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Growing peanuts in Papua New Guinea:

a best management practice manual

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Foreword

The last peanut production manual for Papua New Guinea (PNG) was published in 1977 by the Department of Primary Industry, Port Moresby. The PNG peanut industry has declined significantly since the 1970s, for various reasons. However, peanuts have recently started to regain their popularity and are now seen as an important cash crop for many smallholder farmers. The area planted to peanuts is expanding at a smallholder level, and substantial areas of commercial production are also being planted. This should lead to the return of the peanut industry over the next 5 years.

Publication of this best management production manual is thus timely, and will help the wide spectrum of industry stakeholders interested in growing and marketing peanuts in PNG. The content of the manual comes largely from research funded by the Australian Centre for International Agricultural Research (ACIAR) and is aimed at developing varietal and management practices to improve peanut production and quality (ACIAR projects ASEM/2001/055 and SMCN/2004/041). Expert advice from various sources in Australia (BGA AgriServices, Peanut Company of Australia, Queensland Department of Primary Industries and Fisheries) and PNG (National Agricultural Research Institute, Ramu Agri-Industries Limited and Trukai Industries Limited) has been sought in the preparation of the manual.

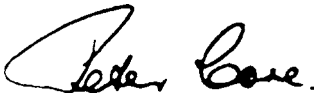
Early studies from research plots indicate that new varieties, grown using improved production practices, have a two to threefold increase in yield over local varieties. To improve peanut productivity in PNG, these results must be transferred to smallholder growers.

This publication is designed to assist agricultural researchers, extension people, smallholder producers, agricultural consultants and commercial producers by providing information on best management practices that will improve peanut productivity and quality.

The manual contains valuable scientific information about crop management topics such as land preparation, varietal selection, seed management, crop protection, postharvest management and marketing. It also contains photographs and figures to assist identification of serious peanut pests and diseases, and explains their control measures, including safety aspects, in a way that is easily understood and adopted by the end user. Key points are summarised in boxes at the beginning of each section for quick reference.

The manual also covers crop modelling, which appears to be a promising and valuable tool to provide advice on what variety to grow, as well as where and when. As peanut production in PNG expands into a range of agroecological zones with varying climatic constraints, crop modelling will indicate the probability of yield and preharvest aflatoxin risk.

This publication will facilitate the re-emergence of the peanut industry with private sector involvement, and provide valuable information on cost-effective and sustainable production of peanuts for smallholders and commercial growers.



Peter Core
Chief Executive Officer
ACIAR

Contents

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Abbreviations and acronyms

ACIAR	Australian Centre for International Agricultural Research
DPI&F	Department of Primary Industries and Fisheries, Queensland
NARI	National Agricultural Research Institute, Papua New Guinea
PMMV	peanut mild mottle virus
PNG	Papua New Guinea
PPE	personal protective equipment

1 Peanuts in Papua New Guinea

- Peanuts are a good income earner and an excellent protein source.
- Growing peanuts improves soil health.
- Residues left after harvest make good animal feed.

1.1 Introduction

Peanuts (*Arachis hypogaea*) are a hardy and well-adapted crop for Papua New Guinea (PNG). They are grown in a wide range of local farming systems, including seasonally drier areas and wet coastal regions (Figure 1). In PNG, peanuts are generally grown from sea level up to 1,850 m above sea level. Occasionally, in a few suitable areas, they are grown up to 1,950 m above sea level.

Peanuts originated in South America. Their history in PNG dates back to the early 1870s. During the late 1950s, exports of PNG-grown peanuts exceeded that of coffee. In 1959, 1,897 tonnes of peanuts were exported; in 1963, 2,212 tonnes were exported. A 1996 survey revealed that PNG production was approximately 21,000 tonnes per year. A 2003 survey of four well-known peanut production areas (Eastern Highlands Province, Markam Valley in Morobe Province, National Capital District and East New Britain Province) produced an estimated 12,600 tonnes of peanuts, which earned a gross income of K29,359,000 (Wemin et al. 2006).

Today, peanuts are an important cash crop among smallholders, peri-urban gardeners and remote villagers. Peanuts are one of the top five popular income-generating crops; after coffee, they provide the major portion of family income in the highlands. Peanuts are particularly important to women, who devote much time and effort to their production and marketing (Photo 1). Farmers in remote villages appreciate peanuts as a crop that is easy to transport to markets, compared with other bulky and perishable crops such as sweet potato, Irish potato, banana, yam and taro. Larger agricultural enterprises see peanuts as an important rotational crop that has the potential to provide a cash return.

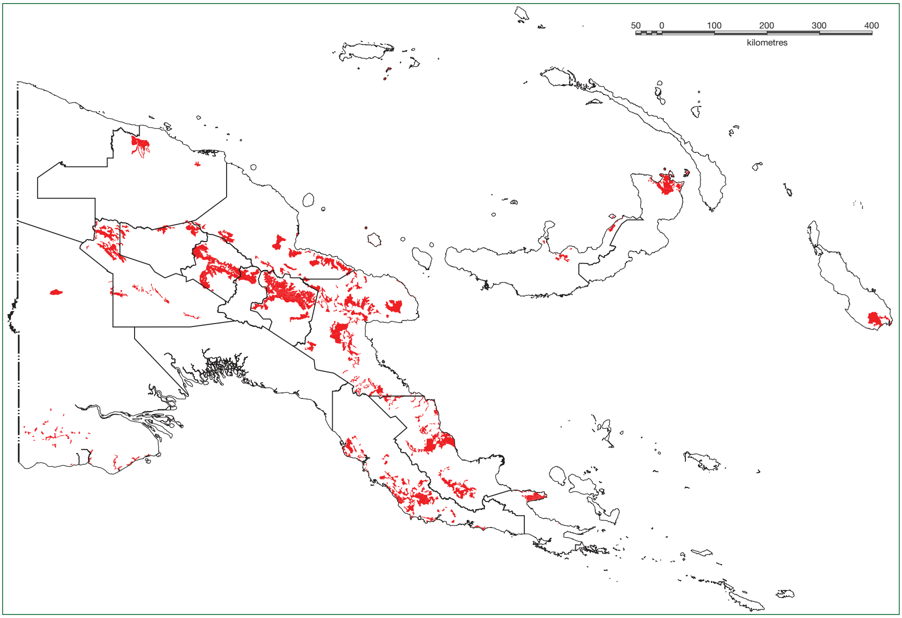

Figure 1 Distribution of peanuts in Papua New Guinea
(Source: Bourke and Harwood 2007)

From the 1960s to the mid 1980s, substantial efforts were made to establish a commercial peanut industry in the Markham Valley. The larger scale production, handling and marketing options resulted in larger field sizes, and the crop gained greater value as a source of income. The Markham area continues to reflect the ongoing importance of peanuts as a cash income source rather than a subsistence crop. The value of the peanut crop and the larger scale of operations mean that this area also has the most mechanised land preparation.

Nearly all peanuts produced in PNG are consumed domestically as food, and they represent an important part of the diet. However, yields can be erratic, and some are low (0.6 tonnes per hectare in the Eastern Highlands compared with 1.5 tonnes per hectare in the Western Highlands).

1.2 Why grow peanuts?

Peanuts are a recognised income-earning crop. In many areas, they are a major source of cash income for women. In coffee production areas, peanuts have been ranked the second highest income earner after coffee.

Photo 1 Earning cash income at a local market (Photo: D. Homare, NARI)

Photo 2 Peanuts are a healthy food source (Photo: L. Kuniata, Ramu Agri-Industries Ltd)

In a 2004 peanut production survey (Wemin and Geob 2004), every farmer indicated that they believed peanuts are a crop here to stay, and that there is much potential for further crop processing.

