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| ***Field: Agriproduction***  **ALTERNATIVES TO MINERAL FERTILISATION: ORGANICS AND BIO FERTILISERS**  Resultado de imagen de organic and bio  fertilizers  **Authors: María Gabarrón Sánchez**  **Martire Angélica Terrero Turbí**  **Silvia Martínez Martínez**  **María Dolores Gómez López**  **Ángel Faz Cano**  **2017**  **Boosting Adult System Education In Agriculture - AGRI BASE**  **Erasmus+ K2 Action Strategic Partnership** |

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1. Introduction

The population growth on the last decades of the century and the expectative of growth until 2050 implies an increase on the food supply while the crop surface is decreasing. FAO expected that the demand for food continues to grow as a result both of population growth and rising incomes. For example, demand for cereals (such as food and animal feed) is projected to reach 3 billion tons in 2050. Therefore, the annual cereal production will have to grow by almost a billion tons (FAO, 2009).

The need to increase the food production globally, in turn generates a pressure on crops which are forced to improve their nutrient availability in less time. As consequence, food producers should overcome nutrient deficiencies of soil using fertilisers. The 16 chemicals elements generally considered essential for plant growth include: C, H, O; N, P, K; Ca, Mg, S; Fe, Zn, Cu, Mn, Mo, B and Cl. The first three elements are furnished to plants in either water or soil air, and the last one (chlorine) is not deficient under field situation. In contrast, all the other elements should been added to soils in chemicals compounds to avoid deficiencies (Hagin & Tucker, 2012). However, these improvement have often caused environmental problems, such as water pollution, trace gas emissions or land degradation (Ludwig et al. 2011), usually derived to the excessive use of fertilisers. In order to minimize the environmental damages several international organizations, such as FAO, USDA or EU have been forced to develop and promote more sustainable agricultural policies at the same time that fertiliser industry have been researching for the complete understanding of soil chemistry, plant nutrition and the behaviour of fertilisers in soil.

The intensity of fertiliser use and its implications for agricultural production and the potential environmental impacts of nutrient run-off from farmland have intensified the discussion about the use of chemical fertilisers and organic farming in recent years. But, what is the organic farming?

The *organic farming* or *organic production* is a system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produces using natural substances and processes (EC 834/2007 of 28th June 2007).

Organic plant production should contribute to maintaining and enhancing soil fertility as well as to preventing soil erosion. Plants should preferably fed through the soil ecosystem and not through soluble fertilisers added to the soil.

In the organic production the fertility and biological activity of the soil shall be maintained and increased by multiannual crop rotation including legumes and other green manure crops, and by the application of livestock manure or organic material, both preferably composted, from organic production. In addition, fertilisers and soil conditioners may only be used if they have been authorised for use in organic production although mineral nitrogen fertilisers are forbidden.

In contrast the most extended agriculture system is the *intensive agriculture*. It consist in the use of a large amount of labour and capital relative to the land area because of the necessary to the application of large amount of fertilisers, pesticides, herbicides… that requires an important investment on machinery and qualified hand-work. Intensive high-yield agriculture is dependent on addition of fertilisers, especially industrially produced NH4 and NO3 (Tilman et al. 2002).

In the European Union, reforms on the Common Agriculture Policy (CAP) have been trying to impulse more environment-friendly agriculture systems, such as the integrated production and the conservation agriculture.

The *Integrated Production/Farming* is a farming system that produces high quality food and other products by using natural resources and regulating mechanisms to replace polluting inputs ensuring sustainable farming (IOBC, 2004). Consist on a fertilisation programme for each crop and the entire rotation crop, enhancing the natural fertilisation and reducing chemicals. To know the nutrient requirements of the soil it should be analysed.

*Conservation agriculture* aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations. The use of chemical fertilisers is not allowed (FAO, 2016).

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| The need to increase the food production globally, in turn generates a pressure on crops which are forced to improve their nutrient availability in less time. As consequence, food producers should overcome nutrient deficiencies of soil using fertilisers which have often caused environmental problems, such as water pollution, trace gas emissions or land degradation.  There are different types of agriculture depending on crop management and type of fertilisers used: organic farming, intensive agriculture, integrated production and conservation agriculture. |

1. Fertilisation concepts

**2.1. What is a fertiliser?**

A fertiliser is a material (organic or inorganic) which main function is to provide nutrients for plants.

The new proposal 2016/0084 for the incorporation of organic fertilisers on the European normative define fertiliser products as a substance, mixture, micro-organism or any other material, applied or intended to be applied, either on its own or mixed with another material, on plants or their rhizosphere for the purpose of providing plants with nutrient or improving their nutrition efficiency.

**2.2. Main elements for plants**

For the vegetative development of plants is essential at least fourteen chemical elements, which are classified by their more or less contained in the composition of plants:

* Macronutrients (primary and secondary) (6)
* Micronutrients (8)
* Primary macronutrients are nitrogen, phosphorus and potassium. They are essential for plants growing to their full potential and besides support essential metabolic function (García-Serrano, 2009; Fertilisers Europe, 2016).

**Nitrogen**, growth and development factor. It is absorbed as NO3- y NH4+, Involved in cell multiplication and considers growth factor; it is necessary to the formation of amino acids, proteins, enzymes, etc.

**Phosphorus**, factor precocity. It is absorbed as H2PO4- It stimulates root development and promotes flowering, ripening and fruit set, intervening in transport, storage and energy transfer, besides being part of phospholipids, enzymes, etc.

**Potassium**, quality factor. It is absorbed as K+ on the ground potassium it is very mobile and play a multiple role. Improves photosynthetic activity; increases resistance of the plant to drought, frost and disease; promotes synthesis lignin, favouring the rigidity and structure of the plants; favours the formation of glucides in leaves while participating in the formation protein; increases the size and weight in cereal grains and tubers.

* Secondary macronutrients are sulphur, calcium and magnesium : Plants also take them up in considerable amounts (García-Serrano, 2009; FAO, 2000).

**Sulphur**, is part of vitamins, proteins, coenzymes and glucosides. Participates in the reactions of oxidation-reduction part of ferredoxin.

**Calcium**, is necessary in the division and cell growth. It is the structural element of cell walls and membranes, and is essential for the absorption of nutrients.

**Magnesium**, is part of the chlorophyll molecule and is therefore essential for photosynthesis and the formation of other pigments. As calcium is constituent of cell walls and as sulphur Influences redox processes.

* Micronutrients required for plants:

**Iron**, involved in the synthesis of chlorophyll and capture and energy transfer in photosynthesis and respiration. It acts in redox reactions, such as reducing nitrates.

**Manganese** participates in chlorophyll formation together with the iron. Also it participates in the metabolism of carbohydrates.

**Zinc** is essential in the formation of auxin, which are growth hormones. Involved in the synthesis of nucleic acids, proteins and vitamin C. It has a positive effect on fruit set, maturation and withering.

**Copper**, involved in photosynthesis and metabolism of proteins.

**Molybdenum**, involved in nitrogen fixation in legumes air, as in the conversion of nitrates into the interior of the plant.

**Nickel**, acting on urease and only recently has been considered essential.

**Boron**, is involved in transport of sugars. Involved in growth regulation by internal plant hormones, in fertilisation, the water absorption, the synthesis of nucleic acids and in maintaining the integrity of the cell membrane.

**Chlorine**, has an activity associated with photosynthesis and participating in maintaining cell turgor.

If soil has a wide supply of nutrients, crops will be more likely to grow well and produce high yields. If, however, even only one of the nutrients needed is in short supply, plant growth is limited and crop yields could be reduced (FAO,2000).

**2.3. Source of nutrients for plants and crop yields**

The crop yield is directly related to the nutrients supplied to the plants, so the availability and balance of these is very important taking into consideration the best practices in soil management and application of fertilisers (organic and minerals) to supply their demands. With the exception of carbon, plants take all the nutrients from the soil solution, thus in order to obtain high yields, fertilisers are needed to supply the crops with the nutrients the soil is lacking (FAO,2000). The table 1 shows the nutrients needed by plants and the source they are taken from:

Table 1: Nutrients source for plant

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| SOURCE | NUTRIENT | |
| FROM THE AIR | Symbol | Element |
| C | Carbon as CO2 (carbon dioxide) |
| FROM THE WATER | H | Hydrogen |
| O | Oxygen as H2O (water) |
| FROM THE SOIL, FERTILISERS AND ANIMAL MANURE | N | Nitrogen |
| P | Phosphorus |
| K | Potassium |
| Ca | Calcium |
| Mg | Magnesium |
| S | Sulphur |
| Fe | iron |
| Mn | Manganese |
| Zn | Zinc |
| Cu | Copper |
| B | Boron |
| Mo | Molybdenum |
| Cl | Chlorine |

**2.4. Nutrients behaviour in soil**

The growth of a plant depends on a sufficient supply of each nutrient, and the yield is limited by the nutrients which are in short supply (yield-limiting minimum factor). As consequence, a sufficient supply of nutrients is important for a correct functioning of the photosynthesis, due to if one of the nutrients from the soil is not present, photosynthesis is retarded. If the nutrient is presents, but insufficient in quantity, the plant develops hunger signs (deficiency symptoms). On intensive agriculture it used to happen with some nutrients as nitrogen, phosphorus, potassium, magnesium and sulphur. Therefore, they usually have to be applied in the form of mineral fertilisers to obtain satisfactory yields (FAO, 2000).

