Almond Rootstocks: Overview

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Abstract. Almond growing has significantly changed over the last decades in the. Production has decreased in some countries such as but in others, including, an important change has taken place. The possibilities for choosing a rootstock have also significantly increased. The use of almond seedlings has always been linked to rainfed conditions and peach seedlings to irrigated conditions. The peach x almond hybrid 'GF- has been the rootstock most utilized in the past years, either for rainfed or irrigated conditions. Nowadays, however, with the high demand for these crops and the new areas planted in substitution of other fruit crops, new rootstock releases are being used more often, mainly newly-bred Spanish rootstocks. The rootstock choice must respond to better management, adaptability to different soil types, and resistance to nematodes. The studies of compatibility with plum species, especially the selection and use of some clonal almond x peach hybrid rootstocks have increased the selection possibilities considerably. In this situation, the red-leaved and root-knot nematode-resistant almond x peach hybrids (GxN) that are well adapted to Mediterranean conditions due to their 'Garfi' parentage, in both irrigated and non-irrigated conditions (mainly 'Garnem'), have become the predominant rootstocks. Particularly noteworthy among the recent releases has been the incorporation of root-knot nematode (RKN) resistance. Special emphasis has also been placed on developing dwarfing rootstocks for high-density orchard systems. New hybrid rootstocks of complex origin are now under experimentation and initial results indicate that they could improve almond production if they fulfil the requirements of modern fruit growing, as discussed in this revision.

Keywords. Nematodes – Rootstocks – Vigour control – *Prunus dulcis* – Drought – Intensive.

Les porte-greffes d'amandier

Résumé. *La culture de l'amandier a évolué au cours des dernières décennies dans le bassin méditerranéen. Bien que dans certains pays, comme en Italie, la production ait diminué, dans d'autres, comme l'Espagne, a eu lieu un changement rapide. Les possibilités de choix des porte-greffes ont également connu une avancée significative. L'utilisation de semis d'amandier a toujours été liée à des conditions non irriguées et le semis de pêchers à des conditions irriguées. Le pêcher*amandier 'GF-677' a été le porte-greffe le plus utilisé dans les dernières années, que ce soit pour les cultures irriguées ou non. Cependant de nos jours, suite à la forte demande de cette culture et au nombre de surfaces plantées en substitution d'autres cultures fruitières, il y a une utilisation croissante des nouvelles obtentions, notamment des nouveaux porte-greffes espagnols. Le choix des porte-greffes doit répondre à une bonne adaptation aux différents types de sol, au système de culture et à la résistance aux nématodes. Les études de compatibilité avec des espèces de pruniers et spécialement la sélection et l'utilisation de certains porte-greffes hybrides clonaux entre amandier x pêcher ont notamment accru les possibilités de choix du matériel végétal. Dans cette situation, les hybrides amandier x pêcher à feuilles rouges et résistants aux nématodes à galles (GxN) bien adaptés aux conditions méditerranéennes en raison de leur parent amandier 'Garfi', à la fois dans des conditions irriguées et non irriguées spécialement 'Garnem', sont devenus les porte-greffes prédominants. Particulièrement remarquable parmi les obtentions récentes a été l'incorporation de la résistance aux nématodes à galles (RKN). Uun accent particulier a été mis aussi sur le développement des porte-greffes de nanisme pour les systèmes de vergers à haute densité. De nouveaux porte-greffes hybrides complexes sont maintenant en expérimentation au champ et les premiers résultats indiquent qu'ils pourraient améliorer la production d'amandes s'ils remplissent les nouvelles exigences des cultures fruitières, comme il l'est montré dans cette révision.*

Mots-clés. *Nématodes – Porte-greffes – Contrôle de vigueur* – Prunus dulcis – *Sécheresse – Culture intensive*.

