

New crops: an alternative for the development of horticulture

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Abstract

New crops have historically played an important role in the progress of mankind; on studying any region of the world, it can be found that many of its most important crops did not originate there, but were new crops at the time of their introduction. Nonetheless, there are still many underexploited or neglected crops and non domesticated species that could develop as new crops in many regions world-wide. The diversification of horticulture to introduce these new crops is growing in interest as they can result in an increase of income for farmers, contribute to a more environmentally friendly horticulture, reduce the risk of crop failure, and increase ethnobotanical knowledge. In order to be successfully established, a new crop must adapt to the new agroecological and production conditions, as well as to the demands of the markets and consumers. Despite the interest in introducing new crops, the lengthy process involved, usually taking many years or decades, may discourage introduction attempts, especially by private companies. However, many examples show that research on the introduction of new crops has been very profitable on a country scale, therefore reinforcing the importance of public research on such projects, particularly in the early stages.

Key words: Underexploited crops, adaptation, stability, public research.

Introduction

Mankind has constantly demonstrated a great interest in new crops as they present opportunities for improving crop production and food supply, to the extent that most of the relevant crops grown in a particular region are usually native to other regions. Thus, any cultivated species grown in an area different to its centre of origin was, at one time, a new crop. Most of the important species for agriculture in the USA¹ such as soybean (*Glycine max*), wheat (*Triticum aestivum*), rice (*Oryza sativa*), beans (*Phaseolus* spp.), lettuce (*Lactuca sativa*), tomato (*Lycopersicon esculentum*) or citrus (*Citrus* spp.) are not native to North America². Historically, the introduction of new crops has occurred thanks to the passage of plant material through trade routes or by contact among cultures. The discovery of America has been the most important marker on the adaptation of new crops, which resulted in an enormous exchange of species between the Old and the New World. Nowadays it is estimated that 40% of economically relevant crops originated in America, a fact that sometimes makes it difficult to imagine Old Worlds culture and gastronomy without many American-originated crops. For example, corn (*Zea mays*), sunflower (*Helianthus annuus*), potato (*Solanum tuberosum*), tobacco (*Nicotiana tabacum*), peanut (*Arachis hypogaea*), cocoa (*Theobroma cacao*), beans, squashes, pumpkins and gourds (genus *Cucurbita*), tomato, capsicum pepper (*Capsicum annum*) and many others originated in the New World, and all of them were “new crops” in the Old World a few centuries ago. On the other hand, many Old World crops adapted well in America³, and this continent has become the main producing area for them, e.g. soybean (Chinese origin), coffee (*Coffea arabica*, Africa and Arabia) or banana (*Musa paradisiaca*, Southeastern Asia)¹. A relatively modern and planned attempt to adapt foreign species was carried out by the British Empire during 18th and 19th Centuries. In the search for economically interesting plants, their collection and evaluation using an impressive colonial network of botanical gardens linked to Kew Gardens was performed in a very

methodical way⁴. There were several outstanding stories of their endeavour, such as the establishment of rubber plantations (*Hevea brasiliensis*) in South-eastern Asia, after seeds and plants were smuggled from Amazon plantations; the search for plantlets of breadfruit (*Artocarpus altilis*), native to Polynesia and destined as food supply for slaves in the Western Indies, and that derived in the famous Bounty mutiny; or, the introduction of cinchona (*Cinchona* spp.) in the colonies of Africa and India from South America, due to the medicinal importance of quinine against malaria.

New Crops and Biodiversity

Over 250,000 flowering species have been described (although the total number is believed to reach around one million). Approximately 50,000 of these species are edible, of which 3,000 have been used as a source of food by mankind⁵. However, at the end of the 20th century only eleven crops (wheat, rice, corn, barley, sorghum/millet, potato, sweet potato/yam, sugarcane and soybean) contribute to more than 75% of the World human food supply. More worryingly, 60% of the calories consumed in the world derive from only three crops (rice, corn and wheat), and the trend is towards a concentration of production to fewer and fewer crops⁶. Among the huge number of edible species, there are several little known species that have either been neglected or only have local relevance that could be very interesting for horticulture diversification. Although the denomination “new crop” seems to be more appropriate for recently domesticated plants, it usually refers to exotic crops. Curiously, most of these “new crops” were domesticated thousands of years ago, although there are examples of recent domestication (centuries XIX-XX), such as various berries belonging to genus *Rubus* that are currently being introduced and improved in Europe⁷, or the present domestication programmes of berries like cloudbberries (*Rubus chamaemorus*), native to Northern Europe⁸.

