

8 Harvesting and drying

- Digging at the right time will maximise yield and quality.
- Leaf fall or yellowing are not reliable indicators of maturity:
  - use the 'shell out' or 'hull scrape' methods to determine digging time.
- Harvest peanuts as soon as maturity is reached:
  - turn the bushes upside down so the pods are off the soil and face the sun
  - do not leave bushes piled up as moulds will develop, deteriorating the crop quality and promoting aflatoxin production
  - strip the pods off the plants within 3–4 days after harvesting, and sun dry.

8.1 Harvesting

Harvesting peanuts is more complicated than harvesting most other crops. Peanuts produce their economic produce under the ground, and not all the pods mature at the same time (indeterminate maturity). To avoid yield and quality losses, correctly timed digging is essential. Research at the Department of Primary Industries and Fisheries (Kingaroy, Queensland) indicated that digging too early or too late significantly reduces the yield and quality of peanuts.

Pod losses can occur in soils that set hard when dry and in soils with high clay content. Vigorous pulling will break pods off underground; when harvesting in these soils, it is best to loosen the soil with a fork before pulling.

8.2 Assessing crop maturity

Assessing crop maturity needs to begin at least 2–3 weeks before you think the crop will be ready to dig. Take plant samples at 4–5 day intervals to determine the most appropriate time to start digging. Make sure that samples are representative of the crop. Ideally, samples should be made up of plants from different parts of the field (Box 4).

There are two recommended methods to assess maturity; shell out (Section 8.2.1) and hull scrape (Section 8.2.2).

Box 4 Preparation for maturity assessment

1. Pull at least six peanut plants from a wide cross-section of the field.
2. Remove all but very immature pods from the plants. Avoid selecting only mature-looking pods.
3. Mix pods from all plants in a bucket and take out a subsample of at least 50 pods.
4. Follow either the shell out or the hull scrape method to assess maturity.
5. The shell-out method is used in short and medium-duration varieties. The hull scrape method is used in long-duration runner type varieties that are not currently grown in Papua New Guinea.

Box 5 Shell-out method of maturity assessment

1. Crack open all the pods and look at the colour of the inner shell.
2. Count the number of shells with dark orange, brown or black colour on the inside of the shell.
3. Calculate the maturity percentage (%) using the following formula:

Maturity % = no. of dark orange, brown or black pods ÷ total no. of pods × 100

See Table 11 to interpret the results of the maturity assessment.

Box 6 Hull scrape method of maturity assessment

1. Hold the 'beak' of the pod downwards and lightly scrape away the outer skin, near where it joins the peg.
2. Count the number of shells with a dark orange, brown or black colour on the scraped area of the shell.
3. Calculate the maturity percentage (%) using the following formula:

Maturity % = no. of dark orange, brown or black pods ÷ total no. of pods × 100

See Table 12 to interpret the results of the maturity assessment.

8.2.1 Shell-out method

Crack open ('shell-out') all the pods and inspect the inside shell colour to determine the maturity of each pod (Table 11), then calculate the maturity percentage (Box 5). See Table 13 to interpret the results of the maturity assessment.

Photos 47 to 49 show different stages of pod maturity determined by the shell-out method. Note that pods shown above the line are mature, and pods under the line are immature.

Photo 48 50% pod maturity shown by the shell-out method (Photo: R. Rachaputi, DPI&F)

Photo 47 20% pod maturity shown by the shell-out method (Photo: R. Rachaputi, DPI&F)

Photo 49 100% pod maturity shown by the shell-out method (Photo: R. Rachaputi, DPI&F)

Table 11 Maturity stage indicators using the shell-out method

Inside shell colour	Maturity stage
Dark orange, brown or black	mature
Yellow–dark orange	intermediate
White–yellow	immature

Table 12 Maturity stage indicators using the hull scrape method

Scrape colour	Maturity stage
Dark orange, brown–black	Mature
Light orange, white or yellow	Immature

Table 13 A guide to harvest timing

Mature pods (%)	Harvesting advice
< 75	Leave the crop another 2 weeks
75–89	Crop is close to maturity, but may need another 4–5 days
> 90	Harvest now

8.2.2 Hull scrape method

This method of determining kernel maturity relies on colour changes under the outer skin of the shell (Box 6 and Table 12). The skin can be scraped using a knife or fingernail; larger operations may use water pressure to blast off the skin. Work reasonably quickly, because the outer skin colour fades. Do not use the hull scrape method if the crop is maturing under conditions of moisture stress. Refer to Table 13 to calculate harvest timing.