I – Introduction

Almond growing in the Mediterranean area has undergone significant changes in recent decades. Whilst in some countries production has substantially decreased, in others a renewal of the concept of almond growing is taking place. In such a situation, not only new cultivars but also new rootstocks are essential tools to achieve success. For cultivars, 'Nonpareil' has been, and continues to be, the essential cultivar in, while in the Mediterranean area the outlook has dramatically changed. In relation to rootstocks, in California the changes have also been smaller, since new releases represent only a small percentage of the new plantings (Socias i Company *et al*., 2009), and peach seedlings, mainly 'Lovell' and 'Nemaguard', remain the most utilized rootstocks, whereas in the Mediterranean area sharp changes have been taking place, with a shift from the utilization of different almond seedlings to the wide implantation of peach x almond hybrids.

Due to the non-irrigated conditions of most Mediterranean orchards, almond seedlings were the dominant rootstock for centuries, because of their deep growth and associated efficiency for mining nutrients and water. However, they are susceptible to root asphyxia and nematodes. Unselected rootstocks, often bitter almonds, were used for producing seedling rootstocks, although some efforts were subsequently directed toward some seedling lines because of their homogeneity (Felipe, 1989) or resistance to nematodes in (Kochba and Spiegel-Roy, 1976).

More recently, peach x almond hybrids are showing promising performance under non-irrigation, due in part to the loss of the deep-mining almond tap-root when transplanting (Felipe, 2000). 'GF– has been the rootstock most utilized for decades worldwide, probably being the almond x peach hybrid clonal rootstock most planted at present, both in irrigated and non-irrigated conditions. Later, several new releases have been increasingly utilized, especially the Spanish rootstocks from the CITA programme ('Garfi' x 'Nemared' series), mainly 'Garnem', rather than the Italian rootstocks from the University of Pisa, probably due to their better management, adaptability and resistance to nematodes (Socias i Company *et al*., 2009).

Other almond x peach hybrids adapted to alkaline soils have been selected in Spain from spontaneous hybrids: 'Adafuel' (Cambra, 1990) in EEAD-Zaragoza and 'Mayor' in CIDA-Murcia (Rodriguez and Carrillo, 2002). However, they suffer several shortcomings, such as difficult propagation and susceptibility to pests and diseases, mainly nematodes (Felipe, 2000). Several diploid plum clones have been selected from the local population of 'Pollizo de Murcia', with three releases: 'Adesoto (Moreno *et al*., 1995) from EEAD-Zaragoza, and 'Monpol' and 'Montizo', from CITA-Zaragoza (Felipe *et al*., 1990, 1997). The main selection objective of these rootstocks was the introduction of waterlogging tolerance and vigour reduction.

Root-knot nematode (RKN) resistance has been the main goal for *Prunus* rootstock breeding for decades and hence for almond. Partial RKN resistance was introduced from an open pollinated 'GF- resistant to *M. arenaria* and *M. incognita* (Esmenjaud *et al*., 1997). In, 'Sirio' (Loreti and Massai, 1998) from the IS series also showed good performance in calcareous soils. Progressively, more resistance was introduced with two interspecific hybrids from *P. davidiana*, resistant to the four main *Meloidogyne* species: 'Barrier' (Roselli, 1998) from, and 'Cadaman' (Edin and Garcin, 1996) from. Partial resistance not only to *Meloydogyne* spp., but also to the ring nematodes (*Mesocrinema* spp.) was introduced through the peach seedling 'Guardian', released as tolerant to Peach Tree Short Life, an important syndrome in the southern United States (Reighard and Loreti, 2008). Several interspecific hybrids were introduced from (Eremin and Eremin, 2002), showing cold hardiness and dwarfing as their main characteristics. In the last 20 years, the interspecific almond x peach hybrids 'Garfi' x 'Nemared' have become increasingly popular. They aim to benefit from 'Nemared' resistance to RKN (Ramming and Tanner, 1983) and from adaptation to Mediterranean conditions from 'Garfi': Three of the selected rootstocks, 'Garnem' 'Felinem' and 'Monegro' (Felipe *et al*., 1997, Felipe, 2009), also provide good vigour and performance in replanting conditions (Gómez-Aparisi *et al*., 2000).