Peanuts are one of the most nutritious crops available and complement cereal and tuber food staples, which on their own lack the essential proteins necessary for a balanced diet (Photo 2). Peanuts can be used as a raw food, or preferably be cooked. As they contain 25–30% protein (on a dry weight basis) and 45% oil, peanuts provide an inexpensive, high-protein and high-energy food for humans and livestock. They can be made into products such as peanut butter (Photos 3, 4) or peanut oil, and are also a widely used ingredient in sweet biscuits, confectionery and ice-cream products.

Because peanuts are a legume crop, they are able to convert nitrogen from the air into a form that is available to the plants. Nodules on peanut roots contain soil bacteria called rhizobia that 'fix' nitrogen from the air. So growing peanuts helps to make soil more

Photo 3 Making peanut butter at a field day (Photo: A. Ramakrishna, NARI)

Photo 4 Savouring the taste of locally made peanut butter (Photo: A. Ramakrishna, NARI)

fertile, because some of the nitrogen they have fixed remains in the soil for the next crop. Returning peanut stems and other residue to the soil also helps improve soil fertility.

All parts of the peanut plant can be used for feeding cattle, pigs and poultry. After the pods are removed, peanut plants are high-quality feed (more than 10% protein) if most of the leaves are retained. The protein content will fall if leaf drop occurs as a result of diseases such as leaf spot or rust. After extracting peanut oil, the remaining meal can be sold as a livestock feed. Empty peanut shells can also be used in cattle ration feed, as fuel, or for floorcovering litter in pig and poultry houses. Although peanuts are a good food source, animals or poultry must not be fed poor-quality peanuts; they may contain aflatoxins (Section 9), which can reduce animal growth and performance and, in extreme cases, can kill poultry.

2 Growth of the peanut plant

- Peanut seeds germinate in 5–7 days and emerge 6–14 days after planting.
- Peanuts are indeterminate in vegetative growth and reproduction.
- Flowering usually starts 3–5 weeks after emergence and continues for 4 weeks.
- Peanuts produce their pods underground.
- Pod maturation takes about 60 days from fertilisation.
- A summary of growth stages is given in Table 1.

2.1 Temperature

Peanut growth and development is controlled by temperature. The ideal growth temperature is 30°C; once night temperatures drop below 17°C, growth slows. Dry matter production drops by 25% when the night temperature reaches 15°C, and drops by 50% at 10°C. Temperatures above 35°C also slow growth.

2.2 Germination and emergence

A peanut seed is made up of an outer testa (skin), two cotyledons (seed leaves) and an embryo. The embryo is not totally protected by the cotyledons and can easily be damaged; therefore, care must be taken during harvesting, storage, shelling and planting.

Peanut seed germinates best between 20°C and 35°C. The crop germinates between 5 and 7 days after planting; a 10–15-cm-long taproot grows into the soil, and the cotyledons start emerging from the seed. Peanut seedlings can push through quite crusted soils. The cotyledons emerge ('crack') from the soil 6–14 days after planting, and unfold above the ground.

2.3 Vegetative growth

Unlike most other legumes, peanuts produce their fruit underground, and have four leaflets per leaf, instead of three. The leaflets partially fold up at night.

Peanuts are indeterminate in vegetative and reproductive development; this means the plant continues to grow leaves and stems while it flowers and sets pods. Therefore, unlike determinate crops, which only have one flowering and fruit set, peanut pods constantly compete with the shoot for carbohydrates and nutrients.

2.4 Flowering

Flowering usually starts around 21–35 days after emergence, and continues at a high rate for about another 28 days, after which it slows considerably. Flowers are produced along the branches, and several can be produced at each node. Flowers can appear throughout the season.

Peanut plants have yellow flowers that open at night and are self-pollinated; therefore, bees are not needed for pollination. Usually, only 15–20% of flowers produce a pod.

2.5 Pegging

About 4–5 days after the ovary is fertilised, it begins to elongate and bend towards the soil. This is called a 'peg', and it enters the soil 8–12 days after fertilisation. The sharp tip of the peg allows it to penetrate the soil to a depth of 1–7 cm, if the soil is cool and moist. Pegs are more sensitive to soil compaction than roots are; as soils become harder, pegs can not penetrate as well.

The fertilised embryo in the tip of the peg develops and enlarges soon after the peg enters the soil. Several pegs can develop from a single node. Once the tips of the pegs have enlarged underground, they are called pods.

Photo 5 A mature peanut plant (Photo: NARI)

2.6 Pod development

Pod development is the period between a peg entering the soil and the shell reaching full size. Pods take about 21–28 days to reach full size.

2.7 Pod fill

From about 60 days after planting, pods (shells) form and these are filled with developing kernels (seeds). The developing kernel takes some nutrients, particularly calcium and boron, directly from the soil through fine hairs on the pod. Refer to Section 4.2 for more information.

Table 1 Summary of peanut growth stages

Germination and emergence	• Seed germinates between 5 and 7 days • Seedling emerges from the ground between 6 and 14 days
Vegetative growth	• Seedling grows into plant • Plant continues to produce leaves and stems
Flowering	• Starts 21–35 days after emergence • Major flowering period is 28 days • A small number of flowers continue to be produced for the rest of the plant's life
Pegging	• Fertilised flowers produce a peg that grows down into the ground • Usually only 15–20% of flowers produce a peg
Pod development	• After the peg enters the ground, its tip starts bulging and develops into a pod • The pod takes about 21–28 days to reach full size
Pod fill	• Peanut kernels (seeds) grow inside the pod
Maturity	• The shells harden • Internal shell colour changes to black • Plants are harvested when a large percentage of pods are mature

2.8 Maturity

As peanut pods mature, the shells harden. The internal shell colour changes from white to black, passing through yellow, orange and brown stages in between. The colour change inside the shell can be used as a guide to maturity (for further details, see Section 8.2.2). When the internal shell turns black, the peanut kernel is fully mature and starts separating from the shell. Photo 5 shows a mature peanut plant.

2.9 Seed dormancy

In most varieties, mature peanut kernels are dormant to some degree. Newly harvested kernels will not germinate straight away. The period of dormancy depends on the variety and storage conditions. If there is enough moisture available, some low-dormancy varieties may sprout in the field before harvest.

3 Planting requirements

- In some regions of Papua New Guinea, peanuts can be grown all year.
- Planting in the dry season without irrigation may cause poor yield and quality; choose the optimum planting time to avoid severe dry spells during crop growth.
- Peanuts can grow on a range of soils and slopes.
- Fields must:
  - be located in a sunny position and not be shaded
  - have a minimum soil depth of 30 cm to allow good crop growth
  - be well drained and not waterlogged
  - not have hard-setting soils
  - be pig and animal-proof.
- Repeated cropping of peanuts in the same ground can cause a build-up of diseases and pests, leading to a rapid decline in yield; crop rotation will:
  - reduce risk of soil-borne diseases and pests
  - decrease weed problems
  - allow other crops to use nitrogen that peanuts leave behind in the soil.

3.1 Choosing planting time

Peanut growth is sensitive to seasonal temperature and water availability. Although peanuts can grow all year in most Papua New Guinea (PNG) provinces, crops may be exposed to severe drought conditions depending on rainfall distribution during the growing period. This results in low yields and poor kernel quality. To achieve high yields, the optimum planting time avoids severe dry spells during the crop growing period.

Data are limited for the best planting dates in many areas of PNG. However, peanut crop modelling research in the upper

Markham Valley, conducted as part of this Australian Centre for International Agricultural Research project, showed that October to January is the optimum window for planting peanuts, and that planting after February can result in poor yields (Figure 2) (Chauhan et al. 2006) Delaying planting in the upper Markham Valley may also lead to high aflatoxin risk (Figure 3); see Section 9 for more information on aflatoxins.

Similar yield and aflatoxin scenarios that used daily weather data from Aiyura, Eastern Highlands Province, showed that September to January was the optimum window for planting peanuts in the Aiyura Valley. Yields declined on either side of the optimum planting window, and crops planted from April to June had the lowest yields (Chauhan et al. 2006).