8.3 Drying

Turn the harvested plants upside down so the bush part of the plant is on the soil and the roots and nuts are upwards. Nuts will dry faster if you lean two or more plants together to keep the nuts away from the soil (Photo 50). If the plants are not inverted, then turning them after a couple of days will help them to dry. Pods should be pulled off the plants after 3–4 days and the loose pods left to dry in the sun (Photo 51). Leaving them any longer on the plant increases the risk of wet weather affecting the pods. Prolonged periods of wetting and drying in the field will encourage the dug plants to develop aflatoxins.

Drying of the loose pods may take 1–2 weeks. Test the peanuts by shaking a few to see if the kernel makes a rattling noise. Then, squeeze the shells of a few pods; if they crack open, they are dry.

Photo 50 Well-inverted peanuts (Photo: DPI&F)

Photo 51 Stripping pods (Photo: R. Rachaputi, DPI&F)



9 Managing aflatoxins in peanuts

- Aflatoxins can cause health problems.
- Harvest peanuts as soon as maturity is reached.
- Ensure peanuts are dry before storing in well-aired conditions.

9.1 What are aflatoxins?

Although peanuts provide valuable health benefits, poor quality kernels (immature, shrivelled, damaged, etc.) are prone to contamination with aflatoxins.

Aflatoxins are a group of toxic compounds produced in peanut kernels by the soil fungi *Aspergillus flavus* and *Aspergillus parasiticus.* These fungi can also infect maize, rice, cassava and nuts. Alfatoxins can cause cancer and other health problems if they are consumed for long periods.

9.2 Health risks of aflatoxins

9.2.1 Human health

Prolonged consumption of peanut kernels contaminated with high levels of aflatoxin can cause illness and may be fatal. Exposure to small doses of aflatoxin over a long period is linked to liver and other cancers in humans. It also lowers the body's resistance to other infections and aggravates the effects of other illnesses and nutritional disorders. Aflatoxin can retard growth of children and cause genetic defects in the fetus if consumed by pregnant women.

9.2.2 Livestock health

Illness due to eating aflatoxin (through peanut cake) is common in livestock. Susceptibility depends on species, age, health, environmental factors, and exposure level and duration.

Poultry are particularly susceptible to aflatoxin, and consumption of even small amounts can impair growth, reduce productivity, decrease egg production, increase susceptibility to disease and result in inferior egg and carcase quality.

Ruminants such as sheep and cattle can tolerate higher levels of aflatoxin compared to humans, but chronic exposure to aflatoxin toxicity can cause reduced weight gain, poor use of feed, decreased fertility, abortion and reduced birthweights. Pigs and goats are also susceptible to aflatoxin.

9.3 Aflatoxins in peanuts

Peanut plants do not show any symptoms following infection of pods and kernels by the aflatoxin-producing fungi. Aflatoxins can be produced during crop production, harvest or storage. Aflatoxins are produced in fungus-infected kernels as the crop nears maturity in hot, dry conditions. If the crop is growing under moist conditions, there is a much lower risk of aflatoxin production.

Mechanical or insect damage to pods or growth cracks in pods provide fungi with easy access to kernels, increasing the risk of infection (Photo 52). Aflatoxin production is fastest when the temperature is between 25°C and 35°C and the moisture content of kernels is between 15% and 30%. Once produced, aflatoxin remains in the kernel.

The level of aflatoxin can increase rapidly if the harvested crop is left for too long in the field to dry. If pods are allowed to become wet, *Aspergillus* fungi can grow on their surface (Photo 53). Storing peanuts that are not properly dried is also dangerous, because the aflatoxin level can increase rapidly. Ensure that pods are dried to < 10% moisture (i.e. shake them to see if the kernels rattle) before bagging and storing.

