Training course packages targeting food operators on the adoption and management of the technological innovations

COMMUNITY GARDENING

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1. FoodLAND technical innovation for local food supply chains: concepts and approaches

The FoodLAND project has the ambition to impact on a large number of supply chains and communities, hence the process of food operators' capacity development has to be tailored and as much participative as possible. Accordingly, one of the assumptions of FoodLAND is that sustainable and nutrition-responsive farming systems can be achieved basically by strengthening the capacity development, and specifically by **a)** empowering farmers and processors through the implementation of capacity building processes and concrete opportunities; **b)** creating or consolidating cooperation and shared knowledge to overcome the lack of coordination among food operators; **c)** addressing the inefficient use of resources; **d)** trying to address and build resiliency to the high vulnerability of food systems to climate change; **e)** enhancing the integration of supply chains by creating commercial and stakeholders' networks; **f)** improving the responsiveness of the production sector to the market demand.

To implement these elements of capacity development, FoodLAND proposed the adoption of specific innovations, among which the organizational ones, to create strong and responsive links between producers and encompassing all the intermediate actors along the food value chain, such as researchers, SMEs, NGOs, local and national authorities. In order to ease the creation of those links and guarantee the sustainability over time of the results, 14 Food Hubs will be created in 6 countries as part of the organizational innovations. Food Hubs are conceived as multi-actors centers of innovation where to develop or enhance the organizational and operational conditions enabling local food supply chains (D3.6).

Functional to the implementation of the Food Hubs and of the innovations, the training courses were designed – in form of capacity development activities – as a two-phase process. Firstly, a training session focused on general, preparatory topics was provided to farmers as described and reported in D3.5 ("Group Introductory Training", GIT). According to the project GA, GIT broad set of goals were: to enhance the knowledge of consumers' nutritional needs and market opportunities, and to boost the notions about climate change, sustainability, resilience, and food culture. Secondly, a specific training session were organized to provide food operators with practical information on the adoption and management of the innovations tested at lab / small scale level and to contribute to validating them at appropriate scale.

However, as the whole approach has been designed by FoodLAND to ensure the inclusion of the local actors from the first moment, both the training sessions were set up accordingly. Indeed, yet in the inception phase of the project, an assessment on participatory methods has been run and Participatory Learning and Action (PLA) approach has been eventually assessed as the best one to ensure the inclusion of multiple perspectives. The main purpose of PLA is to support people within communities to analyze their own situation, rather than have it analyzed by outsiders, and to ensure that any learning is then translated into action (Gosling and Edwards 2003). In addition, a gender-sensitive approach has been applied to the trainings that have been designed considering gender roles and power relations; they have provided equal opportunities to participate in the process by caring to times, venues and use of local languages.

The GITs have been conceived as the first step towards the innovation validation and aim at involving the producers, yet from the inception phase. They are just the first step in a sequence of 6, summed up in **Table 1**. After the GITs, where farmers and processors meet and share their vision and goals for the Food Hubs and exchange information about specific topics, the Food Hubs were created and the innovation tested (first in pre-test, then in pilot phase). The constant iteration between researchers and local actors is a key feature of the project: specifically, the practical trainings focused the single innovations (step 5) are aimed at validating the innovations at adequate scale and planned to trigger feedback loops of control and improvement involving developers and adopters.

Table 1. Activities with farmers and food processors (SMEs) and participatory approach

Step	1	2	3	4	5	6
Task	**T3.3**	**T3.3**	**T3.4**	**T4.1¸T4.5**	**T5.1¸T5.5**	**T5.1¸T5.5**
Activity	Group introductory training	Food Hubs creation	Innovation undertaking	Innovation tests	Individual and group practical training	Innovation pilot and validation

2. FoodLAND practical training: aims and scope

According to the project bottom-up and participatory approaches, following the courses on introductory topics GIT organized in the early project phase (T3.3), and as component creating / strengthening the Food Hubs as local innovation centres, FoodLAND has organized a second set of training activities with food operators based on active learning methods and gender equality principle (Task 5.1-5.9). In this regard, specific mechanisms (being aware of the gender roles and power relations; providing equal opportunities to participate in the process by putting attention to the times, venues, use of local languages, etc.) will be lifted to ensure women's participation. These training packages are aimed at providing the local farmers and food processors with operational instructions on the adoption and management of the validated innovations.

This second set of training activities has been organised – triggering PLA approach – as individual and group practical (demonstration/capacity building) activities to be conducted in parallel to the implementation of the technological research (where relevant) and of the innovation pilots and validation. These technology-centred trainings aim at strengthening the participants' understanding of novel production and post-harvest techniques, innovative tools and systems (e.g., climate smart/precision agriculture, hydroponics, and integrated aquaculture), new technologies for primary and secondary processing, and supply chain management. Thus they aim at fostering knowledge and operational capacity to deploy, manage, and maintain the validated technological innovations – documented by the released guidelines D4.1 ÷ D4.11 (e.g., training pamphlets, user manuals, flow diagrams, and operational recommendations) and practice abstracts D6.5 – validated jointly at appropriate scale.

