A Roadmap for the introduction of Vital Fluid Natural Nitrogen in the Spanish (organic) Horticulture

A desk and field study

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Referaat
Stikstof bemesting is een grote uitdaging in de biologische tuinbouw. Via plasmareactoren kan stikstof uit de lucht worden vastgelegd in water, een oplossing dat kan worden toegepast via het irrigatiesysteem. Spanje heeft de grootste gecertificeerde oppervlakte biologische teelt van Europa. Uit desk- en veldstudie door WUR Glastuinbouw & Bloembollen in samenwerking met VitalFluid, Doornebosch Advies en VanWaarde in het kader van een Topsector Seed Money Project blijkt dat deze innovatie goed past in de Spaanse biologische glastuinbouw en zou kunnen bijdragen aan het verbeteren van de N-aanbod en productie. De provincie Almeria concentreert het grootste aandeel biologische glastuinbouw, een goede kennisinfrastructuur en passende financiële instrumenten voor innovaties. Potentiële gebruikers in de regio bevestigen dat Natuurlijke Stikstof zeker een oplossing zal zijn voor de N-voorziening van vooral vruchtgroente met korte teeltcyclus, en zijn bereid deze over te nemen. Hiertoe moet het succesvol blijken in lokaal uitgevoerde tests, prijsconcurrerend zijn, goedgekeurd worden voor gebruik als input in de biologische tuinbouw en geen negatieve invloed hebben op het bodemleven of de isotopische voetafdruk van de producten. Lokale certificatie-instellingen zullen Natuurlijke Stikstof goedkeuren nadat het is opgenomen in de EGTOP-lijst van toegestane inputs in de biologische tuinbouw.

Abstract
Nitrogen supply is a great challenge in organic horticulture. Natural Nitrogen fixation from ambient air in water through plasma reactors provides an alternative solution for the nitrogen supply in organic farming. Spain has the biggest certified surface of organic cultivation in Europe. Desk and field research by WUR Greenhouse Horticulture & Flower Bulbs in cooperation with VitalFluid, Doornebosch Advies and VanWaarde, within the context of a Top Sector Seed Money Project shows that this innovation would fit well in the Spanish organic greenhouse sector and could contribute to improve the N-supply and therefore the yields of especially short cycle crops. The province of Almeria concentrates the biggest national share of organic greenhouse horticulture, a good knowledge infrastructure and suitable financial instruments for innovations. Potential users confirm that Natural Nitrogen will certainly be a solution for the N supply and are willing to adopt it, provided it is successfully demonstrated under local conditions, is price-competitive, approved to be used as input in organic horticulture and it does not negatively affect the soil microbiome or the isotopic footprint of the produce. Certification bodies will approve Natural Nitrogen after it has been included in the EGTOP list of authorized inputs in organic horticulture.

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Summary

Nitrogen supply is a great challenge in organic horticulture, where the main source of nitrogen must be manure or compost. The availability of price-competitive organic fertilizers is scarce, and yields obtained in organic greenhouses are still lower than under conventional greenhouses. Natural Nitrogen obtained through plasma reactors enabling nitrogen fixation from ambient air in water is a Dutch Innovation that, applied in drip irrigation systems in greenhouses, provides an alternative solution for the nitrogen supply needed for plant growth that can be applied in an organic farming environment.

Spain has the biggest surface of certified organic greenhouse cultivation of Europe. In order to find out to which extent 1) this innovation would fit in the Spanish organic greenhouse sector, 2) could contribute to improve the N-supply and therefore the yields, and 3) to stipulate the best way to introduce the technology successfully, a desk and field research has been conducted by the Business Unit Greenhouse Horticulture & Flower Bulbs of Wageningen University and Research. The project was a cooperation between the Dutch companies VitalFluid, Doornebosch Advies and VanWaarde, with the support of the Agricultural Office of the Embassy of the Netherlands in Madrid, within the context of a Seed Money Project and with financial support from the Top Sector.

Many opportunities have been identified for a successful introduction of Natural Nitrogen in the Spanish greenhouse horticultural Sector. It is recommended to concentrate on the east-southern province of Almeria, which represents the biggest national share of certified organic greenhouse horticulture (4260 ha in 2019). In the region, besides a great number of potential users, there is a good knowledge infrastructure, active learning networks linked to the commercialisation entities, and suitable financial instruments for the introduction of innovative solutions. Despite the low technology level of the companies, modern irrigation systems are present in nearly all greenhouses with above 80% of the companies having automatic irrigation controllers. Provided the Plasma reactors can be incorporated to the existing irrigation equipment heads, the use of Natural Nitrogen will not need bigger investments that the reactor itself and only small changes in the fertilization supply habits for most of the growers. Natural Nitrogen will be applicable and a welcome solution for the organic nitrogen supply problems, with special benefits to be expected for short cycle crops, for which there is little time for mineralization of the organic nitrogen. Compared to the organic fertilizers used in Spain, Natural Nitrogen might improve the pH regulation of the irrigation solutions and reduce the risk for clogging of drippers, reducing the need for replacement of driplines and drippers.

There are also some burdens identified that can threaten or slow down the quick adoption of Natural Nitrogen by Spanish organic growers: on the economic side, the increasing scarcity of water, the high cost of water and electricity, and the relative abundance of nitrogen in water sources might make the technology more expensive compared to the actual N-sources used in organic horticulture. On the legislation side, to be recognised / authorized as input in organic horticulture by the UNE, it first needs to be included in the EU EGTOP lists of authorized inputs. On the marketing side, Natural Nitrogen will have to prove that it does not affect the isotopic footprint of the products cultivated.

Potential users confirm that Natural Nitrogen will certainly be a solution for the N supply, and they are willing to adopt it, provided: a) it is successfully demonstrated under local conditions, b), it proves to be price-competitive compared to actual organic fertilizers, c), it is approved to be used as input in organic horticulture, d), it does not negatively affect the microbiome in the root zone and e), it does not modify the isotopic footprint of the cultivated products.

It is recommended to initiate three parallel paths, one for local demonstration, one for distribution of the reactors and one to achieve the authorization as input:

- Local Demonstration path: This path starts by applying for the Incubator program of the research centre of the Cajamar Foundation, which will automatically involve a local demonstration test at very advantageous conditions. It is recommended to concentrate the efforts on two crops: Tomato, because it is the main crop cultivated in the area in relevant organic farms, and because it has the highest input of fertilizers in both kg N/ha and in total cost per ha in fertilizers. Cucumber is also interesting because it represents the short cycle crops having the greatest difficulties to achieve sufficient mineralization of organic nitrogen in the soil and therefore the biggest potential yield benefits. The tests must include analysis of the isotopic footprint, besides effects on yield, pH regulation, clogging of drippers and impact on soil microbiology. Following demonstration, semi-commercial tests should be initiated in several selected farms belonging to different commercialization entities, as many of them have demonstration and test fields. This is the general "modus operandi" with other technology, as well as seeds or varieties, to which growers are very used. We recommend including both very low technology farms and more technologically advanced farms, in order to avoid that the Plasma technology becomes associated with higher technologically advanced greenhouses.
- Distribution path: this path travels through partnerships with local suppliers of irrigation systems and water technology to farms, as well as partnerships with suppliers of renewable sources of electricity to start advancing on the concept of the in situ production of Natural Nitrogen independently of the grid energy costs.
- Authorization path: This path starts approaching the Spanish Ministry of Agriculture, continues through the EU to achieve the EGTOP inclusion in the list of authorized inputs in organic horticulture, after which national inclusion (UNE) will follow.

1 Introduction

1.1 Problem definition and opportunity

The Spanish organic greenhouse farming sector is one of the biggest in Europe. In 2016 its size was estimated to be over 1,800 ha on a total European organic greenhouse surface of 5,000 ha (Tittarelli *et al.* 2016). Only in the region of Andalucía (the leading greenhouse region in Spain), it has grown to a total of 4,600 ha in 2019 (Martin *et al.* unpublished). These numbers clearly indicate the importance and growth of the Spanish organic greenhouse sector.

For this sector, as for the entire agricultural industry, there is a strong drive to develop towards more sustainable and circular food production. Many challenges are to be faced to achieve the goals laid down in EU and national policy roadmaps, such as the Farm^{2}Fork strategy of the European Union as part of the European Green Deal roadmap. In addition, there is an ongoing technical and scientific discussion about the challenge of dealing with the principles of organic farming in the context of greenhouse horticulture whilst supporting the need for increasing organic greenhouse production in various climatic and geographic conditions (Tittarelli, 2020).

One of the challenges the horticultural sector is facing, is reducing the use of fertilizers, shifting towards more sustainable and circular use. Nitrogen based fertilizers that are produced according to the Haber-Bosch process are dominantly applied in non-organic horticulture. However, this is not suitable for organic horticulture as it does not match the principles of organic farming. Nitrogen is one the main elements needed by plants. It is an essential component of proteins, chlorophyll, vitamins, hormones and DNA. Because nitrogen is an integrant of enzymes, it has an essential role in all metabolic reactions in plants. One of the main differences in production between conventional and organic horticulture lies in the nitrogen supply and extractions by the crops. The main source of nitrogen in organic farming must come from (organic) manure or compost and the use of green manure. Additional fertilizers like liquid nitrogen fertilizers can be used when the compost and (green) manure does not supply sufficient nutrients. Nitrogen supply is a great challenge in organic horticulture, especially in areas with poor soils, like the ones in Almeria, where the so called “enarenado” technique is common. This technique consists of applying a high-quality soil layer, organic matter and a sand mulch layer on top of the original poor soils. The enarenado technique is expensive and many growers are abandoning it to directly apply the organic matter and the sand mulch on top of the original soil, which is much less fertile, which poses a challenge to maintain productivity. Also, excessive use of water and contamination of water with fertilizer lixiviates is a present problem in Spanish horticulture. Therefore, alternative solutions to provide nitrogen for plant growth need to be developed that can be applied in an organic farming environment. The availability of price-competitive organic fertilizers is scarce, and yields obtained in organic greenhouses are still lower than under conventional greenhouses. These differences in yield are mainly attributed to limitations in availability of nutrients since the greenhouse structures and the growing systems are the same under both types of management.

1.2 VitalFluid proposition

VitalFluid, a spin off company of Eindhoven University of Technology, is the knowledge and expertise centre for the development and commercialization of high-tech plasma technology. VitalFluid develops and produces plasma reactors that enable nitrogen fixation in water from ambient air (Hoeben *et al.* 2019, Pemen *et al.* 2016). The result of this process, which requires, apart from water and air only electricity, is the so-called Natural Nitrogen (the previous stage directly after activation is known as plasma activated water). Natural Nitrogen is essentially a potent solution of nitrate in water, which is produced on-farm using (solar powered) electricity, water and air. This can be applied in drip irrigation systems in greenhouses, with a previous neutralization to optimum pH (Natural Nitrogen has a pH 2, too low to be directly used) as an alternative to existing nitrogen fertilizers. Over the past years VitalFluid has been able to develop plasma reactors that allow controlled production of Natural Nitrogen. The next step is the introduction of systems in several markets. The initial focus of Natural Nitrogen is the organic farming sector. Since traditional synthetic fertilizers cannot be applied in organic horticulture, Natural Nitrogen can provide an alternative and additional solution to existing organic nitrogen fertilizers.

The combination of the size and scale of the Spanish organic greenhouse sector, the challenges the organic farming in general is facing and the conditions in Spain, appear to present an enormous opportunity for the introduction of Natural Nitrogen. Natural Nitrogen provides a viable alternative fertilizer for organic greenhouses without the downsides of the traditional synthetic fertilizers.

1.2.1 What is Natural Nitrogen?

Natural Nitrogen is the product of the fixation of the essential fertilizer nitrogen from the air into water through biomimicry of lightning in a thunderstorm. When lightning strikes, the surrounding air, which consists of oxygen and nitrogen, is brought into the plasma phase. When air is brought into the plasma phase, the oxygen and nitrogen molecules in the air become reactive, which results in easily dissolving molecules in water. As in nature, when lightning strikes during a thunderstorm: rain and surface water are then naturally treated with an air plasma. The rain then settles on the earth's surface and flows into the soil. It is one of nature's ways of fixing nitrogen in the form of nitrate, the most important fertilizer for plants. Nowadays, this natural process is accountable for approximately 10% of the total amount of bound nitrogen on Earth.

1.2.2 What is needed to fixate Natural Nitrogen?

This process of nitrogen fixation is, according to the principles of biomimicry, translated one-on-one into a technological innovation: high-tech reactors that produce Natural Nitrogen. Only water, air and (sustainably generated) electrical energy are required for the production. Because of this, Natural Nitrogen can be produced in-situ. The local production has the advantage, compared to synthetic fertilizers, that there are no CO_2 emissions in case green electricity is used, and no pollution and risks for people and environment because of packaging, storage, transport and distribution of the fertilizer.

1.2.3 Advantages of Natural Nitrogen compared to current organic N Fertilizers

The high-tech reactors make organic fertilization, via drip irrigation, possible for every grower. The technology is scalable to the desired level, as nitrogen (as a raw material) is unlimited and free available, and the required amount of greenhouse gas emissions is (due to the lack of transport, storage and distribution) lower than that of other organic fertilizers. Because organic growers can produce fertilizer in-situ only based on water, air and electricity, they become less dependent on suppliers. VitalFluid's technology can therefore contribute to bring circular food production within reach. Compared to current organic nitrogen fertilizers, Natural Nitrogen can be applied in rates that precisely meet the demands of the crop (precision growing), making zero-emission horticulture possible. This is especially important in Spanish horticulture, where aquifers and other groundwater resources are at risk of severe nitrate pollution due to intensive horticulture.

1.2.4 Other suppliers of this technology

Vital Fluid is not the only company that commercializes technology to produce plasma activated water. Other companies are active in the field of Plasma Technology and are looking at agricultural applications. To name a few European companies: PlasmaLeap Technologies (https://www.plasmaleap.com/) from Ireland, N2 Applied (www.n2applied.com) in Norway and Blue Engineering (www.blue-engineering.nl/expertise/plasma) in Venlo, The Netherlands.