Other different almond rootstocks are also under evaluation, such as Replant-PAC (Pinochet, 2010), Root-PAC-40 and Root-PAC-20 (Gasic and Preece, 2014), with 40 and 20% vigour reduction in comparison to 'Garnem'. In USA peach seedlings have recently been described as almond rootstocks 'Controler- (Gasic and Preece, 2014), derived from an open pollinated *P. persica* HBOK series (Harrow Blood x Okinawa) both unpatented, with 60% vigour control respectively, compared to 'Nemaguard' (DeJong *et al*., 2004).

II – Breeding objectives

The most important innovation over recent years is the introduction of 'in vitro' propagation in the nurseries (Loreti and Massai, 2006). At present, in almost all clonal peach rootstocks are produced by micropropagation and most laboratories have been set up for tissue culture of fruit tree rootstocks. The technique allows production of large quantities of materials within a short time in a restricted space. So nowadays propagation for large quantities of plants is not an objective in itself but an inherent need in all breeding programmes, in order to conduct further studies to select other desirable traits in the breeding objectives. Propagation ability is linked to genetics and almond genetics apparently are more difficult than those from peach parentage. Repeated attempts to select a clonal almond rootstock have failed due to the difficulty of vegetative propagation in this species (Felipe and Pascual, 1990). Modern laboratories are able to overcome this issue and several advances have been made focusing on hormone combinations.

Priority objectives reported 25 years ago in stone fruit rootstocks were nematode resistance ranking first place, followed by other adaptational traits associated to abiotic stresses, drought, chlorosis and waterlogging (Rubio Cabetas, 2012). However, observing all the breeding programmes after the survey conducted by Reighard (2002), it can clearly be seen that nematode resistance (root knot, ring and lesion) was still reported as top priority. Adding the number of breeding programmes that are still working with adaptational traits, we can consider the following traits by order of importance: nematodes, waterlogging, vigour control, adaptation to calcareous soils, drought, soil diseases (fungal and bacterial) and cold hardiness. At the moment, 5 years later, minor priorities may have emerged.

Significant progress has been made in the development of broadly resistant rootstocks, more specifically in RKN. Screening methodologies are somewhat laborious, involving either field tank or greenhouse assays. Therefore this is one of the most mature areas, where several genes have already been located on genetic maps (Lecouls *et al*., 2004, Duval *et al.* 2014). However, this recent knowledge has not been the same for other soil-borne diseases caused by bacteria or fungi, which would still be the first priority (Rubio-Cabetas, 2012). Even though RKN resistance could prevent some bacterial damage and help develop resistance to *Agrobacterium* (Rubio-Cabetas *et al*., 2001) in stone fruit rootstocks.

In recent plant material releases calcareous tolerance and some advances in waterlogging traits can be observed, incorporated by almond x peach hybrids and plum selections respectively (Rubio-Cabetas *et al*., 2005).

In the main breeding programmes aim to improve drought tolerance and vigour, and also to increase climate adaptability with low hardiness to adapt early ripening varieties. Almond size control through rootstocks of other *Prunus sp*. has not been achieved satisfactorily in the past. Two commercial almond rootstocks Root-PAC 40 and Root-PAC 20 rarely reduce scion vigour by more than 40 and 20%, which has progressively become a main concern in breeding programmes. Although dwarfing rootstocks are in demand, cold hardiness and dwarfing, characteristics of the Russian hybrids (Eremin and Eremin, 2002) seem to be linked, thus this concern has to be solved for Mediterranean conditions. Such is the case of Root-Pac 20 that would not be appropriate for all Mediterranean conditions.

Size-controlling rootstocks for almond could increase orchard productivity via intensive training systems but they are difficult to achieve. New dwarfing rootstocks for almond must reduce vigour, be graft compatible, and provide good fruit production without reduction of kernel size and quality. Vigour requisites may not necessarily be the same in all almond production countries, since they must be adapted to the mechanical harvesting equipment so medium vigour seems to be acceptable at the moment. However, an agronomical aspect, such as replanting conditions, must acquire more relevance in the near future, since even in the most traditional almond industries, replanting is acquiring more importance because other fruits such as grapes and citrus are now been replaced by almond and an adequate vigour for good performance in replanting conditions on low fertility sites must also become a priority when choosing the almond rootstock.