Why Introduction of New Crops is of Interest?

The diversification of horticulture through introduction of new crops is desirable for several reasons:

a. New crops represent an alternative to growers and markets with produce of high value, and for which usually there is no overproduction. The interest in new fruits and vegetables has increased recently, and there has been an increasing demand for new tastes and innovative foods⁹. In parallel, the increase in population belonging to ethnic minorities in Europe and Northern America and of restaurants specialising in foreign cuisine has led to a demand for horticultural products which are not common in these regions. These crops show good market prospects as new crops in these countries.

b. Diversification may contribute to a sustainable horticulture because:

* The higher the spatial diversity of crops in a particular area (different species in the same region) and/or temporal diversity (crop rotation), the lower the number of problems caused by pests and diseases¹⁰.

* The cultivation of a greater number of crops allows a higher efficiency in the use of production factors. Different crops may show the same requirements at different times and this means a more rational use of infrastructures, machinery and labour, and minimises the problem of seasonal labour¹⁰.

* Physiological and nutritional complementary requirements of different species can be exploited, optimising soil performance and avoiding soil nutrient depletion and proliferation of soil pathogens caused by monocrop¹¹.

* Increasing the number of crops allows an optimum exploitation of the crop×environment interaction by using the most suitable crops for each environment, which avoids dramatic environment alteration, reduces inputs, and minimises contamination¹².

c. A greater number of crops favours stability of production and growers' income because the cultivation of a higher number of species decreases risks against unpredictable environmental and market changes¹³.

d. The introduction of a new crop contributes to improve ethnobotanical knowledge, which is a substantial part of folk culture.

Desirable Attributes in New Crops

Not all crops have the same opportunities for success on being introduced in a certain region. Success will depend on several characteristics of the new crop:

a. Satisfactory performance under the new agroclimatic conditions. In this sense, crops from climates similar to those of the region where the introduction is intended and without restrictive physiology requirements (photoperiod, vernalization, etc.) have more possibilities of becoming successfully established. Moreover, the higher the genetic diversity tested the more chances of a positive result in its introduction. Evaluation of different genetic backgrounds improves the opportunities to exploit variation for local adaptation¹⁴.

b. Easy adaptation to the cultural practices common in the main crops of the new region. Growers will be attracted to a new crop if it adapts well to the existing crop techniques, rather than learning new methods.

c. Prolonged production and supply periods. If a crop is only available for a few weeks in the year, its introduction will be more difficult than that of others that can be produced and offered to the consumer for several months or all the year round.

The cultivation in different areas and the use of forcing techniques and postharvest conservation help to obtain a more extended supply of the product.

d. Resistance to transport and handling, as they are key factors in marketing fruits and vegetables at long distances and on foreign markets.

e. Extended postharvest life, enabling the produce to arrive at markets in good condition and fluctuation in production be regulated if necessary.

f. New crops must adapt to existing marketing channels for horticultural products. Creating a new marketing channel is a very time- and money-consuming process.

g. Original and attractive to consumers. The new product must be attractive to consumers in terms of colour, aroma, shape, etc., and this may change from country to country (or even from region to region).

h. Suitable taste for consumers. Taste preferences vary according to the region. For example, European consumers usually prefer fruits with high sugar level, while Far East consumers prefer more acidic or bitter fruits.

i. Easy to consume and elaborate. It is more difficult to introduce products that require complicated preparation.

j. Healthy attributes. The demand for "healthy" foods containing high levels of fiber, vitamins, minerals or substances with antitumour or diuretic activity has increased, and these attributes can be of great help in introducing a new crop¹⁵.