1.3 This project

Natural Nitrogen is a Dutch Innovation that contributes to the Missions of the Knowledge and Innovation Agenda of The Dutch Top Sectors. Within the context of a Seed Money Project, The Dutch Top Sectors support this project to explore export possibilities for new knowledge and innovation to Spain.
The project is a cooperation between VitalFluid, Doornebosch Advies, VanWaarde and Wageningen University and Research, Business Unit Greenhouse Horticulture & Flower Bulbs, with the support of the Agricultural Office of the Embassy of the Netherlands in Madrid.

1.3.1 Cooperation Structure

VitalFluid has the technological expertise that is essential for the production and application of Natural Nitrogen. They will provide detailed information on their product, including quantitative numbers on the performance of their technology and share their vision on how to implement their technology in agriculture.

VanWaarde is a Dutch strategy consultancy firm with a strong focus on sustainability transition challenges. VanWaarde is a strategic partner of VitalFluid and collaborates with VitalFluid on the development of the corporate strategy. VanWaarde has expertise on setting up market strategies and business models and to transfer these into concrete growth paths.

Doornebosch Advies is a Dutch agricultural consultancy firm with a focus on organic agriculture and the applicable rules and regulations. Doornebosch Advies supports VitalFluid in the analysis of rules that apply to Natural Nitrogen and the application and certification process to obtain the required approval for Natural Nitrogen.

The project team from Wageningen UR Greenhouse Horticulture is composed of two native Spanish speaking researchers with a broad network in the targeted sector in Spain and broad experience in horticulture research, as well as experience in sector studies.

The Agricultural office of the Dutch Embassy and the recently re-established “Landbouwraad” will act as an advisor and supporter of the project. They will contribute with their knowledge of the local market characteristics, through their local network, both on business and governmental level.

2 Aims of the project and methods

The aim of the project is to perform a study to find out what is the best way for the introduction for commercial application of Natural Nitrogen in the Spanish organic greenhouse sector, through exporting of the plasma reactors, knowledge and innovations developed by VitalFluid and its partners.

2.1 Questions to be answered

Knowledge of the Spanish organic greenhouse sector needs to be gathered to be able to define feasibility of application of Natural Nitrogen in Spain and what would be a successful introduction strategy.
Some of the questions that need to be addressed are:

- Analysis of the state of the art of the organic greenhouse sector in Spain: identify companies, public and private institutes, other stakeholders. Gain insight in the structure of the value chain in Spain.
- Define criteria for selection of (local) key-partners such as plant nurseries, major growers, (fertigation) system integrators, experts on rules and regulations, and suppliers of farm inputs.
- Check on suitability of the solutions offered by VitalFluid for the Spanish organic greenhouse sector. What is the level of technology and development of local companies, and would they be prepared for the application of the solutions provided by VitalFluid?
- Gain knowledge of the national and regional rules and regulations that would be applicable to Natural Nitrogen in Spain, as well as the application process.

2.2 Research methods

A series of different tasks has been developed by a methodology that combines 4 types of activities:

2.2.1 Desk Study

For the desk study we made use of the available (recent) literature, statistics, recent news items in blogs and newspapers. This was complemented with a few informal preliminary interviews held online. The questionaries used for the first interviews are included in this report as Annex 1.
This resulted in the focus area, insight in the organization and level of technology of the sector, and the identification of key organizations both public and private organizations representing the organic agricultural sector, identification of the main organic greenhouse farms in Spain, main research and experimentation institutes, which can be key allies for demonstration and experimentation of the product, before entering the market. Priority was placed on those representing organic greenhouse farms, because they are more open to innovation and have larger investment capacities. Attention will be also paid to main certification organizations and to financial instruments to stimulate investments in organic horticulture.

2.2.2 Field Study

After having identified the main players in the value chain, the field study was conducted. The field study consisted of semi-structured interviews in situ with representatives of the identified key organizations. When appropriate, interviews online were organized to enable the attendance and exchange of information with the partners of the Project from The Netherlands. Focus was laid on the following aspects:

- Availability of organic fertilizers (dimensioning of this problem or opportunity).
- Rough quantification of the size of the organic fertilizers market (with special focus on the N component).
- Technological level of the organic farms and possibilities / conditions for fast implementation of the new product.
- Need for adaptation of Natural Nitrogen production units (plasma reactors) to implement in the market and best way to introduce them.
- legislation affecting the feasibility of the application of the VitalFluid technology in different regions of Spain.

2.2.3 Analysis and interpretation of the information obtained

The information collected is analyzed into a set of conclusions: is the introduction of Natural Nitrogen in the organic market in Spain feasible, and under which conditions. The conclusions are then summarized as opportunities and threats, and recommendations are given to get the Natural Nitrogen technology introduced in the Spanish market, the actual suggested "roadmap" towards the successful introduction of this technology as a solution to the N-supply in organic horticulture.

2.2.4 Organization of a workshop with potential users

The plan was to organize a knowledge transfer event and a workshop in a middle-sized location, the auditorium of the Cajamar Foundation in Almería, inviting Key agents and potential users. However, COVID restrictions made this impossible. Instead, a smaller meeting with a group of very experienced technicians of organic production Cooperatives and the main knowledge transfer agents, was held on the 11th of November with 16 attendants. The Natural Nitrogen technology, its potential benefits were presented, and feed-back from the attendants was collected. This allowed to reach fewer potential users but a more in-depth discussion with the ones advising high numbers of growers.

2.3 This report

This report includes the results of the activities and answers to the main questions. The collected information is organised as follows:
First the greenhouse horticulture sector in Spain is described in terms of numbers, organization and value chain. (See chapter 1). These chapter gives the results of the Desk study. A subchapter is dedicated to the organic greenhouse sector, there where it differs from the conventional greenhouse sector. Special emphasis in placed on the value chain structure where it has a relevance for the purpose of this study, which is the introduction of Natural Nitrogen in Spain: who are the main players, the main change influencers, to whom do the main players listen to when taking decisions. Insight is given in the way organic growers normally fertilize: how do they prepare the soil, how do they make their plant nutrition recipes, what technology and what kind of products do they use. Who are the main certifying organizations, the main research organizations? Which financial instruments are there available for growers to innovate?
With this information, a roadmap is suggested to get the Natural Nitrogen technology introduced in the Spanish market, see the recommendations on Chapter 6.

The report also includes:
- A list of key organizations in the Spanish organic horticulture, see Chapter 1.
- Minutes of the small workshop with Stakeholders, Annex 2.
- A list of arguments to approve Natural Nitrogen in organic horticulture based on legislation as prepared by Doornebosch Advies to communicate with the certification bodies, see Annex 2.
- A technical leaflet of the Natural Nitrogen reactor, see Annex 4.
- Certification of ozone by Intereco, See Annex 4.

Please note that along this report we use different names to refer to the "product" resulting from this fixation process: sometimes we use the name of the company," Vital Fluid", most of the times we refer to it as "Natural Nitrogen". Depending on the context, we have also referred to it as "Atmospheric Nitrogen". In previous correspondence (attached as Annex 3) with the certifying bodies it was referred to the product as "Bioplasma Fertilizer". However, during the duration of this research, and as a result of the findings by Doornebosch Advies, it was concluded that the nitrate content of the product leaving the Vital Fluid Plasma reactor is too low to be considered a Fertilizer, according to the definition of Fertilizer, that is why in de document attached as Annex 3, the product Natural Nitrogen is considered "A plant Aid and not a Fertilizer".

3 Results desk study. The (organic) greenhouse sector in Spain

3.1 Acreage of organic cultivation and crops

According to the Spanish Ministry of Agriculture, (Superficies y producciones anuales de cultivos (mapa.gob.es) the total surface of protected vegetable production in Spain was 74.920 Ha in 2020. This includes both regular and organic (or "ecological" as it is known in Spain).
Most of the greenhouse production (82%) is concentrated in the Comunidad Autónoma of Andalucia, 61,482 Ha, of which 47,076 in the province of Almería.
The second Comunidad Autónoma in acreage of protected cultivation is that of Murcia (4,135 ha), The Canary Islands (1,845), Galicia (1,673), The Comunidad Valenciana (1,353 ha) and Extremadura (1,297). All other 11 Comunidades Autónomas have a very small acreage of greenhouse horticulture.

In 2019, Spain had in total 2,35 million ha of organic agriculture, accounting for 17.1 % of the EU-27 organic area followed by France (16.2 %), Italy (14.5 %) and Germany (9.4 %).
Within Spain, Andalucia is the comunidad Autónoma with the biggest surface of ecological production, accounting for 54% of the total national surface. This applies for both, open field and protected horticulture.

From the eight Andalusian provinces, Almería is by far the province with the highest number of hectares of protected cultivation with a certification in organic production, 4261 ha in 2019, representing 75,36 % of the Andalusian total.

The first producers adopting organic cultivation methods did it in the 90's (2.68 %); 38.9% made the transition in the first decade of the 00's and 58.4% from 2010 (Bertuglia and Gonzalez Rea, 2019). From 2013 to 2018, the certified surface triplicated, but the growth rate has slowed down in the last years: in 2019, only 50 new ha of greenhouse horticulture were added. (Blanco, 2020).

The main crops with a certification are tomato, sweet pepper, courgette, cucumber, watermelon and eggplant. According to Alonso *et al.* 2016, more than half of the producers (62%) usually do two cycles short a year and the most popular crops in this type of cycle are tomato and watermelon. On long cycles, where only one crop is made per year, cherry tomato (50%) and tomato (32%) are the majority.

Huelva accounts for 14,82 % of organic certified protected cultivation; it concerns mainly the berry or red fruits sector (raspberry, strawberry, blueberry, blackberry). Granada accounts for 7,81 % of the surface and Málaga for only 1,58 %, both dedicating to cucumber, tomato, sweet pepper, beans, watermelon and courgette. The rest of the Andalusian provinces have a nearly insignificant share in greenhouse horticulture and therefore also in organic protected horticulture.

Because it concentrates by far the biggest share of organic protected horticulture of Spain and given the limited time available and the restrictions and limitations that COVID19 pandemic poses for traveling, we focused on the Andalusian province of Almeria for this study.

3.2 Structures, technological level and inputs

Greenhouse horticulture in the province of Almería is a familiar business. The average size of an agricultural exploitation is 2.4 ha, and it can consist of several (smaller) greenhouses. The greenhouses are located very close to each other, with sometimes just a narrow alley separating two of them. On average, the greenhouse size is 7.500 m^2; the minimum in the province is 500 m^2 and the biggest 87.000m^2.

There are areas with predominantly very small operations, of familiar character and low revenues, smaller than one hectare (Poniente), whereas in another areas (Levante), 55% of the operations are bigger than 4 ha. The bigger operations have become more common in the recent years and correspond to enterprises with a higher investment capacity and higher technological level.

Most of the enterprises have a size of 1 to 4 ha.

The majority of the farms (84%) are privately own; 11% are rented. Most have a male owner (83%). The average age in 2016 was 43, with 35% of the owners below 40: compared to other agricultural sectors, a high percentage of younger entrepreneurs.

Most of the greenhouses (well above 90% depending on the studies by different authors) are very simple structures, covered with a polyethylene sheet, of the traditional type or Type Almería. These present in different shapes: the oldest type, the flat "parral" (the cover is almost flat) which has holes on the roof to prevent collapse by rain or hail, or the improvement of the flat type, the "Raspa y amagado" type (a two-sided roof cover), allowing better ventilation by fixed roof window and better light transmission, and the asymmetric variant. All of these are made of similar structural elements, flexible, forming a wire net that holds the plastic in between, in a sandwich way. The cover, thus, consists of a layer of flexible plastic pressed between two wire nets and prolonging towards the laterals.

A smaller share (2-3%) consists of multitunnel or industrial-type greenhouses. These are in the central part higher, automated, with better light distribution, regulable ventilation windows allowing a better climate control, and appearing in different shapes: French type multitunnel, gothic. Since they require an investment per m^2 of roughly 2 times the investment needed for an Almería type greenhouse, they have become more common in the more technically advanced enterprises. A few (glass) Venlo types have been built in Almería, but they are exceptional and much more expensive than the multitunnel.

Most of the greenhouses have little technology incorporated. Heating is not standard and when present, it consists of air heaters (4% of the total area according to García *et al.* 2016); of which some with direct and some with indirect combustion, for which different fossil sources of energy are used. A nearly anecdotic share of greenhouses) are equipped with hot water heating, using propane gas as source of energy (Valera *et al.* 2014) or, more recently, biomass (like olive pits). The supply of CO_2 is also not a widespread practice, with only a few of the greenhouses with heating using it, commonly purchased bottled.

Another activity for which most of the greenhouses have some technology is for the application of plant protective chemicals (91% of the total), and all levels of sophistication and degree of mobility can be found.

Even in the simplest, less technified greenhouses irrigation is localized (drip irrigation, 99,6 % of operations); thus, the supply of fertilizers can be controlled and very well dissolved in the water. Different types of mixing and injection systems are used, from the very most simple one-tank-and-pump system to fully automatic sophisticated injection systems.
As a complement to the irrigation equipment, many growers use a desalination machine (reversed osmose) as the water from wells in Almería has increased salinity each year. Also, growers use the desalinized water sometimes for the cooling by fogging systems, which are also mostly present in less than 6% of the surface (Céspedes *et al.* 2009), and predominantly consist of low-pressure systems; high pressure misting we can only find in the more technified operations.

3.2.1 Structures and technology in the organic horticulture subsector within the greenhouse sector

If we focus on organic subsector, two prospective studies give a good insight: one by Alonso *et al.* 2016, and one by Bertuglia and Gonzalez Roa in 2019 which also covers the producers under plastic in the province of Granada. The study by Alonso *et al.* (2016), was carried out in farms whose production was certified in organic farming. The method used was stratification by municipalities, according to the number of farms, performing a stratification with proportional allocation by municipalities. The municipal distribution used was published in the Information System on Organic Production in Andalusia (SIPEA) as of January 13, 2014, which registered a total of 418 producers. The municipalities that were considered in the sample design represented 97.4% of the producers of horticultural crops under plastic in organic production in Almería, omitting the municipalities whose proportional allocation was less than one sample unit.
A total of 42 farms were sampled, which represented 10% of the total farms under organic production under plastic in Almería at that moment (SIPEA, 2013). The data were obtained by direct observation of the installation of fertigation of selected farms and conducting surveys aimed at the owners, managers or technicians responsible for the farm. For the elaboration of the survey a questionnaire structured in three blocks was made. In the first, the general data of the producer and the exploitation were collected, in the second, complete information on fertilization management was obtained and in the third data relative to the fertigation facility.