III – Almond rootstock types

1. Almond seedling

Traditionally, the bitter almond seedling has been used without paying attention to its origin, since seed orchards were not intended for seed production. Often seeds were collected from wild almond populations that were cross pollinated by the nearest orchards. This is the origin of seeds collected from their area of origin in East Asia and also in a population of *P. webbii* in, central (Felipe, 1989). Classical Spanish cultivars described as best for rootstocks are 'Atocha', 'Desmayo Largueta', 'Garrigues', 'Marcona', and 'Ramillete' (Ramos, 1976). In Spain the cultivar 'Garrigues' has been the most common, where seedlings are uniform with a strong, deep, root system, although there are some feathers in the graft union area, whereas in the cultivar 'Atocha' we find less feathers. Other cultivars used as seedling rootstocks are 'Marcona' in Spain, 'Mission' in California, 'Chellaston' in Australia and 'Don Carlo' in Italy (Fideghelli and Loreti, 2009). Almond seedlings are generally sensitive to nematodes, fungi, bacteria and capnode.

The most remarkable feature of almond seedlings is their hardiness and ability to grow in poor, high limestone content soils with little natural rainfall. In extreme situations, such austerity allows them to survive better than other crops, although growing almonds under these conditions has little or no economic interest today. Another characteristic is a deep root system; however, observations on different soil types indicate that root growth depth is limited by available oxygen in the soil pores. Therefore, in porous soils roots reach deeper than in more compact soils. A negative attribute of seedlings is that they are not homogeneous in growth development and behaviour and are sensitive to handling and transplanting from the nursery to the field, often with poor survival after planting. They are also susceptible to soil pathogens such as nematodes, *Agrobacterium*, *Phytophthora*, *Armillaria*, etc. and sensitive to neck and root asphyxia and as such they are unsuitable for cultivation under irrigated conditions, except when the irrigation system is localized (drippers, micro, etc.) and the soil has good drainage. As a general rule the almond seedlings are suitable for growing rainfed almonds (Felipe, 1989).

Nowadays the cultivar more often used in as the almond seedling is 'Garrigues' and 'Atocha'. In California the 'Texas' (= 'Mission') cultivar is normally used and in Israel some bitter almond cultivars such as 'Alnem 1' 'Alnem y 'Alnem are resistant to RK nematodes.

2. Peach seedlings

Peach seedlings were selected for irrigated crop production since they are less sensitive to problems affecting almond seedlings, though they are not suitable for cultivation in rainfed soils. Peach is very compatible with almond, and almond cultivars on peach grow rapidly in the first years after planting. Peach seedlings have been selected explicitly for seed production since they typically give more ho-

mogeneous plants. Some good seedling producing cultivars are INRA's 'GF-305', 'Montclar', and the U.S. cultivars 'Lovell', 'Nemaguard', 'Nemared', which have been widely described (Felipe, 1989) and have been used for a long time for both peach and almond cultivars in different countries.

The positive features of peach seedlings are that they are best adapted to cultivation in irrigated soils and the knowledge of their known agronomic performance against some stresses, such as tolerance to certain species of nematodes. In general, peach seedlings cannot be regarded as a definitive solution for the cultivation of almonds, but they represent an improvement for irrigated almond production. In contrast, they remain highly sensitive to some of the common pathogens: *Agrobacterium*, *Armillaria, Phytophthora*, etc. They induce a shorter tree life than almond rootstocks. Plants produced from specific cultivars (e.g., 'Nemaguard' and 'Nemared') are resistant to RKN Meloidogyne spp, and others (e.g., 'Rutgers Redleaf') tolerate heavy soil conditions better. Some cultivars have been used in crosses aimed to introduce resistance to RKN as well as other interesting characters such as red leaf colour.