3. Second training packages on the adoption and management of the tested innovations: an overview

The second training course aimed at consolidating the food operators' knowledge and practical skills to adopt, manage and validate the project innovations and complement the related guidelines. Specifically, the realized training materials provide local farmers and food operators with a set of notions and concrete information on a series of innovative tools and systems as per the following **Table 2**. It is clear that both the contents and formats of the learning packages widely differ across technologies as well as Food Hubs (when the same type of innovation must be validated in different contexts). The diversity that emerges from the proposed solutions reflects the different needs highlighted by farmers and stakeholders as well as the conditions and opportunities characterizing the local communities. Nevertheless, in order to take into due account the existing heterogeneity inside the local communities, the developed learning materials have been let available on the project intranet so as to be used for further training initiatives across the network of Food Hubs.

4. Second training packages on practical information on the adoption and management of the tested innovations

Community gardening

Training materials – Crop management in community gardens

The present training material aims to guide farmers in selecting proper agronomic practices to cultivate community gardens in a sustainable way. Farmers will be able to: i) identify and manage the criteria to plan cultivation over a long-term period (3-4 years) depending on the climate and best crop rotation practice, ii) plan and organize the main crop pruning techniques, iii) schedule mineral fertilization in relation to crop rotation and previous organic matter supply, and iv) recognize the advantages of drip irrigation method.

Planning the crop calendar

Year-round planning of crops' cultivation in the garden is of utmost importance, as it allows for organizing the work, purchasing the materials needed, hypothesizing a possible income, and improving the management of the overall agroecosystem. Planning the cultivation requires the satisfaction of pedoclimatic criteria, particularly temperature and photoperiods requirements. Indeed, the different crops grow only if minimum and maximum temperatures are satisfied. For instance, tomato growth occurs from an average temperature above 10 °C, and its development is significantly reduced at temperatures above 32 °C. Not only the temperature is a crucial factor, but also the photoperiod (e.g., the number of light hours during the day) is critical for some crops. For instance, onion is a crop where the edible product is the bulb: the bulbing process starts only if at least 12 hours of light are available (even 16 hours for some specific cultivars). Air temperature and day length strongly depend on the cultivation site. For Fernena (north-east Tunisia), the minimum, average, and maximum temperature, as well as the daylight hours, are shown per each month of the year.

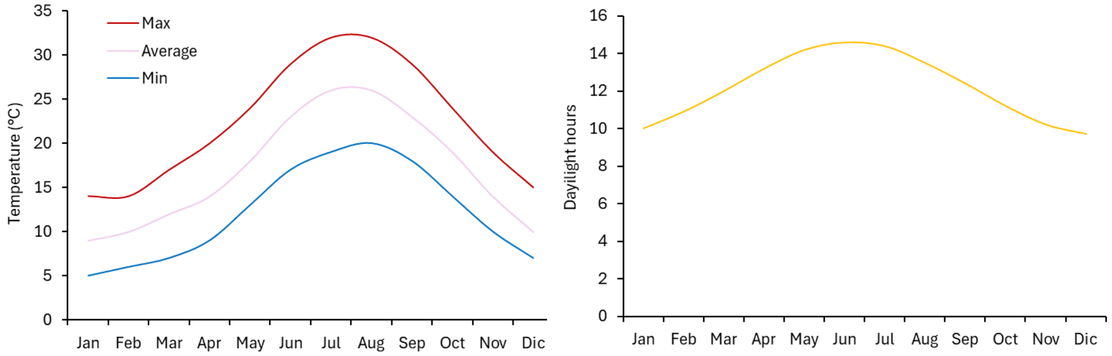

Figure 1 Temperature and daylight hours in Fernena

Table 1 Minimum, maximum, and average temperature (°C) and daylight hours (h d^{-1}) values reported per each month in Fernena

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic

Max Temp.	14	14	17	20	24	29	32	32	29	24	19	15
Average Temp.	9	10	12	14	18	23	26	26	23	19	14	10
Min Temp.	5	6	7	9	13	17	19	20	18	14	10	7
Daylight hours	10.0	10.9	12.0	13.2	14.2	14.6	14.4	13.5	12.4	11.2	10.2	9.7

The following table reports the minimum, optimal, and maximum temperatures of the crops suggested for cultivation, as they can satisfy the demand of local markets. Also, the minimum critical temperature, the minimum temperature that will cause plants' death, is reported.

Table 2 Crop thermal requirements of target crops expressed in °C

	Tomato	Pepper	Eggplant	Onion	Garlic	Strawberry
Max Temp.	>32	>35	>32	>30	>30	30
Optimal Temp.	13-26	20-26	16-25	15-25	15-25	18-22
Min Temp.	10	12	10	5	5	5
Min critical Temp.	2	4	2	-5	-10	-12

Table 3 Crop calendar of target crops in Fernena. Green cells indicate the planting period, orange cells indicate the harvest period.

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic
Tomato												
Pepper												
Eggplant												
Onion												
Garlic												
Strawberry												

Table 3 shows a possible crop calendar based on the thermal requirements of selected crops and Fernena's climatic characteristics.