The study by Bertuglia and Gonzalez Rea was conducted by personal interviews following the completion of questionnaires by 150 producers of the main production areas (Comarcas of Campo de Dalías and Campo de Níjar-Bajo Andarax in Almería and the coastal production areas in Granada).

Differences between both studies can be due to modernization (there is a 3-year period in between both studies) and to the size / location of the sample, but as we will see, the differences between both results are marginal.

The area of organic farms is between 0.6 and 5.0 ha, with the average area of 1.7 ha (Alonso) or 1.9 (Bertuglia), both smaller than the average obtained for the total of farms in Almería that amounted to 2.4 ha (see above). The average time since a producer has made the transition to the organic production system is 6.1 years, which denotes the recent incorporation of producers to this production system, being 8 year the mode.

Just like in conventional greenhouse horticulture, the predominant organic greenhouse consists of a simple structure of the traditional Almeria type, where 68% is the multispan parral "raspa y amagado", and still 24,4% belong to the "flat parral" type. Less than 8% are more modern types like the multitunnel or asymmetric multichapel.

The main type of cover is thermal polyethylene of 800 g, that can be unchanged for 3 years, and is used in 82,5% of the greenhouses.

Nowadays nearly all greenhouses have windows for natural ventilation, both roof and side ventilation exist in 80,35% of the cases. The control of these ventilation windows is only mechanized in 6,5 % of the greenhouses. However, in hardly any organic greenhouses there is a climate control system: only 7,4 % has incorporated a humidification or misting system. Whitewashing the cover is the most common way to control temperature by light reduction (used by 83,58% of the greenhouses in the survey by Bertuglia and Gonzalez Real, 2019). Heating by hot water is present in only 13,1% of these greenhouses, a share very similar to the one obtained by Valera *et al.* 2014 for the total of the greenhouses both conventional and organic.

The technological level of the horticulture in Spain consists mainly of low-tech companies. Structure, organization and technology in conventional and organic are virtually identical, except for the size of the greenhouse which is smaller in organic.

However, because The Natural Nitrogen must be applied with the irrigation equipment, and the penetration of automatic irrigation controllers is at least 81%, the introduction of this innovation will presumably not require great additional investments if it can make suitable for any irrigation system.

3.2.2 Soil preparation

In contrast with the Dutch greenhouse cultivation of vegetables, predominantly in substrate, less than 20% of the surface of total protected horticulture is done in substrate in Almería, as it requires more specialization but less maintenance and in return it gives higher productions (Fernández-Fernández and Cuadrado-Gómez, 1999). The most common substrates are Perlite (6%) rockwool (3.4%) turf (2.5) and cocopeat (4.3%).

The greenhouse sector in Almería cultivates predominantly in the soil: of the cultivated surface in 2013, Valera *et al.* 2014, only 5.5% do it in natural soil, 80% in prepared soil by a technique which is known as "enarenado" (see Figure 1). In the organic greenhouses, the percentage rises to 85.9% of the producers.

This "enarenado" consists of covering the surface of the cultivation ground with a layer of siliceous sand that helps retain humidity. But is a lot more complex than that:

- After the soil is levelled, a first layer (approx. 50 cm) of a soil with a more balanced texture with higher clay content, extracted from locations with a high accumulation of fluvial sediments (tierra de cañada). This layer will help avoid excessive leaching to the subsoil layers, as it rather impermeable and has a high water retention capacity. This layer also avoids the roots reaching the natural soil below.
- On top of the previous, a layer of organic matter (compost, manure or a mixture) is placed where the plant roots will be developing, and has an important function as buffer for the fertilization.
- As final layer, a thinner layer of fine coarse sand (<3 mm diameter) from beaches or dunes (recently obtained from quarries) is used to cover the soil layers.

This cultivation system, like any other, has several advantages and disadvantages. Some of the relevant for the purpose of this report are summarized below (from the ones proposed by Cortés and Camacho, 2009):

Advantages:

- Maintains for a longer period a good soil structure.
- Improves mineral fertilization.
- Improves the solubilization of the nutrients supplied.
- Maintains soil humidity longer, saving water.
- Improves the superficial rooting by the plants.
- Contributes to a higher concentration of the CO_2 above the soil, acting as a carbonic fertilization.
- Avoids the ascension of salts to the lower soil levels, acting as a continuous desalination of the soil.
- Intensifies microbial activity.

Disadvantages:

- Additional costs to normal soil.
- Makes difficult to mechanize the soil preparation to avoid the mixing of the strata.
- Pathogens develop more easily than in normal soil.
- Weed growth is also improved and it is difficult to eliminate them (only manually is possible).
- The soil fertility decreases with time, as the organic matter is mineralized and used by the plants.

Not documented by this source (Camacho and Cortés, 2009) but a disadvantage of this system compared to the Dutch greenhouse substrate system is the fact that in the enarenado, it is not possible to recirculate the irrigation water that is supplied in excess (known as drainage), which avoids emissions of fertilizers to the subsoil and helps save water and fertilizers, as the drainage can be used, replenished with fresh water repeatedly to irrigate the plants. Only 11% of the total surface cultivated in substrates was recirculating the drain water in 2014 (Valera *et al.* 2014), although earlier research (Thompson *et al.* 2000) showed nitrates leaching to the aquifers.

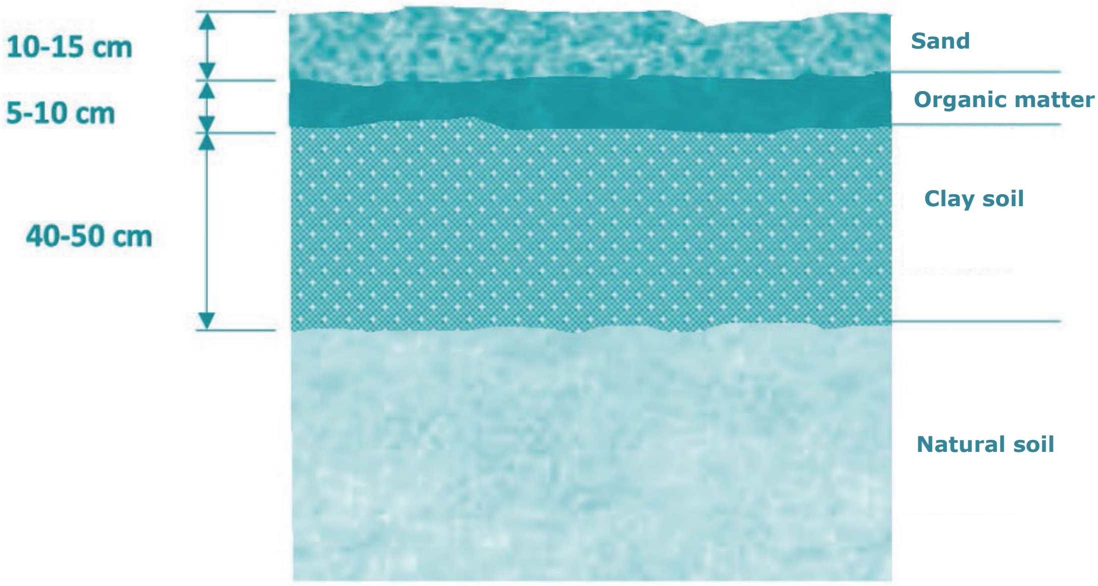


Figure 1 *Schematic representation of the "enarenado" soil preparation system. From Varela Martínez et al. 2014.*

Despite its possible drawbacks because of the emissions of fertilizers through the drainage water, the enarenado seems to be an ideal soil for organic horticulture, that requires soil with all its characteristics. This has probably been one of the key factors to enable the quick transition to organic cultivation.

A main disadvantage of the enarenado in specifically organic horticulture hinders the work of supplying base dressing (organic fertilizer), since the layer of sand must be removed for application and replaced later.

The fact that application of base dressing is difficult and labour intensive in "enarenado" soils, gives a huge potential market for Nitrogen from Natural Origin generated as Natural Nitrogen.

3.2.3 Irrigation systems in organic greenhouse horticulture

85% of those surveyed by Alonso *et al.* 2016, did not change or adapt their fertigation facility when migrating from conventional to organic system.

In practically the totality of the organic greenhouses, fertilizers are incorporated to the soil, besides by base dressing, by means of the irrigation system. Regarding the irrigation head, the more traditional system through fertilizer tanks has been replaced by more modern injection systems. The Venturi system is adopted in 75% of the greenhouses (Bertuglia and Gonzalez Roa, 2019). The most common number of tanks is of 4, with volumes of 1000 litres (Alonso *et al.* 2016).

At least 81 % of the organic growers, the same percentage as of conventional growers, have automatic irrigation controllers.

In 47% of the cases the irrigation network was in poor condition, presenting a high incidence of blockages in emitters, leaks, pressure differences, etc. The irrigation network is made up of dripper pipes in those in which the emitters are half a meter apart, in 76% of the cases. The most used drippers, according to its insertion in the pipe is interline (97.5%). Baeza and Contreras (2014) and Contreras *et al.* 2018, observed that the irrigation facilities of organic production systems in the greenhouses of Almería show a uniformity of irrigation significantly lower (only 48% uniformity) than those of conventional production systems (88 % uniformity) because of the application of organic products applied through the fertigation facility. These matters are not soluble and are incorporated in form of suspension and, although its application through the irrigation system is specified, its continued use can cause problems in localized irrigation facilities such as consequence of its physical properties: insolubility, high viscosity, etc. The results by this study showed that it is necessary to change the management guidelines of the fertilization in organic farming systems in horticultural crops of greenhouse.

The clogging of drippers is a major problem in organic horticulture. This creates a potential added benefit for the use of Natural Nitrogen as source of nitrogen.

The average electrical conductivity of the irrigation water used in organic horticulture is 2.7 dS m^{-1}, although the range used is very wide (0.9 to 7.5 dS m^{-1}) and is fundamentally associated with the water quality of the aquifers in the area of production.

3.2.4 Water sources, quality and cost of the water

For this section, the information was compiled by Varela *et al.* in 2013.
47,5 % of growers collect rainwater from the greenhouse cover and 19 % collect it from outside / other buildings. 70,8 % use water coming from irrigation water communities; this is water collected in common basins, extracted from collective wells, or from a desalinization plant. 17,9 % obtain water from collective wells (belonging to several growers. Private wells are owned by only 6,3 % and it is the cheapest of all, only 0.12-0.23 €/m^3. Water from wells has a very high EC (2,8 to 6,5 dS m^{-1}, so it is mostly (46 %) mixed with water from communal sources with an EC of 2 dS $m^{-1}$and a cost of 0,31-0,39 €/m^3.
Some of the Almería agricultural areas do suffer from a serious water scarcity (Maturana, 2021) and depend on water from desalinization plants. Only in the past month of October 21, the price of the m^3 of irrigation water increased by 80%, due to the increased cost of the electricity (see 3.2.6). Some news sources indicated already in March that in certain areas of Almería water is being paid as expensive as 0.7 €/m^3. That, despite the existence of a Royal Resolution that fixed the maximum price of water at 0.3 €/m^3, which is being applied in other parts of Spain.
Efforts are being made by the local government to increase the desalinization capacity of the existing plants and guarantee sufficient water at a reasonable price of 0.61 €/m^3 (IDEAL, 2021).

For making any estimation of the value of this innovation, the Natural Nitrogen, it is important to take in account the cost of good quality water and the quality of the water needed, as this can influence the price of each mol of NO_3 to obtain through plasma activation. In some areas water may come already with a substantial amount of nitrates, since nitrates leaching to the aquifers is a reality (Thompson *et al.* 2000).

3.2.5 Sources of (organic) fertilizers, quality, costs and drawbacks

As mentioned before, virtually all the farmers under organic certification use fertigation (97.6%). In fact, the management of fertilization is based, significantly, in the contribution of nutrients through fertigation. The only modification of the management of the conventional to ecological production system is the replacement of synthetic chemical fertilizers by authorized fertilizers in organic production according to a prospective study by Alonso *et al.* (2015). The most widely used fertilizers are potassium sulphate (used by 95% of the surveyed), organic nitrogen fertilizers such as vinasse (62%), humic acids and blood meal, as well as chelated calcium (40%). In organic farming to maintain or increase soil fertility the fertilization programs should be based on the incorporation of organic matter in soil. It is about achieving fertility in the medium-long term, which cannot rely exclusively on fertigation programs. Fertigation should be considered a complement to be used only when necessary. Recent studies show that the partial substitution of fertigation by applications in the background of organ-mineral fertilizers do not reduce the productivity of tomato and zucchini in the greenhouse and can help improve soil fertility (Contreras et al.,2014). Del Moral *et al.* (2012) showed that in greenhouses with horticultural crops under organic production and in which a continuous incorporation of organic matter in the soil over a long period of time (10 years), a decrease in the pH and bulk density of the soil has been observed and, as consequently, an improvement in infiltration. In addition, total organic carbon, total nitrogen and cation exchange capacity increased with respect to management in conventional.

The bottom fertilization is a generalized practice since it is carried out by 97.7% of respondents. However, only 34.4% do it every year. The provided organic matter is basically manure (80.1%) and its origin is organic – meaning that this manure is only coming from ecological animal farming – in only 38% of the cases. The majority opt for the application is in the cultivation lines (Figure 2).

Figure 2 *Example of addition of manure to the crop rows before transplant in organic greenhouse in Almería.*

This is mainly due to the cost of labour and the limitation of the contribution of nitrogen of animal origin at 170 kg ha^{-1} $year^{-1}$ to avoid contamination by nitrates of groundwater and the high presence of these in the food itself (EC Regulation 889/2008). 60% of those surveyed do not have manure analysis, compost or plant debris that they contribute to their soil. This, together with the variability in the N richness of manure according to its origin, makes it impossible to know the exact amount applied nitrogen.

According to official data of the MARM (Ministry of Environment) published in 2010, in the intensive horticulture in Andalucía (not distinguishing between conventional and organic), on average 1728 kg of fertilizers are supplied per ha each year. The supply of N fertilizer accounts for 30-35% of the total supply of fertilizers (in kg/ha) and varies greatly depending on the crop: from 228 kg N/ha in greenhouse strawberry to 779 kg N/ha in greenhouse tomato. The supply range of Phosphate fertilizers is lower, varying from 162 kg P_2O_5/ha in strawberry to 493 kg P_2O_5/ha in sweet pepper, and that of potassium (given by this source as K_2O) is higher, ranging from 238 kg K_2O/ha in Strawberry to 1394 kg K_2O/ha in tomato.