3. Clonal rootstocks

Clonal propagation, though more expensive than grafting to seedlings, offers the advantage that the behaviour of the material produced is very homogeneous and growth characteristics are more consistent and better known. In the cultivar 'Garfi', a descendant of 'Garrigues', was selected because it was easier to propagate. Research trials of propagation via rooting hardwood cuttings gave satisfactory results for 'Garfi' when compared with other almond cultivars ('Garrigues' among them), peach, and almond x peach hybrids (Felipe, 1984; Felipe 1992).

4. Plum as almond rootstock

The plum root system has a shallow development and generally the roots are smaller in number and thickness than for peach or almond. Plums are usually more tolerant to certain pathogens and more resistant to the waterlogging conditions in heavy soil. They perform better in heavy soils than almond and peach roots. Therefore, these rootstocks are used when soils are not sufficiently healthy, coarse textured, and aerated. Graft compatibility with almond is highly variable and thus, previous trials are required before a particular combination of almond can be used on plum.

Low vigour plums. The plums corresponding to the species *P. domestica* L. and *P. insititia* L., (i.e. European plums, 'Sanjulián', 'Damas', etc.) are included in this group. In many cases the compatibility is good, but varieties to be grafted on some of the clones have localized incompatibility, and the graft union eventually deteriorates. The well known "pollizos" originating from are fully compatible if they are true "pollizos" and are free of infectious agents such as viruses. It is recommended to use selections that are currently in an advanced commercial stage such as 'Adesoto', and 'Montizo'. The compatibility tests conducted over several years with these rootstocks showed that very few of them had incompatibility problems when grafted with almond varieties. The selected pollizo clones are plums that offer the best prospects for use as almond rootstocks for specific soil conditions or vigour reduction since these offer greater compatibility. Other European plums 'Penta' and 'Tetra' are also being used in with somewhat delayed flowering compared to 'GF-677'. The advantages of these slow-growing plums are that this group is more resistant than almond and peach seedling trees to root asphyxia, as well as root parasites, such as the nematodes *Phytophthora*, *Armillaria*, *Agrobacterium*, etc. Trees are smaller, allowing for semi-intensive cultivation of irrigated almond and also provide good anchorage. Because of low drought resistance, plum rootstocks should only be considered for irrigated crops. The good compatibility of the clones in this group with almond is not universal, hence the risk of localized graft incompatibility with certain varieties of almond. They tend to produce suckers, which are a problem for cultivation.

Vigorous plums. This group includes plums belonging to *P. cerasifera* Ehrh diploid species (Myrobalan), *P. salicina* Lindl. (Japanese plums), some hybrids like 'Marianna (*P. cerasifera x P. munsoniana*) and other diploid plums from different backgrounds**.** This group of plums generally has poor compatibility with almond varieties. Usually it is translocated incompatibility, although in some combinations incompatibility is found at the graft union. Some clonal selections grafted with certain varieties of almond show apparently good compatibility, as in the case of 'Marianna 2624' grafted with some California cultivars and some clones of Myrobalan with certain European cultivars, where there have been some combinations of either almond / Myrobalan or almond / Marianna showing some compatibility (Felipe, personal communication). The advantages of these fast-growing plums are usually rootstocks that provide good vigour and development when grafted with compatible varieties of other species. In addition, they adapt well to different types of soil, and tolerate a certain amount of humidity. They also have some tolerance to *Phytophthora* and *Agrobacterium*. Some selections are resistant to RKN *Meloidogyne sp*. In general, they are easy to propagate vegetatively, provide good anchorage and do not normally sucker. These rootstocks should be used with irrigation only, since their behaviour on dry land is not satisfactory. Their compatibility problems with almond cultivars make these plums virtually impossible to use without prior experience with each particular almond scion / cultivar combination.

