VARIETIES IN OTHER COUNTRIES

Due to their useful economic characters like few or no thorns, large fruits, high fruit yield and oil content, Russian seabuckthorn varieties have been introduced in over 20 countries like CIS countries, China, Mongolia, Canada, USA, India, Finland, Germany etc. Experience of introduction and evaluation of some the countries are given below.

China

As local seabuckthorn species like *H. rhamnoides* ssp. *sinensis*, the most popular one, have small fruits and many thorns, they are difficult to harvest and could not be introduced in orchards for commercial purpose on scale, as initially planned in China. Therefore, improved Russian varieties, mostly thornless have been introduced in many provinces of China at several places. They are being used as pure cultures for commercial cultivation or for cross hybridization. Generally, local names have been given to Russian varieties being cultivated. For breeding purposes, further selections are being carried out after evaluation tests as well as

female Russian seabuckthorn, which have good economic characters, are being used for cross with male Chinese ssp. *sinensis,* which are widely adapted.

About 20 seabuckthorn varieties with large fruits and thornless had been imported by Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yanling from Novosibisk, Moscow and Ulan-Ude of Russia during 1995-2004. They have tentatively selected 9 fine seabuckthorn varieties for evaluation in the 7 experimental sites in this area (Daiqiong *et al.,* 2014). They have characters of fine growth, resistance and higher fruit yield. They have tentatively selected 9 fine Russian varieties of seabuckthorn ("Zirianka, Druzhina, Red torch, Ivshca, Batanical Garden, Buliyate, Panjielieyewa and Yalishanda") and developed 7 experimental bases in the "three Northern Areas" (Qiqihaer, Fuxin, Dalian, Huhehaote, Eerduosi, Wuqi, Ansai) and Loess plateau in China. These regions belong to moist, semi moist and semi-arid areas within dry temperate zone and temperate zone, respectively. There are natural forest and huge plantations of seabuckthorn in these regions. The early evaluation studies found the diameter of fruits of Russian varieties have been found to be 9-14 mm, length of fruit stalk is 2-4 mm, weight of per 100 fruits is 20-60 g and early fruit yield per plant is 0.9-3.1kg. These values are 1.8-2.5,1.3-2.7, 4.6-8.8 and 3.8-6.2 times higher than local wild Chinese seabuckthorn, respectively (Table 6.3). Russian seabuckthorn has the characteristics of larger fruit, no thorns and high yield. The quality, oil contents and active substances of Russian seabuckthorn varieties are higher than local wild Chinese seabuckthorn, therefore, they are important genetic materials for introduction and selecting economic forms for improving the Chinese seabuckthorn.

Table 6.3: Early Results of Characteristics of Fruits of Introduced Russian Seabuckthorn Varieties in some Regions of China

Name of Russian Varieties	*Fruit Length (cm)*	*Fruit Breadth (cm)*	*Length of Fruit Stalk (cm)*	*Weight of 100 Fruits (9)*	*Fruit Yield (kg/piant)*
Zirianka	0.9-1.4	0.7-1.0	0.2-0.4	32.7-52	1.9-2.2
Druzhina	0.9-1.3	0.7-0.9	0.2-0.4	26-40	2.7
Podruga	0.8-1.1	0.7-0.9	0.3-0.4	30-39	2.3
Sibirian Rumianes	0.8-1.1	0.7-0.9	0.2	32-41	0.9
Gold Cascad	0.8-1.1	0.6-0.8	0.3	40	1.2-2.6
Red torch	0.8-1.1	0.6-0.9	0.2-0.3	42	1.8
Ivshca	0.9-1.3	0.7-0.9	0.4	60	2.9
Ornistaya	1.1-1.2	0.8	0.2-0.3	60	2.6
Zarnitsa	1.0-1.2	0.7-0.9	0.3	43	1.5-2.5
Botanical Garden	1.1	0.8	0.3	45	1.6
Panjielieyewa	1.4	1.0	0.3	46	1.9
Buliyate	1.0	0.8	0.3	42	1.3
Yalishandai	1.3-1.5	0.9	0.4	46-60	3.1
Non-seed SBT	1.0	0.8	0.4	23-52	0.6-2.0
OrangexChinese SBT	1.0	0.9	0.3-0.5	31-503	2.1
AzhulaxChinese SBT	0.7-0.9	0.9	0.4-0.5	23-52	0.6-2.0
Chinese SBT(CK)	0.4-0.6	0.3-0.5	0.1-0.2	7-7.4	0.4-0.65

SBT: Seabuckthorn.