The total cost of fertilizers as indicated by the mentioned source (MARM 2010), averages 4.669 Euro/ha per year, and represents on average 14% of the total production costs.
There is a lack of official data and unfortunately there are no scientific publications dealing with the topic of fertilization costs in organic greenhouse horticulture, except some mentions that the cost of fertilization is higher in organic horticulture.

Maintenance of the equipment is a drawback that has been mentioned by different persons and are documented in several press documents (f.i. Blanco, 2020). Specially the fact that the fertilization tanks and drip lines and filters often get clogged by bacteria and organic matter accumulated. Drip lines need to be changed every two or three years, because of the impurities that accumulate and inhibit a normal water flow for irrigation. When moulds and bacteria proliferate in the fertigation tanks, serious problems can occur: The Venturi does not work well, then a litre counter is introduced in the tanks in order to be able to dose and change the programs for additions. It is not EC-based, it is not % based. It is difficult to manage the fertigation to the plant needs.
It would be recommended to take in account the savings derived from a less frequent replacement of the drip lines in any economic analysis to be performed.

3.2.6 Sources and cost of electricity

Greenhouses in Almería have relatively low energy costs. For tomato, for instance, the yearly cost on energy per unit area is only 0.2 Euro/m^2. The electricity price however has increased from June to October 2021 as much as 270%. The price per MWh reached a new record on the 6^{th} of October of 288 Euro, while in February 2021 it was only 28,5 Euro, a 10-fold increase (Fariza and Sahuquillo, 2021).

The potential to cover electricity demand by solar panels or other renewable energy sources in Almería is large, because of the large amount of insolation and the sea brises that dominate the climate. However, the number of farms under self-consumption is testimonial. A limitation is that the amount of space available is small, as greenhouse density is very large. Many growers would have to sacrifice some of their production area most of the time, to install the necessary solar panel area if they would want to use green energy to feed a Natural Nitrogen unit. The actual prices of energy might accelerate the transition to solar panels. Grower mobilizations are expected at the end of November to demand subsidies for investments in solar panels from the Central Government of Spain (Maturana, 2021).

3.3 Commercialization channels and technical advice

The commercialization channel for the agro production in the greenhouse sector in Almeria determines in great measure the way in which the growers operate. In many cases, the commercialization entity (depending on which one) offers the grower much more than only a selling channel:

- Technical advice in the broadest sense (pest control, fertilization, crop management, equipment, technical innovations, compliance with regulations).
- Organizes knowledge exchange meetings, seminars and other events.
- Introduce working protocols and working sequences depending on the quality programs implemented / in the process of implementation.
- Young plant material.
- Supplies for agriculture.
- Laboratory analysis and diagnostic services.
- Market statistics and market intelligence.
- Systems for automatic classification, processing and packing and labelling of the products.
- Commercialization.
- Some cooperatives have own experimental fields / research greenhouses for testing of new varieties, new crops and new technology.
- Sometimes the commercialization entity programs the crop distribution among their growers and along the season.

About 92 % of the growers participating in a survey by Cajamar in 2013 (Valera *et al.* 2014), commercializes his or her production through a single commercialization entity,72,6 % are member of a commercialisation entity.

The Cooperative is the most common associative commercialisation channel, with 40 % of the growers associated to one.

The second most common commercialisation channel is a “SAT” (Sociedad Agraria de Transformación) with 38 % of the surveyed growers belonged to.

The third channel, obviously less relevant in percentage of growers using it (17 %), is the Alhóndigas, like the former Dutch auctions (but are privately owned), because they concentrate offer and demand at one location, and the products are sold by decreasing bids from a starting price related often to the day before. The grower is paid almost immediately. This channel is not very transparent because it provides no information about sold volumes; the grower never can predict to which price the products will be sold, and it penalizes the growers with very good qualities as the price is mostly set for the bulk product. Sometimes deals are closed before the auction and there are often more sellers than buyers, so these last ones can agree on price formation (De Pablo *et al.* 2003).

A very small share of growers (4 %) sells their products on their own or through independent commercialization companies.

Technical advisory services reach 98,5 % of the growers participating in the earlier mentioned Survey by Valera *et al.* 2014. The technicians of the commercialization cooperatives advised in 1997 only 53% of the growers, and in 2013 their share had increased to 70,5% of the growers. Another important information source for growers (21,1%) are the supply companies; the seed supply companies advise in 0.8% of the cases. Private independent consultants have a small share of only 6,1% of the growers.

Due to the important role in the technical advising to growers of the commercialization cooperatives, the introduction of new technology, such as in this case the introduction of Natural Nitrogen, should start by approaching the Technicians that are employed by the Cooperatives.

3.3.1 Key Cooperatives and SAT

When looking at the number of associated growers / the number of hectares holding an organic certification are:

- CASI (Cooperativa Agraria San Isidro, https://www.casi.es/). 3000 growers associated.
- Vicasol (https://vicasol.es/). Vicasol is a cooperative to which 950 farmers are associated representing more than 1800 ha of cultivation, including both conventional and organic.
- Coprohnijar (https://www.coprohnijar.com/). With 200 associated growers and about 400 ha of cultivation, also both conventional and organic.
- Mujiverde (http://www.murgiverde.com). 400 associated growers, representing 1200 ha of cultivation, both conventional and organic, with 4 processing plants.
- Biosabor (https://www.biosabor.com). It is a SAT, having 300 Ha own cultivation under protection. All of them organic but commercializing also produce sourced from external organic growers.
- Ecosur (www.ecosur.com). Ecosur is a S.L., which started in the late 90's producing only ecological vegetables in greenhouse that they exported directly to Germany. Nowadays they have 110 Ha of own production, cultivating a wide range of products that they both export and sell in Spain through a network of specialized franchise shops.

- BioCampojoyma (http://www.campojoyma.com). Another 120 Ha dedicated to production, half of which is own production, belonging the rest to external bio producers. Except for the citrus (lemon and kumquat) all of them under protected horticulture.
- The SAT Costa de Níjar, (http://www.costanijar.com/) is the marketer with the biggest volume of organic product sold (40.5%), which is sourced from certified growers. The products are sold in the National market and exported to several European countries and the USA.

With all these cooperatives, SAT and companies, meetings were held (see Results of Field work). The aim was to understand to what extent the growers struggle with the Nitrogen supply, if they would be open to the Natural Nitrogen, and if not directly, what would be the conditions to adopt this technology.

Some other cooperatives, SAT and companies representing large organic cultivation areas in addition to the already contacted are: SAT costa de Níjar, Biolitoral, MJ Asesores, Biosol Portocarrero and Anecoop.

3.4 Grower associations

By far the most important sector organization in Almería is Coexphal (https://www.coexphal.es), the acronym of the "Asociación de Organizaciones de Productores de Frutas y Hortalizas de Almería (COEXPHAL)". It represents 70 % of the export volume and 65 % of the fruit and vegetable production, as well as 67 % of the ornamental production. The surface of organic greenhouse horticulture represented by the association in the production season 2019/20 reached 1.578 ha; 2.012 hectares if the spring and summer production is included in the computation. The production represented amounts nearly 147.000 ton of produce, or 58% of the officially certified production of Almería (Blanco, 2020).

Coexphal offers a wide range of services to producers, such as: collective insurances, juridical services, market intelligence, a travel agent, IT-Services, publications for knowledge dissemination, courses and trainings, labor regulations, grants and subsidies, an employment department to match offer and demand, laboratory services, certification services (see 3.6.1) and a research center (see 3.7.4).

3.5 Certification and certifying organizations

Again, taking as reference the wide study conducted by Valera *et al.* in 2014 most of the growers (91 %) comply with certification systems or GHP (Good Horticultural Practices).
The normative UNE 155001 «Fruits and vegetables for fresh consumption. Controlled production in protected Cultivation» was met in 30 % of the exploitation, Global Gap in 28 %, The integrated protection norm by the Andalusian Government, (la Junta de Andalucía) in 16 %, Nature's Choice in 12,2 % and Naturane in 8 %. Other norms adopted by growers are, BRC, GRAP, QS and ISO 9000. In general, growers adhere to different certification depending on the type of client, so on average they comply with at least two quality protocols.

The Certification as Organic, obeys the EU regulation 2018/848 by the European Parliament and the Board for Organic Production and labelling of the organic products.

The basic Ecological certification schemes in Spain follow the European regulations:
- Regulation (CE) 834/2007 of the Counsel, from 28 June 2007 about production and labelling of organic products
- Regulation (CE) 889/2008, from 5 September 2008, who stablishes the implementation rules for Regulation (CE) nº 834/2007 of the Counsel about production and labelling of organic products with respect to organic production, its labelling and its control.
- Regulation (CE) 1235/2008 of the Commission from December 8, 2008 by which the rules for the application of the Regulation (CE) nº 834/2007 by the Counsel in what concerns the imports of organic products procedent from third countries.

3.6 Certifying bodies

Meetings were held with two of the three main certifying organisations active in Almería (see Results: Field Work) which are listed and introduced below.

3.6.1 Agrocolor

Agrocolor (www.agrocolor.es) is the leading certification organisation for GLOBAL G.A.P in Spain and works with the main certification schemes of the agro sector (in total 90 labels). Has certified 14.000 producers, representing a total acreage of 500.000 ha. Is in Almería, originating from the cooperative COEXPHAL and has 8 other locations covering the totally of the south of Spain: Almería, Sevilla, Huelva, Granada, Extremadura, Canary Islands, Comunidad Valenciana, Castilla-La Mancha.

Additional to the basic organic certification, Agrocolor also audits and mediates between growers holding already an Organic certification and other European organic certifying organisations, such as:
- Bio Suisse (Swiss organization).
- KRAV (Swedish organization).
- Naturland (German organization).
- Demeter (www.demeter.es), a label for biodynamic agriculture.

Agrocolor also can "recognise" (herkennen) INPUTS for the use in organic horticulture. It is a requirement in the Organic Horticulture Sector that all the inputs used comply with the organic regulations. With this service in which Inputs are recognised, Agrocolor verifies that inputs comply with the regulation. This recognition can be requested by the supplier or the distributor of the inputs, and, if obtained, it is valid for one year.

3.6.2 SOHISCERT

Sociedad Hispana de Certificación S.A., is another leading Agro&Food Certification body, auditing and certifying under different quality and food safety regulations. Also, more than 10.000 exploitations certified from their central base in Sevilla or the offices in Ciudad Real, Jaen and Almería.

Just like Agrocolor, SOHISCERT has a special program for the recognition of INPUTS for Ecological production., based on Spanish regulation by UNE (Asociación Española de Normalización (UNE)) that was facilitated by the Ministry of Agriculture, Fishery and Nutrition. The objective was to unify the criteria and the rules that inputs for organic agriculture need to comply, in terms of labelling and commercialization of fertilizers and crop protection products (UNE 142500 and UNE 315500), and the evaluation of the compliance of the inputs to be included in the certification schemes (UNE 66500).

3.6.3 CAAE

CAAE was the first certification organization in 1991 specialized in organic production. They operate internationally, are authorized by USDA (NOP) for the USA, by MAFF for Japan (JAS) and by the European Commission for third countries (outside the EU). Nowadays, the CAAE is the body that certifies the biggest surface in Europe with 2 million hectares certified belonging to more than 17.000 growers / operators.

As the previous two mentioned organizations, they follow the UNE norms to recognize INPUTS that can be used in organic Agriculture.

The list of inputs authorized by the UNE (November 2021) can be consulted here: eForm (caae.es).

3.7 Research institutes and knowledge transfer

The intensive horticultural sector in Almería has been constantly innovating and incorporating these innovations. The research activities have played a key role in the technological development, (Aznar *et al.* 2014), the competitive position of the sector in the international markets, and the consolidation of the industry. The benefits of research have become evident thanks to a good structure for knowledge transfer and dissemination to the final users, which, thank their success greatly to the geographical proximity. The R&D network consists of different Research institutions and centers, both public and private. The position they have in the sector is schematically shown in Figure 3, as elaborated by Aznar *et al.* 2014.

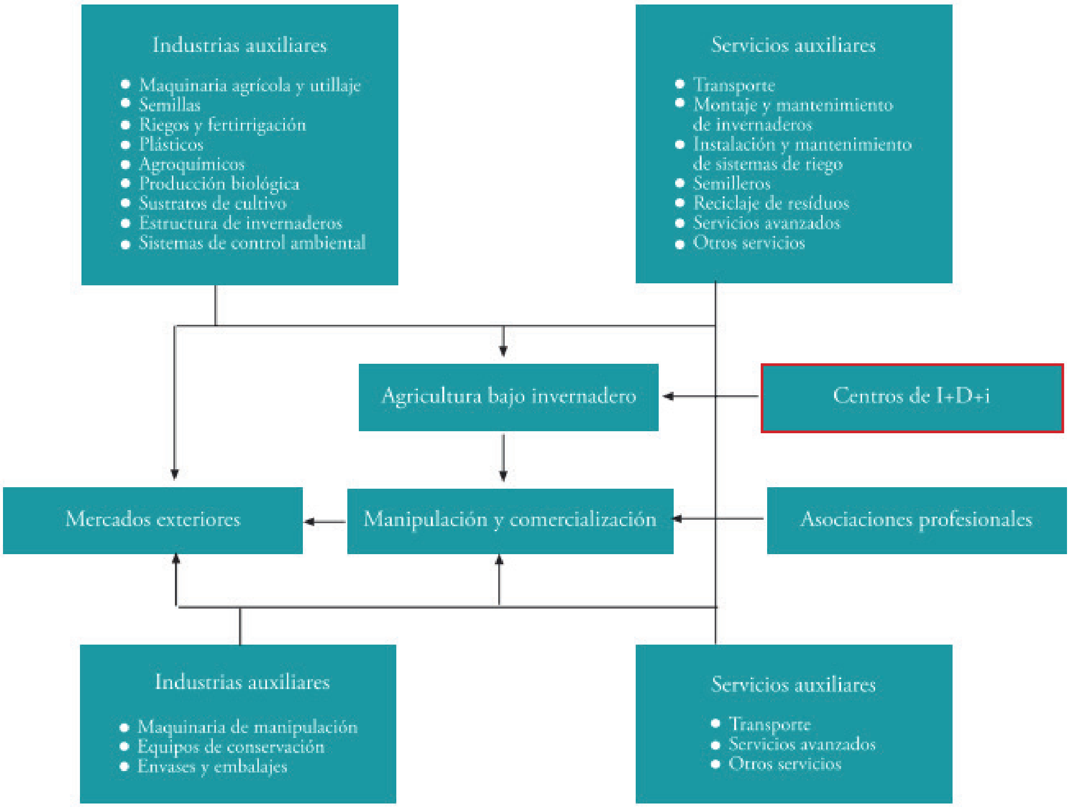


Figure 3 *The position of the Research and Development centres (red rectangle) in the agro-industrial cluster of the province of Almeria. From Aznar et al. 2014.*

Below we introduce the main centers for Research and knowledge transfer.