With some irrigation, dry season crops—grown from June to September—can actually produce higher yields and better quality peanuts than the wet season crop. This is because of the extra sunlight and low disease incidence during these months. Wet weather increases the incidence of leaf diseases such as late leaf spot and rust; therefore, foliar disease management becomes critical for high yields in wet season crops. Peanut crops exposed to long periods of wet and cloudy conditions will generally suffer an increased incidence of diseases, significantly reducing yields. See Section 7.5 for further information on diseases and their control.

Peanut crops are not grown in the highlands at altitudes of more than 1,950 m above sea level. These altitudes are too cold and cloudy, preventing peanuts from receiving enough sunlight for growth.

3.2 Choosing a peanut field

Peanuts can be grown successfully on a wide range of soil types and slopes in PNG. They are grown from flat fields to steep slopes of up to 30 degrees, and from the coastal lowlands to the highlands. To grow a good crop, the plants must receive sufficient sunlight; therefore, they must be planted in an open area that is not shaded by other crops or nearby forests.

Peanuts will grow and produce a crop in most soils, but the soil must not be too hard or too wet at harvest time. Long periods of waterlogging reduce oxygen supply to roots and their nodules, which restricts growth. The best soils for peanut crops are light clay loams and sandy loams. These soil types are well drained, have a good structure and do not set hard.

Hard-setting soils and high clay content soils can make harvesting very difficult. If the soil is too hard, it sticks to the pods and the pegs may break.

Peanut fields need to be kept free of pigs and other animals that can dig up plants, damage growing bushes or root up pods.

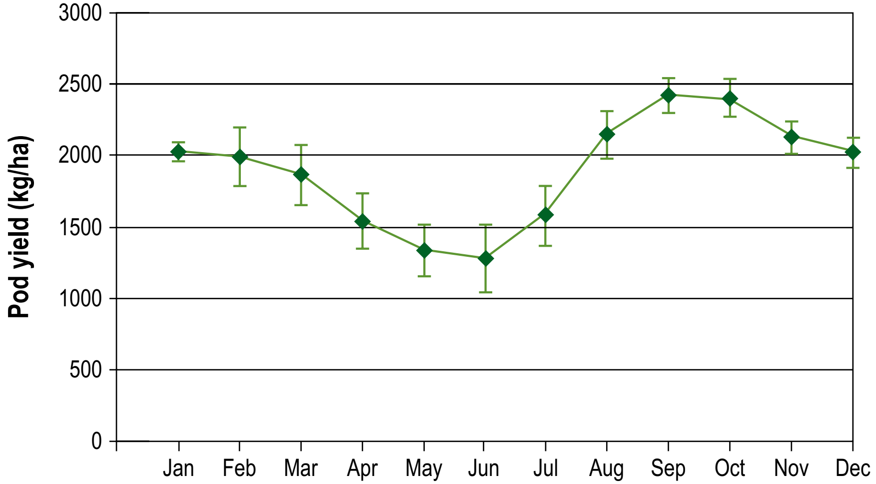

Figure 2 Predicted effect of planting time on pod yield

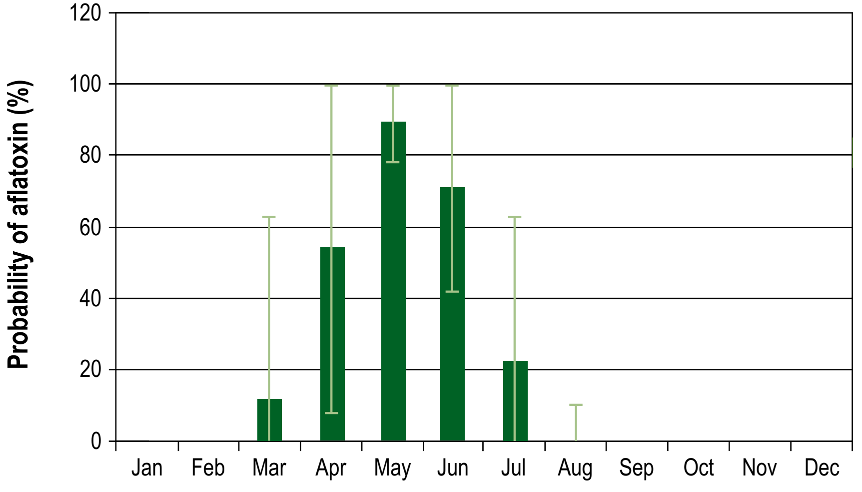

Figure 3 Predicted effect of planting time on aflatoxin risk in short duration varieties grown at Ramu

Note: The yield and aflatoxin scenarios in Figures 2 and 3 are simulated using the Agricultural Production Systems sIMulator (APSIM) peanut model and soil properties and daily weather data of Ramu Sugar during 1995–2006.

3.3 Rotating crops

Peanuts must be rotated with other crops to reduce the build-up of weeds and soil-borne pests and diseases. Planting peanut crops repeatedly in the same soil may reduce yields by up to 15% (DPI&F 2004).

Peanuts fix nitrogen from the atmosphere. Incorporating peanut hay into the soil therefore increases the availability of nitrogen and other nutrients to subsequent crops. Recent research at Ramu Agri-Industries Limited (Dr L. Kuniata, ARD Manager, Ramu Agri-Industries Ltd, pers. comm., 2007) revealed that growing peanuts in rotation with sugarcane increases cane yield compared to cane mono-cropping. Research in Queensland by the Department of Primary Industries and Fisheries has shown that peanuts provide 50–75 kg nitrogen/ha to following crops (Dr Mike Bell, Principal Agronomist, DPI&F, pers. comm., 2008). As additional benefits, these organic nitrogen reserves leach through the soil less than highly soluble nitrogen fertilisers, and peanut crops often break the disease cycles of plant-specific pathogens (Dr Mike Bell, Principal Agronomist, DPI&F, pers. comm., 2008).

Constantly planting peanut crops one after another also encourages weeds to compete with the peanut crop. Planting a mix of crops will reduce particular weed problems. The best approach to weed control is to eliminate or minimise weeds, and prevent them from seeding in all fields and crop rotations.

4 Preparing land and planting

- Good land preparation is very important; ensure you:
  - have a weed-free and well-worked seedbed
  - use raised beds and drains where waterlogging may be a problem.
- Many PNG soils have complex nutrient issues; therefore:
  - use a soil test to check nutrient levels
  - use improved varieties that will respond to higher soil nutrient levels.
- New varieties:
  - offer higher yield potential and better disease tolerance
  - need to be selected for different regions and markets.

4.1 Preparing the land for peanuts

Before planting peanuts, the soil must be clear of weeds and be loose to a depth of 15 cm. However, the soil should not be worked to a fine powder, as this will make it more likely to erode and wash away in heavy rain. On some soils, working the soil until it is very fine will cause it to set quite hard, which can cause problems at harvest. Leaving some small clods will not cause problems.

It is best to start preparing the land 2–3 months before planting. This provides time to control weeds that may germinate, break up any large clods formed at the first turning of the soil, and allow organic material to break down.

Herbicides such as glyphosate and paraquat can be used to control weeds before planting or while preparing the field between crops (see Table 2). Although using herbicides can be quicker and easier than digging or pulling weeds out of large areas, they do cost money, and appropriate safety measures (clothing, boots, gloves, etc.) must be used. Refer to Appendix 1 for safe handling of chemicals.

Table 2 Herbicides available in Papua New Guinea (as at October 2007) that can control weeds before planting the crop

Herbicide trade name[a]	Concentration of active ingredient
Shoot	120 g/L glyphosate
Glyphosate 450	450 g/L glyphosate
Glyphosate Duo	463 g/L glyphosate
Glyphosate 480	480 g/L glyphosate
Glyphosate Super 600	600 g/L glyphosate
Gramoxin	274 g/L paraquat

g = gram; L = litre
[a] While an example of a trade name is provided, this is not a specific recommendation for the named product. There may be other similar products available. Always use herbicides according to the label. Check for re-cropping intervals and withholding periods before using herbicide. Always use appropriate safety equipment when handling chemicals. Refer to Appendix 1 for safe handling of chemicals and Appendix 2 for calibrating a knapsack sprayer.

