Situation and Perspectives of Vegetative Chestnut Material for Wood Production in Spain

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ABSTRACT. In Spain, chestnut cultivation for timber has been carried out mainly by coppice. However, in the northwest mountainous areas, there are grafted chestnut orchards designed for fruit and timber production where interesting clonal varieties for timber quality are preserved. *Phytophthora* spp. infections of chestnut orchards in the mid-1940's and 1950's resulted in the development of two resistance selection programs. According to the `Regulations for Marketing of Forest Reproductive Material,' regulations for chestnut are proposed and the present research program in forest selection in Centro de Investigaciones Forestales de Lourizan is described.

TRADITIONAL CHESTNUT CULTIVATION FOR WOOD PRODUCTION

The Spanish chestnut area spreads throughout northern Spain, from Catalonia to Galicia and to the mountainous ranges of the west and south. The last Spanish forest inventory estimates that chestnut grows in high purity on 126,558 ha (6). Approximately 50% of this area in Asturias and Catalonia is in coppice. The grafted-nut chestnut orchards occupy the remaining 50%.

Chestnut orchards for nut and timber production. Although the grafted chestnut orchards are mainly for chestnut production, there also are cultivated varieties for nut and timber production. This occurs in the cultivation areas where seasonal conditions are very suitable for the vegetative growth of the tree. In these areas, the trees are grafted with double-aptitude forest nut varieties. Most commonly, timber is harvested every 25 or 30 yr by means of a crown thinning operation whose purpose is to renew the tree to obtain good caliber nuts. The main varieties known for their timber quality in northwest Spain, are Parede,"de Presa' and `Garrida' (4). The characteristics of their timber include good growth, straightness of the bole, no evidence of ring shake, stability and good conservation, and beautiful grain, in relation to other varieties and to logs from wild chestnut. The logs of these varieties with a diameter above 70 cm bring $700 when their quality is suitable for manufacturing flat panels.

Chestnut coppice. Coppice is the prevailing method of cultivation in Asturias, Catalonia and to a lesser extent in Extremadura. Sprouts come from restumping nut-producing orchards or from 15-20-yr rotation plantations of high density trees (above 2,000 trees per ha). Small dimension wood has been used by the barrel manufacturing industry in Catalonia and for mining posts in Asturias. With the disappearance of these uses, rotations have been extended to 30 yr for the purpose of producing saw timber (8, 11). Although the production per ha is high (up to 12 m^3/ha/yr), due to the high density of coppice, the economical yield is not high because the price of saw timber of small diameters never reaches prices above $150/$m^3$.

Importance of ink disease. In the past, ink disease, caused by *Phytophthora cinnamomi* Rands or ***P. cambivora*** (Petri) Buism. has determined the number of chestnut orchards in the northern areas of Spain, from Catalonia to Galicia (2) and to a lesser extent in the central-western area. The highest disease incidence has occurred in areas with high humidity and mild temperatures, especially in areas of low elevation and midday exposure. There are no data to confirm the existence of the disease in chestnut orchards in southern Spain.

Currently, ink disease can be found below 600 m elevation in northern Spain and at higher elevations at lower latitudes in central-western areas. With respect to the use of vegetative material, it is still questionable as to whether ink disease affects *Castanea sativa* Mill. seed, to the point that cultivation should be completely abandoned. In this case, the use of resistant material would be imperative. This would necessitate a change from an inexpensive, fast-production nursery system, to an expensive clonal propagation system. Moreover, the use of *C. sativa* plants guarantees a suitable forest quality and adaptation to edafoclimatic conditions of the plantation area. On the other hand, the use of Eurasian hybrid clones requires testing their adaptation for forest quality. However, it seems that resistance to *Phytophthora* spp. is a very interesting characteristic but not absolutely necessary for the chestnut vegetative material in all plantation areas.

Canker disease. *Cyphonectria parasitica* (Murr.) Barr is widespread in the northern area of Spain, as far as Galicia, where it is found occasionally. This is in contrast to the central-western and southern areas of Spain, where it has not been detected.