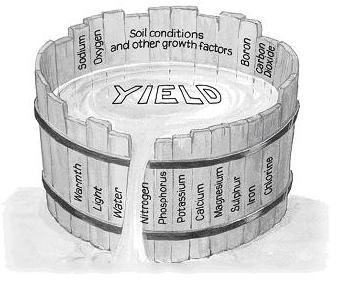


Figure 1. Yield-limiting minimum factor

Clay (clay minerals) and organic matter retain nutrients in a plant available form, constituting the adsorption complex, due to nutrients are carrying positive charges (+) (cations) or negative charges (-) (anions) that make them be attracted by the clay minerals and the organic matter.

The ability of a soil to retain a certain amount of nutrients (storage or adsorption capacity) determines the natural fertility of a soil.

On the other hand, in the soil solution, soil water contains dissolved nutrients that the plant root can take up only in dissolved form. Hence these nutrients have to be released from the adsorption complex into the soil solution to be effectively plant-available.

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Figure 2. Cationic exchange in soil. (Adapted from García-Serrano et al, 2009)

In soil, exists a balance between nutrients adsorbed on soil particles and nutrients released into the soil solution. If this balance is disturbed, e.g. by nutrient uptake through the plant roots, nutrients are released from the adsorption complex to establish a new equilibrium. This process is called diffusion and used to be influenced by the climate conditions.

When organic manure, compost and fertilisers are applied on a soil which cannot supply enough nutrients for an optimal plant growth from their own natural content, the added fertilisers decompose and dissolve and their cations and anions behave as described above (fig. 2).

The process of nutrient adsorption and release into the soil solution is very important. In particular the difference in adsorption strength of cations and anions has an important influence on how and when to apply fertilisers (in particular nitrogen fertilisers) in order to receive the highest efficiency and to avoid pollution by leaching. Organic matter is able to adsorb more nutrients than the comparable amount of clay. Therefore, it is important to build up organic matter (FAO, 2000).

1. Factors to determine agricultural fertility (productivity)

* **Nutrients balance**

Generally in all crops is interesting to calculate the dose of fertilisation balance for each nutrient, *i.e.* inputs and outputs of an agricultural system or specific production unit must be taken into account. Basically, the scheme nutrient balance refers to the inputs of these, either naturally by **precipitation** as rain, **irrigation** water, etc. or **restitution** through mineral and organic fertilisation and outputs derived from export crops and losses from washing, runoff, etc.

Schematically nutrient balance can be maintained with the following contributions:

* The application of organic and/or mineral fertilisers.
* By harnessing the natural biological process of nitrogen fixation, and the efficient application of irrigation water.
* Reinstatement down the remains of the plant and animal production (crop residues, straw, manure, manure, etc.), and organic and mineral fertilisation.
* The addition of nitrogen (N), sulphur (S) and other dissolved nutrients in the water in precipitation.
* Atmospheric nitrogen fixed biologically by bacteria (symbiotic or isolated) and green algae soil.
* The contribution of nutrients caused by weathering and dissolution of mineral soil particles.
* **Soil fertility**

Soil texture and soil structure are especially important for soil fertility and thus for plant growth. Coarse-textured (or sandy) soils do not retain water and nutrients well. Special care has to be taken when applying fertilisers to avoid leaching of nutrients (nitrogen and potassium). Clay soils, on the other hand, can store moisture and nutrients, but may have inadequate drainage and aeration. Breaking up these soils through liming or supplying them with organic matter will improve their structure.

In Mediterranean-Continental zone the climate generally are hot and dry, winters mild to cool and rainy, which is associated with warm-temperate west coasts. The characteristic aspects of Mediterranean climate which have a greatest impact on agricultural production are three-fold: a marked tendency to water shortage during the whole year, high values of solar radiation and the occurrence of violent or extreme weather phenomena. In subtropical regions characterized by a hot, arid climate, soils are normally low in organic matter content (sometimes as little as 0.1 percent), but are often of excellent structure due to an abundance of calcium. Many soils where organic matter quickly disappears from the soil under the influence of climate and microbiological activity, owe their stable structure to iron and aluminium oxides.

Organic matter is essential to improve the physical, chemical and biological soil properties. The presence of organic matter in the soil, among other functions, helps the development or maintenance of the clay-humic, essential to ensure good mobility nutrient complex it helps to maintain a pH optimum soil, essential for the assimilation of certain nutrients on the floor, it facilitates the maintenance of adequate biological activity, among other advantages circumstance that hinders the growth of pathogenic organisms, prevents loss of some nutrients in the soil and promotes the absorption of others.

The components of soil organic matter derived from (Portaet al, 1999):

-The accumulation of debris and residues of plants and animals:

• Biomass senescent naturally incorporated in soils in any ecosystem.

• Organic materials of biological origin provided by the man in agro-ecosystems: dung, crop residues, among others.

• Xenobiotics are those resulting organic nature of industrial synthesis: the most frequently added to the soil are pesticides, but can also be considered and other plastics.

-The decomposition of organic tissue by mechanical action of fauna and microorganisms.

- The degradation or decomposition of complex organic molecules to simpler organic compounds when it entails intervention of microorganisms is called biodegradation.

-The reorganization of some degradation products with microbial synthesis of new organic compounds.

* **Fertilisation as a fundamental mean production**

To achieve full efficiency, i.e. economic production with environmental responsibility, should fertlisation be part of an integrated whole oriented agricultural practices, all, towards this goal.

Fertiliser whether mineral and organic are one more factor to consider on farm, near the ground, variety, rotation, water, etc. and good management of all factors, their adapted to the unique conditions each farm, and the good work of the farmer, depend obtained during the operation agrarian good results, both economic and environmental.

1. Mineral or inorganic fertilisers

According to CE 2003/2003 an inorganic fertiliser is defined as “a fertiliser in which the declared nutrients are in the form of minerals obtained by extraction or by physical and/or chemical industrial processes. Calcium cyanamide, urea and its condensation and association products, and fertilisers containing chelated or complexed micro-nutrients may, by convention, be classed as inorganic fertilisers”.

The chemical characteristics of mineral fertilisers are defined by theirs nutrients content, the concentration in the fertiliser and the chemical form in which the nutrient is present in each product, i.e. the availability for the crop.

The concentration of nutrients and how they are presented, define doses of fertiliser to use, the time application and how they should be incorporated.

According to EU regulations, the amount of nitrogen, phosphorus and potassium should be expressed as follows:

• Nitrogen only as element (N).

• Phosphorous as element (P), in the form oxide (P2O5) or simultaneously. The equivalence between the two forms is: phosphorus (P) = P2O5 x 0,436.

• Potassium as element (K), in the form oxide (K2O) or simultaneously. The equivalence between the two forms is: potassium (K) = K2O x 0.830.

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| Are compounds which the declared nutrients are in the form of minerals obtained by extraction or by physical and/or chemical industrial processes. Its chemical characteristics are defined by the nutrients content, its concentration in the fertiliser and the chemical form in which nutrient is present in each product |

In accordance with the European regulation EC 2003/2003 exists different types of mineral fertilisers, grouped as:

*A. Inorganic straight primary fertilisers that include nitrogenous, phosphate and Potassium fertilisers.*

Through the nitrogenous straight fertilisers there are many types of commercial compounds. The most used in Spain are ammonia nitric fertilisers, urea and ammonium sulphate. The ammonia nitric fertilisers combine the advantages to contain nitrate-nitrogen that has an immediately availability, and ammonia-nitrogen, with a long-time action because of the nitrification process. This composition provides the advantage of make just one application in many crops.

Nitrogenous fertilisers are very versatile products for the farmer because they are mainly applied as the top dressing of different crops. Another advantage is that is not necessary burying these fertilisers because they are highly soluble, and a moderate rainfall or irrigation is enough to reach the roots (García-Serrano et al, 2009).

Prilled urea is always applied on the crop land. As it is a long-acting fertiliser it can be applied to seed, but mainly used in cover in one or two applications. The application must be done in advance in order to the nitrogen be available at the time of higher requirement of the plant. To avoid ammonium volatilisation losses, over all in calcareous soils with dry air and hot temperatures it is recommended bury the urea by tilling. As the same time, is important to do a slightly irrigation of soil after the fertilisation.