Once the best planting period has been defined, the crops to be planted in the year must be identified. Crop rotation is an essential agronomic practice that must be considered: crops modify the soil after cultivation, which can have positive or negative consequences for successive crops. A crop rotation that is poorly planned can significantly reduce the yield of future crops, increase pest incidence, reduce biodiversity, and make the local weeds more competitive. The polyculture system must always be preferred instead of the monocropping system, where the same crop is cultivated. This will reduce the need to use agrochemicals to combat pests and weeds, improve soil fertility, and, in turn, also improve productivity. In general, the main rule that farmers must remember is *to avoid cultivating crops that belong to the same botanical family during* *consecutive growing periods*. Tomato, pepper, and eggplant are different crop species but are part of the same family (Solanaceous). Before returning the same crop in the same space, a safety time is recommended: in the case of tomato, onion, garlic, eggplant, pepper, and strawberry, at least 3-4 years should be waited.

Crops can be divided into those that **improve** the soil fertility (e.g., Leguminous, such as fava beans, peas, beans, lentils, chickpeas), those that **exploit** the soil fertility (cereals), or those that **prepare** the soil by improving its physical structure (maize, tomato, sunflower, potato). The first are usually leguminous crops, as they can fix atmospheric nitrogen in the soil that successive crops can exploit. After their cultivation, they are buried in the soil, the nitrogen fixed is released, and the soil organic matter is increased, reducing the need for chemical fertilizers. Exploiting crops use to leave the soil in worse conditions than the previous ones, which is typical of cereals. Crops with long root apparatus (tomato, maize, potato) can reach deeper soil layers, improving the soil hydraulic properties, increasing the porosity, and, in other words, improving the final soil physical structure, reducing the need for soil tillage. Table 4 proposes a possible crop rotation scheme over three years. As noted, the botanical family never repeats in consecutive growing periods or consecutive years (with few exceptions for leguminous between the first and second year).

Table 4 Example of crop rotation over three years

Year 1		Year 2		Year 3		Year 1	
Crop	Period	Crop	Period	Crop	Period	Crop	Period
Faba bean	Oct-Mar	Lentil	Nov-Apr	Strawberry	Mar-Jun	...	...
Tomato/Pepper/Eggplant	Mar-Jul	Onion/garlic	Apr-Aug	Fennel	Sep-Feb	...	...
Lettuce	Sep-Nov	Cauliflower	Sep-Feb	Maize/Sorghum	Apr-July	...	...

Table 5 Botany family turned in the proposed rotation scheme

Year 1	Year 2	Year 3	Year 1
Leguminous	Leguminous	Rosaceae	...
Solanaceous	Liliaceae	Apiaceae	...
Asteraceae	Brassicaceae	Graminaceae	...

As a general recommendation, farmers are invited to split the assigned plot into three different cultivation sectors. Each sector can be dedicated to a specific year rotation scheme, as in Figure 2. The assigned plot is divided into three sectors (A, B, C). In the first year, Sector A will adopt the rotation scheme Lentil-Onion-Cauliflower. This rotation scheme will be re-adopted in Sector B in the second year and in Sector C in the third year. In the fourth year, the same rotation scheme, Lentil-Onion-Cauliflower, can be adopted again in sector A. This method allows farmers to maintain crop rotation, avoiding monoculture. At the same time, it will enable them to cultivate different crops in the same plot, fostering the principles of agroecology and promoting economic diversification.

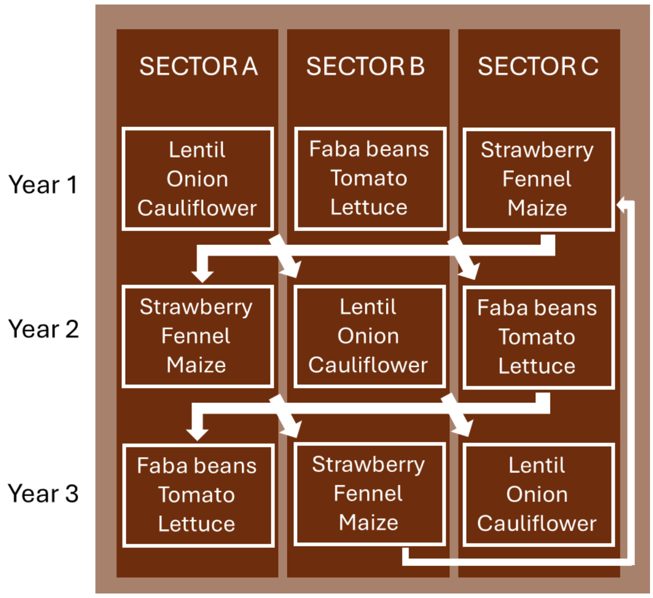

Figure 2 Crop rotation scheme in the assigned plot split into three cultivation sectors

Soil tillage and preparation

To ensure high crop performance, soil tillage is often recommended before crop planting. Different soil tillage techniques exist, but before jumping into the different soil tilling methods, farmers should know that soil tilling profoundly modifies soil structure. Although soil tilling tends to improve the soil structure, negative consequences can emerge if farmers till the soil whenever the optimal soil moisture conditions are not satisfied. If soil is too wet, soil tilling will negatively affect the soil structure, increasing its compaction, especially for clayey soils. Conversely, if farmers till the soil when it is too dry, more energy is required, and excessive soil crushing will occur. **Spading** and **harrowing** are the most crucial tilling methods for vegetable crops in community gardens. These two soil tilling methods differ in the depth of the soil layer tilled, the degree of soil mixing, and the degree of soil crushing.