Source: **Daiqiong** *et at.* **(2014).**

However, the nutritional values of Russian seabuckthorn are lower than Chinese wild seabuckthorn. The height, crown and diameter at butt end of Chinese seabuckthorn are 1.5-2.5 m, 1.3xl.5 m, and 4-5 cm, respectively and these values are 1.2-1.9,1.3-2 and 1.3-2.2 times of Russian seabuckthorn. The main reason was that the introduced Russian seabuckthorn has lower adaptability and resistant capability, especially lower resistance to dry conditions and high temperature during summer, and also to plant diseases and insect pests. On the other hand, Chinese seabuckthorn has strong adaptability and higher content of vitamin C. The adaptability and growth potential of hybrid varieties of the Russian seabuckthorn and Chinese seabuckthorn are promising. The plant height of 4 years hybrid "Orange x Chinese seabuckthorn" was 1.7-2.3 m, while the

length of new branch was 30-48 cm, diameter of fruit was 0.7-1.0 cm and weight of 100 fruits was 23-50 g. These properties and stability of inheritance should be observed successively.

Institute of Yancheng Technology introduced 1-year old seedlings of 8 cultivars from the Institute of Cytology and Genetics Siberian Branch, Novossibirsk, Russia in 1999 (Ruan *et al,* 2004). Plants were maintained at the Institute of Yancheng Technology's Test Garden, Yancheng, Jiangsu Province, China. They were evaluated with cultivars from China and Mongolia. The names of Russian varieties have been changed to local names. The performance and yield of these cultivars are given in Table 6.4.

Table 6.4: Performance Evaluation of Russian Varieties and Hybrids of Russian and Chinese Seabuckthorn

Code	*Variety*	*Native*	*Growth and Yield*
XY	Xiangyang	Russia (ssp. *mongolica)*	Height about 2-3 m, resistant withered disease, no thorn, orange and columnar fruit, mean weight per fruit of 0.98 g and yield of fresh fruit over 22.5 t/ha
CS	Chengse	Russia (ssp. *mongolica)*	Height about 3 m, late maturing, few and in firm thorn, salmon pink and oblong of fruit, mean weight per fruit of 0.66 g and yield of fresh fruit of 12.0-33.0 t/ha
CY	Chuyi	Russia (ssp. *mongolica)*	Height about 2.5 m, no thorn, round fruit, mean weight per fruit of 0.90 g and yield of fresh fruit over 9.0 t/ha
ALY	Aleiyi	Russia (ssp. *mongolica)*	Male pollinator type, strong growth vigour, height over 3.8 m, cold resistance in flower, plentiful pollen and strong viability (95.4 per cent)
ZL	Zeliang	Russia (ssp. *mongolica)*	Selection from wild seabuckthorn, treated by gamma-ray for breeding, height about 2.5 m, longer fruit stalk (6-7 mm), small and infirm thorn, shallowly orange-yellow and columnar fruit, mean weight per fruit of 0.64 g and yield of fresh fruit of 11.4 t/ha
HGG	Houguang	Russia (ssp. *mongolica)*	Hybrid of “Huoju x Zeliang No. 104”, no thorn, oval and orange-red fruit, mean weight per fruit of 0.60-0.70 g
NY	Nuyou	Russia (ssp. *mongolica)*	Hybrid of “118/4 x 120/2” of the cultivars, strongly resistant to cold, oval and orange-yellow fruit, no thorn, mean weight per fruit of 0.90-1.10 g and yield of fresh fruit of 12.7 t/ha
HY	Hongyun	Russia (ssp. *mongolica)*	Seedling of open-pollination of “101T, red-fruit type, strongly resistant to cold, resistant withered disease, oval and red fruit,mean weight per fruit of 0.60-0.70 g
LHYH	Liaohuerhao	China (Hybrid)	Hybrid of “Qiuyisike” from Russia x H. *rhamnoides* subsp. *sinensis* from China, height about 2.2-2.3 m, thorn in top branch and no or few thorns below, dark saffron-yellow and columnar fruit, fruit stalk of 0.3-0.4 cm, mean weight per fruit of 0.55-0.61 g