Rather than growing two peanut crops in succession, it is much better to plant a different crop in the next rotation (Section 3.3). However, if peanuts are to be planted after a previous peanut crop, then removing or burying any peanut residues will reduce the potential for leaf spot infection. To limit the carryover of disease, any volunteer peanuts must be controlled.

If the fields are flat or have drainage problems, using 15–20-cm-high raised beds that are 1.5–2 m wide is recommended (Figure 4). The furrows between the raised beds drain excess water away from the peanuts before damage is caused by waterlogging. Deep drains are often used in the highlands, especially when peanuts are grown in the wet season. Raised beds are also used on heavier Markham Valley soils, where drainage is a problem in the wet season.

Each bed may contain three or four rows of peanut plants. The number of rows will determine how wide the bed is.

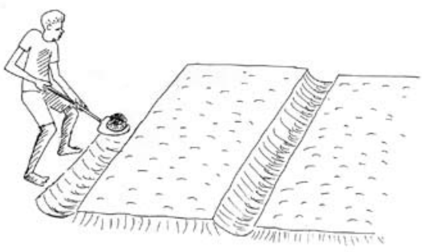

Figure 4 Raised beds are sometimes used if the soil is very wet

4.2 Fertiliser use

The soil nutrition status of Papua New Guinea (PNG) soils is quite variable. Plants will have better, higher quality yields when the appropriate fertiliser is added to some soils.

Peanut soils in PNG are often relatively low in fertility, and inorganic fertilisers are not usually used. Soils in the highlands are generally moderately acidic (pH 4.5–6.0), with low to adequate nitrogen, low potassium and very low phosphorus. On these soils, the application of phosphorus is important for optimum peanut growth and yield. Generally, Markham soils are also low in phosphorus. However, given the current low-yielding varieties grown in PNG, the addition of phosphorus may not result in an economic response. As improved varieties with higher yield potential are adopted, more effective responses to applied fertilisers are likely to be seen.

Peanuts grown with adequate nutrition levels are generally healthier, able to cope better with stresses such as drought and waterlogging, and produce higher yields. As described earlier, peanuts are legumes, and can fix nitrogen from the atmosphere. However, if other nutrients—particularly phosphorus and molybdenum—are low, then the nodulation process will not be effective and less nitrogen will be fixed. Nodulation is often poor on very acid soils, particularly pH < 5.5 (Angelini et al. 2003).

Depending on the soil type, deficiencies of nitrogen, phosphorus, potassium, sulfur and the trace elements boron, iron and zinc may occur. See Photos 6 and 7 for examples of nutrient deficiency, and Appendix 3 for further information on nutrients and deficiencies.

Calcium plays a crucial role in peanut pod filling. Rather than coming from the plant, most calcium used in pod filling comes directly from the soil through fine hairs on the pod. For this reason there must be an adequate supply of calcium in the soil in the pod zone during the pod filling phase. Calcium deficiency results in a greater number of ‘pops’ (unfilled or empty pods). On acid soils (low pH), nutrient availability and pod fill can be improved by applying agricultural lime or calcium formulations such as dolomite. These should be worked into the soil during land preparation, at a rate of 2 tonnes per hectare. Gypsum is another form of calcium. Unlike lime or dolomite, gypsum can be applied when the crop is growing. If gypsum is used, it can be applied just before flowering in a band over the plant and pod zone. A general rate for gypsum application is 600 kg/ha (60 g/m^2). Gypsum does not change the soil pH.

Boron is another nutrient that does not move from the plant to the pods. It also is taken directly into the developing kernels through the fine hairs on the pods. Boron deficiency will result in poor kernel development known as ‘hollow heart’. Boron may be sprayed onto the soil just before planting or during early crop growth (i.e. when much of the spray will still target the soil).

Photo 6 Severe iron deficiency and late leaf spot; note pale yellow young leaves (Photo: R. Rachaputi, DPI&F)

Photo 7 Zinc deficiency; note yellow leaves with green midribs and veins (Photo: courtesy of Trukai Industries Ltd)

Soil pH may have a significant impact on nutrient availability, as the pH of PNG soils ranges from very acid (pH 4.5) to strongly alkaline (pH 8.5). Soils should be analysed to determine soil nutrient levels. See Appendix 4 to find out how to take a soil sample from a peanut field and where to send it for analysis. Table 3 can be used as a guide to understanding the soil test results.

In the absence of soil analysis, the following basal (applied at planting) fertiliser practices are recommended:

- Nitrogen (N): if soil fertility is very low, use 12–18 kg/ha. Be aware that excess nitrogen will reduce nodulation and nitrogen fixation by the plant.
- Phosphorus (P)
  - expressed as P_2O_5: use 60 kg/ha
  - expressed as P: use 26 kg/ha.
- Potassium (K)
  - expressed as K_2O: use 60 kg/ha
  - expressed as K: use 50 kg/ha.

Note: You must check the fertiliser label to see which forms of phosphorus and potassium are used in the mix.

An approximate per-hectare basal fertiliser mix for larger commercial operations is: 40 kg urea + 120 kg triple superphosphate + 80 kg muriate of potash. For smallholders, applying a mixture of 4 g urea and 12 g triple superphosphate per square metre would be equivalent.

Boron sprays should be applied early in crop growth to ensure good soil coverage by the spray. Three applications during crop growth (one at flowering, plus two during the pod filling period) of a multitrace-element foliar fertiliser will provide the required micronutrients (e.g. copper, iron, molybdenum, zinc). Applying basal and foliar sprays is important on the

Table 3 Guide to soil nutrient levels for growing peanuts

Soil property	Critical level[a]	Response range[b]	No action[c]
Aluminium (saturation %)	> 10 (depends on variety)	10–5	< 5
Boron (mg/kg)	< 0.15	0.15–1.3	> 1.3
Calcium (meq/100 g)	< 2 for growth < 4–5 for pod fill (depends on variety)[d]	2–7.5 for growth 4.5–7.5 for pod fill (depends on variety)[d]	7.5
Chloride (mg/kg)	> 600	600–300	< 300
Copper (mg/kg)	< 0.3	0.3–1	> 1
Electrical conductivity, saturated extraction process (dSm/m)	> 3.2	–	< 3.2
Iron (mg/kg)	< 2	2–5	> 5
Magnesium (meq/100 g)	0.5	0.5–2	> 2
Manganese (mg/kg)	< 1	1–5	> 5
Molybdenum	Generally soil tests not recommended Deficiencies can occur at pH < 5.5		
Nitrate (nitrogen, mg/kg)	< 2	2–5	> 5
pH (1:5 water)[e]	< 5 (depends on variety)	–	–
Phosphorus (Colwell[e] mg/kg)	< 10	10–30	> 30
Potassium (meq/100 g)	< 0.2	0.2–0.4	> 0.4
Sodium (meq/100 g)	> 4	4–2	< 2
Sulfur (mg/kg)	< 5	5–20	> 20
Zinc (mg/kg)	< 0.2	0.2–0.4 if pH < 7 0.2–0.8 if pH > 7	0.4 if pH < 7 0.8 if pH > 7

dSm = decisiemens/metre; g = grams; kg = kilograms; m = metre; meq = milliequivalents; mg = milligrams

[a] If the soil test values are above or below the values given in this column, there will be a detrimental effect on plant growth. Action must to be taken to remedy the deficiency or toxicity, or it may be better to plant in a different soil type.

[b] If the soil test values are in this range, peanuts will show some response to remedial actions (e.g. addition of required nutrient).

[c] If the soil test values are outside these values, there is not thought to be any economic response from adding extra nutrients.