3.7.1 Universidad de Almería

The University of Almería (UAL) started activities in 1993/94 and has been traditionally involved in research closely related to the agro and food sector from her environment. It has become the first University in Andalucía in number of research groups in agro & food and has national projection in this field. It counts with own research centres and several patents and models. Its structure can be divided in "Research groups", "Research Centres" and office for knowledge transfer (OTRI).

Among the research Centres, it is worth mentioning for the purpose of this report, the Experimental Centre UAL-ANECOOP, a cooperation with the Cooperative ANECOOP to fulfil the research needs of the members of the cooperative. The experimental Centre covers 154 Ha, of which 8 are greenhouses.

3.7.2 Centre IFAPA La Mojonera

The "Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica" (IFAPA) belongs to the Regional government of Andalucía, more precisely to the "Consejería de Agricultura, Pesca y Medio Ambiente". Their objective is to contribute through research, education and knowledge transfer to the modernization and improvement of the competitivity of the agro & food sector and the fishery, and the organic production. The Central location is in Sevilla, the institute has in total 18 activity centres throughout the 8 Andalusian provinces, of which La Mojonera is one, dedicated to the main subjects sustainable plant production (Greenhouse Horticulture), economy of the food chain, genetics and biotechnology, Agriculture and environment.

Only in 2018, (Memoria IFAPA, 2018), the Centre finalized 17 research projects and conducted 150 knowledge transfer events, reaching 3.568 representatives of the sector. Several these activities (courses and dissemination events) directed to the technicians that advise the exploitation of greenhouse horticulture.

3.7.3 Centro Tecnológico Tecnova

The Fundación for Auxiliary Technology for Agriculture (Fundación Tecnova) is the youngest of all research centres in Almería, dating form 2001. 120 enterprises from the industrial and auxiliary services, post-harvest and packing. It consists of 4 work pillars: training, marketing, internationalization and R&D. Because in 2013 they have been qualified as Support Centre for Technological Innovation by the Ministry of Economy and Competitivity, they have got access to national and international funding for projects of larger size.
Two Technology main themes are covered: horticultural production and post-harvest and packaging. They conduct both own and contract research for companies and cooperate with public and private research centres. At the same time, they are a technological service provider in six different fields: horticultural production, post-harvest and packaging technology, testing, gastronomic development, innovation management and knowledge transfer.

Their Experimental Centre has 12 ha with greenhouses of different types for trials where the companies can perform research and validate their technologies or products before launching them to market. And a Technological Centre located at the facilities of PITA with two pilot plants, one for the fresh cut industry and one agro-industrial. The Centre is completed with laboratories for tissue culture and analysis (physical and chemical), an experimental kitchen for fresh cut, taste panel facilities, classrooms and offices. It has become the most important technological service provider in Andalusian agro&food.

3.7.4 Centro de Innovación y Tecnología de Coexphal

Coexphal is an association of exporters founded in 1977. Nowadays it has a double mission: provide services that contribute to improve the competitive position of their members and represent and defend their interests in negotiations with the local, regional, (Junta de Andalucía), national (Central Government) and international (The EU) governments.

It is the biggest association of Almería, gathers 60 horticultural enterprises and represents 65 % of export and 70 % of the provincial production. In 2001 Coexphal was recognized by the Ministry of Science and Technology; in 2002 «Technological Agent » by the Consejería of Employment and Technological Development; by the Junta de Andalucía «As Centre for Innovation and Technology».

Coexphal participates actively in R&D projects, and initiates innovation activities in different fields: quality control, biological pest control, disease control, pesticide residue and reduction of environmental impact. Activities are organized around the Laboratory (LABCOLOR) and the Knowledge transfer (OTRI). R&D projects among innovative members are organized from here, as well as knowledge transfer events (courses, field trips and seminars), participation of Coexphal in national and international working groups and European projects; identify technology offer and demand and funding possibilities.

3.7.5 Estación Experimental de Cajamar Caja Rural «Las Palmerillas»

Cajamar Caja Rural, comparably to the Dutch “Rabobank” has played a key role in the development and expansion of the intensive horticulture under protection by the creation of financial products and services that could provide solutions for the investments needs.

Vinculated to and financed by the financial institution Cajamar, the first Research centre of the province Almería was founded in 1975, the "Estación Experimental «Las Palmerillas». This centre has contributed very actively to the introduction of new production technology to increase the productivity and the profitability of the horticulture. A total of 14 ha in El Ejido dedicated to research with different types of greenhouses, laboratories and the equipment needed for research and knowledge dissemination.
Cajamar Centre has developed both own R&D lines and has also dedicated to the testing and adoption (or when needed, adaption) of technologies from elsewhere. They are a national but also international reference in the greenhouse horticulture in Mediterranean or semi-arid regions, because of the applied character of their work. They are the closest to "WUR Glastuinbouw". For years, they have been the leading Research Centre for organic greenhouse cultivation.

In our opinion, and in the opinion of some of the sources spoken (see Results field work), this would be the most adequate centre to conduct local demonstration tests with Natural Nitrogen as N-fertilizer in the organic horticulture. Therefore, interviews were conducted with representatives of the Centre, and a workshop was held during one of the regular scheduled meetings with technicians from the cooperatives.

3.7.5.1 Incubator program

The Cajamar Foundation has launched recently an Incubator program for start-ups and young enterprises, with the working title "Incubadora de Alta Tecnología especializada en la Innovación Tecnológica y Gestión Sostenible del Agua".

Through our interviews we learned about this new initiative from Cajamar.

The incubator is partially funded by European Regional Development Funds (FEDER in Spanish). Cajamar Innova arises with the aim of providing entrepreneurs with ways to transform their ideas around the use and management of water into competitive services and products that favour the generation of value and employment and sustainable territorial development. Their goal is to help start-ups that work on water technology and how to improve their use efficiency, not just in the Agricultural sector, but also in urban, industrial, touristic and other important regional sectors. Given the importance of agriculture in Almería, most start-ups joining the incubator are focused on agriculture. To join the incubator, they look for innovation projects with a high growth potential, scalable and with an international vision. Cajamar Innova gives entrepreneurs the support they need in each phase of their project development (proof of concept, validation of prototypes and pilots, first sales and scaling). For that, they make infrastructure, resources, and technical and technological support available to entrepreneurs. They help with the validation of their projects in real environments, to identify market niches and support for the search for financing and investment. For the validation of prototypes and pilots they have a unique infrastructure because they have two experimental and research centres: next to the one already introduced in Almería focused on greenhouse production and subtropical fruit trees, there is one close to the city of Valencia (in Paiporta) with a focus in open field horticulture and citrus.

In summary, companies selected to join the incubator program, are offered:

- **Co-creation space:** Collaborative space with the resources and infrastructures to develop the projects.
- **Individual accompaniment:** Throughout the entire life cycle of the business project, from the idea to the commercial scaling.
- **Blended programs:** With online content, to facilitate remote access, if required.
- **Specialized mentors and advisors:** persons of recognized prestige, which will help promoting the - project.
- **Specific training programs:** With business and technology workshops.
- **Market access:** They facilitate companies to contact potential clients and/or partners.
- **Financing and investment:** Support in the search for financing and investment.
- **Zero equity:** Fundación Cajamar does not take equity participation in the companies joining the program.
- **Other services:** Access to different services that will contribute to the development of the company.
- **Post-program accompaniment:** After the program, Cajamar Innova will continue to collaborate with the companies.

As this program seems to be very advantageous for the introduction of Vital Fluid in Spain, we organized a joint meeting between responsible of the Incubator program and a responsible of VitalFluid.

3.7.6 Subsidies and incentives for investments in new sustainable technologies

Growers that belong to cooperatives have access to EU funds aimed at improving the technology in their greenhouse farms. These are the operational funds (https://www.fega.es/es/PwfGcp/en/regulacion_mercados/fondop/Fondos_operativos.jsp) which could be perhaps used by organic growers in the future to purchase Vital Fluid technology.

Young organic farms in the region of Andalucía, can also get financial help to start their new businesses (https://www.juntadeandalucia.es/servicios/procedimientos/detalle/7206.html). In this same region, and regardless of the age, there are often subsidies available to modernize greenhouses (https://www.juntadeandalucia.es/servicios/procedimientos/detalle/13145.html)

4 Results field work

This chapter summarizes and organizes the information obtained from the interviews held with the different stakeholders as indicated in the previous chapter.

4.7.1 N-availability and costs

Most of the interviewed representatives of the cooperatives agree that N-Fertilization is a limiting factor in organic agriculture. Specially in short cycle crops, like cucumber since there is little time for the organic nitrogen to mineralize in the soil.

Only one of the technicians from the enterprises interviewed denied having issues with N-supply, which they have perfectly controlled with the following strategy

- Application of organic matter on the soil.
- Incorporation of the vegetable waste from the previous season on the soil.
- Make some rotations with Leguminosae crops to help fix more nitrogen in the soil.

However, we have doubts that this interviewed person simply had little time and did not fully understand what Natural Nitrogen is, and just wanted to get rid of the meeting by stating that N is not a problem in the farms where she advised.

About the costs of the organic N the different sources mention very different prices and it is almost impossible to find reliable information. The MAPA report the expense on fertilizers and soil on 1.854 million Euro in 2019 for both mineral and organic. Estimations of the Spanish Association of Producers of Fertilizers (AEFA) the total organic business in Spain could reach 400 million euro including the solid organic fertilizers and the solid organo-minerals. One must realize that we are talking about a very heterogeneous group of products and that there are no official statistics about it.

All sources spoken agree that the cost of fertilization is higher in organic horticulture compared to conventional: some of the sources spoken mention a cost 10 times higher to the synthetic fertilizers per unit. Existing organic nitrogen sources can cost around 40-50 cents per mol. Other informants mention that some sources of organic N are cheaper and cost only 7 Euros per Kg N and others cost as much as 20 Euros. But other sources speak of “only” 2 Euro/m^2 per year, and that would be approximately five times as much as in conventional horticulture (0.41 Euros/m^2 for tomato). In any case, the costs have increased a lot lately, and when technicians made some quick calculations for themselves, they often agree that, when the prices of electricity and water are more “normalized”, one mol of N from the Plasma will probably be competitive, provided the cost of the installation is competitive.

4.7.2 PH-regulation of nutrient solutions

Another aspect of the actual N-fertilization in organic farms seems to be the pH regulation. Now, the only acids that can be used are acetic acid and citric acid; according to most of the technicians, these acids are extremely expensive and do not work well in regulating pH.

Only one technician did not agree with that statement: she claimed that they do perfectly fine with acetic acid, which is very cheap and has some very positive secondary effects acting as a repellent for *Tutta absoluta*, a major pest (caterpillar) in tomato. Again, this statement can be biased by the wrong perception of what Natural Nitrogen is and the urgency to finish the meeting as soon as possible. This same technician was present in a later presentation to a larger group of colleagues, which all claimed how interesting would be to have natural source of N such as the one produced by Vital Fluid and how much it could help in current issues such as N availability for the crop and pH regulation. She did not say anything this time.

4.7.3 The isotopic footprint

Something that was mentioned by several technicians was the concern about a new to implement "isotope test". It might just be a rumour, as none of the certifying bodies mentioned it, but there has been research conducted from 2015 and it has been a subject widely commented in newspapers in the last years.

Conventional nitrogen fertilizers have values of δ15N (relative density of N15 atoms) close to zero, because they are synthesized from atmospheric nitrogen, which has a δ15N of cero (by convention).
Organic fertilizers (blood and bones flours, manure, purines) used in organic agriculture, contain higher δ15N since the successive biochemical and physiological processes involve some isotopic fractioning that makes them richer in the heavy isotope (in this case the nitrogen-15).

As such, an isotope test can theoretically contribute to detect "fraud" in N-fertilization in the organic agriculture by analysing samples of the products after the harvest with an isotopic relations mass spectrometer. Preliminary tests by the Junta de Andalucía with cucumbers (Cuevas Román *et al.* 2015) showed that a good distinction was possible between conventional and organic grown product for two of the three analysed types of cucumbers.

Media sources mention that certain importing companies in Europe already are using this technique, which is known as "The isotopic footprint". In our conversations, technicians were not unanimous about it, as some claimed that this test is about to be implemented officially, others said it is just a question of time, to be able to better control potential frauds by a minority of growers

They explained that when the isotope analysis is implemented, this will enhance those committing fraud to switch to a more natural technology like Natural Nitrogen, provided that the atmospheric nitrogen is not considered as inorganic in the analysis. They said it would be interesting to know, with a trial here in Almeria, what would be the isotopic footprint from atmospheric Nitrogen, and the products cultivated with it, after it has been fixated by the Plasma in the Vital Fluid reactor.

4.7.4 Conditions to adopt Natural Nitrogen by organic growers

All the interviewed representatives from the Cooperatives (except for one, who claimed that N-supply has never been a problem in organic horticulture) agree that Natural Nitrogen can be a very interesting addition to their actual fertilizing packages.

The ones interested (the majority) confirm special interest in the pH regulating activity.

Conditions for them to adopt the technology would be:
- The technology needs to be tested under local conditions and demonstrated.
- The technology needs to be price-competitive compared to actual fertilizers.
- The technology needs to be approved (or at least its use should not be disapproved) to be used as input in organic horticulture.
- Natural Nitrogen must not negatively affect the microbiome in the root zone.
- Natural Nitrogen must not modify the isotopic footprint of the produce.
- (the amount of non-organic nitrogen in the soil/ the products). It is possible to perform such tests through SIRA (stable isotopes ratio Analysis) method at a commercial laboratory for instance Agroisolab (www.agroisolab.com/organic-produce).