The spading is manually realized with the help of a spade. It consists of a slice of soil, cut with the spade and then overturned. This generates soil richer in air but with a high degree of turfs that limit crop implantation with sowing or transplant. To this aim, the harrowing objective is to crush the turf with the rake. While the spading can also reach 20-25 cm (depending on the height of the spade that enters the soil), the harrowing is limited to the most superficial soil layer. The proper success of the harrowing, which will prepare the soil for the sowing or transplant, strongly depends on the soil's moisture. If the soil is too dry, then more energy is needed as soil turfs are very compact when they dry out, and the final results are unsuitable for any crop plantation. Conversely, if turfs are too wet, they stick to the rake, impeding any successful soil pre-planting preparation.

In addition to soil tillage methods, we must distinguish soil preparation methods. The latter consists of rearranging the first soil layers to make it more welcoming for some crops. Indeed, in some conditions, the farmers could stimulate water drainage from the soil, for instance, in clayey soils or for some crops that do not tolerate soil waterlogging (onion, garlic, strawberry). A raised bed is often an optimal solution to address this concern (Figure 3), and they can be manually realized with different tools, including hoe, spade, and rake. The raised beds are realized after spading and harrowing by moving the soil from the side to the center. In case of waterlogging, the excess water will drain out the bed from the sides. The recommended width of the beds should not exceed 1 m, though narrower beds are also frequent (e.g., 40 cm), while the height should not exceed 25 cm to avoid the crush and falling of the bed with the rains. The sides of the beds should be inclined to intercept the sun rays, which will accelerate the water draining and ensure better bed stability.

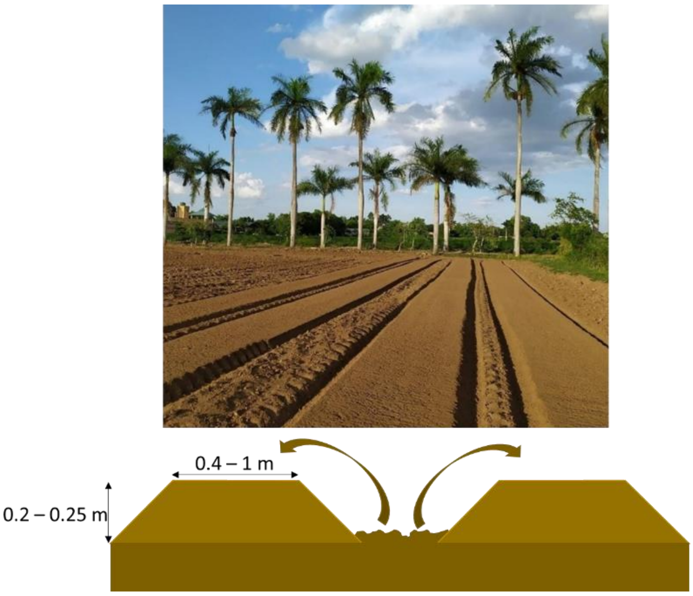

Figure 3 Raised bed (Credits Cerasola V.A.)

During soil tilling and/or preparation, basal fertilization with organic matter, such as compost or cow manure, is usual. This aspect will be deepened in the specific section.

Sowing and transplanting

Crop planting in vegetable cropping systems usually follows two types of agronomic practices: sowing and transplanting. The first one is often done for high-densities crops (e.g., onion or carrot) or for systems where water is a scarce resource: indeed, when plants are directly sown in the soil, their root apparatus can explore better the soil, as compared with plants that are transplanted. However, if sowing is chosen, the following caution must be considered:

- The soil surface must be accurately prepared, ensuring the greater possible homogeneity. Heterogeneous soils would result in heterogeneous germination and emergence.
- Ensuring water availability to allow germination, but avoid excessive water supply. A smaller but frequent amount of water is preferable to a less frequent massive water supply.
- Ensuring the nutritional requirements of the plants. Farmers must consider that nutritional requirements at this stage are minimal, and more detailed information will be indicated in the specific section of plant nutrition.
- Weeds must be accurately controlled before the sowing, as they are more competitive than the germinating plants.
- Choosing the optimal sowing depth. It is crucial as it will affect the proper germination process. If the seed is sown to an excessive depth, the sprout could deplete all the nutritive substances accumulated in the seed before germinating. As a general rule, the depth should be a maximum of 2-3 times the larger width of the seed. For instance, if the width of the onion seed is 3 mm, the depth of sowing should not exceed 6-9 mm.

