Green almond production protocol

JoSME, 2022

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Preface

This Protocol has been prepared in the framework of the project "Enhancement of Jordanian SMEs inclusiveness, competitiveness and sustainable innovation"- JoSME, funded by the Italian Cooperation and implemented by CIHEAM Bari.

This protocol provides guidance of entrepreneurs as producers (individual and/or gathered in associations and cooperatives), packers, traders, exporters involved in the green almond chain. The aim of this protocol is to provide indications about the management of the green almond to achieve quality and safety of the product in order to enhance added value in the domestic and international markets

1. Introduction

The almond (*Prunus dulcis* or *Prunus amygdalus*) is an important nut native to southwest Asia, from northwestern Saudi Arabia, north through western Jordan, Israel, Lebanon, western Syria, to southern Turkey. Domesticated almonds appear in the Early Bronze Age (3000–2000 BC) of the Near East.

The fruit of the almond is a drupe, consisting of an outer hull and a hard shell with the seed, which is not a true nut. The almond tree prospers in a moderate Mediterranean climate with cool winter weather. California produces over half of the world's almond supply.

Although almond belongs to the subgenus *Amygdalus* (*Rosaceae*, subfamily *Prunoideae*) of the genus *Prunus*, which comprises all stone fruit species, it is generally placed among nuts.

The almond growth cycle is adapted to a Mediterranean-type climate, with its traditional low-input moderate-return dry-land cropping systems, high tolerances to drought, easy propagation by seed, the rapid development of the tree and adaptation to marginal soil, summer drought and heat, combined with its food value, this place almonds in a traditional sustainable mixed culture system with other drought-tolerant crops (*Gradziel, T.M. 2017*).

In most agricultural areas of Jordan (except for the Jordan valley and Aqaba) the climatic conditions suited very well almonds due to its low chilling requirement, rapid early shoot growth and high tolerance to summer heat and drought. The growth usually resumes at the end of winter or early spring, when buds enlarge and flowering starts early before any other temperate fruit trees.

Fig. 1: Development stages of almond buds, flowers and nuts.

A: Resting bud.

B: Swelling bud.

C: Sepal appearance.

D: Petal appearance.

E: Stamen appearance.

F: Open flower.

G: Petal fall.

H: Set fruit.

I: Young fruit.

J: Developed fruit.

K: Suture opening.

L: Ripe fruit.

(*Company, R. S., 2017).*

2. Agricultural practices

2.1. Land Preparation and Soil Management

Almonds grow on a wide variety of soils varying from finest valley soils to rocky soils. They do not thrive well in heavy or poorly drained soils. However, they grow and produce best crops in deep, well drained soils of light to medium texture (*Verma, M. K. 2014*). Almond trees also tolerate calcareous soils that dominate some cultivated areas in Jordan.

Before planting, a deep ploughing at more than 50 cm. is recommended to facilitate root development and water infiltration in the soil in one direction; a second deep ploughing can be done in the opposite of the first when the soil is dry, later on a superficial ploughing is performed to settle the soil down and crumble the soil to make it ready for planting new trees, (*Arquero, O. and Jarvis-Shean, K. - 2017*).

The most important factors that are taken into consideration when establishing a new field are the following:

- Soil depth and necessity of analysis of soil (physical, chemical and biological properties);
- The degree of inclination or slope of the site;
- The ratio of rocks in the site compared to soil texture;

- The orientation of the site relative to the sun;
- The prevailing wind direction at the site.

The land in the production stage is plowed two or three times a year by means of a disc plow. It is preferable to shallow plough almond orchards in the spring to remove weeds that compete with trees in absorbing water and to do another plough in the fall after the first rains.