9.4 Reducing the risk of aflatoxin contamination

Detailed strategies to manage aflatoxin risk are contained in the aflatoxin management brochure, 'Contaminated peanuts: a potential threat for the human immune system and nutritional health' (Ramakrishna et al. 2005). See also the 'Further reading' section.

9.4.1 Minimising preharvest aflatoxin risk

Plant crops when late season and preharvest crop stress from high temperatures and low rainfall is least likely to occur.

Where possible, plants should be irrigated every 7–10 days during the last 4 weeks to avoid water deficits.

If the crop is severely stressed, with no rain forecast, then consider harvesting 1–2 weeks early. Leaving peanuts in the ground in hot, dry conditions can severely increase the incidence of aflatoxin contamination.

Turn the harvested plants upside down so the bush part of the plant is on the soil and the roots and nuts face the sun. Nuts will dry faster if you lean two or more plants together to keep the nuts away from the soil. If the plants are not inverted, then turning them after a couple of days will help them to dry.

9.4.2 Minimising postharvest aflatoxin risk

Thresh (remove) pods from plants as soon as possible after digging. Dry the pods by placing them in the sun on mats, plastic or canvas sheeting for at least 3 days. Turn them at least once a day to help rapid and uniform

Photo 52 Severe aflatoxin infection as a result of insect damage (Photo: R. Rachaputi, DPI&F)

Photo 53 *Aspergillus* fungi growing on re-wetted pods; note that the development of infection is not usually this obvious (Photo: R. Rachaputi, DPI&F)

drying. When properly dried, the shells should be brittle and the kernel will be hard, crisp or crunchy.

Do not place damp peanuts in bags; they may become infected with fungus and aflatoxin contamination levels will increase. Damp peanuts may become unsaleable.

Before storing, marketing or consuming, thoroughly clean out poor quality (mouldy, broken, insect damaged or shriveled) pods and kernels, as they have a high risk of aflatoxin contamination.

Only clean, dry peanuts should be bagged and stored. If peanuts become damp or get wet, remove them from the storage bag as soon as possible and dry them thoroughly.

Do not re-wet the peanuts before or during sale as this can result in rapid increase in mould growth and aflatoxin levels. Wetting and drying will also reduce the taste and eating quality.

10 Marketing of peanuts

- 90% of Papua New Guinea peanuts are sold fresh in local markets.
- Prices vary significantly depending on the available supply.
- Food safety regulations must be strictly adhered to when marketing peanuts in bigger markets.
- Peanuts have the potential for further development into a profitable and viable industry.

10.1 Current markets

The production, use and marketing of peanuts in Papua New Guinea (PNG) dates from early contact with Europeans and missionaries. During the colonial administration, farmers enjoyed direct export market prices.

Although broadacre peanut cropping has declined due to collapsing export and processing industries, peanuts still remain an important cash crop among settlers, peri-urban gardeners and remote villagers. Peanuts generate a major portion of family income in the highlands, although coffee is the major cash crop.

A survey of four major peanut growing provinces estimated that peanuts are grown on approximately 14,000 hectares annually (Wemin and Geob 2004). The annual production estimate of 12,600 tonnes earned a gross income of K29,359,000. Nearly all the peanuts produced in PNG are consumed domestically as food, and they represent a significant component of both the rural and urban PNG diet.

Peanut farmers sell their produce in urban, town and local roadside markets in various forms, to suit consumer preference. These include:

- fresh on bunch
- fresh and loose
- boiled on bunch
- boiled and loose
- roasted on bunch
- roasted and loose
- dried
- fried and salted.

Most products are sold loose; packaging is not a common practice in rural markets. More than 90% of farmers sell peanuts fresh on bunch, followed by fresh and loose, immediately after harvest. Women and girls do most of the retail and roadside market selling. Some household-produced peanut butter is also sold in roadside markets; but local peanut products, including peanut butter, are yet to find a place in semi-urban or urban markets.