INTRODUCTION OF ASIATIC SPECIES AND BREEDING FOR RESISTANCE TO INK DISEASE

Introduction of Asiatic chestnut species in Spain. As a result of ink disease *(Phytophthora* spp.) in the late 19th or early 20th century, during a period when chestnut was an important resource, several organizations of the Spanish government introduced Asian chestnut seeds, between

1917 and the 1940's. The species introduced included *Castanea crenata* Sieb. and Zucc. (varieties `Shiba,"Tamba' and 'Korea') and *C. mollissima* Bl. These varieties were introduced initially in the Basque area (north), and later in Galicia. During this period, several testing sites were set up; the fundamental objective was to disseminate resistant material for plantations. Consequently, it has been difficult to obtain results from this activity. However, data indicates that: a) forest quality was poor, in comparison to *C. sativa;* b) there was a lack of affinity between grafts of *C. crenata* and *C. sativa* varieties; and, c) adaptation to dry climate areas was poor (3).

Breeding for resistance to ink disease. In Spain, chestnut breeding was initiated in 1921 (5). Hybridization techniques between *C. sativa* and *C. crenata,* were begun and a small collection of interspecific hybrids (*C. sativa* x *C. crenata)* were obtained; some are still preserved today. Some decades later two breeding programs were developed in northwest Spain, Program of the Centro de Fitopatologfa Agricola of La Coruna and Program of the Mission Biológica de Pontevedra.

Program of the Centro de Fitopatologia Agricola of La Comilla. During the period between 1939 and 1958, a chestnut breeding program was developed, aimed at the selection of *Phytophthora* spp. resistant clones to be used as rootstocks of autochthonous chestnut varieties. The research activities were as follows:

1. The biology of different *P. cinnamomi* strains was studied and the most virulent ones were selected. From 1941 to 1944, research examined ways to improve *in vitro* and *in vivo* inoculation techniques for plants recently germinated by the introduction of inoculum below the root collar (14, 15, 17). Changes in the inoculation technique were made in 1954 (19), and since 1956, evaluations and subsequent revisions have been made by examining previous test plots of infected soil plantations (20).

2. Pollen preservation techniques and the viability test were improved in 1941 and 1942 (16).

3. A breeding program was developed between 1942 and 1958 that was based mainly on the creation of first generation interspecific hybrids *C. sativa* x *C. crenata* and *C. sativa* x *C. mollissima* (15, 16, 17, 18, 19, 20, 21). Forty-seven *C. sativa* trees were used as female parents, all originating from a small geographical area. The 10 trees used as pollinators came from Asiatic chestnuts introduced in the 1920's. Nine pollinators were *C. crenata,* including seven of the variety `Tamba,' one of the variety `Shiba' and one of the variety 'Korea.' Only one *C. mollissima* pollinator was used. Mating regimes for the F1's were irregular factorials because not all the pollinators were used in all pollinations. Between 1953 and 1958, F2 hybrids were obtained through open pollination of the F1 hybrids. Likewise, the F3 hybrids were obtained through open pollination of F2 hybrids made two decades earlier by Gallástegui (5).

4. Phytophthora cinnamomi resistance testing was carried out by inoculating recently germinated plants. Subsequent testing was repeated using infected soil. The testing of F2 and F3 hybrids always was done by planting in infected nursery soils.

5. Due to the difficulties in rooting semi-herbaceous and ligneous cuttings, the layering system, developed in France, was adopted as a method of vegetative propagation in 1944 (12). Later, it was used as the method for selecting clonal material (16, 18).

Forty of the selected clones are being multiplied through layering in commercial nurseries, although the selection of rootstocks has not been completed.

Program of the Misión Biológica de Pontevedra. During the period between 1954 and 1965, another selection program for ink disease resistance was developed in northwest Spain, primarily for the production of forest trees. After the Convegno Internazionale sul Castagno celebrated in Cline°, Italy in 1966, the major objective became the selection of material for nut orchards, although a selection program for this purpose has not been finalized. The development of the program consisted of the following:

1. Phytophthora cinnamomi and *P. cambivora* resistance was tested through inoculation of the root collar with a mixture of 19 fungal strains (16 from northwest Spain, 1 from southern Spain and 2 from Holland) using wet soil conditions. Inoculations were repeated for three consecutive years (22).

2. Material was tested for ink disease resistance. References to the tested material are limited (9, 22), but we can assume that F2 and F3 plants were essentially obtained from open pollination of the F1 and F2 hybrid trees *(C. sativa* x *C. crenata)* obtained by Gallastegui (5). All of this material was used for the production of commercial plants, with the propagation carried out via layering.