Many vegetables are only important at a local level, although some of them show interesting characteristics worthy of introduction in other regions. An example of African and Asian origin vegetable crops with potential for their introduction in several mild climate regions can be found in Table 1. Another example comes from the Andean region called "la Sierra", a mild climate area which holds an enormous range of fruits with good prospects for their introduction into other mild climate or subtropical regions¹⁶. A successful story was the introduction of tree tomato or tamarillo (*Cyphomandra betacea*) into New Zealand. Tamarillo cultivation has been fully established for several decades on the North Island^{17, 18}, and the fruit is part of the so-called "kiwi" gastronomy¹⁹. From our experience, tamarillo, pepino (*Solanum muricatum*) and cape gooseberry (*Physalis peruviana*) fit many of the desirable attributes described above and have shown satisfactory results in some European countries^{20, 21, 22} and therefore are of interest for horticultural diversification in Europe.

Introduction of New Crops: A Usually Lengthy Process

There are few cases of instant success in the introduction of new crops. Many crops were introduced into the Old World after the discovery of America, although their level of acceptance varied with some of them not succeeding at first. Two different examples are found in two relevant vegetables: pepper and tomato. Capsicum peppers, had an early acceptance and its cultivation was fully established a few years after being introduced. At that time, hot peppers became an alternative to black pepper (*Piper nigrum*) and this surely contributed to its rapid world-wide distribution²³. On the contrary, tomato, nowadays the most important vegetable, did not have the same success and was slow to become fully accepted. It was brought into Europe a few years after the discovery of America. However, it was consumed firstly in Spain and Italy only, whereas the rest of European countries rejected it (perhaps

because of its red coloured skin, usually an indication of toxicity in nature, and also because many Old World *Solanaceae* are toxic) restricting it to ornamental use until the 19th century²⁴. The same reasons could explain its late introduction in the USA, despite its geographical proximity to Mexico²⁵. Potato was another Andean solanaceous crop with slow acceptance in Europe. It was first grown merely as a curiosity and later as food for cattle, and was only finally accepted as human food in the 18th century. Like the tomato, it was believed to be a poisonous plant. In fact, all organs, apart from tubers, are poisonous.

Nowadays, scientific and technologic advances can reduce the lengthy process of centuries ago in the introduction of a new crop because of present knowledge in plant physiology, pathology, genetics, breeding, and biotechnology. However, this process is still relatively lengthy and affected by many unpredictable factors, taking several years or decades²⁶. The most important steps in the development of a new crop are mentioned below. The first stage involves a study of the suitability of the new crop. It is essential to evaluate the attributes it shows (originality, nutritional key points, potential market, and adaptation to agroecological conditions). Having knowledge of the climate and soil characteristics and how it is grown in its region of origin are essential, as well as those conditions that could result in an improvement in its behaviour. All this information will aid the search for potential growing areas, as frequently, a species shows its optimum behaviour under a limited range of environmental conditions.

Once these aspects have been compiled, the next step is to conduct preliminary field plot research. The goal of this research is to test or develop genotypes or varieties that show satisfactory adaptation and to obtain basic information about production practices and pests and diseases affecting the new crop. A critical aspect deals with the use of sufficient genetic variation in the trials. Many attempts to adapt a new crop to a new region have failed because of the use of limited genetic variation (one or two cultivars)¹⁴. In this way, different genotypes show different behaviours under the same environmental conditions, and this may allow for the selection of individuals or populations with the most satisfactory behaviour (i.e. exploiting genotype×environment interaction) either for direct cultivation or as a start point for breeding programmes. At this stage, studies about susceptibility to endemic pests and diseases should be conducted in order to develop resistant or tolerant cultivars. Another key point is identifying growing techniques that can improve the productive potential of the new crop. After this, a more extensive evaluation should be conducted. This usually needs the involvement of growers and industry and the technical assistance of research centres. Basically, it deals with trials to evaluate the performance of adapted plant material at different locations in the proposed production area, postharvest and product processing research, and marketing studies in order to determine the best marketing channels and to evaluate consumer's opinion²⁷.