The wholesale price of bagged peanuts sold in urban markets changes with demand and supply. During the seasonal peak period, when the market becomes flooded with peanuts, farmers sell at K25–40 per 30-kg bag. During the low supply, high demand off-season, the same bag fetches K70–100. A Fresh Produce Development Agency snapshot survey revealed that the price of dried nuts in major urban markets across the country ranged from K1.70–14.00 per kg, depending on the location.

Significant volumes of peanut products, such as blanched or roasted nuts, peanut butter and oil are imported for sale in supermarkets for urban consumption. This suggests that domestic production and processing could be expanded to displace imports, as long as food safety standards are met.

10.2 Future markets

Peanuts grow well in many regions of PNG, and have potential to be developed into a more profitable and viable industry for the country. For example, peanuts have potential for significant value-adding as foods, such as nut-in-shell, kernel and processed snack food, and can cater to the needs of various consumer markets. Increasing demand for vegetable oil in high-growth countries such as China and India mean that peanut oil prices will remain high for some time.

The PNG population is presently growing at a mean annual rate of 2.3% (Keig 1999). More than 75% of the total population—about 4 million people—are smallholder semi-subsistence farmers sustained by their own food production systems, and supported by some cash crops (Allen et al. 1995).

The domestic demand for peanuts and processed products is high in rural and urban markets. It is highly likely that peanut production and demand will increase as the population grows and agriculture is intensified. However, developing a viable peanut industry that will meet domestic requirements, as well as export capacity, must consider the following throughout the peanut supply chain:

- consistent, reliable supply of good quality peanuts
- adequate storage capacity
- ability to control aflatoxin contamination during production, storage and processing
- high standard of hygiene practices in peanut processing facilities
- appropriate packaging materials and pack sizes
- market intelligence and management.

Better production practices, marketing strategies and transport infrastructure will boost peanut production, help maintain quality, and increase crop utilisation and incomes of many peanut producers in rural PNG.



Glossary

Aflatoxin	Chemical produced by fungal species in the genus *Aspergillus* that can be dangerous to humans and animals.
Agricultural lime	Crushed limestone that has been prepared for use in agricultural industries. Not to be confused with lime that is used with chewing betelnut.
Blanching	Removing the skin (seed coat) from a peanut kernel.
Chlorotic	Fading of leaf colour from green to yellow or white.
Cotyledons	First leaves produced by a plant embryo. They have a simpler structure than later leaves.
Defoliate	Remove leaves prematurely.
Determinate	Growth of a plant stem, branch or shoot that stops when flowers are produced.
Dolomite	Calcium magnesium carbonate.
Embryo	Young plant contained in the seed.
Fertiliser—basal	Fertiliser applied at planting, in the row or around the base of plants.
Fertiliser—foliar	Liquid fertiliser applied to plant leaves.
Fungicide	Chemical used to control fungal diseases.
Furrow	Long groove or trench in the soil.
Gypsum	Source of calcium that is more soluble than lime. It can also be used to correct sulfur deficiency; it does not affect soil pH, so it can be used to provide calcium to alkaline soils.
Herbicide	Chemical used to control weeds.
Indeterminate	Growth of a plant stem, branch or shoot that is not stopped when flowers are produced (i.e. branch, stem or shoot continues to grow and produce flowers).
Inoculum (peanut)	*Rhizobium* bacteria (generally in a peat mix dressing) applied to the seed or soil to encourage nitrogen fixation in the developing plant.