[d] Runner type varieties (those that spread along the ground) are more tolerant of low calcium than bunching types (those that tend to be upright in growth).

[e] Standard testing process used

eroded and poor soils of the lower Markham, as these are alkaline (often > pH 8), which limits uptake of some micronutrients.

4.3 Peanut varieties

Peanut varieties have shown some adaptation to specific growing environments in PNG. Generally, varieties that perform well in the lowlands do not grow well in the highlands; similarly, highland varieties tend not to be suitable for lowland conditions.

The most commonly grown peanut cultivars in the highlands are Hagen or Goroka shorty (with two or three-seeded pods), Goroka red and Turoom. Yarang or pukpuk is favoured in the lowlands.

Peanut variety trials conducted in this Australian Centre for International Agricultural Research project indicate that short season types are more adapted to highland conditions than medium or long season varieties. Short season varieties take around 130 days (18–19 weeks) to mature in the highlands, whereas long season types take up to 170 days (23–24 weeks) (Table 4). However, longer season types may have a larger kernel size, which can be an advantage for some markets.

Some of the new varieties being evaluated in the highlands have shown significant yield advantages. In field trials, short season varieties yielded 3.3–4.7 tonnes per hectare and medium season varieties yielded 2–3 tonnes per hectare, whereas local varieties yielded 0.5–2 tonnes per hectare (Ramakrishna et al. 2006).

The most popular variety in the upper Markham is Yarang or pukpuk, which takes about 15–16 weeks to mature. At Ramu Sugar, a number of new varieties out-yielded the local varieties. The short season varieties take up to 90 days (13 weeks) to mature, whereas the medium season varieties take at least 120 days (17 weeks) (Table 4).

Table 4 New peanut varieties adapted to highlands and lowlands of Papua New Guinea

Region	Variety ID	Preferred planting time	Good plant population per hectare	Maturity (weeks)	Kernel weight (g/100 seeds)	Disease resistance	
						Leaf spot	Rust
Highlands	ICGV 96466	Sep–Dec	250,000	18	61	MS	MT
	ICGV 95179	Sep–Dec	250,000	18	80	MS	MT
	ICGV 95271	Sep–Dec	250,000	18	48	MS	MT
	ICGV 94358	Sep–Dec	250,000	18	47	MS	MT
Lowlands	Yarang (pukpuk)	Oct–Mar	150,000–200,000	17	48	MS	MT
	ICGV 94299	Oct–Mar	200,000	14	60	MS	–
	ICGV 94341	Oct–Mar	200,000	14	51	MS	
	ICGV 95271	Oct–Feb	150,000–180,000	15	48	MS	MS
	ICGV 95248	Oct–Feb	150,000–180,000	15	62	MS	–

g = gram; ID = identification; MS = moderately susceptible; MT = moderately tolerant

ICGV = ICRISAT Groundnut Variety (ICRISAT = International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India)

5 Seed

- Keep good peanuts for seed and keep varieties separate.
- Seed is delicate:
  - do not handle roughly
  - store seed unshelled in a cool place.
- Treat peanut seed to prevent seedling diseases.
- *Rhizobium* bacteria ‘fix’ nitrogen in the nodules on peanut roots:
  - peanut seed should be inoculated with *Rhizobium* bacteria.

5.1 Producing quality seed

Try to use only sound, mature seeds for planting. Any seeds that are small, immature, shrivelled or damaged should not be planted, as they may not emerge or may not develop into a healthy plant.

Peanut seed is easily damaged during shelling, storage and planting. It must be handled gently and not thrown or dropped.

Although not currently practised in Papua New Guinea (PNG), one way to ensure high quality seed is to grow a small, very well managed crop specifically for seed. Adequate calcium (from lime, dolomite or gypsum) and micronutrients, especially boron, need to be available in the soil around the pod. The pod takes up these nutrients through its fine hairs, instead of from the plant.

If you keep seed from a general crop, make sure you keep only the best quality peanuts from each field. The seed will need to be grown to full maturity, harvested under good conditions, carefully dried and cleaned and then stored in bags.

5.2 Seed storage

In the PNG lowlands, it is important to store seed for **no longer** than 6 months, because high humidity and temperatures during storage cause germination to drop significantly. Seed will store much better in the highlands, because of the cooler temperatures. For example, in the highlands at Aiyura, seed viability declined at 0.15% per week, whereas in the hotter lowlands at Erap, it declined at 2% per week. The viability declined even faster when stored above a fireplace (Saese et al. 2006).

Always store planting seed in a cool, dry location. Repeated wetting and drying will reduce the seeds' germination and vigour.

Store planting seed unshelled; shelling before storage will reduce its viability. Seed storage trials showed that after 6 months storage under lowland conditions at Erap, peanuts stored as nut-in-shell had a germination rate of 66%, whereas peanut stored as shelled kernel had a germination rate of only 46% (Saese et al. 2006). Shelled seed is also more attractive to rats and mice, and more easily infested with insects and disease.

Each variety should be stored separately. Different varieties will have different planting and harvest times, and vary in pod size, quality, kernel colour and taste. Therefore, to ensure the planting seed remains pure, it is important to keep the varieties separate. This will also help with marketing the crop.

New peanut varieties (see Table 4) are becoming available in PNG. These varieties will mature earlier and have different taste characteristics and colour. Some of these new varieties will also have better disease resistance and higher yield. By keeping them separate, growers will be able to successfully phase out less favourable varieties.

5.3 Seed germination

Seed for planting is the biggest cost to most peanut growers. Seed used for planting must be of good quality. A simple viability test (Box 1) will identify the quality of planting seed.

Good planting seed should germinate quickly and have a germination rate greater than 90%. If the intended planting seed is slow to germinate and less than 80% of seed emerges, consider discarding the seed and obtaining a fresh supply. If this is not possible, try changing the planting rate (e.g. planting two seeds per hole instead of one).

5.4 Seed treatment

Peanut seed should be treated to stop diseases and insects in the soil reducing seed germination and establishment. If the seed is not treated, then seedling establishment can be reduced by up to 50%.

Seed should be treated with a combination of fungicide and insecticide before planting (Box 2). A trial showed that coating seed with a combination of fungicide and insecticide improved seed emergence rates (Saese and Fahey 2006).

A common practice is soaking seed overnight in water before planting. However, there is no evidence to suggest that this improves field establishment. Soaking seeds in neem oil, which is another practice, may retard seedling growth.

Box 1 Seed viability test procedure

- Take a sample of pods from each batch of planting seed.
- Shell out the pods, discarding obviously bad kernels.
- Count out 50 kernels from each seed batch.
- Place each 50-seed lot in a tray or container lined with paper or cloth.
- Dampen the paper or cloth, but do not leave free water lying there; keep the paper or cloth moist—do not allow the test seed to dry out.
- Cover the tray with a cloth and keep the tray in a warm, dark, sheltered place for 4–5 days.
- Observe and count how many seeds are germinating normally and strongly.
- When you have counted the germinated seeds, use the following formula to convert this number to a germination percentage (%).

Germination % =
Number seeds germinated ÷ total number seeds in tray (50) × 100

Example: 46 of the 50 seeds in the tray germinated
Germination % = 46 ÷ 50 × 100
Germination % = 92

5.5 Seed inoculation

Healthy peanut roots are covered with nodules (Photos 10 and 11), which are the nitrogen-making 'factories' of the peanut plant. These are formed by bacteria called rhizobia, which infect roots and form the round nodules that fix nitrogen.

Different strains of rhizobia infect different legumes. Peanuts are not as specific as most other legumes, and so several *Rhizobium* strains will fix nitrogen for them. Usually, there are enough native rhizobia in the soil to infect peanut crops. However, treating peanut seed with *Rhizobium* inoculum when they are planted in a new patch of soil is recommended. It is relatively cheap to inoculate peanuts in new soil, and there may be yield benefits in introducing the most efficient *Rhizobium* strains.