2.2. Propagation and planting materials

Traditionally almond was propagated from seeds and it is still used in some growing areas. In this way a very strong taproot is produced, often reaching very deep levels in the soil (*Company, R. S. 2017*). Wild bitter almonds seedlings are usually used by Jordanian farmers as rootstock to graft selected almond cultivars for green fresh consumption and it also used as a rootstock to graft other stone fruits like plums, peaches and nectarines, because of their known tolerance to drought, calcareous soils (*Al-Ghzawi, A. et al 2009*) and probable resistance to peach root borer *Capnodis spp.*(*Dicenta F. et al. 2001*), a highly destructive insect in stone fruit plantations in Jordan. Hybridization programs were initiated to introduce new almond cultivars for many traits related to quantity, quality, disease and insect pest resistance. New rootstocks were also developed mainly to resist drought, calcareous soils, nematodes and soil diseases, like "GF" rootstock, which is a hybridisation of almonds. "GF" rootstock originally was selected for peach but it also showed excellent performance with almonds under natural rainfall conditions in arid regions and also shows a vigorous root system (*Rubio-Cabetas M. J. 2017*).

In Jordan selected almond varieties are planted mainly for green fresh almond consumption. The main green fresh almond varieties planted in Jordan are *Balady* (early variety), *Oujeh* (crunchy and mid-season variety) and *Mkhmal* (late variety).

Balady Oujah Mukhmal

Figure 2: Local almond varieties consumed as a green fresh.
Source: Agricultural Almonds Cooperative Association, 2022.

2.3. Planting steps

In the past almond was planted from seeds from a chosen productive tree, but normally it will not be like the mother plant. At present almond orchards are established with grafted true to type plants from nurseries and commercialized as plants with bare roots or in soil. Planting with bare roots must be done during winter dormancy, between December and February (*Arquero, O. and Jarvis-Shean, K. 2017*). Immediately after planting three steps must follow:

- Irrigation: to moisten the soil and to remove the possible air pockets between the roots and the soil;
- Pruning: this is done to facilitate tree formation and to obtain a straight trunk for easier maintenance and harvesting;
- Staking: it is done by placing a suitable strong stalk in the soil to a depth of 50 cm, away of 5 to 10 cm from the plant on the side of the prevailing wind and tied with an elastic material.

Grafted almond transplants are usually planted in normal planting systems, medium densities or high densities, as in the following table.

Table 1: planting densities and the number of trees per 10 Dunums (1 ha) - Kumar, D. et. Al. 2012.

Planting system	Planting distance	Trees/ha (density)
Normal system	6 x 6 m	278
Medium density	4 x 4 m	625
Medium density high	3.5 x 3.5 m	816
High density A	3 x 3 m	1,111
High density B	2.5 x 2.5 m	1,600

Figure 3: Almond plantation (4 x 4 m - Density: 625 trees/ha) (Verma, M. K.).

2.4. Flowering and fruiting

Almond flowers are variable in size, shape and colour depending on the cultivar, are not self-pollinating and require bees for pollination.

Figure 4: Types of Almonds' flowers

Different sizes of almond flowers.

Different colours of almond flowers.

Flowering start with vegetative buds becoming flower buds; this process takes place during the summer season previous to bloom, close to mid-August depending on the cultivar, and has two main requirements:

- Adequate developmental stage of the tree;
- Equilibrated nutrient status.

Preserving the nutrient balance of almond trees is a crucial management practice to avoid alternate bearing since when the crop level is excessive, the effort of the tree in raising this crop reduces the possibility of allocating nutrient reserves to flower initiation in the following season (*Company, R. S. 2017*).

Flower opening starts when the chilling requirements are fulfilled, which is low for most almond varieties, that's why the almond is one of the earliest fruit trees to bloom. To continue flowering, the flowers need heat accumulation to full bloom which is followed by pollination, fertilization and fruit growth. The fulfilment of the chilling requirements of almonds is important to produce quality fruits. Almond cultivar's chilling hours' requirement range is very wide from 200 to 600.

2.5. Plant formation and pruning

Shape pruning of young trees and yield pruning of almond trees are fundamental applications which are necessary. Fruit trees are pruned for several purposes such as limiting the height of the tree, controlling the canopy of the tree, maintaining the balance between vegetative and generative growth, producing good quality and highly productive fruits every year and increasing production and size of the fruit (*Ikinci, A., et al, 2016*).

Plant formation and pruning in general affect fruit tree vegetative and productive development, longevity, productivity, disease and pest management, harvesting, and other agricultural practices like easiness of pruning and fruit thinning which affect the quality of the final product. Suitable shape and pruning also allow greater light interception by the tree canopy which increases the productivity and quality of the fruits.