4.7.5 Opportunities as seen by the potential users

The potential users are confident that at a flow of 20 l/min, in one hour you might have enough acid for 1 ha and 1 week, when compared with Nitric Acid.
That a chiller is also needed, and hot water will be produced is not seen as a drawback, but they see this hot water as potentially interesting for heating, but the question is, whether the volume produced enough to cover heating requirements.

Another opportunity is mentioned during the workshop, and that is, that when the Plasma Reactor or machine to generate the Natural Nitrogen, which uses electricity, would be associated at the production site with a way to generate renewable electricity, like a solar panel or a small wind turbine, then the production of Nitrogen is not dependent on the fluctuations of the energy price, which makes it even more interesting.

4.7.6 The possibilities to recognise Natural Nitrogen as input by the Certification Bodies

According to spoken sources (outside the certification bodies), it should be first stated that in principle, an input should not be object of certification. Either it is included in the EGTOP (Expert Group for Technical Advice on Organic Production) and then in the Input Annexes of the national regulatory bodies or not. In the first case, it can be used in organic cultivation, in the second not, and if use detected, it can be a subject of sanction. Only growers can be certified. However, certifying bodies developed the input authorization since many companies seem to use it a marketing strategy.

The list of by UNE accepted products in organic horticulture consists now of more than 700 inputs and can be consulted on the website of the CAAE:

www.portal.caae.es/ApplicationBuilder/eFormRender.html?code=AA4BB22B591CC99C11BB66FA8AC0CECC&FormApplication=CAAE-INSUMOS-WEB_New%20InsumosUNE
Discussions were held with the main certifying bodies in Andalucía that could possibly include the use of Natural Nitrogen as Recognized INPUT in the organic horticulture.

These discussions took place in the presence of Berdi Doornebosch from Doornebosch Advies, who had already been in contact with the certifying organisations and who had prepared an extensive document in which she listed the arguments in favour of Natural Nitrogen as a plant aid, not as a fertilizer (See Annex 2).

After a first positive contact with the CAAE, in which the product was found “extremely interesting, environmentally friendly technology”, and in which it was expressed that there would be a bigger potential to certify Natural Nitrogen as a disinfecting/pH regulation product than as a fertilizer.

Unfortunately, the message from the different representatives of the certification organisations was unanimous and clear: the organisations would not initiate the process to certify Natural Nitrogen because the use of Nitrogen from the air is not included in the list of authorized products in organic agriculture. Whether this is a fertilizer or a plant aid, it should be recognised. Neither is Water within the RE 834/2007 of organic production, so they cannot certify equipment that treats water, that is, there is no "ecological water"

They all mentioned a precedent, where a few years ago another company already unsuccessfully tried to certify atmospheric Nitrogen, obtained through a different process as the one used by Vital Fluid (not through Plasma Reactor). The Ministry clearly stated that since atmospheric Nitrogen was not included in the EGTOP regulations, they could not include it in the list of products allowed in organic agriculture.

The way to go, according to these specialists, must start with EGTOP including atmospheric N in the authorized list of INPUTS. Then the different national legislation of the individual countries will follow. This is going to be a long, slow process, which may take years.

The interviewed persons recommend Vital Fluid to initiate as soon as possible negotiations, so that EGTOP includes atmospheric Nitrogen as authorized for use in organic cultivation. Nitrogen is a very sensitive topic in organic agriculture, where only Nitrogen from an organic origin is accepted.

The place to start the conversations is the contact point of the Ministry of Agriculture, which depends on the General Direction of the Food Industry. Below the full adress and contact details.

“Punto de contacto nacional de España para el Programa de Control de la Producción ecológica”.
Subdirección General de Control de la Calidad Alimentaria y Laboratorios Agroalimentarios (SGCCALA)
Ministerio de Agricultura, Pesca y Alimentación (MAPA), Paseo Infanta Isabel, 1 - 28014 Madrid, Teléfonos: 913475397/913475394 Fax: 913475410, e-mail: sgccala@mapa.es.

The persons to contact there are the actual Director, Jose Miguel Herrero Velasco (91 347 53 61/8477dgia@mapa.es) or the Subdirector, Francisco Maté Caballero (913471916 - ext:41916 fmate@mapama.es).

4.7.6.1 Ozone as precedent for disinfection in organic horticulture

Another illustrative precedent is the recent authorization by Intereco to use Ozone for soil disinfection (Annex-4). The interviewed technicians mentioned that before it was authorized, certification auditors did not pay attention to the equipment when they found it in the horticultural exploitation.

In the discussions with the certification organizations, they state that Ozone is different because it can be used in cleaning facilities. For that reason, a priori, they could certify an ozone-generating equipment for cleaning ecological production facilities. The same path is being walked to authorize hydrogen peroxide as disinfection agent in organic, and some other products such as ethylene absorbing bags. However, discussions with Intereco did not bring us any further, as they stated that they can not certify “Water”.

4.7.7 The possibilities to partner with the supply industry

After the suggestions by the representatives of the Top Sector and some of the interviewed technicians, Novagric (https://www.novagric.com/es/) the company with the largest share of the market for fertigation equipment in the greenhouse sector, was approached. They were the ones pushing for ozone machines to be certified, and in the first contact, they expressed to be potentially interested in partnering with Vital Fluid to sell the equipment or to incorporate it to fertigation units in Spain, if an agreement can be reached.

A second meeting was organized, in the presence of Vital Fluid representatives. Novagric is specialized in Turnkey Greenhouse projects, operating from 1978 and a serious player in the Spanish Greenhouse market and abroad (projects implemented in 130 countries). The projects cover all different types of greenhouses, except for the “Dutch” types (glass Venlo), water collecting basins and the full internal equipment. Novagric has its own R&D dept. and design their own irrigation-fertilization equipment. Water treatment equipment, including desalination and disinfection has become a separate business for other markets. However, water treatment is sometimes a must for agriculture and can be an integrant part of the total greenhouse technology package incorporated. Novagric thinks the product “Natural Nitrogen” is surprising and very interesting for his business. He believes it can be an interesting product to be incorporated to their irrigation equipment.

Conditions to incorporate the equipment to generate Natural Nitrogen are:
- To perform an analysis of the economic viability of the product (joined activity of Novagric team and Vital Fluid’s team). Some questions to calculate the return on investment of the equipment:
  - Inputs (only water and electricity).
  - Waste (no waste).
  - Output (0.06 kwh / mol NO3?).
  - Life span of the machine? (10-15 years?).
  - Parts that need replacement and at what term? (agree on a maintenance schedule; a local Maintenance partner; Novagric could be that partner!).
  - No worries or issues about certification.
- perform local tests. For that, a possibility is to incorporate it in Novagric’s own trials and demonstration fields in the province of Murcia. This is a showroom where they bring potential customers to show the greenhouses and technology.
- Get as much as possible information about results from other tests (in The Netherlands, the US or in Spain)
- The results of tests must prove that the product is interesting, and the price is also competitive in organic farming.

Both parties have agreed on a visit to The Netherlands (end of 2021) by the CEO of Novagric to discuss the technology and the questions from the company to calculate the return on investment and the feasibility of a possible cooperation.

4.7.8 The possibilities for performing local demonstration trials

All the members of the Commission of organic technical advisers lead by Coexphal agreed, when presented with Vital Fluid technology, that the interest is huge and that a trial would be needed as soon as possible, in the Cajamar Foundation Experimental Station, if possible, where they usually carry all their organic cultivation experimentation. Although a test would be possible by direct approach to Coexphal and the Cajamar Foundation, a possibility, probably cheaper for the company, would be to become a member of Cajamar Innova, the water technology companies' incubator (see 3.7.5.1). As this program seems to be very advantageous for the introduction of Natural Nitrogen in Spain, we organized a joint meeting between a responsible of the Incubator program and a responsible of VitalFluid.

A selection process will be open in December and Vital Fluid has been invited to apply. According to the responsible spoken, Vital Fluid qualifies very well, and chances of acceptance during the open selection by the involved jury are high. Vital Fluid has expressed the intention to apply.

If selected for the program, the incubator will pay all the expenses involved in the performance of the local test (greenhouse space, research capacity) and including the connection of their equipment with the irrigation heads, if required. The incubator will not pay for the Plasma equipment or the assembly and transport of the machines.

Providing Vital Fluid is selected for the incubator program, and after proven success, there are several possibilities to initiate semi-commercial tests in a few selected farms belonging to different cooperatives, as many of them have demonstration and test fields. This is the general "modus operandi" with other technology and seeds/ varieties, to which growers are very used.

We recommend to include both very low technology farms and more technologically advanced farms, in order to avoid that the Plasma technology becomes associated with higher technologically advanced greenhouses.

5 Conclusions

Through this study, we have obtained answers to the formulated research questions.

- The organic greenhouse Sector in Spain has been described and analysed with focus on the southern province of Almeria, which has the biggest national share of organic greenhouse horticulture and a good knowledge infrastructure and suitable financial instruments for the introduction of innovative solutions.
- The solution offered by VitalFluid and partners is very suitable for the Spanish organic Greenhouse Sector as a solution for the organic nitrogen supply problems and potential users are willing to adopt it under certain conditions (see 5.3).
- Natural Nitrogen can not be considered a fertilizer according to the National regulations but can be considered a plant aid. To be recognised / authorized as input in organic horticulture, it first needs to be included in the EU EGTOP lists of authorized inputs, after which national inclusion in the UNE will follow.
- Local key partners for possible follow-up have been identified and negotiations were initiated.

With the objective of this study in mind, finding out the best way to introduce Natural Nitrogen in the Spanish Organic Greenhouse Sector, the main conclusions to be drawn from the desk study, the field study and the small workshop have been classified as "opportunities" or "threats" and are listed below.

We finalize this Conclusions section by enumerating the Conditions for a successful implementation of Natural Nitrogen in Spain as resulting from the study.

5.1 Opportunities

- From the 2,35 million ha of organic agriculture in Spain, both open field and protected, 54% concentrates in the southern Comunidad Autónoma of Andalucia. Within Andalucia, the South Eastern province of Almería represents 75,36 % of the Andalusian protected cultivation total with a certification in organic production, 4261 ha in 2019. **So Almería clearly offers the biggest possible market share and projection for the introduction of Natural Nitrogen**.

- Organic greenhouse farms in Almeria are, with 1.8 ha size on average, a bit smaller than conventional greenhouse exploitations. At the actual reactor capacity (1 reactor needed for 1 ha), the Almería market offers room for **about 4000 Natural Nitrogen reactors**.

- The technological level of the greenhouse horticulture in Spain consists mainly of low-tech companies. However, an irrigation system is present in most of the exploitations, with at least 81 % of the organic growers having automatic irrigation controllers. **The introduction of Natural Nitrogen Plasma Reactors would not require other big additional investments for growers than the cost of the reactor itself if it can be incorporated to the existing irrigation equipment heads.**

- 86% of the producers cultivate in a specially prepared soil known as "Enarenado". Compost, organic matter and fertilizers are incorporated to the soil by base dressing. Fertilizers are, just like in conventional horticulture, commonly applied during the cultivation cycles by means of the irrigation. **The use of Natural Nitrogen generators would not require big changes in the fertilization supply habits for most of the growers.**

- Most of the potential users / advisors agree that N-Fertilization is a limiting factor in organic agriculture, leading to lower yields than in conventional horticulture. This is especially serious in short cycle crops, like cucumber, since there is little time for the organic nitrogen to mineralize in the soil. **This creates a competitive advantage for Natural Nitrogen in especially short cycle crops.**

- The **clogging of drippers and other components of the** irrigation network **is a major problem in the organic horticulture because of** leaks, pressure differences and low uniformity of local irrigation, and requires frequent replacement. **This creates opportunities for the Natural Nitrogen as it is expected to reduce the clogging and reduce the replacement frequency of the drippers.**

- Another drawback of the actual N-fertilization practices in organic farms seems to be the pH regulation of the fertirrigation solutions which the authorized organic weak acids acetic and citric acid which are (according to users) expensive and little effective in regulating pH. **This creates another competitive advantage for Natural Nitrogen as a pH regulator.**

- The cost of fertilization is higher in organic horticulture than in conventional: 2 Euro/m^2 per year, approximately five times as much as in conventional. Despite the great variability in prices mentioned and the lack of reliable price information, quick calculations by potential users during the meetings and workshop lead to the conclusion that **potentially lower prices per mol N could make Natural Nitrogen price competitive.**

- A chiller is needed associated to the Vital Fluid technology to cool down the hot water produced in the process of Plasma Activation. The potential users do not see this as a drawback, as a potentially **interesting source of low-value heating**, provided the volume produced is enough to cover the rather limited heating requirements of greenhouses in this region.

- 72,6 % of the organic greenhouse farms are member of a commercialisation entity, being the Cooperative and the "SAT" (Sociedad Agraria de Transformación) the most common commercialization forms. Because **these play a major role in the technical advising to the introduction of the new technology should be promoted through the Technical advisors employed by the Cooperatives and SAT's.**

- Almería counts with an extensive, internationally, and nationally recognised research, demonstration and knowledge dissemination network to perform local tests both at the research and demonstration level and at semi-commercial level. **This creates opportunities for demonstrating the new technology to generate Natural Nitrogen to potential advisors and final users.**

- Growers associated through cooperatives have access to both regional subsidies and as well as operational EU funds aimed at improving the technology in their greenhouse farms. **The existence of sufficient financial support instruments can create opportunities for growers to invest in Vital Fluid technology.**

5.2 Threats

- **The relative abundance of N in water sources compared to the Netherlands.** In some areas water from wells has a very high EC (2,8 to 6,5 dS m^{-1}) and may come already with a substantial amount of nitrates from previous nitrates leaks to the aquifers. This might reduce the need for nitrate supply even in organic horticulture or reduce the competitive advantage of having a Plasma reactor.

- **The isotopic footprint tests** that according to press releases and some of the spoken sources, might be introduced soon, to detect inorganic fertilizers in products cultivated under organic certification. It is now unknown what would be the δ15N (relative density of N15 atoms) atmospheric Nitrogen fixated through the Plasma, compared to that of Organic fertilizers, normally richer in the heavier N-15 isotope.