Results of breeding programs. The hybrids selected for *Phytophthora* spp. resistance in the aforementioned programs have not undergone any further selection over the past few decades. Selections from both programs are maintained in the collection of the Centro de Investigacion Forestal de Lourizanin a way that is difficult to distinguish the clones from either collection. However, the programs have had great social repercussions, at least in northern Spain. The criticism has been that chestnut used in the plantations has to be *Phytophthora* spp. resistant. Consequently, the nurseries of northwest Spain have been directed to produce resistant material. This directive has been imposed even in geographical areas in which *Phytophthora* spp. does not present much of a problem, although some failures have occurred. There, also are areas where the adaptation of hybrid material has not been good because of late spring frosts or dry summers. Generally speaking, *Phytophthora* spp. resistant material has been produced without distinguishing between timber or nut production.

Although the development of these programs ceased several years ago, some interesting results were obtained. Plantings made under Atlantic climate conditions during the last thirty years have performed well with regard to *Phytophthora* spp. resistance. Growth during the 23 yr has

Table 1. Wood production of chestnut hybrid in plantations after 23 yr growth under Atlantic climate conditions.

	Plantation/Plot				
	Noya	Lerez		Cuntis	
	I	I	II	I	II
Number of trees/ha	229.20	248.83	330.27	650.50	856.84
Dbh (cm)	32.36	34.65	28.48	20.36	20.16
Basal area (m^2/ha)	16.54	24.58	23.07	22.71	29.46
Top diameter (cm)	38.15	42.11	37.90	29.68	31.23
Top height (m)	19.04	15.80	15.99	19.84	19.32
Main crop volume (m^3/ha)	161.15	187.93	171.30	178.84	224.50
Saw volume (1) (m^3/ha)	142.51	171.90	147.80	91.48	110.59
% saw volume	88.42	91.47	86.28	51.25	48.00
Volume increment (m^3/ha/year)	7.00	8.17	7.44	8.82	10.70

averaged between 9 and 11 m^3/ha/yr, even though the material was a mixture of clones with various growth characteristics (Table 1). The low density plantings (200-350/ha) already have produced between 142-170 m^3/ha of saw timber after 23 yr. Under these conditions, it seems very possible to imagine clonal forestry using plantings of material selected for forest quality with a low number of trees per ha, yielding both nuts and timber.

REGULATIONS AND ALTERNATIVES FOR MARKETING OF FOREST CHESTNUT MATERIAL

In Spain, the regulations that govern the commercialization of forest reproduction materials are a translation of the European Economic Community directives on forest reproduction, set forth in 1966,1969 and 1975 (1). Two categories of certified reproduction materials were established by regulation, "selected" and "controlled" materials.

The requirements for the admission of base materials (seed stands, seed orchards and clones) for the production of forest trees in the "selected" category are: wood production volume above the average for the area; suitable quality; confirmation of sanitary status; and, an age effective for the population and geographical situation.

For the admission of base materials within the "controlled" category, its superiority has to be shown with regard to representative controls by means of experimental tests in both the nursery and field. Identifications are made and behavior and production are measured.

Although chestnut is not presently included among the species with compulsory regulations for forest certification, it is possible to obtain the certification of base materials from the Instituto Nacional de Semillas, as long as the regulatory requirements are fulfilled. In all European chestnut areas, nurserymen produce plants for forest use from commercial lots of edible chestnuts or from clones that *Phytophthora* spp. resistant, but have not gone through a selection process for wood production. Consequently, it is very important to include these selections among the species for which the regulation is compulsory. This is especially important when it is expected that important reforestation will occur with this species in the European area. A short-term solution for chestnut would be the approval of selected materials that include:

1. C. sativa seed stands that fulfill the minimum requirements of quality and sanitary status directed to the production of seeds to be used in areas where the incidence of *Phytophthora* spp. is rare.

2. Phytophthora spp. resistant clones with good form and vigor aimed at use in Atlantic climate areas. This includes about 30 clones, according to Libby and Rauter (7) and Muhs (10).

PRESENT RESEARCH PROGRAM AT THE CENTRO DE INVESTIGACIONES FORESTALES DE LOURIZAN

With the purpose of producing *Phytophthora* spp. resistant material for the "controlled" category, a selection of forest clones was carried out using the collection of resistant clones selected three decades ago (Figure 1). The selection was based on the bole quality, branching habit and vigor. The nut quality was taken into account to produce plantations for nut and timber uses. The final selection includes 40 clones. To fulfill the requirements of the regulation for controlled reproduction materials, the following experimental methods or criteria were established:

1. Identification. Nuclear stock was propagated and planted with the original material, along with reference material, whose purpose was to aid in identification. Morphological identification was carried out as to the origin of the plant, following the procedure of the UPOV for chestnut (13). For the isozyme identification, several enzymatic systems with good variability were chosen.