2.5.1 Plant formation:

At planting time, in order to produce a well-balanced tree, almond transplants can be shaped and formed into open centre, by doing the following:

- Cut back to 1 m above the ground level;
- Retain 3-4 main branches at angles of 45˚ to 60˚ of the main trunks.

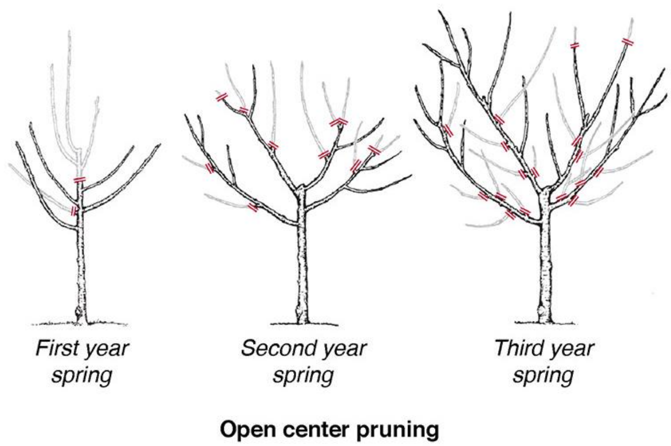

Figure 5: Open centre pruning of a fruit tree.

2.5.2. Pruning

Almonds produce most of their fruit on short spurs which remain fruitful for about 5 years. Pruning programme should be planned in such a manner that 20% of fruiting wood is replaced each year. The aim is to have at any time numerous 1 year old shoots of a length of 35-50 cm, as these shoots will normally produce nuts for the next 4 years. Older branches have to be removed.

In case of old trees lacking vigour, growth can be stimulated by severe pruning. Suckers should be removed all the time when appeared. Suckers could be used to replace damaged tree tops or rootstock suckers might be grafted with the same cultivar or new ones.

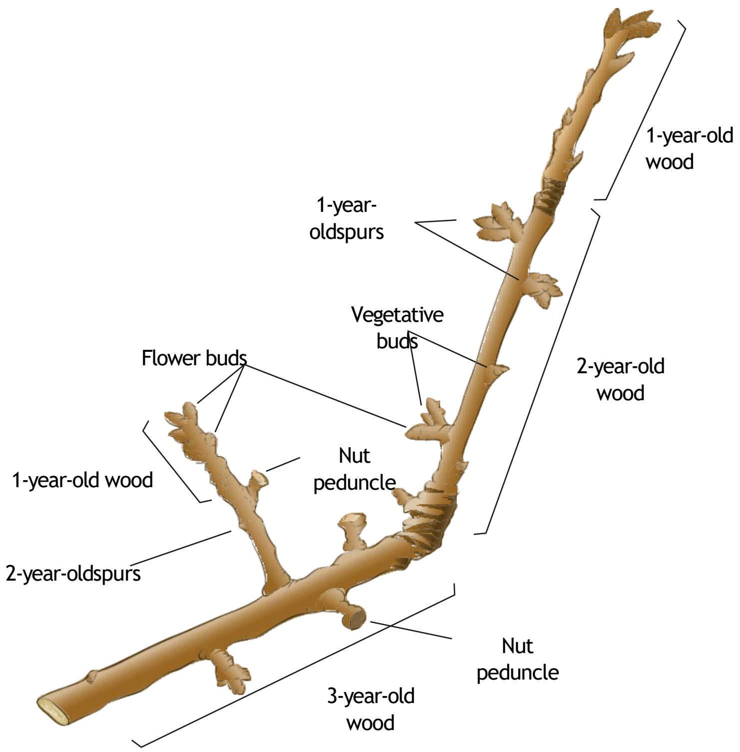

Figure 6: Almond bearing habit. One-and 2-year-olds pursborne on 2-and 3-year-old wood, respectively (Tombesi, S., 2016).