Inorganic	Of mineral origin.
Insecticide	Chemical used to control insect pests.
Kernel	Plant seed containing the embryo and stored food reserves.
Larva	Immature stage of insects (grub or caterpillar).
Leaflet	A blade of a compound leaf.
Legume	Plant belonging to the family Leguminosae (Fabaceae).
Loam	Soil containing a mixture of sand, silt and clay particles that give it a good texture.
Micronutrients	Nutrients necessary for plant health and required in relatively small quantities.
Mono-cropping	Growing the same crop repeatedly.
Mycelium	Vegetative part of a fungus.
Node	Point on a stem that leaves or buds grow from.
Nodulation	Formation of nodules on plant roots after infection with *Rhizobium* bacteria.
Nodule	Small rounded lump growing on plant roots containing *Rhizobium* bacteria.
Organic	Containing carbon and produced by living things.
Ovary	Reproductive part of the plant from which the peg grows in peanut plants.
Pathogen	Disease-causing agent.
Peg	Develops from the fertilised ovary of a flower from the peanut plant. The peg enters the soil after pollination.
pH	Measure of acidity or alkalinity: pH 7 is neutral, < 7 is acid, > 7 is alkaline.
Pod	The tip of the peg after it has enlarged underground. The pod contains developing peanut kernels.
Pollination	Transfer of pollen from an anther to the stigma to fertilise the flower.
Premature	Occurring before the normal or expected time.
Sclerote	Hard, often rounded, resting body of a fungus
Seed dormancy	A period when seed will not germinate, even in favourable growth conditions. After this period, seed will grow normally.
Self-pollinated	Transfer of pollen from the anther to the stigma of the same flower. Differs from open pollination, in which pollen is transferred from the anther of one flower to the stigma of a different flower.
Spore	Reproductive unit of a fungus.

Taproot	Main central root of the peanut plant that grows downwards.
Terminal leaflet	Leaflet at the top of the plant.
Testa	Seed coat or skin.
Thresh	Separate pods from plants.
Toxin	Poison produced by a living organism.
Vector	Insect or other organism that transmits disease agents.
Volunteer peanuts	Plants that have grown from seed or pods that were left in the ground at harvest.
<	less than
>	greater than

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Appendix 1 Safe handling of chemicals

The following precautions should be taken when handling chemicals:

- Read the label before use, and follow safety directions on the label.
- Use appropriate personal protective equipment (PPE) as specified on the label.
- Avoid spraying during high winds or before storm rain.
- Make sure any spray drift moves away from you.
- Change clothes and wash with soap after using chemicals.
- If you get chemicals on your skin, wash immediately using soap and water.
- Do not eat, drink or smoke while using chemicals.
- Do not store chemicals in old food or drink containers.
- Store chemicals in a secure place out of reach of children.

Chemicals enter the body by:

- breathing in vapours and dust (nose, mouth and lungs)
- absorbing chemical drift or splash (skin or eyes)
- swallowing (mouth and stomach).

These areas of the body should be protected when using farm chemicals.

The highest risk of contamination occurs when measuring out the concentrate from the chemical container close to your body. The minimum PPE to use when mixing chemicals, spraying toxic insecticides or mixing peanut seed dressing onto peanut seed is:

- *hat* that can be washed
- *goggles or face shield* to protect eyes
- *respirator* to prevent breathing in fumes and dust or accidental splash into mouth
- *overalls* that are non-absorbent, have long sleeves and are worn outside boots
- *gloves* that are chemical-proof; leather or fabric gloves are not suitable
- *rubber boots*; leather boots are not suitable.

For spraying lower toxicity herbicides such as Roundup in the field, the minimum PPE is:

- *hat* that can be washed
- *disposable respirator*
- *overalls*
- *rubber boots*.

Remember: always wear rubber gloves when mixing or planting treated peanut seed.

Knapsack cleaning: After use, rinse the knapsack with clean water and pump the handle several times, spraying out enough times to clean the line to the nozzle. Do not wash the knapsack in creeks or rivers.

Dispose of empty chemical containers by punching holes in them (to prevent their use as water containers), and burying them away from people and animals.

At the end of spraying, clothes should be washed thoroughly using generous amounts of laundry detergent. Wash boots and gloves.

Appendix 2 Calibrating a knapsack sprayer

- It is essential to use the correct quantity of pesticide and spray volume per unit area.
- Ensure that the knapsack is in good working order, with a good nozzle and basket strainer.
- The operator must be fully trained and wearing full personal protection equipment (PPE).
- Double check calibration calculations to ensure they are correct.

The steps in calibrating a knapsack sprayer are as follows.