Finally, if results are promising and there are both good market expectation and the capacity for stable production, the product can be released. This requires both an adequate advertising campaign to promote the new product in the market, and also assistance to growers in order to guarantee an adequate supply.

Is Research in New Crops a Profitable Business?

One of the greatest research successes in horticulture has been the dramatic increase in the yield of several crops. However, research efforts have been concentrated on a few species that have become more competitive but at the same time has led to a reduced crop diversity. Nonetheless, the yield of many vegetables has reached levels increasingly difficult to improve on. New crops research focusing on plant breeding and growing techniques has been scarce. As a result, a higher response is expected to relatively small research efforts. However, the development of a new product is a slow and complex process with uncertain results, particularly in the often unstable sector of horticulture. Moreover, only 1-5% of initial inventions finally reaches the market, and only one in one thousand becomes a high return investment²⁸. From an industry point of view, the success of a product should cover the investment employed in its development and, of course, there must be profit. This profit is sometimes lower in agriculture than in other sectors due to the sharing of incomes between growers, suppliers and a range of intermediaries²⁹, and this fact may discourage industry initiative. However, several cases show that investment in new crops may be highly profitable and returns on new crops research are, on the whole, many times higher than the initial investment. The introduction of soybean in the USA from China is a great success story. Nowadays, USA is the main world producer of soybean, a success, considering the plant was only introduced in the 18th Century³⁰ and its interest as crop began at the end of the 19th Century in several agricultural experiment stations. The development of soybean as new crop cost American taxpayers 5 million dollars from 1912 to 1941. However, USA soybean export trade just in the year 2000 was estimated at 6.6 billion dollars³¹. Another example comes from kiwifruit (*Actinidia* spp.) introduction into New Zealand. This exotic and half-domesticated plant was first introduced into New Zealand from Chinese forests at the beginning of the 20th Century and was cultivated as an ornamental until the 1950s. Finally, New Zealand growers decided to exploit its image as an exotic fruit in the 1960s and 1970s. From then on, this crop has provided "kiwi" growers with very high profits, particularly in the 1970s and 1980s, when kiwifruit production and marketing were performed exclusively by New Zealand³². Currently, kiwifruit is the biggest horticultural export in New Zealand through ZESPRI with a total value of about 600·10⁶ NZ dollars (250·10⁶ US dollars)³³. These are just two examples of how research into new crops has been very profitable, but there are many others.

Conclusions

New crops have contributed dramatically to the increase in production and diversity of food and other agricultural commodities. However, during the last Century a decrease has been experimented in the diversity and number of crops of economic relevance. Because new crops may have a beneficial effect on the economy, environment and culture, this trend should be reversed and introduction of new crops be encouraged. However, as the introduction of new crops usually implies long term investment, public research should fill the gap in the early phases of research.

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Table 1. Ten indigenous vegetable crops from Africa and Asia with local importance and promising perspectives as new crops for mild climate regions^{34, 35, 36, 37}.

African origin

Cowpea (*Vigna unguiculata*)
Egusi melon (*Cucumeropsis mannii*)
Eru (*Gnetum* spp.)
Fluted Pumpkin (*Telfairia occidentalis*)
Garden eggs (*Solanum aethiopicum*)
Kiwano (*Cucumis metuliferus*)
Livingstone potato (*Plecthrantus esculentus*)
Okra (*Abelmoschus* spp.)
Roselle (*Hibiscus sabdariffa* var. *sabdariffa*)
Spider plant (*Cleome gynandra*)

Asian origin

Bamboo (*Dendrocalamus* spp.)
Bitter melon (*Momordica charantia*)
Chinese mustard (*Brassica juncea* var. *rugosa*)
Chinese chives (*Allium tuberosum*)
Fuzzy melon (*Benincasa hispida* var. *chieh-gua*)
Oriental lotus (*Nelumbo nucifera*)
Silk squash (*Luffa acutangula*)
Snake bean (*Vigna unguiculata* cv. *sesquipedalis*)
Taro (*Colocasia esculenta*)
Winter melon (*Benincasa hispida*)