Rhizobium inoculum needs to be kept out of sunlight in a cool place (4°C is ideal) until it is ready to be mixed with the seed. Once the seed has been inoculated, it must be kept out of direct sunlight to keep the rhizobia

Box 2 Seed treatment options

1. Mix equal parts of Captan and Quintozene. Apply 3 g per 1 kg of peanut seed, mixing gently in a bag or container. A commercial formula (trade name – 'Peanut Seed Protectant Fungicide') of this mix is registered in Queensland. In PNG, some growers have been adding 1 g of Carbaryl insecticide to this mix to control insects. (Note: Use of Carbaryl as a seed treatment is not registered in Queensland.)
2. In the absence of Quintozene, 2 g of Captan mixed with 1 kg of seed has shown some success. Similarly, PNG growers have been mixing Captan with 1 g of Carbaryl for insect control.

Note: When handling chemicals, all safety procedures must be followed (Appendix 1). Photos 8 and 9 show safe ways of handling chemicals.

Photo 8 Preparing to treat seed; note use of safety equipment (Photo: M. Hughes, DPI&F)

Photo 9 Treating seed before planting (Photo: M. Hughes, DPI&F)

alive. Another method of applying inoculum, which has shown some success overseas, is mixing it with water and applying it to the furrow just before the seed is sown.

Once suitable rhizobia are established in peanut fields, applying nitrogen as a starter fertiliser to help the plant may only be of benefit in the first 4–5 weeks after germination.

Photo 10 Plant showing strong root nodulation (Photo: Y. Tomda, NARI)

After this stage, 15–20 small nodules will have formed on the plant root system, and they will have started producing nitrogen.

You can tell whether a nodule is fixing nitrogen by cutting through it and observing the colour on the inside. If the inside colour is pink to red, the nodules are fixing nitrogen; green nodules are no longer fixing nitrogen, white nodules are young and brown nodules are old.

Photo 11 Plant showing poor nodulation (Photo: Trukai Industries Ltd)

6 Planting the crop

- Plant wet season crops early.
- Plant at times that will avoid crops maturing in hot dry conditions.
- A good even plant stand is needed to obtain high yields.
- Plant in rows.

6.1 When to plant

When crops are grown through the wet season, plant them early so that they will mature at the end of the season. This reduces the risk of waterlogging at harvest; too much rain at harvest can rot the crop.

Mature peanuts in saturated soil—especially soils with high clay levels that hold more moisture—will begin to rot after 3 or 4 days. Usually the pegs rot first, leaving the pods in the soil. The kernels can also start to sprout in the shell. Peanuts maturing on lighter, well-drained soils do not have such a high risk of rotting.

Planting should also be timed to avoid maturing in hot dry conditions. This will help to maintain peanut quality and reduce the risk of aflatoxin contamination (Sections 3.1 and 9).

6.2 How to plant

Peanuts are best planted in rows (Photo 12). This allows access for weeding, crop protection and harvesting without compacting the soil close to the plants. About 200,000 plants per hectare are needed to obtain good yields. Plant 20% more seed than the desired plant population per hectare to allow for seedling losses. The current practice in Papua New Guinea (PNG) is to dribble seeds at random (Photo 13); this may not reduce emergence, but it makes weed control and harvest more difficult.

To plant peanuts in rows, first mark out straight rows with a stick to show where to plant the seeds. Plant the seeds at a depth of no more than 5 cm, and use only slight pressure to compact the soil around the seed. A planting depth of 2–4 cm works well when soil moisture is adequate. Use raised beds to make planting easier; you can plant rows closer together and use the drainage channels between beds as a walkway.

Note: Always use rubber gloves when handling treated seed. Refer to Appendix 1 for safe handling of chemicals.

6.3 Seed rates

Tables 5 and 6 will help you calculate the amount of seed or spacing to use when you plant.

Table 5 Planting requirements for desired plant population

Variety	Seed size (g/100 seeds)	Desired plant population/ha	Desired plant population/ m^2	Amount of seed to be planted (kg/ha)[a]	Number of seeds to be planted (seeds per m^2)[a]
ICGV 96466	70+	250,000	25	175	30
ICGV 95179	70+	250,000	25	175	30
ICGV 95271	45–49	250,000	25	120	30
ICGV 94358	45–49	250,000	25	120	30
Yarang (pukpuk)	45–49	200,000	20	120	24
ICGV 94299	50–59	200,000	20	140	24
ICGV 94341	50–59	200,000	20	140	24
ICGV 95271	45–49	180,000	18	110	22
ICGV 95248	60–69	180,000	18	150	22

g = gram; ha = hectare; ICGV = ICRISAT Groundnut Variety (ICRISAT = International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India); kg = kilogram; m^2 = square metre

[a] Assuming 20% germination failure

Photo 12 Peanuts planted in rows (left, preferred method) and randomly (right) (Photo: R. Rachaputi, DPI&F)

Photo 13 Farmer planting randomly (not recommended practice) (Photo: R. Rachaputi, DPI&F)

Table 6 Seed spacing at different row populations and row widths

Desired plant population/ha	Number of seeds/ha required to achieve the desired plant population	Spacing between rows (cm)	Seed-to-seed spacing within a row (cm)
250,000	300,000	60	5
		45	7
		30	11
200,000	240,000	60	7
		45	9
		30	14
180,000	220,000	60	8
		45	10
		30	15

cm = centimetre; ha = hectare

7 Looking after the peanut crop

- Weeds must be controlled in peanut crops, especially in the first 4 weeks; therefore:
  - hand weed small plots
  - follow label directions when using herbicides
  - use crop rotation as an important weed control method.
- Insects are not usually a problem in peanuts; however:
  - rotate crops to reduce insect attacks
  - monitor pests to guide insecticide spraying.
- Dressing the seed with an appropriate fungicide will reduce seedling diseases; other effective aids for disease control are:
  - cultural control of leaf spot diseases and peanut leaf rust
  - regular crop inspections for early disease detection.

7.1 Weed control

Weeds can reduce peanut crop yield by 50–90%. Therefore, it is important to keep the field free of weeds before planting and during early crop growth.

Weeds make harvesting more difficult. High weed populations will also reduce the quality of peanuts harvested, due to competition for nutrients and moisture. The crop should be kept weed free, particularly during the first 4 weeks after planting.

Manual weeding, by hand or using a spade or hoe, is a better option than chemical control for small plots (Photo 14). Planting in rows greatly helps manual weeding. Make sure you do not damage the peanut plant roots when you pull or dig weeds out. Also avoid spreading soil over the peanut plants, as this will encourage disease.

You can leave many types of pulled weeds on top of the soil as mulch for the crop. However, certain weed species, such as

Photo 14 A family weeds a peanut crop by hand (Photo: D. Homare, NARI)

pigweed, will continue to grow and must be removed from the plot. Similarly, weeds that have already produced seed should not be left in the field to spread their seed.

Tables 7 and 8 contain information about chemical herbicides that can be used for weed control in Papua New Guinea (PNG).