Ammonium sulphate is used in the mixture-fertilisers while simple phosphate fertilisers are fertilisers for application in background or seed which are generally constituents of compound fertilisers. They are for example single superphosphate, triple super-phosphate, dicalcium phosphate...

As well as simple phosphate fertilisers, potassium fertilisers are mainly applied in seed and can be used for the manufacture of complex fertilisers, or as constituents of blended fertilisers, incorporating nitrogen and phosphorus potassium fertilisers. They are for example potassium chloride, potassium sulphate, kainite...

*B. Inorganic compound primary nutrients fertilisers such as, NPK, NP, NK and PK fertilisers.*

Compound fertilisers are products that contain two or three of the elemental nutrients: nitrogen, phosphorous and or potassium. Also, they can content secondary nutrients and micronutrients, always respecting the minimum contents required by the EU regulation.

The manufacturing process of compound fertilisers ensure that in each granule of the complex has exactly the same amount of N, P and K, contrary that happens with blending fertilisers where each granule has only one or two nutrients on different proportions.

The amount of nitrogen in compound fertilisers can be shown in different forms: nitric, ammoniated or ureic, depending on the feedstock used on the manufacturing process. Phosphorous always be presented as water soluble form and as neutral ammonium citrate being completely available for the crops plants.

Potassium (water soluble) can become from potassium sulphate or chloride. The first one is often used in saline soils or with chloride sensitive crops while the application as chloride is suitable for all soil, over all in calcareous soils, with the exception of saline soils (adapted from García-Serrano et al. 2009).

*C. Inorganic fluid fertilisers including straight fluid fertilisers and compound fluid fertilisers.*

Within the straight fertilisers, the crystalline urea is used particularly in foliar applications and also in fertigation. Its low biuret[[1]](#footnote-1) content, less than 0.25%, allows its application on the leaves. It is recommended to use when plants need a quick supply of nitrogen or have difficulty root absorption due to excessive soil moisture, cold, drought or excessive pruning.

Ammonium nitrate and urea solutions with a 32% N-content are the only N-fertiliser that has this nutrient on his three forms: ureic (50%), ammoniated (25%) and nitric (25%) which makes it a very versatile product. This nitrogen solution of 32% is used in winter cereal cover with spray application and maize cultivation with application by fertigation.

The 20% N-fertiliser solution is recommended for it use on fertigation or sprayed on cereal cover.

Compound fluid fertilisers are suspensions and solutions of NPK fertilisers. The first ones are saturated solution which a piece of nutrients is not completely dissolved being on suspension by the clays action that avoids the precipitation of suspension particles. This kind of fertilisers includes a huge variety of NPK, NP and NK formulations, usually with a high graduation. The features that define it are: the density (1.4 to 1.5 kg/l); the particle size (<2mm); viscosity and pH (6 -6.5). They may be sprayed onto the soil surface on the same doses and time that other solid or liquid compounds and can be used with herbicides and others products at the same time.

NPK fertilisers solutions are solutions saturated in fertilising salts that contains N, P2O5 and K2O applied in fertigation. According to the pH they are classified as neutral (pH ~7) or acid (pH~2), that determines their application. Neutral solutions are applied with high quality irrigation water minimizing the risk of precipitation while acid solutions should be used with saline irrigation waters, rich in calcium and magnesium carbonates but exist the risk of precipitation. The feedstocks for its fabrication are usually urea, mono-ammonium phosphate and ammonium orthophosphate for neutral solutions and phosphoric acid and potassium chloride for acid solutions.

Formulas used for liquid fertilisers solutions used to be low graduated in order to avoid the crystallisation at low temperatures. Its main features are: density (~1.2kg/l) and crystallisation temperature that should be ≤0 (adapted from García-Serrano et al. 2009).

*D. Inorganic secondary nutrient fertilisers*

The Inorganic secondary nutrient fertilisers such as calcium phosphate, kieserite, magnesium sulphate etc., support to the soil the enough amount of calcium, magnesium and sulphur that plants need to growth, obtaining an optimum yield. These elements only should be added when the crop is unable to obtain from the soil or are a lacking of them.

Some ways of managing crops as fertigation, and the incorporation of new varieties of plants with more exigent nutrient requirements make necessary the addition of this kind of fertiliser.

*E. Inorganic micro-nutrient fertilisers which includes only one micro-nutrient such as, boron, cobalt, copper, iron, manganese, molybdenum or zinc.*

Plants need these elements in low concentration but their lack can have adverse effect to the crop development. Its concentration in soil is variable depending on different factors but this type of fertilisers only must be used when a lack of any of the micronutrient is detected.

1. Organic fertilisers

Organic fertilisers are defined as carbonaceous materials mainly of vegetable and/or animal origin added to the soil specifically for nutrition of plants (UNIDO & IFDC, 1998). It is important not to confuse organic fertiliser with organic amendment.

The first one has as main objective to provide nutrients to the plants while organic amendments provide nutrients to the soil improving the amount of organic matter, physical properties and the chemical and biological activity of soil.

In any case, both must have subjected to a treatment or manufacturing process prior to the application. In addition, in the case of livestock waste they must comply with EC regulation 1069/2009 of 21 October. Those products that do not meet this requirement fall outside the scope of regulations governing these products fertilisers. Specifically fresh manure and sewage sludge are expressly excluded and their use in agriculture, as organic fertilisers or amendments shall be subjects its specific regulation.

Depending on the primary nutrient content and the origin of organic feedstock used in the manufacturing on the organic fertilisers, they can be divided into several groups. The richness in nutrients will be expressed in %N, %P2O5 and %K2O. They are:

*A. Nitrogen fertilisers.*

1. Nitrogenous fertiliser from animal origin. Solid product obtained by the treatment with or without mixture of animal debris.
2. Nitrogenous fertiliser from vegetable origin. Solid product obtained by the treatment with or without mixture of vegetable debris.
3. Compound nitrogenous fertiliser from animal and vegetable origin. Solid product obtained by the treatment with or without mixture of animal and vegetable debris.

*B. Phosphate fertilisers*.

1. Phosphate fertiliser from animal origin. Solid product obtained by the processing of bones.

*C. Ternary fertilisers-NPK.*

1. NPK fertiliser from animal origin. Solid product obtained by the process of manure (with or without animal bedding) without minerals acids including composted offal fish.
2. Compound NPK fertiliser from animal and vegetable origin. Soil product obtained by the treatment of manures mixed to vegetables and/or animals debris.

*D. Binary fertilisers- NP and NK*.

1. NK fertiliser from animal origin. Solid product obtained by the treatment with or without mixture of animal debris.
2. Compound NP fertiliser from animal and vegetable origin. Solid product obtained by the treatment with or without mixture of animal and vegetable debris.
3. NK fertiliser from vegetable origin. Liquid product obtained by the distillation of by-products of beet, sugar cane or grapes.

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| Organic fertilisers are manufactured carbonaceous materials from vegetable or animal origin that provide nutrients to plants, being expressly excluded fresh manure and sewage sludge from the regulation of fertilisers. |

All organic fertilisers must be made from animal and/or plants debris. In the market we can find fertilisers made from blood meal, bone meal, menhaden fish, kelp… but usually are a mixture of some them.

2. 1. **Organic-mineral fertilisers**

They are obtained by mixture of inorganic and organic fertilisers and sometimes with peat, lignite or leonardite; but in any case they must have subjected to a treatment or manufacturing process prior to the application as happens with organic fertilisers.

According to their composition and its presentation (solid or liquid) are distinguished the following groups:

1. Nitrogen fertilisers.

1. Organic-mineral nitrogenous fertiliser. Solid or liquid.

2. Organic-mineral nitrogenous fertiliser with peat. Solid or liquid.

3. Organic-mineral nitrogenous fertiliser with lignite or leonardite. Solid.

2. Ternary fertilisers-NPK.

1. Organic-mineral NPK fertiliser. Solid or liquid.

2. Organic-mineral NPK fertiliser with peat. Solid or liquid.

3. Organic-mineral NPK fertiliser with lignite or leonardite. Solid.

3. Binary fertilisers- NP and NK.

1. Organic-mineral NP fertiliser. Solid or liquid.

2. Organic-mineral NP fertiliser with peat. Solid or liquid.

3. Organic-mineral NP fertiliser with lignite or leonardite. Solid.

4. Organic-mineral NK fertiliser. Solid or liquid.

5. Organic-mineral NK fertiliser with peat. Solid or liquid.

6. Organic-mineral NK fertiliser with lignite or leonardite. Solid.

7. Organic-mineral PK fertiliser. Solid or liquid.

8. Organic-mineral PK fertiliser with peat. Solid or liquid.

9. Organic-mineral PK fertiliser with lignite or leonardite. Solid.

* 1. **Organic amendments**

The aim of the organic amendment is to improve the amount of organic matter and nutrients in soil. Depending on the feedstock used on the manufacturing process they can be divided on:

*A. Humic amendments.*

Allow direct contribution to soil humic compounds which may come from the transformation of animal or plant debris and organic matter mainly as sedimentary peats, lignites and leonardites, linked to the process of coal formation.