1. Determine the target acceptable spray volume range (normally 150–300 L/ha).
2. Determine the desired walking speed of the operator (normally 1 m/sec or 60 m/min. Operators can walk faster, but as their task progresses, they tire and walk slower. It is better to start off at a reasonable walking speed and maintain that speed throughout the day).
3. Select a suitable nozzle for the application: for herbicide applications, this will normally be Lurmark Polijet AN 1.2 Green or AN 1.8 Blue (1.0 m or 1.5 m swath width at 50 cm nozzle height above the ground, respectively). Hollow-cone nozzles are used for insecticide and fungicide applications.
4. Set the pump pressure: for herbicides, this will normally be high (H) when fitted with a spray management valve (SMV), and low (L) when a SMV is not fitted. Pressure will generally be set on H for most insecticide and fungicide applications.
5. Fill the knapsack with clean water, and carry it as normal on your back.
6. Hold the lance as normal, with the nozzle 30–50 cm above ground level. Spray water on the ground and note the true spray width at the plant canopy height.
7. Pump with slow, regular deliberate strokes at about 1 stroke per second and spray into a bucket for a fixed interval (about 1 minute). The pressure relief valve in the tank will indicate if pumping is sufficient. The aim is to occasionally hear the valve releasing extra pressure. If the valve is constantly releasing pressure, reduce the pumping rate; if the pump never releases pressure, increase the pumping rate.

8. Measure the quantity of liquid delivered into the bucket using a measuring cylinder (not an old pesticide container!).
9. Repeat Steps 5–8 three times, and ensure that the volume sprayed is within a 10% range. If it is not, repeat once again and discard the extreme values.
10. Calculate the nozzle flow rate and spray volume per hectare (ha) using equations (1) and (2) below.

(1) Nozzle flow rate (L/min) =

$$\frac{\text{Mean volume sprayed into bucket (mL)}}{\text{Spraying time (min)} \times 1000}$$

Example:

After spraying for 1 minute, 2,200 mL of water was measured in the bucket.

$$\text{Nozzle flow rate (L/min)} = \frac{2{,}200 \text{ mL}}{1 \text{ min} \times 1000}$$

Nozzle flow rate (L/min) = 2.2 L/min

(2) Spray volume per hectare =

$$\frac{\text{Flow rate (L/min)} \times 10{,}000}{\text{Spray width (m)} \times \text{walking speed}}$$

Example:

Flow rate was calculated from equation (1) above to be 2.2 L/min. Spray width was measured at 1.8 m and walking speed was measured at 60 m/min.

Spray volume per hectare =

$$\frac{2.2 \text{ L/min} \times 10{,}000}{1.8 \text{ m} \times 60 \text{m/min}}$$

Spray volume per hectare = 204 L/ha

11. Ensure that the calculated spray volume per hectare is within the range set in Step 1. If it is not, then either change the nozzle or adjust the walking speed, and repeat Steps 2–10. For example, using the above example, changing the nozzle from a Green Polijet to a Blue Polijet will increase the flow rate. It is preferable not to change the walking speed, unless it is going to be a permanent change, because it is very difficult to control and a lot of training is required to achieve a constant walking speed.
12. To calculate the amount of chemical that is required (either in litres or kilograms) per knapsack or spray tank, use equation (3) below. Obtain the amount of chemical to be applied per hectare from the current chemical label. Do not use old labels, books or your memory, as the formulation may be different.

(3) Chemical to add (L or kg) =

$$\frac{\text{Spray tank capacity (L)} \times \text{product label rate/ha}}{\text{Spray volume (L/ha)}}$$

Example: The spray tank to be used is a 15 L knapsack. The chemical label states an application rate of 1.5 L/ha is required. The spray volume per hectare was calculated using equation (2) as 204 L/ha.

$$\text{Chemical to add (L or kg)} = \frac{15 \text{ L} \times 1.5 \text{ L/ha}}{204 \text{ L/ha}}$$

Chemical to add (L or kg) = 0.110 L or kg/ha (note: this, is equal to 110 mL/ha)

Appendix 3 Nutrients and symptoms of nutrient deficiency

Information on the role of the major soil nutrients in plant development and the signs of nutrient deficiency is given below, compiled from Crosthwaite (1994) and Smith et al. (1993).

Boron (B)

Boron is essential for sugar transportation and is required for production of pollen, seeds and cell walls. In peanuts, most boron (and calcium) is taken up by the pod directly from the soil, rather than being supplied from the plant. Pod boron deficiencies can therefore occur without any visible leaf or stem symptoms.