Source: **Ruan** *et* **al. (2004).**

As early as 1990, the Institute of Berries of Heilongjiang, Academy of Agricultural Sciences, Suiling, Heilongjiang, China had introduced the varieties of seabuckthorn from the Lisavenko Research Institute of Horticulture of Russia, to carry out experiments on the breeding and cultivation (Shan *et ah,* 2014). The promising Russian varieties, locally named were "Chuyi, Hunjin, Chengse and Wulangemu" to cultivate in the region.

Canada

Selections of Russian varieties (ssp. *mongolica)* were released for propagation in nurseries for commercial cultivation in 2000 in Saskatchewan, Manitoba and Alberta. The nurseries were raised at Prairie Plant Systems in Saskatoon, D'nA Gardens in Elnora, AB and Day Spring Nurseries in Teulon, MB. The orchards are in early stage of evaluation (Wang, 2007). The early results of evaluation some of the selections are as follows:

Breeding Strategies of Russian Seabuckthorn (Hippophae rhamnoides ssp. mongolica) Varieties

Chuyskaya

It was introduced from Russia in 2001 and fruit is harvested during mid to late August. It has few or no thorns. For pollination, "Sergei" variety is used. The weight of 100 fruits is 97.3 g, moisture content being 87.4 per cent and yield is 1.3-1.9 kg/plant.

Samarodok

The fruit yield is 0.8-1.3 kg/plant, weight 72.7 g/100 and moisture 87 per cent.

Vitaminnaya

It was also introduced in 2001 and harvested by mid to late August. It is also thornless or mild thorny. It is pollinated by "Sergei". The fruit yield is 2 kg/plant and fruit weight being 61.7 g/100 with moisture content 88.9 per cent.

Orangevaya

Introduced from Russia in 2001, harvested during mid to late August, cross pollinated by "Sergei" and has few or no thorns. The fruit weight is 58.8 g/100 and yield being 6 kg/plant.

Obilnaya

It has similar features like "Vitaminnaya", but less yield of 2.2 kg, and but larger fruit weight 86.4 per cent and moisture content 86.6 per cent.

USA

The cuttings of 5 cultivars of Russian seabuckthorn ("Dar Katugne, Tchyskaja, Orangevaja, Maslitchnaja and Tchuiskaja") were introduced from the Altai region of Russia to Trout Lake (sandy loam soil of volcanic origin, pH 5.6) and White Salmon (alluvial soil, pH 5.5), Washington in 1996 (Lobatcheva *et al,* 2002). The saplings were transplanted to the fields at the end of April, 1997. All the plants were treated with standard agronomic practices, with additional irrigation during hot and dry summer seasons. Plant and fruit performance of each cultivar was closely monitored. The yield, oil content and composition of fruit of cultivars were evaluated after 4 years of plantation.

Performance of 3 cultivars "Dar Katugne", "Orangevaja" and "Tchuiskaja" was most successful. These cultivars achieved 115 to 125 cm height after 4 years. Most of the morphological features were similar to original ones as estimated in Siberia. Leaf and berry size, and colour and plant thorniness are presented in Table 6.5. The fruit yield (Table 6.6) was about 25 per cent less than estimated in Siberian growing conditions. However, oil percentage of the dried fruit, total carotenoid content, and flavour was similar with plants grown under the western Siberian conditions (Table 6.6).