Humic amendments are beneficial for soil as contain acids functional groups involved in cation exchange reactions of soils; clays interact with and stabilize soil aggregates, preventing erosion and have an important role in micronutrient availability, since they form complexes with metals such as iron, manganese, zinc and copper, besides helping to improve plant uptake of phosphorus, nitrogen, potassium, calcium and magnesium.

Some sources of humus for amendments are livestock products, such as manure, lissiers or slurries, and vegetables debris.

*B. Peats.*

Become from the biochemical degradation of plant material accumulated in anaerobic environments or semi-anaerobic (peat bog). His interest lies in its high content of organic matter used for the recovery of degraded soils, as a ground support, as raw material for the manufacture of substrates and as a natural organic amendment in general (adapted from García-Serrano et al. 2009).

*C. Compost.*

Defined as the output from a controlled process of aerobic microbial decomposition of biodegradable organic wastes we can differentiate three types of compost depending on the feedstock: compost, vegetable compost and composted manure. In all cases the organic matter content should be ranged between 35% and 45% (adapted from García-Serrano et al. 2009).

Other way to obtain nutrients from organic sources are the green manure crops. They are cultivated plants incorporated into the crop land, usually during the flowering period, in order to make an agronomic improvement. They used to locate

among orchards lines or between two mainstream crops in the rotation when they are spaced in time. Sometimes, the cultivation of green manure accompanied during part of its cycle to the main crop, overlapping. Its main function is to provide a complementary nutrition during the rotation crops, either through free N-fixation, or effectiveness in making nutrients available for crops that otherwise would be inaccessible or lost. The N-fixation is done through a symbiosis process between some legumes plants (vetch, pea, bean, etc.) and the bacteria Rhizobium sp. known as Mycorrhization.

The presence of mineral nitrogen in soils, mainly nitrates, damage nodule formation and nitrogen fixation from the air, causing rapid aging on the nodules formed. The biomass produced by the legume depends on the specie, soil fertility, climatic conditions during the growth and the time of mowing for soil incorporation. It is best to allow growth to reach full bloom, where the biomass produced is high; and it has not yet been a shift of nutrients to seeds. Are considered strongly fixing species to alfalfa, clover, lupines… whose capacity usually exceed 200 kg N/ha year; fixing medium to beans, vetch…fixing 100-200 kg N/ha year; and fixing little chickpeas, lentils, peas, vetch, bitter vetch…with less than 100 kg N/ha year.

On the other hand, legumes and other species (oats, rye, radish, rapeseed, etc.) used as green manure are able to absorb mineral nitrogen present in the soil between the main crops, avoiding losses and making it available to the following crop. In short, the use of green manure is a significant cost savings for the farmer, who must incorporate his farm less organic fertiliser (compost, manure, etc.) to maintain their production.

Green manures included in crop rotation not enrich the soil with phosphorus (P), potassium (K) or other nutrients, unlike happens with nitrogen, but avoid its loss. This occurs mainly in three ways:

* 1. Nutrient transport from depth layers to the surface
  2. Increasing the amount of microorganisms in the soil and its activity. These microorganisms are capable of dissolving insoluble inorganic phosphorus compounds by production of organic acids, releasing phosphorous above their own nutritional demands amounts, so it is available to plants.
  3. Reducing the erosion. The destruction of the topsoil, where the majority of nutrients and organic matter are located, involves the irreversible loss of soil quality and continuous increase in fertiliser application and water to prevent the drastic drop in yields.

Broadly, green manure crops do not increase the level of soil organic matter except in exceptional cases. This is because the material incorporated into the soil is young, little woody and with a high nitrogen/carbon relation, especially if it is legumes. However, if our soil has a low level of organic matter and we want to increase it using green manures, we should sow cereal, mixed or not with legumes, and bury them just after flowering, as at this time the maximum green mass is obtained appreciable formation of cellulose and lignin capable of forming stable humus (adapted from Guzmán & Alonso, 2008).

1. Environmental impacts of organic and mineral fertilisation

Sustainable agriculture must be focused in productive and profitable systems, especially systems able to preserve the environment improving it in long term. According to a document published by the International Fertiliser Industry Association (IFA, 2000) the basic principles of soil management for sustainable agricultural systems are:

• Replenish nutrients removed

• Maintain the physical condition

• No build-up of weeds, pests and diseases

• No increase in soil acidity or toxic elements

• Soil erosion must be controlled to be equal or less than the rate of soil genesis.

1. 1. **Mineral fertilisation impacts**

The main environmental impacts of agriculture come from the conversion of natural ecosystems to agriculture, from agricultural nutrients that pollute aquatic and terrestrial habitats and groundwater, and from pesticides, especially *bioaccumulating* or persistent organic agricultural pollutants. Pesticides can also harm human health, as can pathogens, including antibiotic-resistant pathogens associated with certain animal production practices. How can such costs be minimized at the same time that food production is increased? In one sense the answer is simple: crop and livestock production must increase without an increase in the negative environmental impacts associated with agriculture, which means large increases in the efficiency of nitrogen, phosphorus and water use, and integrated pest management that minimizes the need for toxic pesticides (Tilman et al, 2002).

Nitrogen fertilisation can increase emission of gases that have critical roles in tropospheric and stratospheric chemistry and air pollution (Cicerone, 1988; Hall, 1996.) Nitrogen oxides (NOx), emitted from agricultural soils and through combustion (Delmas et al, 1997), increase tropospheric ozone, a component of smog that impacts human health, agricultural crops and natural ecosystems. As much as 35% of cereal crops worldwide are exposed to damaging levels of ozone (Chameides et al, 1994). NOx from agroecosystems can be transported atmospherically over long distances and deposited in terrestrial and aquatic ecosystems. This inadvertent fertilisation can cause eutrophication, loss of diversity, dominance by weedy species and increased nitrate leaching or NOx fluxes (Vitousek et al, 1997). According to this, nitrogen inputs to agricultural systems contribute to emissions of the greenhouse gas nitrous oxide.

Nitrogen loading to estuaries and coastal waters and phosphorus loading to lakes, rivers and streams are responsible for over-enrichment, eutrophication and low-oxygen conditions that endanger fisheries (Nordhaus and Kokkelenberg,1999; Downing et al, 1999).

Some solutions are proposed to solve this problem that will require significant increases in nutrient-use efficiency, that is, in crop production per unit of added nitrogen, phosphorus and water (Tilman et al, 2002). Some practices and improvements that could each contribute to increased efficiency, such as:

* Cover crops or reduced tillage can reduce leaching, volatilization and erosional losses of nutrients and increase nutrient use.
* Closing the nitrogen and phosphorus cycles, such as by appropriately applying livestock and human wastes, increases crop production per unit of synthetic fertiliser applied. Multiple cropping systems using crop rotations or intercropping (two or more crops grown simultaneously) may improve pest control and increase nutrient- and water-use efficiency.
  1. **Organic fertilisation impacts**

Environmental impacts from organic fertilisers is associated with excessive application. In case of intensive livestock production areas the major problems of environmental degradation where the production of manure greatly exceeds the capacity of the land to assimilate these wastes. In addition to this problem the direct runoff from intensive cattle, pig and poultry farms on the land. To the typical pathways of degradation, that of surface runoff and infiltration into the groundwater, is added the volatilization of ammonia which adds to acidification of land and water.

However, organic fertilisation practices is often perceived to have generally beneficial impacts on the environment, reducing them when it is rational management and providing nutrients for soils, compared to mineral fertilisation.

1. Mineral vs organic fertilisation

Mineral or inorganic fertilisers are widely used in agriculture to optimise production, and organic fertilisers are a significant additional source of nutrient input. Organic farmers do not apply synthetic mineral fertilisers. Nitrogen and phosphorus fertilisers greatly enhance crop production, but losses of nitrogen and phosphorus from agriculture contribute to loss of biodiversity, climate change, acidification and pollution.