Deficiency symptoms: Kernel develops a 'hollow heart' and the embryo may darken. The shells may also be deformed, and shells may crack at random. These symptoms often show up long before plant symptoms.

Plant symptoms include stubby, rosetted branches (similar to calcium deficiency). Branches may crack and nodes may discolour. Leaves may develop yellow–green mosaic patterns.

Calcium (Ca)

Calcium stiffens plant cell walls and is important in cell wall elongation and cell division. It controls the flow of liquids through cell membranes and is a major determinant of kernel development and quality.

Deficiency symptoms: Severe lack of calcium in the podding zone will cause 'pops' (pods of full size but lacking kernels, i.e. empty shells). Mild deficiency will cause the kernel to darken and reduce its germination and vigour.

Plants are stunted, young leaves wilt and apical buds die. Brown spots appear on the leaves and eventually give the leaf a bronze colour. Roots are short, stubby and discoloured.

Copper (Cu)

Copper is vital in the formation of enzymes and is necessary for photosynthesis. Copper deficiency is not common, and usually occurs only on sandy soils.

Deficiency symptoms: Leaves show interveinal chlorosis (yellowing), and leaf tips and margins die. The leaf tip may distort as this occurs. Leaves wither and drop off. The plant is severely stunted.

Iron (Fe)

Iron is involved in nitrogen fixation processes and the formation of chlorophyll; it also carries oxygen around the plant. Iron deficiency usually only occurs on alkaline soils (> pH 7). Waterlogging or excess lime application on some soils can also cause iron deficiency.

Deficiency symptoms: Plants are usually stunted and pale. Leaves show interveinal chlorosis (yellowing) and eventually turn very pale yellow to almost white.

Magnesium (Mg)

Magnesium is a component of chlorophyll and is necessary for photosynthesis and the production of amino acids. Peanuts tend to be less susceptible to magnesium deficiency than many other crops.

Deficiency symptoms: Yellowing of leaves, beginning at the margins and moving to the midribs; followed by an orange discolouration, then death of the older leaves. The underside of older leaves often has a brown discolouration. Young leaves look normal.

Molybdenum (Mo)

Molybdenum is essential for protein production and nitrogen fixation. Molybdenum deficiency is most likely on moderately acid soils (< pH 5.5).

Deficiency symptoms: Because nitrogen fixation does not occur in plants with molybdenum deficiency, the plant will show the symptoms of nitrogen deficiency.

Note: Similar symptoms will occur if nodulation has failed, or the rhizobia have died due to waterlogging.

Nitrogen (N)

Nitrogen is in most components of plant cells; it is essential for production of plant proteins.

Deficiency symptoms: In young plants, leaves appear a uniform lighter green to yellow. In older plants, older leaves are affected more than younger leaves. The stems have a reddish discolouration.

Phosphorus (P)

Phosphorus is used in the development of plant membranes, and in genetic material used in energy transfer. Phosphorus is also required for photosynthesis.

Deficiency symptoms: Light flecking of the leaf, which becomes more yellow until parts of it die. Severely deficient plants are stunted and have small leaflets that are often blue–green. Later, these leaves develop pale spots between the veins, turn yellow and drop off. Stems may develop a purple colour.

Potassium (K)

Potassium helps control cell water levels. It is essential for the process of opening and closing stomata (pores that take up carbon dioxide from the atmosphere and release

oxygen). Potassium is also essential for transporting photosynthetic materials around the plant.

Deficiency symptoms: Leaf tip and margin yellowing, followed by early leaf drop. Symptoms occur first on the older leaves. Stems may have some dead spots and are shorter and thinner.

Sulfur (S)

Sulfur is necessary for the formation of new cells and chlorophyll, and for protein production.

Deficiency symptoms: Symptoms tend to be hard to diagnose. Young leaves show a pale yellowing, while old leaves remain a darker green colour (similar to other disorders).