Table 7 Herbicides registered in Australia for pre-plant or pre-emergence weed control that can be used in Papua New Guinea

Chemical[a]	Concentration of active ingredient	Trade name example[b]	Target weeds Common name (scientific name)
Acifluorfen (for pre-emergence control)	224 g/L	Blazer	Apple of Peru (*Nicandra physalodes*) Black bindweed (*Polygonum convolvulus*) Blackberry nightshade (*Solanum nigrum*) Fat hen (*Chenopodium album*) Jute (*Corchorus olitorius*) Narrow leaf plantain (*Plantago lanceolata*) Noogoora burr (*Xanthium pungens*) Pigweed (*Portulaca oleracea*) Redshank (*Amaranthus cruentus*) Scarlet pimpernel (*Anagallis arvensis*) Turnip weed (*Rapistrum rugosum*) Wild gooseberry (*Physalis minima*) Wild radish (*Raphanus raphanistrum*)
Pendimethalin (pre-plant, incorporated into soil)	330 g/L	Stomp 330 E	Barnyard grass (*Echinochloa* spp.) Button grass (*Dactyloctenium radulans*) Crowsfoot grass (*Eleusine indica*) Early spring grass (*Eriochloa* spp.) Fat hen (*Chenopodium album*) Green amaranth (*Amaranthus viridis*) Mexican clover or white-eye (*Richardia brasiliensis*) Mossman river grass (*Cenchrus echinatus*) Native millet (*Panicum decompositum*) Pigweed (*Portulaca oleracea*) Scarlet pimpernel (*Anagallis arvensis*) Stink grass (*Eragrostis cilianensis*) Weeping love grass (*Eragrostis parviflora*) **Chemical may suppress the following weeds:** Blackberry nightshade (*Solanum nigrum*) Caltrop (*Tribulus terrestris*) Peppercress (*Lepidium* spp.) Stagger weed (*Stachys arvensis*)
Prometryn	900 g/kg	Prometryn 900DF	Bell vine (*Ipomoea* spp.) Caltrop or yellow vine (*Tribulus terrestris*) Green amaranth (*Amaranthus viridis*) Pigweed (*Portulaca oleracea*) Thornapple (*Datura* spp.)

Table 7 (continued)

Chemical[a]	Concentration of active ingredient	Trade name example[b]	Target weeds Common name (scientific name)
S-metolachlor (for pre-emergence control)	960 g/L	Dual Gold	Barnyard grass (*Echinochloa* spp.) Crowsfoot grass (*Eleusine indica*) Lovegrass (*Eragrostis* spp.) Pigeon grass (*Echinochloa* spp.) Summer grass (*Digitaria ciliaris*) Wandering Jew (*Commelina benghalensis*)
Trifluralin (pre-plant incorporated into soil)	480 g/L	Triflur 480	Black pigweed or giant pigweed (*Trianthema portulacastrum*) Crab grass (*Digitaria* spp.) Mossman river grass (*Cenchrus echinatus*) Pigweed (*Portulaca oleracea*) Redroot (*Amaranthus* spp.) Redshank (*Amaranthus cruentus*) Summer grass (*Digitaria ciliaris*) **From seed only** Barnyard grass (*Echinochloa* spp.) Caltrop (*Tribulus terrestris*) Guinea grass (*Panicum maximum*) Johnson grass (*Sorghum halepense*)

g = gram; kg = kilogram; L = litre

[a] Consult product labels for information on application rates and safety; always use herbicides according to the label. Check for re-cropping intervals and withholding periods before using herbicide. Always use appropriate safety equipment when handling chemicals. Refer to Appendix 1 for safe handling of chemicals and Appendix 2 for calibrating a knapsack sprayer.

[b] While an example of a trade name is provided, this is not a specific recommendation for the named product. There may be other similar products available.

Table 8 Herbicides registered in Australia for post-emergence[a] weed control that can be used in Papua New Guinea

Chemical[b]	Concentration of active ingredient	Trade name example[b]	Target weeds Common name (scientific name)
2,4-DB	400 g/L 2,4-DB present as potassium and sodium salts	Buticider	Spiny emex (*Emex* spp.) Thornapple (*Datura* spp.)
Acifluorfen (post-emegence treatment)	224 g/L	Blazer	Annual ground cherry (*Physalis angulata*) Apple of Peru (*Nicandra physalodes*) Bell vine or common morning glory (*Ipomoea purpurea*) Black pigweed or giant pigweed (*Trianthema portulacastrum*) Blackberry nightshade (*Solanum nigrum*) Jute (*Corchorus olitorius*) Noogoora burr (*Xanthium pungens*) Pigweed (*Portulaca oleracea*) Redshank (*Amaranthus cruentus*) Sesbania (*Sesbania* spp.) Thornapple (*Datura* spp.) Turnip weed (*Rapistrum rugosum*) Wild radish (*Raphanus raphanistrum*) Wild gooseberry (*Physalis minima*)
Bentazone	480 g/L	Basagran	Annual ground cherry (*Physalis angulata*) Apple of Peru (*Nicandra physalodes*) Bellvine (*Ipomoea plebeia*) Cobblers pegs (*Bidens pilosa*) Hairy wandering Jew (*Commelina benghalensis*) Noogoora burr (*Xanthium pungens*) Star burr (*Acanthospermum hispidum*) Thornapple (*Datura* spp.)

Table 8 (continued)

Chemical[b]	Concentration of active ingredient	Trade name example[b]	Target weeds Common name (scientific name)
Fluazifop	128 g/L	Fusilade forte	Barnyard grass (*Echinochloa* spp.) Crowsfoot grass (*Eleusine indica*) Johnson grass seedlings (*Sorghum halepense*) *Panicum* spp. Rhodes grass (*Chloris gayana*) Summer grass (*Digitaria ciliaris*) Volunteer cereals
Imazapic	240 g/L	Flame	Awnless barnyard grass (*Echinochloa colona*) Barnyard grass (*Echinochloa crus-galli*) Black pigweed or giant pigweed (*Trianthema portulacastrum*) Blackberry nightshade (*Solanum nigrum*) Blue billygoat weed (*Ageratum houstonianum*) Common sida (*Sida rhombifolia*) Glossy nightshade (*Solanum americanum*) Green amaranth (*Amaranthus viridis*) Green summer grass (*Brachiaria subquadripara*) Guinea grass (*Panicum maximum*) *Ipomoea* spp. Milkweed or Mexican fire plant (*Euphorbia heterophylla*) Nutgrass (*Cyperus rotundus*) Pigweed (*Portulaca oleracea*) Summer grass (*Digitaria ciliaris*)
Imazethapyr	700 g/L	Spinnaker 700 WDG	Apple of Peru (*Nicandra physalodes*) Awnless barnyard grass (*Echinochloa colona*) Barnyard grass (*Echinochloa crus-galli*) Bathurst burr (*Xanthium spinosum*) Bellvine (*Ipomoea* spp.) Common sida (*Sida rhombifolia*) Fat hen (*Chenopodium album*) Fierce thornapple (*Datura ferox*) Jute (*Corchorus olitorius*) Nutgrass (*Cyperus rotundus*) Thornapple (*Datura* spp.) Wild gooseberry (*Physalis minima*)

Table 8 (continued)

Chemical[b]	Concentration of active ingredient	Trade name example[b]	Target weeds Common name (scientific name)
Paraquat	250 g/L	Gramoxone	Annual ground cherry (*Physalis angulata*) Apple of Peru (*Nicandra physalodes*) Bellvine or common morning glory (*Ipomoea* spp.) *Datura* spp. Milkweed or Mexican fire plant (*Euphorbia heterophylla*) Stagger weed (*Stachys arvensis*) Wandering Jew (*Commelina benghalensis*)

g = gram; L = litre

[a] Post-emergence herbicides will only control small grasses.

[b] Consult product labels for information on application rates and safety; always use herbicides according to the label. Check for re-cropping intervals and withholding periods before using herbicide. Always use appropriate safety equipment when handling chemicals. Refer to Appendix 1 for safe handling of chemicals and Appendix 2 for calibrating a knapsack sprayer.

[c] While an example of a trade name is provided, this is not a specific recommendation for the named product. There may be other similar products available.

Photos 15 to 28 show some weeds that grow in peanut crops.