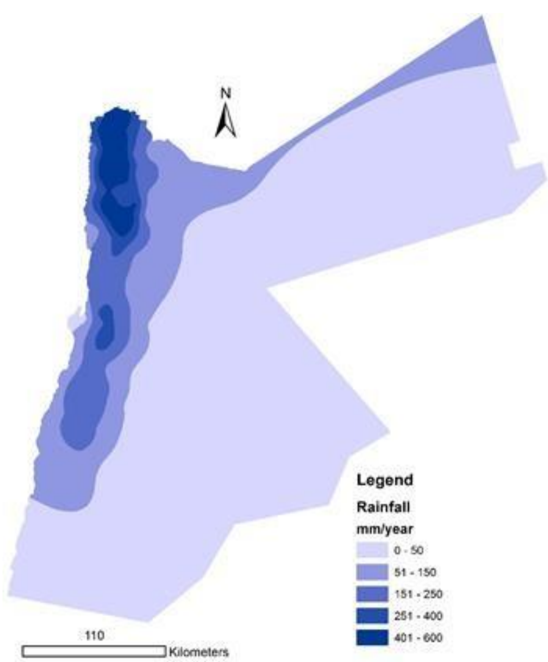

Figure 7: Rainfall patterns map of Jordan, (Odeh, T. 2020).

2.6. Water management and irrigation

Mediterranean crops, such as almond, are adapted to long and dry summers with high temperatures and little rain, which greatly limit agricultural productivity in those climates (*Jacobsen, S.-E, 2012*). As a drought tolerant tree, almond water requirement is estimated between 300 to 400 mm and mostly depends on rainfall to fulfil partially the water requirements of the trees, supplementary irrigation of 3-4 irrigations at an interval of 10-15 days (*Verma, M. K.*) is needed during critical developmental stages at seedling stages till 3 years old, at flowering (Feb to March), during fruit development (April, May and June) and in hot summer days, to compensate for bad rainy seasons.

2.7. Nutrient and soil fertility management

Almond requires a number of elements for growth and development and, if any of these are deficient, growth and production are impaired. These elements are either present in the soil or provided as fertilizers. The primary macro-elements N, P and K, are required in higher quantities while S, Ca and Mg are required in smaller quantities. The micro-nutrients B, Zn, Cu, Fe, Mn, Cl, Mo and Ni are required in much smaller amounts (*Muhammad, S. 2107*). Soil fertility can be improved by the following practices:

- Adding mature manure and compost to the soil;
- Plating cover crops, especially nitrogen-fixing crops like lupine, faba bean, peas, chickpea etc.;
- The use of soil conditioners such as zeolites, which are locally available, may have the potential to regulate nutrient bioavailability, improve certain physical and biological processes in the soil, enhance water-holding capacity and cation exchange capacity, and thus improve nutrient uptake. (*Lopes, J. et al. 2022 and Martins, S. et al. 2022*).

Under rainfed conditions, where most of the almonds are produced, the application of fertilizers is restricted to late winter or early spring following the rainy season. After mid-spring to late summer, the lack of rain prevents the efficient use of fertilizers applied to the soil. In these conditions, foliar sprays could be a complemental strategy to improve the nutritional status of trees and if applied post-harvest can enhance flowering in the following spring (*Arrobas, M. 2019*). Special attention should be put on the deficiency of Boron, an essential micronutrient involved in the physiological processes of plants.

3. Common almond tree diseases, insects and their management

3.1. Brown rot of flowers and fruits or blight of twigs, (Monilinia spp.)

This is a fungus that infects the twigs and buds of almonds. The sensitivity of almonds to this disease varies according to the varieties, and there are more sensitive varieties than others.

Almond trees can be prevented from disease by getting rid of infected branches from previous seasons and not planting varieties sensitive to the disease. If conditions are suitable for the disease, spraying with fungicides should be started in the pre-flowering stage, and if the appropriate conditions for infection with the disease persist, it is recommended to spray trees again after flowering.

Figure 8: Symptoms of Brown rot disease on almond fruits caused by Monilinia spp.

3.2. Leaf curl disease, (Taphrina deformans)

It is a fungal disease that affects the leaves of almonds, where the *Ascomycetes* spores of the fungus present on the branches and buds of the tree from the previous season, infecting the new leaves in the presence of suitable conditions for the development of this fungus. The leaf curl disease fungus spreads at the beginning of the leaf growth stages.