#### Table 2: Advantages and disadvantages of mineral and organic fertilisers.

|  |  |  |
| --- | --- | --- |
|  | ADVANTAGES | DISADVANTAGES |
| ORGANIC  FERTILISERS | * Improve soil structure * Increase soil ability to hold water and nutrients * Work over the time (long effectiveness) * Natural incomes * Slow release of nutrients * Difficulty to over fertilise and harm plants * Little risk of toxic build ups chemicals and salts * Sustainable and environmentally friendly * Can do it yourself | * Expensive (on first term, later need to add fewer amounts than other fertilisers). * Best releasing of nutrients in warm and moisture soils * Inexact application (unknown exactly composition) * Need of microorganism for nutrient releasing. * Slow release of nutrients |
| INORGANIC FERTILISERS | * Provide rapid nutrition * Quickly release of nutrient * Rate application known (highly analysed to produce the exact ratio desired) * Cheaper in short terms (but expensive in long term because need lot of applications) | * Synthetic incomes (non-renewable sources as fossil fuels and earth materials) * Easily leachable * Can burn plants by over fertilisation * Can build up toxic chemicals and salts * Not promote life or soil health * Not improve soil structure * Release greenhouse gases * Long term use can change soil pH |

1. Bio-fertilisers

Are made from one or more live microorganisms (fungi and bacteria) which help provide or improve nutrient availability after application on crops. Also, allow farmers to save power, decrease soil and water pollution, increase soil fertility and promote biodiversity, all with a lower production cost than chemical fertilisers. This is translated into economic benefits for farmers by the effect of lower costs associated to the fertilisation process and higher yields in crops.

Bio-fertilisers are divided in:

*A. Nitrogen fixing bio-fertilisers:*

Some microorganisms such as Azospirillum, Azotobacter, Beijerinckia (i.e. microorganisms establishing rhizogenotics associations with grasses), Rhizobium, Bradyrhizobium, Azorhizobium (i.e. bacteria that establish symbiosis with legumes), Frankia (i.e. symbiotic actinomycetes with woody plants), Nostoc (i.e. green algae that establish symbiosis with various plants) or Anabaena (i.e. ferns) have the ability of transform atmospheric nitrogen into ammonium that supply to crops.

The development of nitrogen fixation process by bacteria depends on specialized microorganisms, i.e., those who are carriers of the nitrogenase enzyme, which are responsible for producing it, through biological and physic-chemical processes.

Rhizobium induces legume to form nodules, establishing a metabolic cooperation where bacteria reduce nitrogen (N2) to ammonium (NH4) that is transferred to the plant tissue to be assimilated into proteins and other complex nitrogenous compounds. At the same time, leaves reduce carbon dioxide (CO2) into sugars through photosynthesis and transport it to the roots. This is the moment where Rhizobium provides ATP to the process of diatomic nitrogen immobilization (using it as energy source) and facilitates the development of photosynthetic processes and plant growth (Carvajal & Mera, 2010).

The most well-known and perhaps the most common mycorrhizal symbioses involve arbuscular mycorrhiza (many crop species) and ectomycorrhizal (only woody species; mostly tree and shrub species), although several other types (e.g., Ericaceous, Orchidaceous, Ectendo-mycorrhizae) also exist. The positive role of mycorrhizae in plant production is well documented, with many cases of growth and yield enhancement, particularly in highly dependent, susceptible plants. The plant response can be due to various reasons, although in most cases it is due to an increase in effective root area for water and nutrient extraction, since the mycorrhizal hyphal network works as a natural extension of the plant root system. The plant donates C to the mycorrhizae in exchange for a greater ability to use native soil resources. Other benefits of the mycorrhizal association are an enhanced protection against pathogens, improved tolerance to pollutants and greater resistance to water stress, high soil temperature, adverse soil pH and transplant ‘shock.’ (AGP-FAO, 2016).

There are several methods available to enhance nitrogen fixation (Montañez A., 2000):

• host plant selection (breeding legumes for enhanced nitrogen fixation)

• selection of effective strains able to fix more nitrogen

• use of different agronomic methods that improve soil conditions for plant and microbial symbiont

• inoculation methods

*B. Phosphorous solubilising fertilisers:*

Phosphorus is the second important key element after nitrogen as a mineral nutrient in terms of quantitative plant requirement. Although abundant in soils, in both organic and inorganic forms, its availability is restricted as it occurs mostly in insoluble forms (Sharma et al, 2013). Only soluble P, mainly as orthophosphate, can be available to plant uptake.

Only 0.1% of the total P exists in a soluble form available for plant uptake (Zhou et al. 1992) because of the fixation into unavailable form. This fixation is defined as the remove of available phosphate from the soil solution into the soil solid phase by two types of reactions: (a) phosphate sorption on the surface of soil minerals and (b) phosphate precipitation by free Al3+ and Fe3+ in the soil solution (Sharma et al, 2013).

Phosphate-solubilizing microorganisms (PSM) are a group of bacteria, fungi actinomycetes and even algae who have the ability to transform inorganic or organic forms of P to soluble P available for plants.

In addition to Pseudomonas and Bacillus, other bacteria reported as P-solubilizers, including Rhodococcus, Arthrobacter, Serratia, Chryseobacterium, Gordonia, Phyllo-bacterium, Delftia sp. (Wani et al. 2005; Chen et al. 2006), Azotobacter (Kumar et al. 2001), Xanthomonas (De Freitas et al. 1997), Enterobacter, Pantoea, and Klebsiella (Chung et al. 2005), Vibrio proteolyticus, Xanthobacter agilis (Vazquez et al. 2000), Rhizobium, Burkholderia, Achromobacter, Agrobacterium, Micrococcus, Aerobacter, Flavobacterium, Mesorhizobium, Azospirillum, Pantoea and Erwinia, among others (Orberá et al, 2005; Poonguzhali et al, 2008; Cordero-Elvia et al, 2008; Sharan et al., 2008).

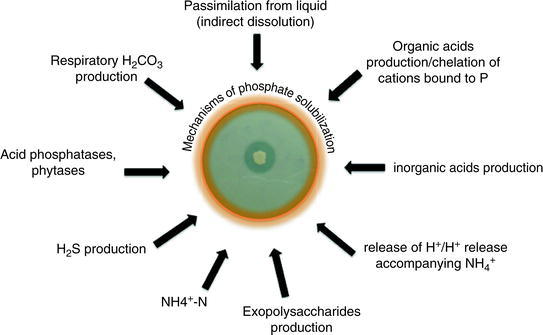
Main mechanisms of PSM to solubilize phosphorous are:

a) The action of organic acids produced by the microorganisms.

b) Chelation of the elements responsible to the phosphate insolubility.

c) Direct adsorption of insoluble phosphorus compounds by microorganisms who accumulate them into their cells to transform in soluble form released later.

These mechanisms are influenced by environmental factors as pH, salinity and temperature.



#### Figure 3. Mechanism of phosphate solubilisation (Zaidi et al, 2009).

*C. Growth promoting microorganisms*

Various other beneficial rhizosphere organisms entitled plant growth promoting bacteria (PGPB) have been used, mostly as seed inoculants. PGPB affect plant growth through direct growth promotion (hormonal effects), induced systemic resistance, mineralization, substrate competition, niche exclusion, detoxification of surrounding soil and production of antibiotics (AGP-FAO, 2016). Different mechanisms were found to be involved in plant growth promotion, either by rhizosphere or endophytic bacteria. Plant growth regulators produced by PGPB are substances, as signal molecules, which are made by the metabolic activity of these microorganisms. These signal molecules act as chemical messengers and play a fundamental role as growth and development regulators in the plant (Dawwam et al, 2013).

Several bacterial species and genera have been used as plant growth promoters, including pseudomonas (e.g., Pseudomonas fluorescens, P. putida, P. gladioli), bacili (e.g., Bacilus subtilis, B. cereus, B. circulans) and others (e.g., Serratia marcescens, Flavobacterium spp., Alcaligenes sp., Agrobacterium radiobacter) (AGP-FAO, 2016), Enterobacter, Rahnella, Rhodanobacter, Stenotrophomonas, Xanthomonas, Phyllobacterium, Klebsiella sp, Erwinia sp., Azospirillum brasilense, Bacillus sphaericus (Dawwam et al, 2013).

We can find several commercial fertilisers made from one or more of these microorganisms but unfortunately, the use of PGPB nowadays is still limited because of the poor understanding of the interactions between these microorganism and the host plant and the indigenous soil microflora.

*D. Seaweed extracts*

Seaweed extract are commonly known as seaweed liquid fertilisers (SLF). They contain highly effective nutritious and promoters of faster germination of seeds and increase yield and resistant ability of many crops. More specific benefits of SLF are improve root structures, improve plant development like flowering and leaf development and fruit set, and enhanced ability to tolerate plant disease and climatic stresses. There are also benefits that relate to improved soil structure, soil water holding capacity and improved soil microbiology. However, the mode of actions for these benefits are not well understood yet. (Ganapathy-Selvam et al 2014; Arioli et al, 2015).