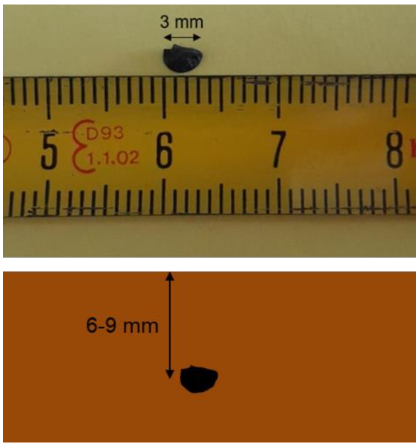

Figure 4 Sowing depth of onion

Although seeds are the propagation material for most crops, other materials can also be used. For instance, onions can be propagated from seed or bulb, while the bulb is usually used for garlic plantation.
The alternative practice is transplanting. Plants with 3-5 true leaves (cotyledons are not considered as true leaves) are transplanted. The advantage is evident, as it allows reducing the time the crop stays in the field by 30-40 days, saving water and fertilizers, and at the same time having more developed plants planted from the start of the crop that can better compete with the weeds.
Plant spacing will result in several plants per surface unit (plant m^{-2}), defined as plant density. The recommended plant densities per crop are reported in Table 6.
The transplant or sowing must be done close to the irrigation pipe that delivers the water to the soil (drip irrigation pipes) but not too close to it. A distance of 10 cm between the irrigation pipe and the transplanted plant or sown seed is recommended.
Table 6 Sowing and transplanting information for target crops. The symbol + indicates that such practice is not very frequent, while the ++ suggests that such practice is more frequent.

	Tomato	**Pepper**	**Eggplant**	**Onion**	**Garlic**	**Strawberry**
Sowing	+	+	+	++	+	not used
Sowing depth (cm)	1 – 2	1 – 2	1 – 2	0.6 – 0.9	2 – 4	-
Sowing propagation material	Seed	Seed	Seed	Seed	Bulb	-
Transplant	++	++	++	+ (bulb)	not used	++
Plant density (plants m^{-2})	1 – 3.5	2.5 – 3.7	2.1 – 3.3	50 – 100	23 – 27	5 – 8
Distance between rows (cm)	80 – 120	90 – 100	60 – 80	10 – 20	30 – 33	80 – 90
Distance within rows (cm)	35 – 100	40 – 50	50 – 60	10 – 20	12 – 15	15 – 20

Crop management techniques
Once the crop is established, it needs to be managed, and management techniques depend on the species. Solanaceous plants (tomato, pepper, and eggplant) should be **tutored** and **pruned**. Mainly for tomatoes, their growth is continuous, and if the plant is not stuck to a tutor, it will fall with the risk of breaking the stem and increased risk of disease development. Tutoring can be done differently, using vertical wires or sticks fixed to the soil.

Figure 5 Tutoring system of solanaceous plants: stick tutoring (left and middle[1]) and vertical wires (right[2])

Pruning is a standard practice in Solanaceous plants that should always be performed. It consists of removing the new sprouts emerging from the leaf axilla. These sprouts will subtract the nutrients used for fruit development; therefore, if not removed, the fruits will be reduced in dimension, penalizing the final yield.

Concerning pruning, another essential practice is the **topping**. This is mainly done for tomatoes, where the growth is indeterminate, but it is also frequent for peppers. When the height of the tomato is no longer sustainable for the farmer (around 2-2.5 m), then the apex of the plant can be cut off, while for pepper, the topping is done early at 35-40 cm (in general above the sixth leaf): in pepper, the topping will result in the generation of 3-4 stems from the plant that will generate more fruits. Each new stem must be inclined by 45° respective to the central stem, modifying the architecture of the plant: the plant will assume an aspect similar to a pot. Each new stem could maintain up to 3 fruits; however, as it will produce many more flowers, it is the farmer's responsibility to balance the plant's productive load. Indeed, it is still part of the pruning the so-called **fruit thinning**. It consists of removing some fruits to maximize the enlargement of the remaining fruits or to allow the correct growth of the plants. In pepper, each new stem derived by the topping can support up to 3-4 fruits: just after the flowering and fruit setting, the farmer should therefore identify the better little fruits in each new stem (e.g., the biggest, or those without shape imperfections), and manually remove the remaining ones.

[1] https://quandosipianta.it/legatura-pomodori/
[2] https://www.freshplaza.it/article/9313500/clip-e-spaghi-bio-connubio-perfetto-per-non-utilizzare-plastica-nel-tutoraggio-delle-piante/

Fruit thinning is also done at early crop stage. Indeed, eggplant and pepper can produce fruits at early stages after crop establishment (a few weeks after the transplant), and maintaining these fruits will limit the plant's growth, producing fewer fruits in the rest of the growing period.

Figure 6: The sprout emerging from the leaf axilla must be removed. The photo is derived from reference.[3]

Crop fertilization

Fertilization is an essential practice that aims to provide the nutrients required for the crops' growth. Fertilization strongly affects crop productivity, and at the same time, if it is not correctly managed, it can seriously affect the environment. The nutrients required by the crops are usually divided into macronutrients and micronutrients. The crops need massive amount of macronutrients (nitrogen, phosphorus, and potassium), while only small amounts of micronutrients (magnesium, molybdenum, calcium, iron…) are sufficient to satisfy the crop requirements. In general, micronutrients are not frequently supplied to the crops grown in soil, as the soil already contains micronutrients in adequate amounts. However, specific micronutrient deficiencies can be observed.