- **Acceptance of the Natural Nitrogen as authorized input by the UNE.** The certification bodies will not initiate the process to certify Natural Nitrogen until the use of Nitrogen from the air is included in the EGTOP list of authorized products in organic agriculture.

- **The increasing scarcity and costs of water and electricity.** Both have experienced a tremendous increase in the last months. At the moment of writing this report, water could have a relatively high cost of 0,7 €/m^3 and one MWh electricity was well above 280 Euro. Water is needed for irrigation anyway, so it should not become a real burden to let it go through the Plasma generator before reaching the irrigation system. The cost of electricity could make one mol of N generated through the Plasma suddenly financially uncompetitive or provide a great impulse to growers to become energetically independent by the installation of solar panels, which is at this moment only testimonial.

5.3 Conditions for successful implementation of Natural Nitrogen in Spain

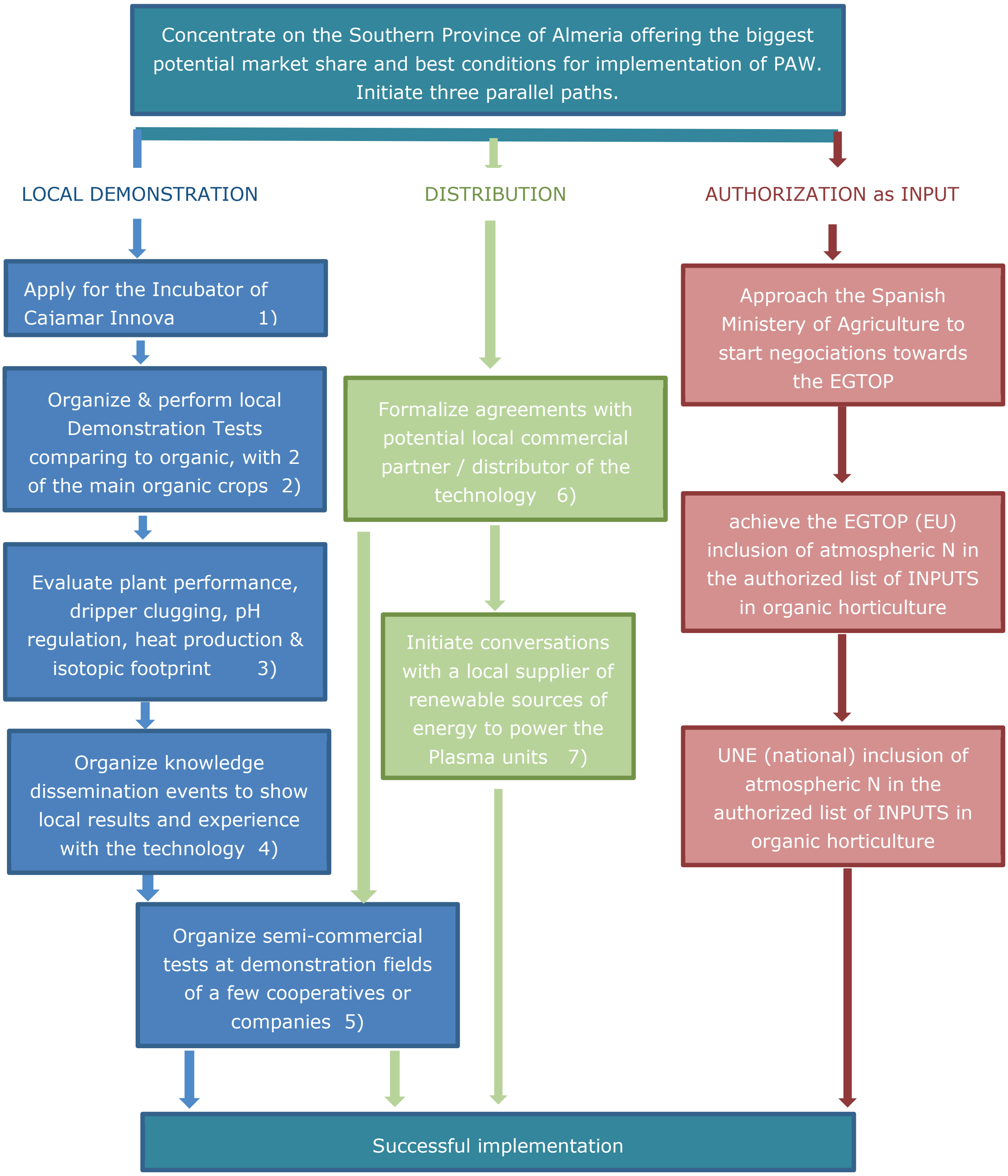
All the spoken sources in the field work agree that Natural Nitrogen can be a very interesting improvement of the N-fertilization situation and a valuable addition to their actual fertilizing packages, confirming special interest in the pH regulating activity. A local supplier of turn-key greenhouse projects with a major market share in irrigation equipment and a separated business in water treatment equipment has expressed interest in partnering with Vital Fluid to introduce the Technology in Spain.
The conditions for potential users and this potential partner to distribute and adopt the technology would be:

- The technology needs to be tested under local conditions and demonstrated.
- The technology needs to be price-competitive compared to actual fertilizers.
- The technology needs to be approved to be used as input in organic horticulture. (Its use should not be disapproved).
- Natural Nitrogen must not negatively affect the microbiome in the root zone.
- Natural Nitrogen must not modify the isotopic footprint (the amount of non-organic nitrogen in the products cultivated).

6 Recommendations

A schematic Road Map suggest how to improve the N-fertilization situation in the Spanish organic horticulture. A set of specific recommendations is listed for the different steps.

6.1 A suggested roadmap for the introduction of Natural Nitrogen in Spain



6.2 Specific recommendations for the different steps

1. The research centre of the Cajamar Foundation Experimental Station has been identified as the most suitable location to perform a first local demonstration test. Within the Cajamar Foundation, a special program (The incubator for young enterprises supplying water technology) will open a new project selection process in December. Applying for this program will automatically involve a local demonstration test at very advantageous conditions. In the event that the company is not selected, conversations should be held to find out other co-funding possibilities to perform the tests locally at the Cajamar Foundation.

2. It is recommended to concentrate on the cultivation of tomato and cucumber. Tomato, because it is the main crop cultivated in the area in the relevant organic farms, and because it has the highest input of fertilizers in both kg N/ha and in total cost per ha in fertilizers. Cucumber because it represents the short cycle crops where the biggest difficulties to achieve sufficient mineralization of organic nitrogen in the soil.

3. It is recommended to include in the performance evaluation of the Natural Nitrogen, an analysis of the isotopic density of the different N-isotopes in the final product, as this is a serious concern by local potential users.

4. Provided Vital Fluid is selected for the incubator program, knowledge dissemination is included in the program. If the company is not selected, they should negotiate that performing the tests locally at the Cajamar Foundation will include at least one knowledge dissemination event.

5. After proven success of the first demonstration tests, semi-commercial tests should be initiated in a number of selected farms belonging to different cooperatives, as many of them have demonstration and test fields. This is the general "modus operandi" with other technology and seeds/ varieties, to which growers are very used. We recommend to include both very low technology farms and more technologically advanced farms, in order to avoid that the Plasma technology becomes associated with higher technologically advanced greenhouses.

6. Conversations have been already initiated with the biggest local supplier of irrigation systems and water technology to farms. We recommend continuing these conversations as the company has offered also to perform analysis of the economic feasibility for growers and demonstration tests at their facilities in Murcia.

7. As during the workshop indicated by the technicians of the cooperatives, we recommend initiating conversations with suppliers of renewable sources of electricity to start advancing on the concept of the in-situ production of Natural Nitrogen independently of the energy costs.

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Annex 1 List of questions interviews

1. ¿Cuáles son las principales fuentes de Nitrógeno empleadas actualmente en los planes de fertilización en agricultura ecológica de invernadero?
2. ¿Supone un gasto importante para el productor? Qué porcentaje supone la nutrición y en particular la nitrogenada de los gastos de cultivo?
3. Como valores una alternativa como la que propone Vital Fluid?
4. La legislación para buscar una autorización para la tecnología de Bioplasma Nitraid, ¿es autonómica, nacional o europea?
5. ¿Ves algunas limitaciones legales para poder certificar esta tecnología de fertilización en el ámbito de la agricultura ecológica?
6. ¿Consideras que, dado que la tecnología también tiene efecto desinfectante, sería más fácil buscar su autorización como producto de protección vegetal para la raíz?
7. ¿Cómo ves la integración de esa tecnología en los sistemas de fertirriego existentes en agricultura ecológica?
8. ¿Crees que sería mejor hacer un ensayo primero en algún centro de experimentación? ¿Cual sugerirías en Almería tanto por calidad del trabajo como por mejor transferencia de resultados al sector?
9. ¿Qué otros agentes relevantes en el mundo de la agricultura ecológica en España debemos contactar y entrevistar?
10. ¿Qué zonas de agricultura ecológica ves que podrían ser más receptivas a esta tecnología?

Annex 2 Minutes of the workshop with stakeholders

Meeting with the COEXPHAL commission of Technical Advisers in the Experimental Station of the Cajamar Foundation in El Ejido (11th November 2021)

Attendants: Representatives from (Murgiverde), (Agrotec Consulting), (Cophronijar), (CASI), (La Palma), (SAT Hortichuelas), (Cajamar Innova), (Estación Experimental de la Fundación Cajamar), (Estación Experimental de la Fundación Cajamar), (Estación Experimental de la Fundación Cajamar), (Coexphal) and other companies (confidential).
This commission of technical advisers gathers once a month in the Experimental Station of Cajamar once month to monitor ongoing experiments, research and to propose new and interesting paths of research. They have a strong (but not unique) focus on organic cultivation.

Minutes: The president makes an introduction where he explains that he heard from Vital Fluid and Natural Nitrogen some months ago. He was about to find out more for this commission when he heard that Esteban Baeza was developing the Seed Money Project for WUR, they were very interested in hearing more.
Esteban gives a presentation of the company Vital Fluid, the Natural Nitrogen, potential uses (fertilization, pH control, disinfection) as well as a summary of the ongoing trial in Bleiswjik and a summary of the latest newsletter.

The main technical questions by attendants:
- In which form is the Nitrogen in the Bioplasma Fertilizer? ¿Is it all nitrate or is there any ammonium? Esteban answers that to the extent of his knowledge, it is all Nitrate. It is nitric acid, since Natural Nitrogen has a pH of 2, and must be previously neutralized when used for fertilization purposes.
- Where do the temporary disinfecting properties come from? ¿Is there Hydrogen Peroxide or other substance in the water? Esteban responds that the low pH helps, but apparently not the only substance responsible for the disinfecting properties. Vital Fluid is probably still researching on this.

Regarding the certification, an attendant indicates that inputs do not have to be certified at all. Either they are included in the Annexes of permitted inputs generated by the Spanish Ministry or not. Thus, the only way is to go to the EGTOP and get atmospheric nitrogen indicated as an admitted input in organic cultivation. Certifying bodies have developed the certification of inputs as an extra business that some companies use as a marketing strategy.

Another attendant asks what the price is of producing Bioplasma Fertilizer. Esteban shows them the numbers of the latest prototype and some of them, after some quick numbers on their notebooks state that it does not look prohibitive. Of course, it is mentioned that with the actual electricity prices, it is scary, but someone mentions that fertilizers price has also risen sky high.

The representative of the grower's association indicates that in a place like Almería, he sees organic farms with their Vital Fluid Unit and a windmill and/or PV panels feeding the electricity required to produce atmospheric nitrogen. Most people agree.

They mention that they would be very interested in a trial to be done in Almería, preferable in the Experimental Station of Cajamar. Cajamar Innova could be the tool to achieve that at the lowest possible cost for Vital Fluid.

After this discussion, they need to switch to other topics, so the meeting is finished thanking them for their interest and questions.

Annex 3 The arguments to approve Natural Nitrogen in organic agriculture based on legislation

The document below was prepared by Doornebosch Advies, as a preparation for the discussions with the certifying bodies in Spain.

Approval for the use of VitalFluid Natural Nitrogen in organic agriculture based on legislation
The organic regulations consist of the main regulation 834/2007 and the implementing rules of regulation 889/2008. Based on the main regulation 834/2007 we conclude that the use of Natural Nitrogen in organic agriculture is allowed, based on different articles. First, we explain why Natural Nitrogen is not a fertiliser, but a plant aid, based on the European fertilizer's regulation (EU 2003/2003) and relevant national legislation of Spain. Subsequently we provide an overview of the relevant articles to substantiate the authorization of Natural Nitrogen as a plant aid in organic agriculture in Europe.

Natural Nitrogen is a plant aid, not a fertiliser
Natural Nitrogen is not a fertilizer, because it falls outside the definitions which have been set by the European Union and national legislation of Spain.
Article 12 of regulation 834/2007[1] gives an overview of the rules for organic plant production. Article 12.1e forbids the use of mineral nitrogen fertilisers:
Article 12

1. *In addition to the general farm production rules laid down in Article 11, the following rules shall apply to organic plant production:*

(e) mineral nitrogen fertilisers shall not be used.
There is no definition of mineral nitrogen fertiliser in regulation 834/2007. Also, regulation EU 2003/2003, the fertilizer regulation, does not contain a definition for mineral nitrogen fertiliser. In Annex I, table A.1 a list of inorganic nitrogen fertilizers and their definition is given. The lowest minimum nitrogen content in this table which is mentioned is 10% of the weight. It is clear that Natural Nitrogen does not fall within these definitions. The definition of 'nitrogen fertilizer solution' in table C.1 of Annex I (see Figure 1) is the definition which best fits for Natural Nitrogen. However, the minimum nitrogen content for this type of product is 15% of the weight. The amount of nitrogen in BioPlasma Plantaid is therefore too low to be qualified as an EG fertilizer. When a fertilizer is not classified as an EG fertilizer, national legislation applies. We will discuss the relevant national legislation of Spain.