5. Interspecific hybrids

The Mediterranean area has a long-standing tradition of almond tree cultivation. Among the interspecific hybrids between *Prunus*, almond and peach are the best known and most widespread. There are several commercially propagated selections: 'INRA-GF-677', 'Adafuel' and controlled crosses such as ''Garnem' 'Monegro' 'Felinem', especially 'Garnem are the most well-known and widespread to date. In recent years some other peach x almond hybrid clones are under study with both species and with several species of plum, which may be of interest when the compatibility has been studied and they show a satisfactory behaviour at agronomic level. Those recently propagated are 'Replantpac' a Myrobalan x almond hybrid whose compatibility with almond has also been studied (Pinochet, 2010), Root-Pac 40 (complex almond x peach hybrid) and Root-Pac 20 (P.besseyi x P. cerasifera).

6. The positive characteristics of hybrid between almond and peach

One of the features that attracted attention from the beginning was the remarkable vigour of the plants that were used. This aspect is interesting for the cultivation of almonds for good growth in either rainfed or irrigated conditions, which in turn results in an earlier onset of production. Experience to date shows that there are differences in development that achieve the same variety when grafted on different clones of this type of hybrid. The clones used so far acceptably adapt to different soil types and better support the almond seedling cultivation in irrigated conditions. Also better performance than the almond seedling has been observed in rainfed cultivations in both growth and production.

7. Negative characteristics of hybrids between almond and peach

The selected clones that are already in use accumulate many good qualities, but also have negative aspects that can and should still be improved. A common feature of almost all of them is that propagation is not as easy as one would wish in a good rootstock. Some techniques have been developed for multiplication and with acceptable results (Pascual and Felipe, 1988), but the normal nursery still finds it difficult to multiply their own plants. Most of the clones used are still sensitive to *Agrobacterium* and *Armillaria* and they are, in varying degrees, susceptible to root asphyxia. One negative aspect is high vigour. In the last five years some progeny from a private breeding programme between different interspecific *Prunus* has been used as rootstocks to reduce vigour in some intensive orchard trials: Replant–R, Root-PAC-40 Root-PAC-20. However there is insuf-

ficient available data to predict the behaviour of those rootstocks in the forthcoming years and trials with more cultivars are needed. These hybrids with medium vigour, equivalent to the peach seedlings or less, are commercially available for use in intensive plantations, etc. and in USA the most recent 'Controler- are also being studied.

IV – Clones of peach × almond hybrids in use

'INRA-GF677' is a natural hybrid of peach and almond found in Lot et Garonne (France), introduced in 1939 and selected in the French resort of La Grande Ferrade (INRA, Bordeaux), (Bernhard and Grasselly, 1981). The leaves are intermediate in appearance and size between almond and peach. The appearance of the branches is closer in winter peach for its thick and downy buds. The flower is rosacea pink. Regarding growth habit, it is open and branched, producing many feathers. The root system consists of numerous strong roots. As almond rootstock is very vigorous, it enters fruition rapidly and produces a large yield. Its behaviour with rainfed almond rootstocks is very good, the almond almost always overcoming the almond seedling almost always almond. The resistance to asphyxia is similar to the common peach seedling and it is more resistant to chlorosis. It is also sensitive to *Agrobacterium* and nematodes. The propagation of 'INRA-GF-677' is not easy, although progress has been made in the development of the right to obtain acceptable commercial returns techniques, therefore between cuttings with leaves in summer and by hardwood cuttings in autumn; the latter procedure should be followed in the early autumn in highly permeable soils. Numerous prospective hybrids producing branches in hedge planting system and make their preparation a slow and expensive operation in the nursery for subsequent grafting, as vegetative growth ceases in favour of branch growth. The 'INRA-GF-677' is a standard rootstock for difficult soils (calcareous, arid, exhausted). It also tolerates moderate salinity levels and has a good tree growth and higher productivity with the traditional cultivars. However it does not perform well in replanting conditions and branching in the nursery is common. It is highly susceptible to *Phythophtora*, *Armillaria*, *Agrobacterium* and *RKN*, and may also be inappropriate with modern varieties that are very productive at least under irrigated conditions. It is also as sensitive to waterlogging as all the almond x peach hybrids. However it is an excellent rootstock for the cultivation of almonds, in rainfed and irrigated conditions whenever the soil is free from RKN and not very compact. It supports all varieties of almond and transplants well, however we must ensure good tree formation with green pruning and pinching and winter pruning should be lenient in the early years. This clone represented more than 15% of clonal rootstocks in (Arquero *et al*., 2002)