Figure 9: Leaf curl disease caused by Taphrina deformans (Verma, M. K.).

In the event of high relative humidity or rain in small quantities with the prevalence of moderate temperatures, the fungus infects the leaves and begins to develop, and at the end of spring and with the rise in temperatures, the ability of the fungus to develop declines. Spraying operations against the disease begin immediately with the emergence of leaves, and spraying operations continue if there are appropriate conditions for the spread of the disease. When the disease appears on the leaves, it is preferable to remove the affected leaves and dispose of them outside the orchard.

3.3. Almond Anthracnose, (Colletotrichum spp.)

It is one of the most widespread fungal diseases in almond trees, capable of infecting flowers, fruit and branches. The conditions suitable for the spread and development of this fungus are determined by relatively high temperatures with the presence of high air humidity, in conjunction with rainfall in the period from the beginning of flowering to the late stages of spring. The symptoms of this disease are similar to those of brown rot and are represented by rot and fruit drop.

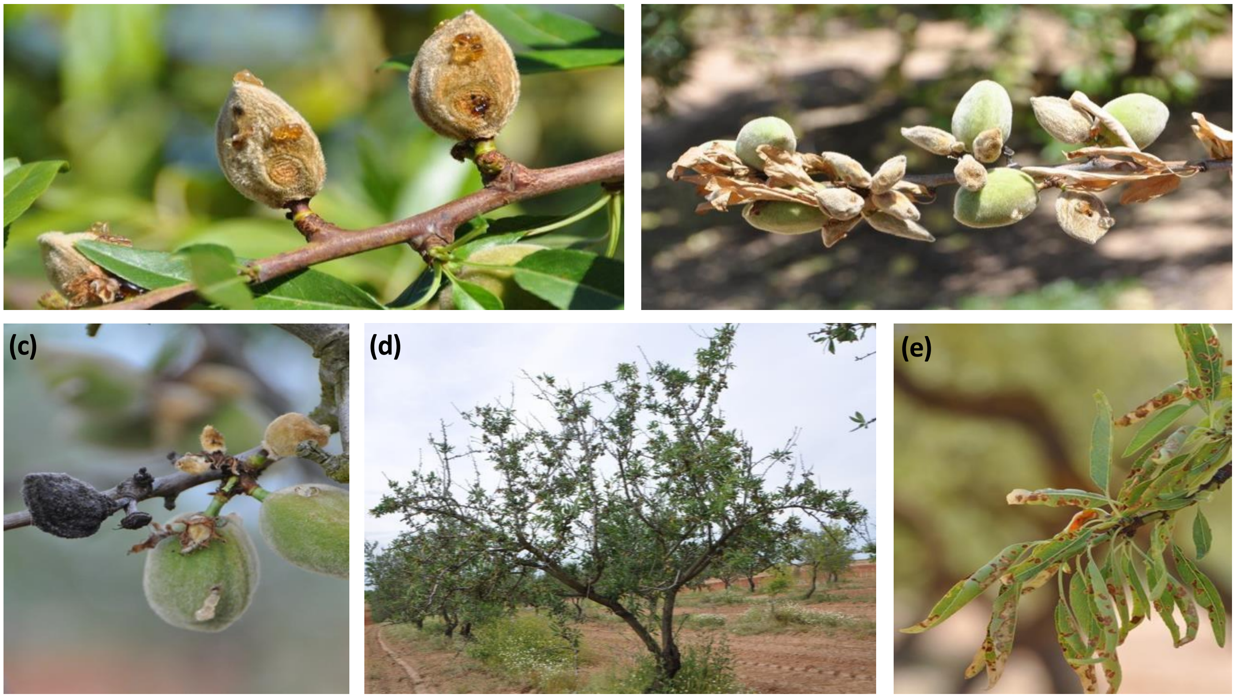

Figure10: Almond Anthracnose, (Colletotrichum spp)

(a) Anthracnose caused by Colletotrichum spp. depressed, sunken, round and orange lesions on green almonds; (b) branch with mummified fruits and necrotic leaves; (c) mummified fruits from infections caused the previous year and remaining in the tree canopy; (d) defoliation and die back of shoots and branches as a consequence of the toxins produced by the pathogen; (e) necrotic irregular lesions in the tips and margins of the leaves (López-Moral, A. et al 2020).

