Section 4: Fertilizers

When using soil or soil-based media, you might not need to fertilize the seedlings immediately because the substrate has residual fertility. However, with most soil-less substrates and during the production phase, seedlings need the addition of balanced nutrients. In this chapter, we describe the essential plant nutrients and discuss various organic and inorganic fertilizers.

Fertilizers provide plants with the nutrients necessary for healthy growth. Apart from the macronutrients N, P, K, Ca, Mg, and S there is a known suite of micronutrients (Fe, Mn, B, Cu, Cl, Zn and Mo) that play important roles in the plant's metabolism.

When you use soil- or compost-based media, the substrate might contain enough nutrients for good plant growth. However, it is advisable to analyse the substrate for available plant nutrients regularly. If laboratory facilities are not available locally, institutions such as ICRAF offer this service for a fee[1]. Although the optimal ranges are not known for most agroforestry tree species, figures for some general groups are available and can be used as guidelines. You can also monitor the plants themselves for symptoms of deficiency.

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When using soil-less substrates, apart from compost, it becomes very important to fertilize seedlings. Most soil-less media contain few or no nutrients and, with a few exceptions, their CEC is very low. Seedlings need nutrients from the growth substrate after the nutrients provided in the cotyledons become depleted. This is usually within the first couple of weeks after emergence — from then on, plants grown in a soil-less substrate need to be fertilized regularly and frequently.

Fertilizer can be applied in various forms as either organic or inorganic fertilizer.

[1] For information contact the Laboratory Manager, ICRAF Plant and Soil Laboratories, PO Box 30677, Nairobi, Kenya. Tel +254 2521450, fax +254 2521001, email: icraf@cgiar.org.

Macronutrients		
name (symbol)	**function**	**deficiency symptoms (very general)**
nitrogen (N)	Important component of amino acids and proteins.	Old leaves turn yellow, plant growth retarded, small leaves. Be careful: too much nitrogen leads to overgrown plants which are highly susceptible to diseases.
phosphorus (P)	Provides energy (ATP). Helps in transport of assimilates during photosynthesis. Important functions in fruit ripening.	Small plants with erect growth habit; thin stems, slow growth. Leaves appear dirty grey-green, sometimes red.
potassium (K)	Important in maintaining cell turgor, phloem transport, cell growth and cell wall development (K deficiency leads to susceptibility to pests because cell walls are weakened).	Older leaves show first chlorotic, later necrotic borders. Younger leaves remain small.
calcium (Ca)	Stabilizes cell membranes and cell walls, interacts with plant hormones. Ca is extremely immobile and can only be taken up through young, unlignified roots.	Deficiency is often only visible in retarded growth.
magnesium (Mg)	Component of chlorophyll– photosynthesis is hindered when deficient. Binds ATP to enzymes. Important for protein synthesis.	Old leaves chlorotic from middle or between veins, rarely necrotic. Leaves orange-yellow, drop prematurely.
sulphur (S)	Component of etheric oils, vitamin B, vitamin H, amino acids, and has important functions in protein synthesis.	Similar to N-deficiency but symptoms show first on young leaves.

Micronutrients		
name (symbol)	**function**	**deficiency symptoms (very general)**
iron (Fe)	Component of chloroplasts. Part of the redox system in the electron transport during assimilation, and important for RNA synthesis.	Young leaves turn yellow to white.
manganese (Mn)	Important for enzyme activation, photolysis. When deficient, protein synthesis and carbohydrate formation are hindered.	Youngest leaves show chlorotic spots, later they grow into necrotic areas parallel to the veins.
copper (Cu)	Found in chloroplasts. Important for carbohydrate synthesis and protein synthesis.	Youngest leaves are chlorotic or necrotic, fruit set is insufficient.
zinc (Zn)	Has enzyme activating function, e.g. starch synthetase; is found in chloroplasts.	Small leaves and short internodes; thin shoots.
molybdenum (Mo)	Important component of enzymes, specifically nitrate reductase and nitrogenase. Essential element for all nitrogen-fixing plants.	Old leaves develop necrotic borders,often the symptoms are caused by secondary N-deficiency.
boron (B)	Found in cell walls, important for transport of assimilates and cell growth. If deficient, shoot tip dries.	Youngest leaves are deformed, thick, dark green to greyish. Root system development is hindered.
chlorine (Cl)	Important in maintaining cell tugor, increases sugar content in fruits.	Deficiency symptoms occur only in halophytes (salt-loving plants), mainly as loss in turgor.