'Adafuel' is a clone selected in the Aula Dei Experimental Station (Spain) (Cambra and Iturrioz, 1986), from a collection of over sixty spontaneous hybrids from various Spanish regions. It comes from a hotbed of 'Marcona' almonds. The leaves are deep, narrow, green and slightly curved lengthwise. Although aspects between peach and almond resemble the 'Marcona', the almond leaf has left its mark on 'Adafuel'. It is erect, as a tree nursery, branches in winter are dark, resembling 'Marcona' almond, althought not produce many feathers as 'INRA-GF-677', it is also still abundant in this clone. The flower is rosacea bright pink. The root system consists of abundant and strong roots. It is a vigorous rootstock, compared to 'INRA-GF-677' and as an almond rootstock, is stronger in irrigated conditions than in rainfed conditions. The resistance to asphyxia is the same as that of peach seedlings. It is more resistant to chlorosis that the 'INRA-GF-677'. At the moment, it appears to be quite resistant to Phytophthora and does not seem as sensitive to *Agrobacterium* as 'INRA-GF-677'. However it has shown sensitivity to nematodes. With slight differences, it has the same capacity and the same problems for propagation as the 'INRA-GF-677'. Production of woody cuttings in mother plants is good though with many feathers. In the nursery, rooted plants are upright which facilitates grafting. It is an interesting rootstock for cultivation in replanting and in calcareous and poor soil conditions. For the experience gained so far in reference plantations, 'Adafuel' is proving to be an excellent rootstock for almond, provided the soil is free of nematodes. It supports all almond varieties.

'Felinem' 'Garnem' and 'Monegro'. (Felipe, 2009). These three clones were selected from the progeny obtained in the cross between the Spanish almond 'Garfi' (*Prunus amygdalus* Batsch.) as the female parent and the North American peach 'Nemared' [*P. persica* (L.) Batsch] as the pollen donor. 'Garfi' almond had been previously selected because of its good morphological characteristics and easy clonal propagation (Felipe, 1989; Felipe *et al*, 1997). 'Nemared' was chosen mainly as a source for root-knot nematode resistance (Ramming and Tanner, 1983). This progeny was selected at the Servicio de Investigación Agraria de la Diputación General de Aragón (Spain), now Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA). These rootstocks have strong, thick, root systems. This aspect is interesting for the cultivation of almonds with a strong growth either under rainfed or irrigated conditions and also results in an earlier onset of production. Unbudded trees of 'Garnem', 'Felinem' and 'Monegro' are vigorous and no differences in size are noticeable between them. The vigour induced in grafted cultivars is comparable to that induced by 'GF- or 'Hansen, with a similar productivity. Non-grafted plants are vigorous and in the nursery exhibit erect growth with little or no feathering during the first season (Felipe, 1989). Fruits are green with reddish tones. The mesocarp is thin and non-edible, leaving a free stone. Despite their similar morphology and performance, the three clones may be distinguished by molecular markers (Serrano *et al*., 2002).

Their level of tolerance to iron chlorosis is similar to that of 'GF- and 'Adafuel' (Felipe, 1989). They also tolerate drought conditions well, with higher resistance to water stress in 'Monegro'. Adaptation to poor soils is good if the soils are well drained. Incorporation of root-knot nematode resistance was the primary breeding objective in order to replace several widespread nematode susceptible peach x almond hybrids used for peach production in, especially in replanting situations (Pinochet, 1997). They are very resistant to the main root-knot nematode species attacking *Prunus* showing a broad spectrum of resistance (Marull *et al*., 1994; Esmenjaud *et al*., 1997). Like most almonds and almond x peach hybrids, they exhibit low tolerance to root asphyxia caused by waterlogging. They are also susceptible to the root lesion nematode *Pratylenchus vulnus* (Pinochet *et al*., 1996) and to crown gall caused by *Agrobacterium* tumefaciens.