Farmers can artificially supply the nutrients by using different sources and **methodologies**. The sources of fertilizers are mainly classified as organic and non-organic (mineral) fertilizers. The former are materials derived from biological material (animal manure or compost), while the latter are fertilizers derived from industrial processes (e.g., ammonium nitrate, NPK fertilizers…). The main agronomic difference between these two fertilizers is in the speed with which nutrients are made available to plants: organic fertilizers are composed by a complex matrix that binds the different nutrients and releases them much more slowly for plant uptake than mineral fertilizers. Often, the speed of nutrient release from organic fertilizers is insufficient to sustain some crops' rapid growth. Therefore, mineral fertilizers should be integrated. Organic fertilizers, however, provide enormous benefits to the soil that mineral fertilizers are unable to ensure, such as:

- Increase of organic carbon in the soil, which positively affects the soil microorganisms
- Improvements in soil density and soil structure, with positive benefits in crop growth
- Increase in soil water retention, improving the resilience of crops to drought periods

Given the slow release of nutrients, the organic fertilizers are supplied to the soil at the moment of soil tillage. The optimal supply rate depends on several factors, first of all, organic material's maturation degree. Indeed, compost or animal manure must be sufficiently mature before being

[3] https://www.ortodacoltivare.it/coltivare/sfemminellatura-pomodori.html

supplied to the soil (at least 6 months). A rate of 1-3 kg m^{-2} is considered adequate for mature organic fertilizers.
Organic fertilization is often insufficient to satisfy crop growth, and mineral fertilizers can be integrated accurately. However, farmers should be aware of the risks of mineral fertilizers, and they should not exceed in their use for different reasons:

- Excessive mineral fertilizers will increase the production costs without positive economic benefits
- Excessive mineral fertilizers promote excessive plant growth delaying, or even reducing, the productivity
- Excessive mineral fertilizers can pollute the soil and the groundwater

So, balanced fertilization is essential, based on integrating organic and mineral fertilizers.
Given the aforementioned risks, mineral fertilizers cannot be supplied entirely at the start of the growing period. The best choice is to split the supply of mineral fertilizers at different moments along the crop growth cycle, following the crop's nutrient requirements.
As a general rule, the global nutrient supply should be fractioned at least in three moments:

- Sowing/Transplant
- Before the rapid vegetative growth
- At flowering (except for garlic and onion)

If crop rotations are respected, part of the nitrogen will be supplied from the Leguminous crop that precedes the crop, and it can be estimated to be 80-100 kg N ha^{-1}.
In the following table, the expected crop nutrient uptake is indicated.

Table 7 Crop nutrient uptake to be satisfied with organic and mineral nutrition

	Average yield (t ha^{-1})	Nitrogen (N) kg ha^{-1}	Phosphorus (P) kg ha^{-1}	Potassium (K) kg ha^{-1}
Tomato	100	200	150	300
Pepper	40	170	75	225
Eggplant	35	140	60	180
Onion	30	100	60	120
Garlic	12	125	60	120
Strawberry	30	160	75	225

The objective of fertilization is to restore the expected nutrient uptake by considering all the nutrients' inputs, including organic matter supply, nitrogen fixed by Leguminous, and the integration with mineral fertilizers. Therefore, the farmers should calculate how much mineral fertilizers they must supply to satisfy the crop requirements (Table 7).
The calculation must consider two aspects:

- Are organic fertilizers supplied at soil tilling?
- Is the preceding crop Leguminous?

If the answer to the previous questions is "yes," farmers must account for the nutrients supplied by organic fertilizers and fixed by the leguminous crop.

Table 8 Nutrients supplied by 10 ton ha^{-1} (equivalent to 1 kg m^{-2}) of compost or animal manure

	Nitrogen (N) kg ha^{-1}	Phosphorus (P) kg ha^{-1}	Potassium (K) kg ha^{-1}
Organic fertilizers	80	60	60
Leguminous crop	100	0	0

Calculation of mineral fertilizers for a tomato crop (N, P, K)
Considerations:

The farmer supplied 2 kg m^{-2} of compost at the soil tillage. 2 kg m^{-2} of compost is equivalent to 20 t ha^{-1}. Given that 10 t ha^{-1} supplies the nutrients indicated in Table 8, 20 kg ha^{-1} will supply double those nutrients (160 kg N ha^{-1}, 120 kg P ha^{-1}, 120 kg K ha^{-1}).

The crop preceding the tomato was fava beans (leguminous crop).