Organic fertilizers

Compost from vegetative matter or animal manure has been discussed in the previous section as an organic component of potting substrates. Due to its generally high nutrient content it is also a valuable fertilizer and helps improve the physical and chemical properties of soil-based mixtures.

Organic fertilizers

animal manure	Manure differs in its nutrient composition depending on the animal source (see page 49) and the season. This source will only have consistency if it is collected from reputable commercial farms where animals are fed a controlled and constant diet. In all cases where animal manure is used, include it in a composting programme. Leave manure to rot for 6–10 weeks to reduce the risk of 'burning' plants due to high nitrogen concentrations. This is particularly important for chicken or other bird manure in which nitrogen levels are very high. You can test whether manure is ready by using the same method you can use for compost: put two handfuls of the moist material into a small plastic bag and leave it sealed for 24 hours in a dark place. If it heats up considerably and there is a strong smell of ammonia when you open the bag, it is not ready to use yet. Apart from nutrients, manure adds a high amount of organic matter to a potting substrate and improves its physical conditions. Analytical monitoring of the nutrient composition of manure is essential for uniform plant production. Weeds and insects can easily be introduced into the nursery with manure unless it is properly composted. Manure can also be suspended in water and used for irrigation. This practice utilizes mainly the nitrogen component in manure.
composted green matter	Like manure, compost properties vary with its components, the composting duration and the temperatures maintained during composting. If possible, do a chemical analysis of each batch before you use it. It takes considerable time and experience to produce compost of a uniform quality from batch to batch (see page 39).
animal waste	These include hoof and horn meal, bone meal, fish meal and chicken feathers. They are fertilizers which slowly release nutrients into the substrate. Hoof and horn meal and feathers are rich in nitrogen; bone and fish meals rich in phosphorus. These materials also have a positive influence on the porosity of the substrate.

Tentative soil fertility thresholds for pines and eucalypts (in ppm)				
element	pines		eucalypts	
	min	max	min	max
P	25	200	25	200
K	8		10	
Ca	20		40	
Mg	3		3.5	
Mn	5	200	5	200
Cu	1	20	1	20
Zn	1.5	30	1.5	30
B	0.3	5	0.5	5

Approximate nutrient contents of fresh manure of various farm animals			
	nitrogen (%)	phosphoric acid (%)	potassium (%)
cow	0.35	0.2	0.1–0.5
goat/sheep	0.5–0.8	0.2–0.6	0.3–0.7
pig	0.55	0.4–0.75	0.1–0.5
chicken	1.7	1.6	0.6–1
horse	0.3–0.6	0.3	0.5

Inorganic fertilizers

Granular inorganic fertilizers

Inorganic fertilizers are divided into single fertilizers, compound fertilizers and full fertilizers (see page 50). They can be applied by broadcasting or by mixing with the irrigation water ('fertigation'). Fertilizers are commonly known by the contents of the main nutrients N, P and K. The numbers on the bags show the content of these components. For example 20–10–20 fertilizer contains 20% N, 10% P, usually in the form of P_2O_5[2], and 20% K, usually in the form of K_2O[3]. Urea, a single fertilizer containing only nitrogen is labelled 46–0–0, indicating that it has 46% nitrogen, but neither phosphorus nor potassium. The remaining parts are made up of the non-N (P_2O_5, K_2O) parts of the molecules and inert carrier materials.

When soil-less growth media are used, fertilizing with full fertilizers which also include micronutrients is necessary. Especially under tropical conditions and with irrigation, plants can grow actively throughout the year. This means that they need nutrients continuously and fertilizer needs to be applied at frequent intervals (weekly or fortnightly). Fertilizer should not be applied during germination, because it leads to increased bacterial and fungal infections. As seedlings develop, fertilizer schedules have to be adjusted. Some people use a mixture of fast- and slow-release fertilizers so that seedlings are planted into the field with a fertilizer reservoir.

Types and examples of granular fertilizers	
single fertilizers	contain only one nutrient: urea (N) superphosphate (P) rock phosphate (P)
compound fertilizers	contain two nutrients: DAP (N,P) CAN (N,Ca)
full fertilizers	Contain all three main nutrients: NPK 20-20-20 (N,P,K) NPK 17-17-10 (N,P,K) Also available with some or all necessary micronutrients: NPK 12-12-17-2 (N,P,K + Mn) Bayfolan (N,P,K + micronutrients)

[2] to convert $\%P_2O_5$ to %P multiply with 0.44

[3] to convert $\%K_2O$ to %K multiply with 0.83

How to calculate the right fertilizer concentration
Usually, fertilizer requirements are given in ppm (parts per million), or mg/kg or L. If you use a 19–19–19 fertilizer, a 50–80 ppm solution is recommended for frequent use. Calculate the correct amount like this:

- In a 19% N (or P_2O_5, or K_2O) fertilizer, 100 g fertilizer contains 19 g or 19 000 mg N (or P_2O_5, or K_2O)
- a solution of 50 ppm is wanted (50 mg N in 1 L)
- 100g x 50 mg/ 19 000 mg = 0.263 g or 263 mg.