The GN series clones used so far are acceptably adapted to different soil types and are a better support than the seedling almond for irrigated cultivation. Good performance has also been observed of many rainfed cultivations, having overcome the seedling rootstocks in growth and production. Transplantation is easier than the seedling almond. 'Garnem', 'Felinem' and 'Monegro' propagate well by hardwood and herbaceous cuttings in aerated and well drained soils. Best results for hardwood cuttings are obtained in autumn. Cuttings are easily obtained thanks to the lower level of shoot branching. They also propagate very well in vitro. Nursery operations are facilitated by the low presence of feathers and red leaves, as well as by the long vegetative period of the plants, allowing the production of nursery plants in a shorter period. The percentage of bud uptake is high for all known peach, nectarine and almond cultivars (personal communication by different nurserymen). These rootstocks have been selected primarily for almond showing good graft compatibility with numerous almonds. Tests made with almond varieties grafted on various clones of hybrids between almond and peach have shown that even within this group of rootstocks, there are differences in agronomic performance.

V – Current rootstock trials

The main remarks on the choice of the rootstock are fruit tree growing intensification and quality, with the need to control vigour and management costs. Another consideration is high water and fertilizer use efficiency and specific soil and climatic conditions with soil borne pathogens. Additionally the choice of rootstocks for almond growing in hot-arid climates must be based on the scarce availability or poor quality of water or strict irrigation schedules imposed by the irrigation boards. Therefore rootstocks must be tolerant to water stress with deep and extended root systems together and adapt to heavy soils with poor drainage and highly saline soils are need.

Recently in the last five years some trials for almonds have been conducted on different types of rootstock. From the traditional almond x peach rootstock 'GF-, 'Garnem', 'Felinem' y 'Monegro' other older hybrid rootstocks such as 'Barrier' and 'Isthara' were used as well as some plum selections such as 'Adesoto' and 'Montizo' with some new released interspecific hybrids of different origins such as Root-PAC-40 and Root-PAC-20 to try to elucidate in the short medium term which are the best rootstocks for each specific situation to respond to the almond growth expansion in the Mediterranean area. In Table 1 we review the most recent trials established mainly in but also in where almond growing is expanding and they will give responses for the almond growing in the near future.

Table 1. Rootstocks involved in recent almond trials established mainly in Spain but also in USA and Australia

Country	SPAIN	SPAIN	SPAIN	SPAIN	SPAIN	SPAIN	AUSTRALIA	USA
REGION	Aragón	Aragón	Cataluña	Cataluña	Cataluña	Andalucia	Victoria	California
YEAR	2011	2011	2009	2010	2012	2015	2014	2012
	Rootpac-40*	R-20**	GF-677*	Cadaman		Garrigues	Nemaguard	Lovell
				Garnem		Garnem	GF557	Nemaguard
				GF677		GF-677	GF677	Empyream 1 = Barrier 1
				Ishtara		Nemaguard	GF749	Avimag = Cadaman
				MB 1-37		R90	Adafuel	HBOK50
				(PxA) x Myrobalan		RR	Garnem	Hansen
				Puebla de soto	MB-1-37	IRTA-1	Felinem	Bright's
				Rootpac-20		MONTIZO	Monegro	BB106
				Rootpac-40		TETRA	Brights Hybrid	Paramount = GF677
				Rootpac-R		R-20	Hansen 536	Flordaguard x Alnem
						R-40	Cornerstone	PAC 9908-02
						REPLANT	Nickels	HM2 +
						R-20	Krymsk 86	Viking
						R-40	Atlas	Atlas
							Cadaman	Krymsk 86
							Nemaguard	Rootpac R

* Training System.

** Graft Compatibility.

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