C. **Inorganic fluid fertilisers**

C.1. *Straight fluid fertilisers*

No	Type designation	Data on method of production and essential ingredients	Minimum content of nutrients (percentage by weight) Data on the expression of nutrients Other requirements	Other data or type designation	Nutrient content to be declared Forms and solubilities of the nutrients Other criteria
1	2	3	4	5	6
1	Nitrogen fertiliser solution	Product obtained chemically and by dissolution in water, in a form stable at atmospheric pressure, without addition of organic nutrients of animal or vegetable origin	15 % N Nitrogen expressed as total nitrogen or, if there is only one form, nitric nitrogen or ammoniacal nitrogen or ureic nitrogen Maximum biuret content: ureic N × 0,026		Total nitrogen and, for any form that amounts to not less than 1 %, nitric nitrogen, ammoniacal nitrogen and/or ureic nitrogen If the biuret content is less than 0,2 %, the words 'low in biuret' may be added

Figure 1 *Definition of nitrogen fertiliser solution from table C.1 of annex I of EU 2003/2003.*

1 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0834&from=NL#page=9.

Spain

In Spain Decreto real 506/2013 is the national fertilizer legislation. In this legislation also the definitions of "abono inorgánico nacional" (national mineral fertilizers) is included in annex I. In table 1.1.1 of this annex is an overview of nitrogen fertilizers. The definition under number 8 of liquid nitrogenous fertilizer (see Figure 2) is most suitable for BioPlasma Plantaid. This definition is almost the same as the definition in table C.1 of regulation EU 2003/2003 and table, except that for the form of nitrogen is referred to table A.1 of regulation EU 2003/2003 or table 1.1.1. of decreto real 506/2013. This definition states that a fertilizer must contain at least 15% of nitrogen of the total mass, it is clear that Natural Nitrogen is not included in this definition. This means that Natural Nitrogen is not seen as a fertilizer in Spain, since it does not meet the requirements in national legislation for fertilizers.

N.º	Denominación del tipo	Informaciones sobre la forma de obtención y los componentes esenciales	Contenido mínimo en nutrientes (porcentaje en masa) Información sobre la evaluación de los nutrientes Otros requisitos	Otras informaciones sobre la denominación del tipo o del etiquetado	Contenido en nutrientes que debe declararse y garantizarse. Formas y solubilidad de los nutrientes Otros criterios
1	2	3	4	5	6
03	Solución de nitrato amónico y amoníaco, con o sin urea.	Producto obtenido por vía química mediante una disolución estable a la presión atmosférica de los tipos de abonos nitrato amónico, amoníaco, con o sin urea.	– 35% de N total, en forma nítrica, amoniacal y, en su caso, ureica. – Contenido máximo en biuret: 0,5%.		– Nitrógeno total – Nitrógeno amoniacal – Nitrógeno nítrico – Nitrógeno ureico (si procede).
04	Ácido nítrico.	Producto obtenido por vía química, cuyo componente principal es el ácido nítrico.	10% de N total, en forma nítrica.		Nitrógeno nítrico.
05	Solución ácida de abono nitrogenado con azufre.	Producto obtenido por vía química, mediante reacción controlada de ácido sulfúrico con urea.	– 8% de N total, en forma ureica – 40% de SO_3 soluble en agua.		– Nitrógeno ureico – Trióxido de azufre soluble en agua.
06	Solución de sulfato amónico-nitrato amónico.	Producto líquido obtenido químicamente o por disolución en agua, cuyos componentes principales son sulfato amónico y nitrato amónico.	9% de N total – N amoniacal: 7,5% – N nítrico: 1,5% – 12% de SO_3 soluble en agua.	La denominación del tipo podrá ir seguida según los casos, por una o varias de las menciones siguientes: Para aplicación directa al suelo – Para fabricación de soluciones nutritivas – Para fertirrigación.	– Nitrógeno total – Nitrógeno amoniacal – Nitrógeno nítrico – Trióxido de azufre soluble en agua.
07	Abono nitrogenado mixto.	Producto obtenido por combinación química o por mezcla de abonos CE nitrogenados simples, con excepción de urea con nitrato amónico y aquellos que sean incompatibles químicamente.	– 20% de N total – 4% de N, al menos, en dos de las siguientes formas: nítrica, amoniacal o ureica – Contenido máximo en biuret: 0,8%.	Nombre de los abonos CE utilizados en su obtención.	– Nitrógeno total Si superan el 1%: – Nitrógeno nítrico – Nitrógeno amoniacal – Nitrógeno ureico.
08	Solución nitrogenada.	Producto líquido obtenido químicamente y/o por disolución en agua, en forma estable a la presión atmosférica, de abonos nitrogenados CE del grupo A.1 o del grupo 1.1.1 de este anexo o productos similares que no alcancen la riqueza exigida para esos tipos, sin incorporación de materia orgánica de origen animal o vegetal.	– 15% de N total – Contenido máximo en biuret: N ureico × 0,026.		– Nitrógeno total Si superan el 0,5%: o Nitrógeno nítrico o Nitrógeno amoniacal o Nitrógeno ureico Podrán declararse: – CaO soluble en agua (si supera el 0,2%), – MgO soluble en agua (si supera el 0,2%) y – SO_3 soluble en agua (si supera el 2,5%). – Si el contenido en biuret es inferior al 0,2% podrá incluirse la indicación "Pobre en biuret".

Figure 2 *Table 1.1.1 van Real Decreto 506/2013.*

Overview relevant articles in EU organic regulation
834/2007, opinion 8[2]:

The development of organic production should be facilitated further, in particular by fostering the use of new techniques and substances better suited to organic production.

The use of Natural Nitrogen fully complies with this opinion, since it is a new technique which is suited for use in organic production. It is produced through biomimicry of a natural process. Only the natural inputs water, air and electricity are used, and no residues are present in the final product.

834/2007, Title II objectives and principles for organic agriculture[3]

2 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0834&from=nl#page=2.

3 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0834&from=nl#page=6.

Following the opinions and general definitions, the objectives and principles for organic agriculture are specified in regulation 834/2007. Use of Natural Nitrogen complies to these objectives and principles, since Natural Nitrogen does not contain any contaminants, no residues are left and there is no damage to the environment and the production of Natural Nitrogen is a natural physical process, a biomimicry of nitrogen bound to water by lightning.

834/2007, article 4b[2]:
Organic production shall be based on the following principles:
(b) the restriction of the use of external inputs. Where external inputs are required or the appropriate management practices and methods referred to in paragraph (a) do not exist, these shall be limited to:
(i) inputs from organic production;
(ii) natural or naturally derived substances;
(iii) low solubility mineral fertilisers.
The use of Natural Nitrogen complies to article 4b (ii), since the ingredients of Natural Nitrogen are water and air, which are natural substances. Natural Nitrogen is produced on-site, so there is no transport or packaging of the product. It can be produced from materials which are already present on site: water and air. No external inputs are needed. The production process is a biomimicry of a natural process: nitrogen fixation in water through lightning. Natural Nitrogen is not a fertiliser, and therefore does not have to comply to the rule that only low solubility mineral fertilisers are allowed.
834/2007 article 16, products and substances used in organic farming and criteria for their authorisation[4]
Article 16 specifies the criteria for products and substances used in organic agriculture. Article 16.1 states that this includes the following uses:
(a) as plant protection products;
(b) as fertilisers and soil conditioners;
(c) as non-organic feed materials from plant origin, feed material from animal and mineral origin and certain substances used in animal nutrition;
(d) as feed additives and processing aids;
(e) as products for cleaning and disinfection of ponds, cages, buildings and installations for animal production;
(f) as products for cleaning and disinfection of buildings and installations used for plant production, including storage on an agricultural holding.
The use of Natural Nitrogen as a plant aid is not covered by the uses specified in article 16.1. Article 16.5 states that products which are not used for the purposes as specified in article 16.1, and do not fall under article 16.4, are allowed for use in organic agriculture, but only if it complies with the objectives and principles of title II and the general criteria of article 16.2a & b.

Article 16.2 provides the general rules for use of inputs in organic agriculture:

1. *The authorisation of the products and substances referred to in paragraph 1 is subject to the objectives and principles laid down in Title II and the following general and specific criteria which shall be evaluated as a whole:*
   (a) their use is necessary for sustained production and essential for its intended use;
   (b) all products and substances shall be of plant, animal, microbial or mineral origin except where products or substances from such sources are not available in sufficient quantities or qualities or if alternatives are not available;

Natural Nitrogen can be a suitable solution for organic greenhouse companies to fulfil their need for additional nutrients. Natural Nitrogen only contains nitrate, no contaminants, organic matter or heavy metals. Therefore, it is very suitable for use in environments where food safety is an issue. It is possible to dose the nutrients according to specific plant needs.
Article 16.4 and 16.5:

4 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0834&from=nl#page=12

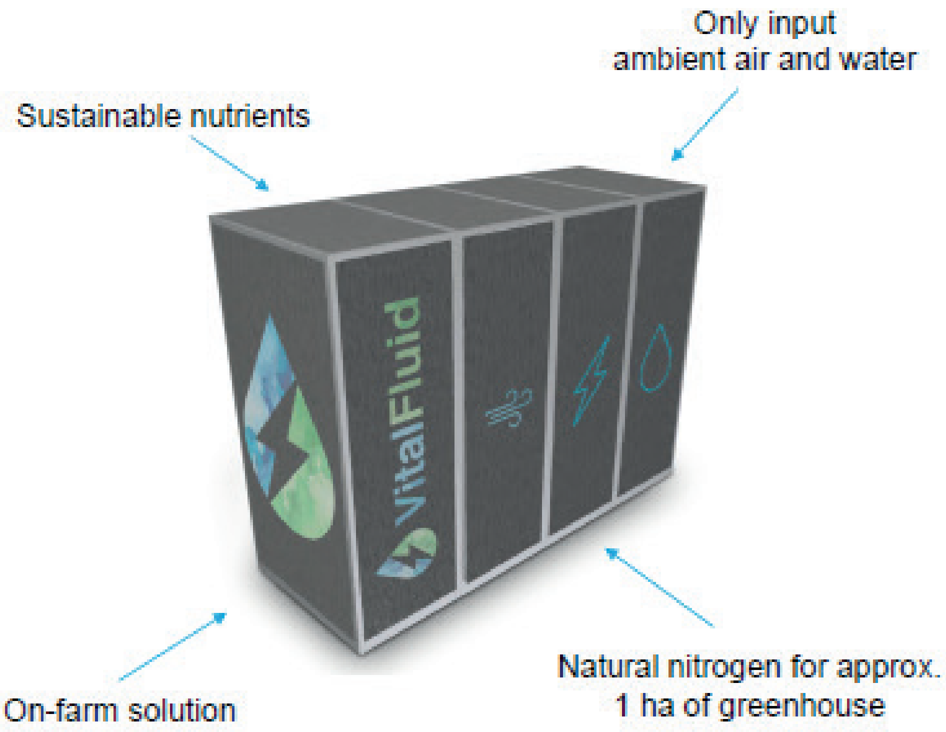
4. Member States may regulate, within their territory, the use of products and substances in organic farming for purposes different than those mentioned in paragraph 1 provided their use is subject to objectives and principles laid down in Title II and the general and specific criteria set out in paragraph 2, and in so far as it respects Community law. The Member State concerned shall inform other Member States and the Commission of such national rules.
5. The use of products and substances not covered under paragraph 1 and 4, and subject to the objectives and principles laid down in Title II and the general criteria in this Article, shall be allowed in organic farming.
In countries without national criteria for inputs, the use of Natural Nitrogen falls under article 16.5 and should thus be allowed.
Based on the EU Organic regulation, the European Fertilizer legislation EU 2003/2003 and national legislation of Spain, use of Natural Nitrogen should be allowed in organic agriculture in Europe.

Annex 4 Technical leaflet NN reactor

VitalFluid
Global Leader in Plasma Activated Water Applications

Freya Natural Nitrogen system

Sustainable nitrogen source for greenhouse cultivation



VitalFluid
Global Leader in Plasma Activated Water Applications

Lightning in a box

By copying lightning VitalFluid has developed a nature-based solution to supply natural nitrogen as a sustainable nutrition source for plants and crops. Produced on-farm, it uses only water and ambient air as inputs. The Freya Natural Nitrogen device can easily be installed and connected into greenhouse drip irrigation systems. Including a service and maintenance package VitalFluid will monitor and optimize the system. VitalFluid Natural Nitrogen is the most sustainable nitrogen source available in horticulture.

Features

- Sustainable
  - By only using ambient air, water and green electricity the nutrient is carbon neutral.
- An excellent plant uptake
  - The device produces NO_3- which is directly absorbed by plants and crops.
- Precision feeding
  - Concentrates can be managed due to on-farm production.
- Ensure food safety
  - The natural process results in pure nitrogen dissolved in water, therefore no risks of contaminants or residues exists.
- Allows for full recirculation of irrigation water
  - VitalFluid Natural Nitrogen enables recirculation of irrigation water because the feed water contains no harmful residues. No issues of accumulation of harmful by-products.
- PH control
  - The PH of VitalFluid Nitrogen is very low so easy to neutralize high PH fertilizers/water.
- No block of drippers
  - Clean water with only dissolved nitrogen will not block your irrigation system drippers.

Specifications

Production Capacity	:	13.5 mol natural nitrogen per hour (NO_3- 837 gr) suitable for approx. 1 ha greenhouse
Water Input	:	5-20 L per minute
Dimensions	:	Length 1.6 m Depth 1.2 m Height 2.5 m
Weight	:	Approx. 1000 kg
Power	:	Approx. 15 kW 480 V 50 Hz
Remote monitoring	:	Freya is connected to the service centre VitalFluid to allow remote support and monitoring

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Annex 5 Certification of ozone by Intereco

INTERECO

Coordinadora de Certificación y Promoción Agroecológicas (INTERECO)
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46008 Valencia CIF G 12575460

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ANEXO PDM191015

Nombre comercial	Usos
OZONO ECO ASP	- Limpieza y desinfección de instalaciones de riego, herramientas empleadas en agricultura. - Desinfección de equipos e instalaciones agroalimentarias mediante aplicación de ozono gaseoso y agua ozonizada. - Desinfección de equipos, recipientes, utensilios para consumo, superficies o tuberías relacionados con la producción, transporte, almacenamiento o consumo de alimentos o piensos (incluida el agua potable) para personas y animales. Impregnar materiales que puedan estar en contacto con alimentos.

Los referenciales técnicos de INTERECO se elaboran tomando como referencia los criterios establecidos en la normativa europea de producción ecológica (Reglamento CE 834/2007 y Reglamento CE 889/2008).

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