Table 6.5: Features of 3 Seabuckthorn Cultivars Introduced from Western Siberia (Altaiskii Krai, Russia) Grown Washington State after Five Years of Growth

Cultivar	*Plant Height (cm)*	*Leaf Length (cm)*	*Leaf Colour*	*Fruit Colour*	*Fruit Weight (9/100)*	*Plant Thorniness*	*Start of Flowering*	*Start of Ripening*
Dar Katuni	115	16	silver green	Red	46	Thorny	May 27	Sept. 25
Orangevaja	125	17	dark green	Yellow orange	67	Thorny	May 29	Sept. 28
Tchuiskaja	118	17	silver green	Orange	68	Less thorny	May 22	Sept. 22

Sourcer. **Lobatcheva** *et al.* **(2002).**

Cultivar	*Fruit Yield (kg/plant)*	*Fruit Size (mm^2)*	*Dry Matter (per cent)*	*Oil Content (per cent of dry fruit)*	*Total Carotenoids (mg per cent)*	*Taste*
Dar Katuni	3.6	28	31	27.6	25.6	Acidic sweet
Orangevaja	5.1	26	39	38.9	35.8	Like orange
Tchuiskaja	6.52	25	33	31.3	42.8	Bitter sweet

Source: **Lobatcheva** *et al.* **(2002).**

Belarus

Belarus was a part of former Soviet Union, therefore, seabuckthorn varieties were introduced from Russia to Belarus. Institute of Fruit Growing, Samokhvalovichy, Belarus collected 19 Russian seabuckthorn varieties during 1980s. Further during 1992-2006, evaluation work of 23 Russian seabuckthorn varieties was done. Seven promising hybrids were developed by V.A. Phephelov. Recently, variety "Plamennaya" having high fruit productivity (17 t/ha), large fruit (0.8 g) and rich in compounds was released for cultivation (Shalkevich and Radkevich, 2009).

India

The first Russian seabuckthorn variety was introduced through seeds at Research Farm of CSK Himachal Pradesh Agricultural University at Kukumseri, Lahaul, a dry temperate region of Himalayan state of Himachal Pradesh (Singh and Singh, 2004; Singh *et al,* 2011). Named with code word as "HI-1" (H. *rhamnoides* ssp. *mongolica),* a mild thorny form, presently it is being multiplied and will be provided to growers. The fruit weight is about 30 g/100, oil content of yellowish fruits is about 5 per cent. The fruit yield is about 5.4 kg/plant and productivity is 10.2 tonnes/ha. It is harvested in August month. Further two more Russian varieties have been introduced, which are under evaluation process.

CONCLUSION

Russia has a long history of breeding work on the improvement of seabuckthorn forms. Several cultivars and varieties were developed over the last 70 years. Russian seabuckthorn varieties are characterized by large fruits (30-120 g/100), high productivity (6-18 tonnes/ha), mild thorny or no thorns and high oil content (4-9 per cent) and carotenoids and easy harvesting, however, lesser in vitamin C content (50-150 mg/100 g). The Altai region of Siberia is the main area of natural distribution of many promising forms of seabuckthorn. Varieties have been developed by selection, hybridization and mutagenesis methods, mainly at 5-6 institutes. There are some important economic characters, which need to be considered before their introduction in other regions. Russian varieties have been introduced successfully in CIS states, China, India, Europe and north America. There have been some difficulties too like failures, or small size and fruit yields and re-occurrence of thorns in dry regions like Loess plateau, China. However, hybridization of Russian female plants (ssp. *mongolica)* and local male plants (ssp. *sinensis)* have been very successful in such regions. Among the various Russian varieties, the most successful varieties are "Chuyskaya", which has been introduced in Russia and other countries on large scale. Some of the Altai forms have also been susceptible to diseases and pests too on introduction in new regions. But largely, Russian seabuckthorn varieties have been very successful and becoming the basis of commercial cultivation globally.

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