Zinc (Zn)

Zinc is involved in protein and hormone production, and may also have a role in starch production. Peanuts are able to tolerate lower levels of zinc than many other crops. Zinc deficiency is unlikely to occur in acid soils (< pH 7.0).

Deficiency symptoms: Leaves show interveinal yellowing, often associated with a browning of the leaf midrib.

Appendix 4 Taking a soil sample for analysis

Soil analysis provides knowledge of the nutrient and chemical properties of a soil, and identifies any issues that may need correction to improve crop growth.

In both natural and cropping situations, soils vary considerably in chemical and physical composition. This variation may occur over short distances and in soils that appear uniform to the eye. Therefore, to gain an overall picture of the soil's properties, it is important to minimise the effects of variation when taking soil samples.

In cropping situations, topsoil samples are the most common. Unless otherwise requested, topsoil samples must include soil taken from a depth of 0 cm (soil surface) to 10 cm to ensure a correct analysis. If a sample is taken too shallow (i.e. not taken to 10 cm), the analysis results will show higher nutrient levels; if the sample taken is too deep (i.e. greater than 10 cm), the analysis will show lower nutrient levels. If the topsoil is less than 10 cm deep, then only sample to the bottom of the topsoil and note this when sending the sample for analysis.

Cleanliness is important when taking soil samples. Because only a very small portion of the soil in the paddock is used for the sample, great care must be taken not to contaminate it. Common sources of contamination are soil from other areas on tools or in bags, fertiliser or chemicals in buckets or sample bags, cigarette ash, and oxidation from zinc-coated iron or aluminium sheets.

Selecting areas for sampling

- Different types of soils, or soils that have different cropping or fertiliser histories, need to be sampled separately. Areas that show obvious differences also need to be sampled separately.
- The areas to be sampled need to represent the overall soil as much as possible. Avoid areas that are obviously poorer or healthier, have issues such as waterlogging, or have had different fertiliser practices.
- Do not sample from areas that have had fertiliser or lime added within the previous 3 weeks.
- Although there are many methods for deciding which particular site in the field to take each sample from, the overall principle is to select enough areas and samples to provide a good representation of the soil. Generally, the more sample sites, the more representative the sample will be. Some services recommend taking

samples along a diagonal or V-shaped transect, while others prefer a grid or zigzag sampling pattern. Some texts recommend 30–40 sites be sampled, while others are satisfied with 15–25 sites. In small gardens, 10 sample sites are probably satisfactory.

- Mapping the field and sample sites is recommended. These sites can then be used for future reference when trends over time are being observed, or can be found again if there is a problem with the sample.

Taking the soil sample

- Only use clean equipment to take and store soil samples.
- At each sample site, clear the soil surface of organic matter without removing any soil.
- Take the sample using a tube sampler or spade, taking care to remove the correct depth of soil. If clay or a major change in subsoil occurs at less than 10 cm, take the sample from the surface to the change and state the depth this occurred at when sending the final sample for analysis.
- Combine samples in a clean container or bag. Do not use old fertiliser or lime bags.

Sending the sample for analysis

- When all samples have been taken, break up any lumps in the container or bag and thoroughly mix the soil.
- Take small portions (up to 20) from the mixture in the container or bag to obtain a final sample of 0.5–1.0 kg.
- Place the final sample in a clear container or bag (not an envelope or glass jar; the jar may break).
- Label the samples clearly with:
  - your name and address
  - locality, area, field or a form of identification to locate the field again
  - depth of sample taken (usually 0–10 cm)
  - crop to be grown and advice required.

  Other information that may be beneficial to include with the sample:
  - crop history (e.g. previous crop or fallow, virgin soil from forest or grassland)
  - known fertiliser history
  - any previous abnormalities or issues in crop growth.
- Send samples to the laboratory as soon as practical.

Complete soil test analyses can be obtained through:

NARI Chemistry Laboratory, Pari Road, PO Box 8277, Kila Kila, Boroko NCD
Phone 321 0218

Limited soil test analysis can be obtained through:

National Analysis Laboratory, Unitech, PO Box 79, Unitech Road, Lae
Phone 473 4571

OR

NARI Aiyura, PO Box 384, Kainantu EHP
Phone 737 3561

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