A rational use of bio-fertilisers provides benefits as the improving on the soil structure and particles aggregation allowing better aeration and water leaching. Also improve some chemicals conditions of soil such the availability of nutrients for roots absorption and the ability of plants to adsorb nutrients by the action of microorganisms in bio-fertilisers but above all, to increase the microbial biodiversity of soil that and consequently to help the fitting against pathogens microorganisms by the establishment of competence relationships.

Nowadays, a lot of scientific studies support the use of bio-fertilisers and exist several commercial mixtures of microorganisms that can be used in crops.

* 1. **Bio-fertilisers impacts**

There is controversy over the advantages of using bio-fertilisers and their effectiveness as growth stimulators, because of the term refers to the use of micro-organisms and organic compounds that improve the ability of plants to assimilate nutrients -- as opposed to the conventional purpose of fertiliser, which is simply to provide more nutrients.

Applying bio-fertilisers is unlikely to harm plant life or the environment in any way, but there is little to guarantee that they will help either. This is a distinct disadvantage compared to nutrient-based fertilisers that reliably provide quantifiable results. The reason for this lies in the myriad factors that have to be aligned for the microbes in bio-fertilisers to be effective for the purpose they are prescribed. Their effectiveness is a product of complex chemical and biological interactions that are themselves affected by moisture, temperature, pH and other environmental variables. If the conditions aren't right for the microbes to multiply and do their work, their populations are likely to peter out, and the user will have wasted time and money on a product that was not suitable for the soil conditions.

According to a work done by Carvajal-Muñoz and Carmona-Garcia, (2012) biological practices can offer a wide range of opportunities for the development of better agrarian practices due to the advantages and benefits provided for the soil, products and farmers. Nevertheless, limitations of these practices are also well studied and recognized, which implies that feasibility studies should be carried out to find out better solutions for each particular case in agricultural activities. Next in this section, some limitations (Chen, 2006) are mentioned to highlight the need of future research on some issues:

* Compost products have highly variable concentrations of nutrients. In addition, implementation costs are higher than those of certain chemical fertilisers.
* Extensive and long-term application may result in accumulation of salts, nutrients, and heavy metals that could cause adverse effects on plant growth, development of organisms of the soil, water quality, and human health.
* Large volumes are required for land application due to low contents of nutrients, in comparison with chemical fertilisers.
* Main macronutrients may not be available in sufficient quantities for growth and development of plants.
* Nutritional deficiencies could exist, caused by the low transfer of micro- and macro-nutrients.

1. Fertilisers allowed in organic farming

The EC 834/2007 rules the organic farming production and which fertilisation ways can be used in. In organic farming the use of external inputs is restricted except in case where the nutritional needs of plants cannot be met using the inputs required or the appropriate management practices and methods based on ecological system and use of natural resources. In this case, only fertilisers and soil conditioners referred to in Annex I of the EC 889/2008, 5 of September may be used in organic production and only to the extent necessary. Operators shall keep documentary evidence of the need to use the product.

The use of chemically synthetized inputs are strictly limited to very exceptional cases as when the appropriate management practices do not exist and the external inputs such as natural or naturally-derived substances and low solubility mineral fertilisers are not available on the market or when the use of them contribute to unacceptable environmental impacts. In any case, the organic farming rules can be adapted where necessary and within the framework of this regulation.

Some of the allowed fertilisers in organic agriculture are listed below:

•Compound products or products containing only farmyard manure.

•Dried farmyard manure and dehydrated poultry manure.

•Composted animal excrements including poultry manure and composted farmyard manure.

•Liquid animal excrements.

•Composted or fermented household waste

•Peat

•Mushroom culture waste

•Vermicompost and insects

•Guano

•Composted or fermented mixture of vegetable matter

•Products or by-products of animal origin as: blood meal, hoof meal, horn meal, bone meal or degelatinized bone meal, fish meal, meat meal, feather, hair and ‘chiquette’ meal, wool, fur hair and dairy products.

•Products and by-products of plant origin fertilisers

•Seaweeds and seaweed products

•Sawdust and wood chips

•Composted bark

•Wood ash

•Soft ground rock phosphate

•Aluminium-calcium-phosphate

•Basic slag

•Crude potassium salt or kainite

•Potassium sulphate, possibly containing magnesium salt

•Stillage and stillage extract

•Calcium carbonate

•Magnesium and calcium carbonate

•Magnesium sulphate (kieserite)

•Calcium chloride solution

•Calcium sulphate (gypsum)

•Industrial lime from sugar production

•Industrial lime from vacuum salt production

•Elemental sulphur

•Trace elements

•Sodium chloride

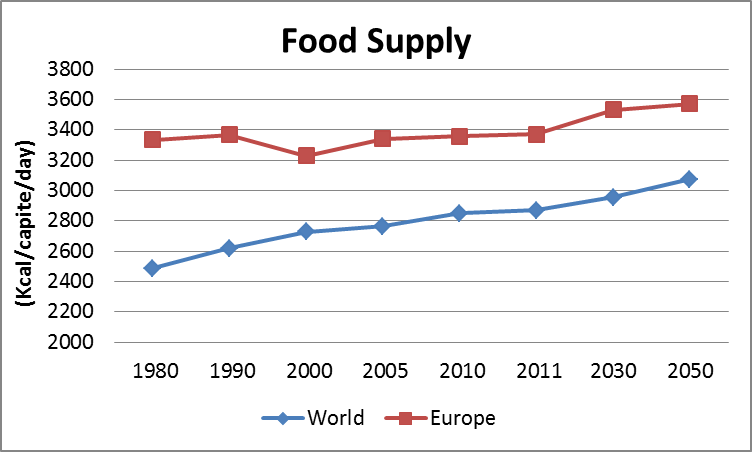
•Stone meal and clays

To know more about the origin and restriction about these products see the Annex I of Regulation EC 889/2008.

1. Fertilisers status at European Union

Total food demand and its composition present and future is to a large extent determined by the total size of the population, average per capita income, income distribution and the degree of urbanization. A FAO study (Bruinsma, 2012) reveals that the population in Europe is strongly urbanized where only about the 30% of its population is classified as ‘rural’. According to UN projections (UN, 2010) the share of its urban population in total will continue to increase from some 70% at present to over 80% by 2050. Hence, the agricultural labour force will declines from about 50 million persons (or 17% of the rural population) at present, to only some 15 million persons (4%) by 2050. Although these projections should be interpreted with care, they clearly show that the number of persons dependent on (primary) agriculture in the region is a very small and declining fraction of the total population.

Food consumption in terms of kcal per capita per day is a key variable for tracking and projecting developments in food security. Nearly all countries in the region had by 2005/07 already reached comfortably high levels of Daily Energy Supply (DES). The food demand projections for the region’s countries therefore foresee only a slow further increase in the DES, on average for Europe and Central Asia an additional 160 kcal (Fig. 4).



#### Figure 4. European and world food supply.

#### (FAOSTAT food supply sheet and FAO, 2012).

On the same way annual agricultural production could in 2050 be nearly 20% higher than in 2005/07. This is entirely due to increased crop production to meet additional demand for biofuels. Excluding this, annual crop production growth in the EU would be a mere 0.10 %.

The arable land area in developed countries as well in European Union has been on a continuing decline since the late 60s (Figure 5) declining nearly a 15 % from 417 million ha in 1961 to 355 million in 2005/07, while some crop production projections says that would reach to a further 10 % decline in the arable area over the period to 2050. Actually, arable crops suppose the 61% of the fertilised area in western Europe and the 85% in eastern European countries according to data from European Fertilisers studies.



#### Figure 5. Total arable land projections (FAO, 2012)

Projections about the increase in food consumption coupled with the lower availability of arable land force to obtain higher yields from the available land that will lead to an increase in fertiliser use. Management techniques such as precision agriculture however offer opportunities to substitute information for fertiliser.