2. Behavior and production. Nuclear propagation stock clones were collected for micropropagation nursery tests and subsequent use in field tests and stock plant production.

Finally, vegetative propagation techniques play an important role in this project. Because of the problems inherent to the layering procedure, in regard to plant

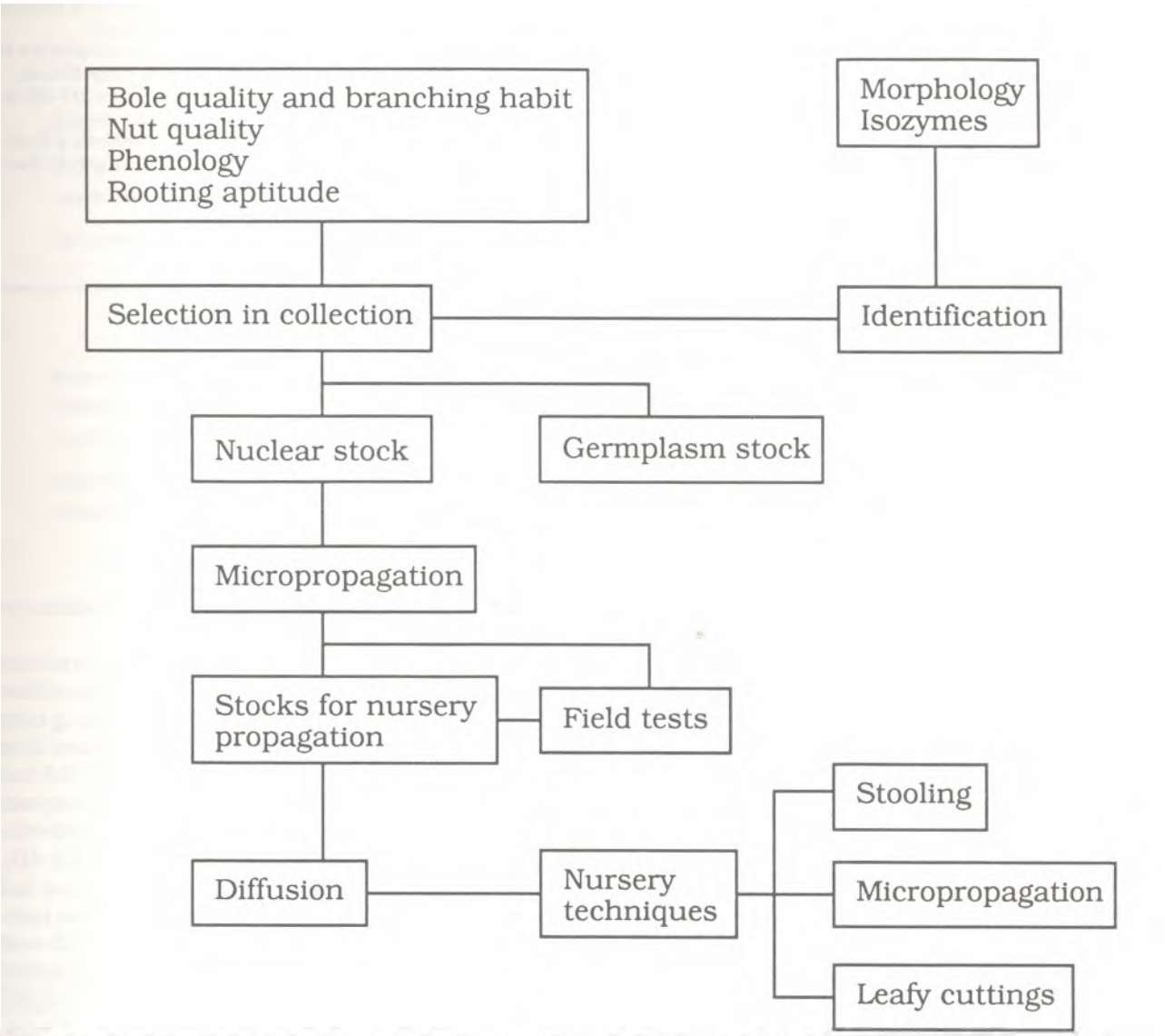

Figure 1. Work scheme developed at the Centro de Investiagciones Forestales de Lourizán in hybrid clones resistant to *Phytophthora* spp.

quality, the development of cuttings and microcutting techniques that can substitute for layering as a propagation methodology are important parts of this research program.

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