Prevention of this disease basically consists of removing infected branches and fruit from the previous season. Fungicide treatments may be necessary, as a preventive activity, if conditions suitable for the spread of the fungus occur.

3.4. Aphids (Aphis spp.)

Figure 11: Leaf curl Aphid (Verma, M. K.).

A leaf aphid is a small insect that infects many plants and feeds on the leaves of almond trees. Usually, the eggs of aphids are present on the tree from the previous season, and these eggs begin in the spring season and in conjunction with high temperatures to develop, the eggs hatch and emerge from them as small insects very similar to insects full. A leaf insect can produce several generations of aphids in one season, and aphids can move from one host to another in the same season. Aphids attack young trees, causing great damage to them.

Approved insecticides are recommended when infestations are very high. The aphid infestation must be treated immediately when it attacks the young plantings because the aphid attacking those plantings can lead to the death and loss of those seedlings.

3.5. Stone fruits crown borer (Capnodis anthracina).

The *Capnodis*, a Buprestid insect beetle is one of the most devastating insects of stone fruits orchards including almonds in the highlands of Jordan (*Al-Antary, T. 2020*).

Black beetle with white spots, the length of the adult insect is 4 cm, and the length of the larva is about 12 cm. *Capnodis* are active at the beginning of spring and continue until the end of summer. *Capnodis* and their larvae cause great damage to almond trees, as the beetle lays its eggs in dry soil, under stones or sometimes inside cracks. Then those eggs hatch to release the larvae that attack the roots and the crown and destroy the tree.

A single female can lay around 100-1,000 eggs during its life cycle and the longevity of an adult insect varies from four months to one and a half years.

Figure 12: Capnodis spp. infecting almond, symptoms. Larvae, Adult (Al-Antary, T. 2020).

Periodical visual monitoring of almond trees is strategic to identify infected trees and adult beetles before any programmed control measures specially in early stages where insecticide treatments may have effect and reduce damage. The insecticides can target the adult beetles at the end of spring when it starts to emerge and feed on the leaves before starting oviposition of her eggs on the soil near the tree trunk. Insecticides also can target the larvae which already infested the crown area of the trees.

3.6. *Almond seed wasp (Eurytoma amygdali)*

The almond seed wasp, *Eurytoma amygdali* (Hymenoptera: Eurytomidae), is a key pest of almonds in a number of European countries and in the Middle East (*Athanassiou, C. G. 2008*). It is a seriously harmful insect in Jordan, especially for green almonds, and can cause a loss of up to 50% of the fruit.

Figure 13: Infested almond fruits by the Almond seed wasp (larvae in green and dry almond fruits and the adult insect) (Al-Antary, T. 2020).

The infested fruits usually become blackish in colour with small masses of gums due to larval feeding and it is important for the farmer to collect these infested fruits and destroy it to reduce incidence the next season; other agriculture practices to control this insect can be used by avoiding planting sensitive varieties and planting relatively resistant ones and using yellow sticky traps for monitoring and mass trapping. When needed, spraying with relatively contact safe pesticides can be timed with the first appearance of the emerged wasp adults (Al-Antary, T. 2020).

3.7. *Sustainable Pest Management*

The approach to pest management should take into consideration the reduction or total exclusion of usage of pesticides through the application of the IPM or Organic Agriculture methods.

3.7.1 Organic production

It is a comprehensive system of farm management and food production based on the interaction between best practices in environmental and climate action, a high level of biodiversity, the preservation of natural resources and the application of strict animal welfare criteria and rigorous production standards that meet the preferences of a growing number of consumers for products made with natural substances and processes totally excluding chemicals. Organic production therefore responds to the growing demand for food produced by means and methods that contribute to the protection of the environment and biodiversity, animal welfare and rural development. Any farmer applying for the method has to provide certifying his activities/products under an approved Certification Body (third independent party) against a specific law/Regulation (in case of export to European countries, EU Reg. 848/2018).