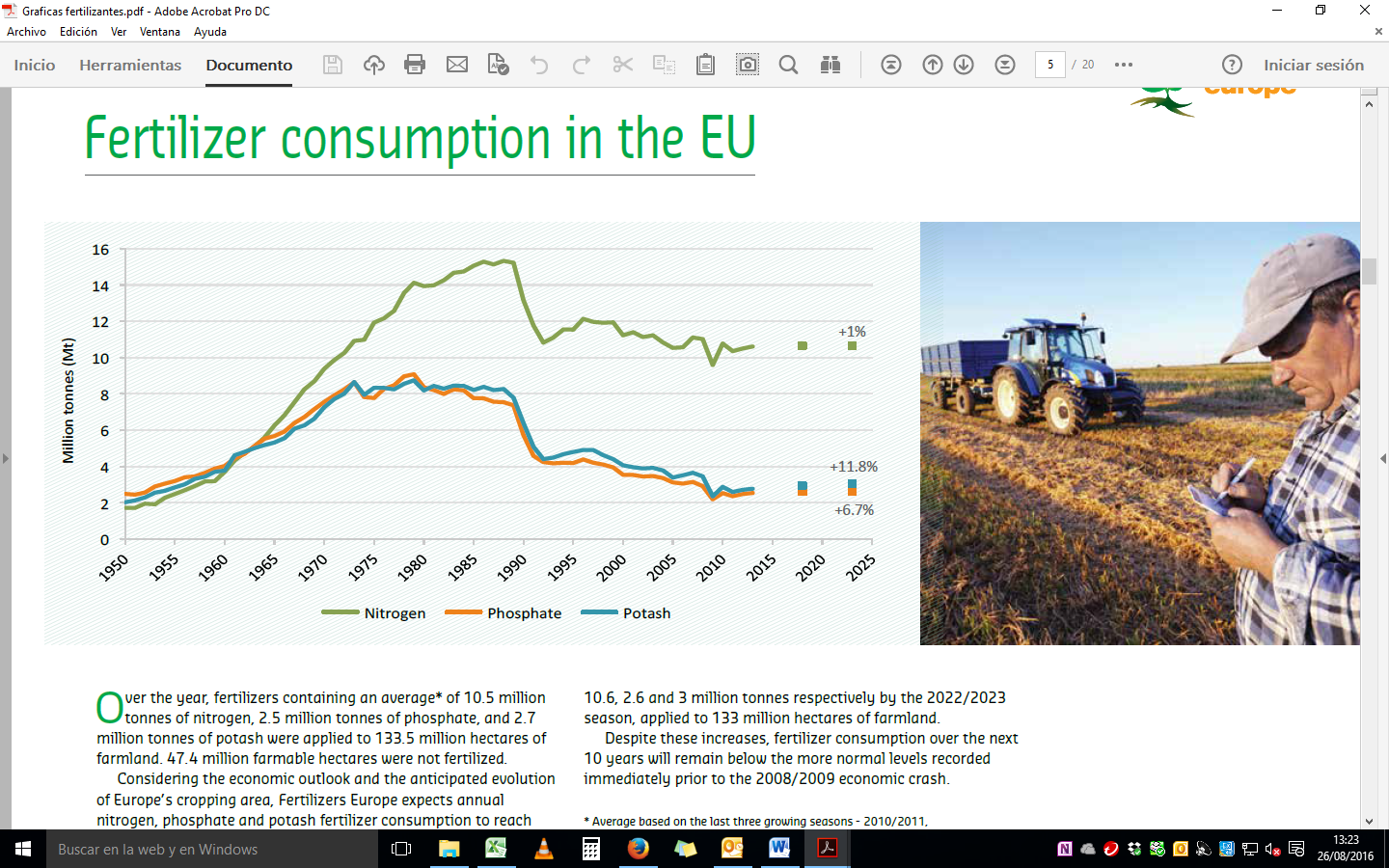
Although average fertiliser application rates in the EU have been more or less constant since the early 1990s (after haven fallen from much higher levels), such rates could edge up again due to a shift in production towards oil crops and fruits and vegetables which require on average higher fertiliser applications per hectare.

According to Fertilisers Europe total mineral fertiliser consumption in EU-27 mounted from 10.6 million tonnes of nitrogen (N), 1.3 million tonnes phosphorous (P) and 2.9 million tonnes of potassium (K) in 2006/2007 to 10.5, 1.1 and 2.5 in 2012/2013 (Table Y). Considering the economic outlook and the anticipated evolution of Europe’s cropping area, Fertilisers Europe expects annual nitrogen, phosphate and potash fertiliser consumption to reach 10.6, 2.6 and 3 million tonnes respectively by the 2022/2023 season, applied to 133 million hectares of farmland (Fig. 6).

Despite these increases, fertiliser consumption over the next 10 years will remain below the more normal levels recorded immediately prior to the 2008/2009 economic crash.

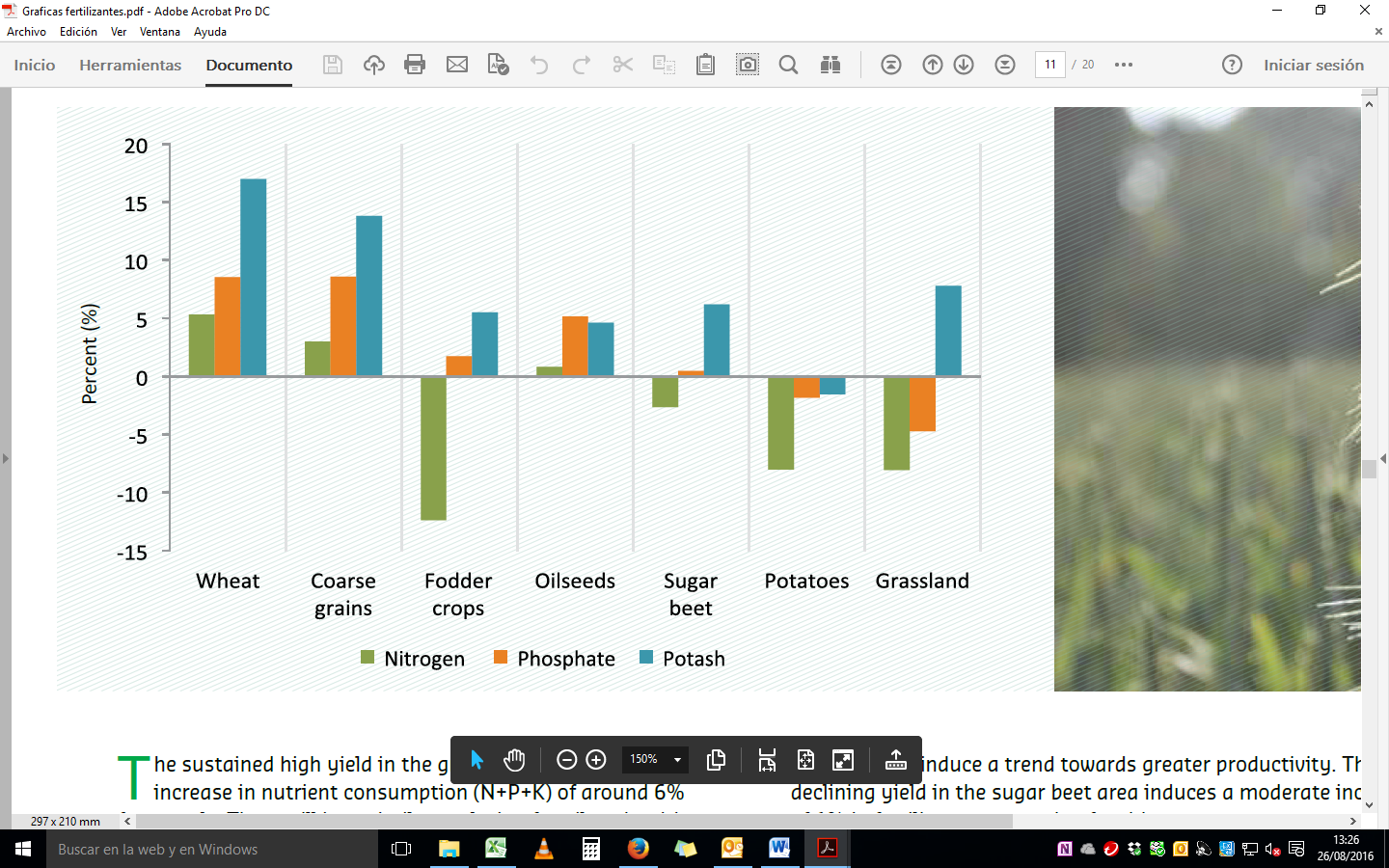
#### Table 3: Total mineral fertiliser consumption in million tonnes (Fertilisers Europe).

|  |  |  |  |
| --- | --- | --- | --- |
| UE-27 | N (Mt) | P(Mt) | K (Mt) |
| 2006/2007 | 10.6 | 1.3 | 2.9 |
| 2007/2008 | 11.2 | 1.4 | 3.1 |
| 2008/2009 | 9.7 | 0.8 | 1.7 |
| 2009/2010 | 10.2 | 1.0 | 2.0 |
| 2010/2011 | 10.8 | 1.1 | 2.4 |
| 2011/2012 | 10.4 | 1.0 | 2.2 |
| 2012/2013 | 10.5 | 1.1 | 2.5 |



#### Figure 6. Projection for mineral fertiliser consumption (Fertilisers Europe).

In the western Europe cereals account for 37% of arable crop cultivation, which in turn makes up 61% of the fertilised area, against the 10% represented by permanent crops and 29% of the grasslands. Contrary, in the Eastern Europe the arable production represents the 85% of the fertilised area, including the 56% of cereals crops while permanent crops and grasslands decrease until 3% and 11% respectively. Therefore cereals seem the main crop in both Western and Eastern Europe. The anticipated cropping pattern in the European Union over the next 10 years sees a stabilization of the cereals area with an overall increase of 0.4%. This stabilization, however, is compensated by a sustained high increase in yield that will lead to an increase in nutrient consumption (N+P+K) of around 6%. The sustained high yield in the grain area will lead to an increase in nutrient consumption (N+P+K) of around 6% for cereals at the same time that is expected a decrease for grassland at around 5% (Fig. 7).