For each litre of fertilizer solution, dissolve 263 mg of granular 19–19–19 fertilizer.

Controlled-release fertilizers

Controlled-release fertilizers provide an attractive alternative to granular fertilizers. These are fertilizer 'cocktails' that slowly release nutrients to the substrate. The release depends on water availability or soil temperature. Controlled-release fertilizers are more expensive than the more common water soluble fertilizers, but they have several advantages:

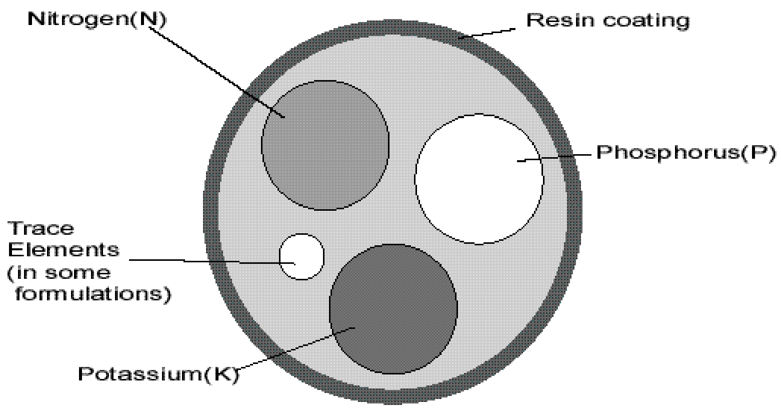
- the danger of over-fertilizing is reduced as the release of fertilizers occurs gradually
- fertilizing is necessary only occasionally, sometimes only once in a season
- a balanced fertilizer mixture is provided at all times as the plants get what they need at different growth stages
- nutrients do not leach from the substrate so the plants receive all the nutrients applied.

Experimenting with controlled-release fertilizers will help you determine the best application rates and times.

Controlled-release fertilizers provide an attractive alternative to granular fertilizers.

The principle of controlled-release fertilizers

In products using the Osmocote® technology, resins based on natural organic oils, such as soybean or linseed oil, are used to coat fertilizers. Different thicknesses of resin coating are applied to the base fertilizer to achieve different release periods. Water enters the granule and dissolves the nutrients and they pass through the coating at a rate controlled by the soil temperature. As temperatures fluctuate the rate of nutrient release changes, matching plant demand as growth rates rise and fall in correlation with these changes. The resin coating remains intact throughout the life of the product. When all nutrients are expended the coating dissolves. There are products for specific markets, such as ornamentals, vegetables and nursery production. They last from 3–4 months to 16–18 months depending on the soil temperature. Estimated lifetime is based on an average temperature of 21°C; release rates change by about 25% for every 5°C. In a tropical environment with an average soil temperature of 28°C, a product labelled four months would last roughly three months.



Examples of controlled-release fertilizers				
fertilizer	**analysis (N-P-K)**	**release mechanism**	**length of time it lasts at 21℃**	**N source**
Lesco	20-6-12	temperature	4–6 months	sulphur coated urea and amononium nitrate
MagAmp	7-40-6 + 12Mg	moisture	4–12 months	magnesium ammonium phosphate
Osmocote	18-6-12 14-14-14 13-13-13 19-6-12 17-7-12	temperature, coating thickness; no change with media moisture	8–9 months 3–4 months 8–9 months 3–4 months 12–14 months	ammonium nitrate and ammonium phosphate
Sulphur coated urea	36-0-0 + 17S	temperature, media moisture, coating thickness	up to 6 months, approx. 1% per day	sulphur coated urea
Ureaform	38-0-0	increases with temperature, maximum at pH 6.1 and 50% water saturation; bacterial action	60% in 6 months	urea-formaldehyde

Most of these products are available on the international market, sometimes under a different name. For example, "Season Long" 20-10-20 is a product of Phostrogen that acts using the osmocote technology.

Further reading

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