Nutrient gap to be restored with mineral fertilizers (kg ha^{-1}) = Gap (**CALCULATED per each macronutrient, N, P, K**)
Crop nutrient Uptake (kg ha^{-1}) = CU (**Table 7**)
Nutrients supplied with organic fertilizers (kg ha^{-1}) = OF (**Table 8**)
Nutrients supplied by leguminous crop (kg ha^{-1})= LC (**Table 8**)

Eq. 1 $$Gap = CU - OF - LC$$

For tomato, the calculus will be as follows:

Table 9 Fertilization table accounting for crop nutrient uptake (CU), nutrients supplied by organic fertilizers (OF), and leguminous (LC). Equation 1 is computed to calculate the gap of nutrients required (Gap)

	Crop uptake (CU)	**Organic fertilizers (OF)**	**Nutrients from leguminous (LC)**	**Gap of nutrient required (Gap)**
	kg ha^{-1}	*kg ha^{-1}*	*kg ha^{-1}*	*kg ha^{-1}*
Source	*Table 5*	*Table 6*	*Table 6*	*Eq. 1*
Nitrogen	200	160	100	***-60***
Phosphorus	150	120	0	***30***
Potassium	300	120	0	***80***

The final mineral fertilizers required are 30 kg ha^{-1} of phosphorus and 80 kg ha^{-1} of potassium. Notably, the final amount of nitrogen is -60 kg ha^{-1}, meaning that the organic fertilizers and leguminous crops provide more nitrogen than the amount required by tomatoes. Therefore, about 60 kg ha^{-1} will remain after the tomato crop at the disposal of the successive crop.

The effective dosage of mineral fertilizers

Once the amount of nutrients to be supplied via mineral fertilizers has been calculated, the typology of fertilizers must be chosen. Different fertilizers are available, but given the calculation in Table 9, any fertilizer that contains nitrogen should be used (given the extra nitrogen supplied by organic matter and leguminous crops). Considering that only a tiny part of phosphorus should be provided and that soils already contain phosphorus, its supply could even be avoided. Therefore, in our example, the farmers could supply only the potassium.

Figure 7 Bag of potassium sulphate. The concentration of NPK is indicated by the arrows

The fertilizer that allows the supply of only potassium is potassium sulfate. All mineral fertilizers, including potassium sulfate, are sold in bags, where there are always reported **some numbers**: in Figure 7, the numbers 0-0-50 are reported. These numbers represent the percentage in weight of different macronutrients contained by that specific fertilizer, and *they are always reported in the same order, following N, P, and K (nitrogen, phosphorus, and potassium).* From this bag, we notice that the nitrogen and phosphorus concentration in the potassium sulfate is 0%, while the potassium is 50%. This means that 1 kg of potassium sulfate supplied to the soil will apply only 500 g (50% of 1 kg) of potassium, which will be available for the crop.

Supposing we want to supply 80 kg ha^{-1} of potassium to the tomato, we should perform a simple calculation, indicated in Equation 2, where the Gap of nutrients to be restored with mineral fertilizers (Gap, resulting from Eq. 1) is divided by the concentration of the nutrient in the fertilizer (Conc) multiplied by 100.

Eq. 2 $$Fertilizer\ rate\ (kg\ ha^{-1}) = \frac{Gap}{\frac{Conc}{100}} = \frac{80}{0.5} = 160\ kg\ ha^{-1}$$

In our specific case, the result of the equation is equal to 160 kg ha^{-1} of potassium sulfate.

The reader is invited to note that the unit of measure is *kg ha^{-1}*, meaning that the 160 kg of potassium sulfate should be supplied in one hectare, corresponding to 10000 m^2. However, farmers will cultivate only a tiny fraction of one hectare, which is easier to be considered in m^2. Following the recommendation in the chapter on crop rotation, the farmer divides the soil into three sectors and will cultivate only one sector with tomatoes, with a dimension of 33 m^2 (10 m x 3.3 m). The farmer should recalculate the quantity of potassium sulfate to be supplied in sector A (Figure 8), considering the effective portion of soil cultivated (Eq. 3)

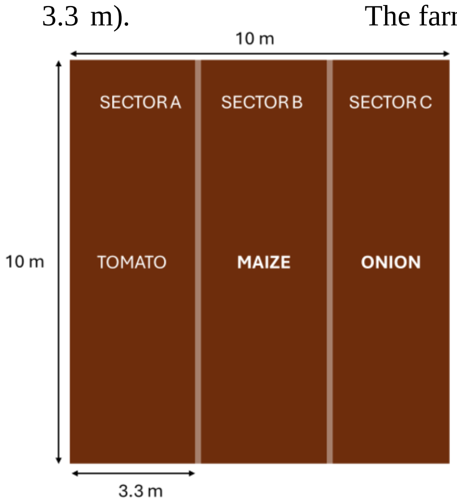

Figure 8 Sectors dimension of the plot

The equation will be readapted as follow:

Eq. 3 $$Fertilizer\ rate\ (kg) = \frac{Gap}{\frac{Conc}{100}} \times \frac{Area\ cultivated}{10000}$$

The final quantity of potassium sulfate to be supplied in the considered area (33 m^2) will be **0.528 kg**.

When to supply the fertilizers?

Once the fertilizers rate have been calculated, the farmer should define when to supply them. As nutrients contained in mineral fertilizers are quickly available for plant uptake, their supply should be avoided in one time at the beginning of the growing period. Mineral fertilizers should be provided at different crop stages.