#### Figure 7. Changes in fertiliser use by crop (Fertilisers Europe).

In order to decrease the mineral fertiliser consumption and their environmental problems associated, the new Common Agriculture Policy (CAP) at the E.U. try to promote greening agriculture. It consist in a global way to manage croplands (e.g. obligatory crop rotation, grassland maintenance) to maximize the crop yield putting on value some wastes and do it in a sustainable form with the environment.

Today the European Commission adopted an ambitious new Circular Economy Package to help European businesses and consumers to make the transition to a stronger and more circular economy where resources are used in a more sustainable way. Actually, the main problem about organic and bio-fertilisers is that inclusion in the existing Fertilisers Regulation of types of products sourced from organic or secondary raw material is challenging. Regulators hesitate because of the relatively variable composition and characteristics of such materials. The existing Fertilisers Regulation is clearly tailored for well characterized, inorganic fertilisers from primary raw materials, and lacks the robust control mechanisms and safeguards necessary for creating trust in products from inherently variable organic or secondary material sources. Furthermore, the links with existing legislation on control of animal by-products and waste are not clear. As consequence, a producer of fertilisers sourced from organic or secondary raw materials, established in one Member State and seeking to expand its market to the territory of another Member State, is often faced with administrative procedures making the market expansion prohibitively expensive. The resulting lack of critical mass hampers investment in this important sector of the circular economy. The problem is of particular importance for producers established in Member States with a small domestic market compared to the surplus of organic, secondary raw materials (typically manure) of which they dispose (2016/0084 (COD)).

This situation is against the new circular economy purpose that want boost the EU's competitiveness by protecting businesses against scarcity of resources and volatile prices, helping to create new business opportunities and innovative, more efficient ways of producing and consuming. It will create local jobs at all skills levels and opportunities for social integration and cohesion. At the same time, it will save energy and help avoid the irreversible damages caused by using up resources at a rate that exceeds the Earth's capacity to renew them in terms of climate and biodiversity, air, soil and water pollution. Action on the circular economy therefore ties in closely with key EU priorities, including jobs and growth, the investment agenda, climate and energy, the social agenda and industrial innovation, and with global efforts on sustainable development (COM(2015) 614 final).

By stimulating sustainable activity in key sectors and new business opportunities, the plan will help to unlock the growth and jobs potential of the circular economy. It includes comprehensive commitments on eco-design, and targeted action in areas such as food waste or consumption.

To achieve these objective European Union has to developed legislative proposals on fertilisers as <<2016/0084 (COD) Proposal for a regulation of the European Parliament and of the Council laying down rules on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009>>. With this proposal the Commission intended to ease the access of organic and waste-based fertilisers to the EU single market, bringing them on a level playing field with traditional, non-organic fertilisers. This will create new market opportunities for innovative companies while at the same time reducing waste, energy consumption and environmental damage (E.C., 2016).

The Regulation sets out common rules on converting bio-waste into raw materials that can be used to manufacture fertilising products. It defines safety, quality and labelling requirements that all fertilising products need to comply with to be traded freely across the EU. Producers will have to demonstrate that their products meet those requirements, as well as limits for organic contaminants, microbial contaminants and physical impurities before affixing the CE-mark.

This would contribute to the following circular economy objectives:

• It would allow valorization of secondary raw materials, hence enabling improved use of raw materials and turning eutrophication and waste management problems into economic opportunities for public and private operators.

• It would increase resource efficiency and decrease import dependency for raw materials essential to European agriculture, in particular phosphorus.

• It would boost investment and innovation in the circular economy, hence creating jobs in the EU.

• It would contribute to relieving the fertilisers industry from its current pressure to reduce CO2-emissions under ETS, by allowing it to produce fertilisers from less carbon-intensive feedstock.

In short, organic fertilisation is a good practice for crops but also a good business opportunity.

The projected increase of urban population and food supply joined to the decrease of rural labour force and arable land will required an improvement on the crop yields and a larger fertiliser consumption. The European Union has recently launched a series of measures to avoid it and the environmental problems related (Greening agriculture), at the same time that develop new business opportunities in the field of food consumption and wastes (New Circular Economy). Hence, it has been necessary to propose a new regulation which includes organic and waste-based fertilisers.

1. Analysis of crop soil, plants and water for good management of fertilisers
   1. **Soils analysis**

Soils is considered an habitat for plants, so physical, chemical, and biological properties affect plant growth. The **physical properties** of a soil largely determine the ways in which it can be used. The proportions of the four major components of soils, inorganic particles, organic materials, water, and air, can vary greatly from place to place and with depth. **Chemical properties** of soils are important in that, along with their physical and biological properties, they regulate the nutrient supplies to the plant. It is important taking into account these nutrients supplied by the soil or applied as inorganic fertilisers, organically by manures and others or bio-fertiliser will improve crops development maintaining the nutrients balance and supplying the lack of it on soils. The **biological properties** of the soil are dictated by the macroorganisms and microorganisms. Good physical and chemical properties supply the right environment and sufficient nutrients to the organisms for optimal biological activity. This in turn improves the soil physical and chemical properties through improved structure and nutrient cycling.

The best fertilisers to use for growing crops depend on many factors, such as which nutrients are needed, the soil structure and chemistry and the method that will be used to apply the fertiliser. The best method of estimating which and how much nutrients are needed is through **soil testing** and the sustainable management of fertilisers to protect the environment based on organic fertilisers and bio-fertilisers which are less harmful than inorganic fertilisers.

The first step in maintaining soil fertility is to know current nutrient levels, so the higher the level of nutrients in the analysis soil, the lower the required amount of fertiliser (Fig. 9). This is accomplished by soil testing, which is an important soil management tool and effective basis for nutrient and lime recommendations. The goal of soil testing is no longer simply to find out whether the soil contains adequate plant nutrients for optimum growth. It also is a tool for determining whether nutrient levels are excessive and prone to move off-site. Soil fertility today is a social issue as well as a crop production concern.

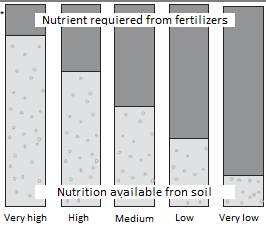


Figure 9. \*Fertilisers used at “very high” levels are for “starter” or “maitenance” purpose. (FAO, 2000).

Soil tests each field every 1-3 years, depending upon crop rotation, field history, and the value of the crop. Testing every 3-5 years is probably sufficient for agronomic crop fields with a stable rotation, long-term record of soil tests, and no recent manure or compost applications (only commercial fertiliser since the last soil test). Choose a reliable, experienced laboratory that makes recommendations suitable for the soil types and growing conditions in the location.

**Soils analysis**

*Physical determinations:* texture

*Chemical determinations:* CE, pH,

total nitrogen, C / N, total carbonates,

active lime, MO, available phosphorus,

exchange cations (K, Na, Mg, Ca).

* 1. **Plants analysis**

The plant will give a reliable information on its total nutritional status at the date of sampling and thus indicate any actual supplementary fertiliser needs (of the current crop). With plant testing the concentration of the different nutrients (and thus their proportion) is determined chemically in the plant sap or in the dry matter. If a nutrient is below the minimum concentration (“critical value”), which is different for each nutrient, it is likely that the application of a fertiliser containing that nutrient will increase yield. It is important that the “critical values” established are related to the expected yield level.

Plant analysis is particularly valuable in permanent crops and widely used in fruit trees (citrus) and oil palms.

**Plants analysis**

*Chemical determinations: nitrogen,*

*phosphorus, potassium, calcium, magnesium, iron, zinc, manganese, copper, boron, sodium.*

* 1. **Water analysis**

Water sampling and analysis is a vital part in agricultural and environmental applications for studying the quality of water treatment process, distribution system, or source of water supply. The water and wastewater should be checked for chemical, physical (turbidity and solid matter) and biological contamination before used it, to avoid environmental pollution (most of diseases can be spread to plant, animal, and human by water contaminated) (Estefan et al, 2013).

**Water analysis**

*Chemical determinations: pH, EC, anions and cations.*

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1. Biuret is a potential toxic compound for plants that appear during the manufacturing process of urea. [↑](#footnote-ref-1)