3.7.2 Integrated Pest Management

It is defined as the careful consideration of all available methods of plant protection and the subsequent integration of all appropriate measures to discourage the development of pest populations. The use of plant protection products and other forms of intervention are maintained at levels that are economically and ecologically justified while reducing or minimising risks to human health and the environment.
When using chemical pesticides, the choice of plant protection products must be very careful. First of all, only those approved for the crop and the target must be chosen, then toxicity (for the environment, users and consumers) and residuality of the individual pesticides used must be taken into account in addition to the aspects just mentioned, also in relation to the maximum residue limits imposed in the countries of production and export.

3.7.3 Pesticides limits in the export countries

Before exporting the product to a foreign country, it is necessary to be aware of the regulations in force concerning the use of chemicals and maximum permitted residues. In particular, a maximum residue limit is set for each plant protection product approved for use on the crop. It is therefore necessary to check, by means of multi-residual laboratory analyses, whether or not the production complies with this established limit.
Conversely, if a plant protection product has been withdrawn or not approved in the country to which it is intended to be exported, it will have a predefined maximum limit of 0.01 mg/kg, which is equal to the lower limit of analytical quantification. In practice, there should be no traces of that substance on the product to be marketed.

Useful information can be checked on the official EU pesticide database, in the case of exports to European countries, or on the FAO pesticide database for all those countries that do not have their own regulations.

https://food.ec.europa.eu/plants/pesticides/eu-pesticides-database_en

https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/commodities-detail/en/?c_id=254
Codex standard for pesticide maximum residue levels (MRLs) in food and feed which is amended each year by the Codex Committee on Pesticide Residues (CCPR).

Active Ingredients allowed in EU countries on Almond: type, safety period and EU MRLs

Active Ingredient	Org.	Type	Safety period (days)	EU MRL mg/kg	Active Ingredient	Org.	Type	Safety period (days)	EU MRL mg/kg	Keys
Acetamiprid		I	7	0,07	NAA		P	7	0,06	A = Acaricides
Pelargonic Acid		H P	3	-	Mineral oil		A C I	20	0,01	B = Biological auxiliaries
Bacillus amyloliquefaciens		F	-	-	Oxifluorfen		H	-	0,05	C = Adjuvants
Bacillus subtilis ceppo QST 713		F	-	-	Paclobutrazol		P	-	0,01	H = Herbicides
Bacillus t. sub. kurstaki		I	3	-	Paecilomyces lilacinus		N	-	-	F = Fungicides
Boscalid		F	28	0,05	Pendimethalin		H P	-	0,05	I = Insecticides
Captan		F	-	0,07	Pyretrins		I	2	1,00	L = Limacides
Clorantraniliprole		I	21	0,05	Propaquizafop		H	30	0,01	M = Pheromones
Coniothyrium minitans		F	-	-	Pyraclostrobin		F	28	0,02	N = Nematocides
Cydia pomonella Granulovirus		I	3	-	Pyraflufen ethyl		H	21	0,02	P = Phytoregulators
Dazomet		H F I N	-	0,01	Quizalofop-P-etile		H	-	0,01	Approved for Organic
Deltamethrin		I	28	0,02	Cupper		F	14	30,00	
Diflufenican		H		0,01	Potassium salts of fatty acids		A I	-	-	
Emamectin benzoate		I	7	0,01	Spinosad		I	7	0,07	
Aluminium phosphide		A I	6	0,09	Tebuconazole		F	-	0,05	
Magnesium phosphide		I	7	0,09	Trichoderma		F	-	-	
Glyphosate		H	-	0,1	Trichoderma		F	3	-	
Isoxaben		H	-	0,05	Ziram		F	150	0,1	
Lambda-cyalothryn		I	7	0,01	Sulfur		A F	5	-	
Metaldeide		L	20	0,05						
Metam-potassium		H	-	0,01						
Metam-sodium		H	-	0,01						
Metribuzin		H	-	0,1						

Source: EU DB, 2022 November

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