Sowing/Transplant: 20% of the calculated final rate, manually localized 10-15 cm away from the row close to the plant seed

Before the rapid vegetative growth: 40% of the calculated final rate (localized as before)

At flowering (except for garlic and onion): 40% of the calculated final rate (localized as before)

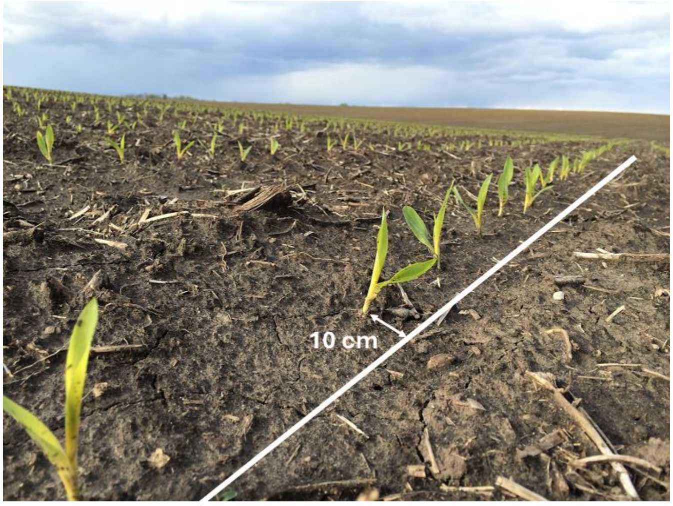

Figure 9 Distance of application of fertilizers, following the white line. Figure take from[4]

Table 10 Timing of fertilization for different growth stages of different target crops

	First fertilizer application	Second fertilizer application	Third fertilizer application
Tomato/pepper/eggplant	At transplant	At the 7^{th} leaf (20-25 days after transplant)	At flowering 40-50 days after transplant
Onion/garlic	At sowing	At the 2^{nd} leaf (45 days after the sowing)	At the 4^{th} leaves (75 days after the sowing)
Strawberry	At transplant	40 days after the transplant	Just after the first harvest

[4] https://www.farmprogress.com/sorghum/thinking-in-furrow-for-improved-performance

Irrigation

Irrigation is an essential practice in arid environments, but it can lead to excessive water consumption if not correctly managed. In community gardens, water is a shared resource that must be carefully managed, and overexploitation by one farmer determines a depletion of water availability that will affect the farmer's community. Farmers can save irrigation water by intervening in two main different elements. The first is a *structural* element, as the farmer can decide the technology to use when irrigating the crop (irrigation system). The second is a *managerial* element, as the farmer can manage the irrigation, answering the question of *when* and *how much* to irrigate. The latter requires technical skills and instrumentations (Excel skills, temperature sensors, soil moisture sensors) that cannot be explored in depth here.

Different irrigation systems exist, having a different irrigation efficiency. We refer to irrigation efficiency as the percentage of supplied water utilized (absorbed) by the crop. In the location area (Fernena), sprinkler irrigation is the most diffused irrigation system. This system aims to simulate the rain using a high-pressure pump with high energy consumption. This system has an appreciable irrigation efficiency (70%), but significant water-saving improvements can be achieved. Indeed, when water is supplied to the crop with sprinkler irrigation, the entire surface of the soil is wet, including those portions where the crop is not present (e.g., corridors between two rows of plants). Roots do not intercept this water which evaporate, representing a water loss. In a vegetable cropping system, where the distance between the rows of plants is much higher than in other crops (e.g., barley, wheat), the amount of water lost by evaporation is enormous. Reducing the water evaporation from the soil is possible by localizing the water close to the root apparatus with drip irrigation, which can achieve up to 95% irrigation efficiency. This irrigation technique consists of supplying the water using drippers, which permit the outflow of the water drip by drip at very low pressures (typically 1-1.5 bars, providing savings in energy use) and at very low flow (depending on the dripper type used, ranging from 0.5 to 4 liters per hour, $l\ h^{-1}$). The drippers are incorporated in little pipes of 2-3 cm in diameter, usually called driplines, that are placed close to the rows of plants (10 cm away). Driplines are made of a thin layer of polyethylene, which cannot tolerate high pressures. The maximum pressure the dripline can tolerate is written in the product label and is proportional to the thickness. The dripline will explode if the water inside the irrigation system exceeds the maximum pressure; therefore, monitoring the internal pressure with a manometer and adjusting the internal pressure with the pressure regulator accordingly is essential.

Drip irrigation wet only a portion of the soil, significantly limiting the water losses through evaporation and avoiding wetting the plant. The final result is a less humid environment with positive secondary effects on crop health. Indeed, excessive humidity, such as that generated by sprinkler irrigation, is dangerous as it can potentially increase the risk of fungal diseases. An additional structural element that can be integrated into drip irrigation is mulching. It covers the soil with an organic or non-organic material from which the crop emerges. Mulching can further minimize water evaporation from the soil and have additional benefits to avoid weed emergence. Mulching is essential for some crops, such as strawberries, as it will prevent the fruit from touching the soil, increasing its shelf life. Among the different mulching materials, we report cereal straw and biodegradable mulching.

Figure 10 Drip irrigation system in a tomato field (Credit Cerasola V.A.). Note that the soil is wetted by the driplines.