Photo 15 Apple of Peru (Photo: M. Hughes, DPI&F)

Photo 16 Blackberry nightshade (Photo: M. Hughes, DPI&F)

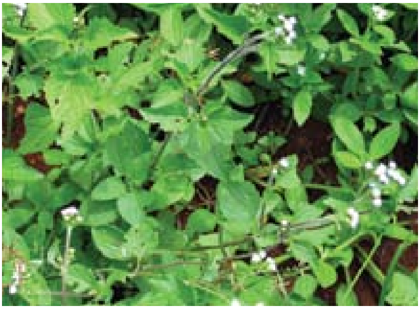

Photo 17 Blue billygoat weed
(Photo: M. Hughes, DPI&F)

Photo 18 Cobblers pegs
(Photo: M. Hughes, DPI&F)

Photo 19 Crowsfoot grass
(Photo: B. English, DPI&F)

Photo 20 Green amaranth
(Photo: M. Hughes, DPI&F)

Photo 21 Milkweed
(Photo: M. Hughes, DPI&F)

Photo 22 Nutgrass
(Photo: M. Hughes, DPI&F)

Photo 23 Pigweed
(Photo: B. Wera, NARI)

Photo 24 *Sida* sp.
(Photo: B. English, DPI&F)

Photo 25 Star burr
(Photo: M. Hughes, DPI&F)

Photo 26 Wandering Jew
(Photo: M. Hughes, DPI&F)

Photo 27 White-eye
(Photo: M. Hughes, DPI&F)

Photo 28 Wild radish
(Photo: M. Hughes, DPI&F)

7.2 Controlling weeds through crop rotation

Crop rotation is another important method of weed control. Constantly planting peanut crops one after another will encourage a shift in weed type, resulting in severe competition with the peanut crop. Planting a mix of crops will reduce the development of particular weed problems. The best approach to weed control is to eliminate or minimise weeds, and prevent weeds from seeding in all fields and crop rotations.

7.3 Insects and their control

In PNG, only a few severe insect pests of peanut require control with insecticides—white grubs, jassids and aphids. Crops must be regularly inspected to enable appropriate control measures to be applied. Table 9 lists registered insecticides that can be used in PNG. Photos 29 to 40 show examples of common insect pests and the damage they can cause.

7.3.1 White grub ('muna')

White grub ('muna') larvae feed on roots and pods, killing the plants and reducing plant population and yield. For example, the plant population in a heavily attacked field in the Ramu Valley fell from 20 plants per square metre to 12 plants per square metre within 8 weeks of planting. Similar situations have occurred in the Eastern Highlands.

Even moderate grub densities of around 2–10 grubs per square metre will reduce yields. Dig out suspect plants and destroy the larvae, and avoid planting in infested areas. In PNG, applying Confidor insecticide (25–50 mL in 10 L of water) at planting can prevent white grub and other soil-dwelling pests developing in peanut crops. White grub larvae can also be killed during ploughing and repeated harrowing of land, especially from October to November, when beetles mate.

7.3.2 Caterpillars

Helicoverpa caterpillars and *Spodoptera* armyworms feed on leaves and young stems of peanut crops. These caterpillars are effectively controlled by a range of tachinid flies, and therefore rarely require insecticide spraying.

Stemborers (moths) are present in the Lower Markham and in the Upper Ramu Valley (the Sausi area in Madang Province). These larvae hollow out the stem, but do not appear to cause economic damage. The larvae are also parasitised by wasps in the genus *Apanteles*; therefore, insecticide spraying is unnecessary.

7.3.3 Mealy bugs

Mealy bugs feed on stems and roots. This insect is generally considered to be of little importance; however, during dry periods, they can cause severe damage. Avoid planting peanut crops going into the dry season when the crops will be subjected to moisture stress and mealy bug damage.

Table 9 Peanut insect pest insecticides registered in Australia that can be used in Papua New Guinea

Chemical[a]	Concentration of active ingredient	Trade name example[b]	Target insects Common name
Chlorpyrifos	500 g/L	Chlorpyrifos 500	Cutworm Wingless grasshopper
Dimethoate	400 g/L	Rogor	Aphids Green vegetable bug Jassids Peanut mite Thrips
Methamidophos	580 g/L	Nitofol	Whitefringed weevil
Methomyl	225 g/L	Lannate L	Heliothis
Terbufos	150 g/L	Counter 150G	Whitefringed weevil Whitegrubs

g = gram; L = litre

[a] Consult labels for information on application rates and safety; always use insecticides according to the label. Check for withholding periods before using an insecticide. Always use appropriate safety equipment when handling chemicals. Refer to Appendix 1 for safe handling of chemicals and Appendix 2 for calibrating a knapsack sprayer.

[b] While an example of a trade name is provided, this is not a specific recommendation for the named product. There may be other similar products available.

7.3.4 Aphids and jassids

Aphids are usually found in low numbers in all areas and cause little damage. The main symptom of aphid damage is wrinkling of the upper leaves. Aphids are the main method of spreading the virus disease, peanut mild mottle virus (PMMV).

There are many natural predators (such as ladybird larvae and jumping spiders) that keep aphid numbers under control. This also limits the spread of PMMV.

Jassids are also common, but their feeding is not always obvious. In severe infestations, the ends of plant leaflets turn yellow and then die from the toxins that are injected by the insects when they feed on the leaves. This is known as ‘hopper burn’. Leaves and stems of affected plants may also become distorted. Jassid infestation and damage to peanut crops is highest during the dry season. The resulting plant damage from the insect attacks may also be a contributing factor for increased aflatoxin risk. Jassids may also transmit viral diseases to the plants.

Photo 29 White grub damage (Photo: L. Kuniata, Ramu Agri-Industries Ltd)

Photo 30 *Helicoverpa* (heliothis) caterpillar (Photo: L. Kuniata, Ramu Agri-Industries Ltd)

Photo 31 Mealy bug on peanut pod (Photo: H. Brier, DPI&F)

Photo 32 Vegetable jassids (Photo: H. Brier, DPI&F)

Photo 33 Lucerne jassid (Photo: H. Brier, DPI&F)

Photo 34 Severe hopper burn (Photo: H. Brier, DPI&F)

Photo 35 Black field earwig
(Photo: H. Brier, DPI&F)

Photo 36 False wireworm larva
(Photo: H. Brier, DPI&F)

Photo 37 Large wireworm larva
(Photo: H. Brier, DPI&F))

Photo 38 Wireworm larva inside peanut pod and kernel (Photo: H. Brier, DPI&F)

Photo 39 Green vegetable bug
(Photo: B. Wera, NARI)

Photo 40 Black field cricket
(Photo: H. Brier, DPI&F)

When aphid and jassid populations reach high levels, spraying the crop with insecticides such ad dimethoate can provide good control. Karate or permethrin are also used in PNG to control these pests, but unlike dimethoate, these insecticides can also affect important natural enemies of other pests such as *Helicoverpa* and stemborers. To minimise aphid and jassid damage, avoid growing peanuts in the dry season.

7.3.5 Earwigs, wireworms and false wireworms

Earwigs, wireworms and false wireworms bore holes in pods. Earwigs are the most serious podborer. Pod damage varies from very little to 100%, with a mean of 15% of pods damaged.

Earwigs occur at a high incidence in localised regions; damage is generally more severe in the Lower Markham, and is minor in the long rotation fields of the Upper Markham. In PNG, Confidor treatment for white grub control is sufficient to control earwigs, wireworms and false wireworms as well.

Aside from the physical damage caused by podborers and white grubs, invasion of damaged pods by *Aspergillus* fungi, which can produce aflatoxin, is of major concern. Heavily damaged pods should be discarded during hand harvest, but pods with small holes may be retained.

7.4 Rodents and other pests

Other pests, such as pigs and rats, can also damage peanut crops and eat the pods. There is no simple solution to control pigs, other than fencing. To reduce the risk of pest attack, make sure peanuts are dug, dried and threshed in a timely manner.

7.5 Diseases and their control

7.5.1 Seedling disease

Peanut seedling diseases are a significant problem. Seed dressings can reduce this problem, and increase establishment rates from 50% to 90% (Section 5.4).

7.5.2 *Verticillium* wilt

In the Eastern Highlands, *Verticillium* wilt can kill up to 50% of peanut plants. It is also found in the western end of the Ramu Valley (Kesowai-Sausi, Madang Province). Stem rot, which is often associated with *Verticillium* wilt, can also kill plants; it often occurs in overworked soils that have low soil organic matter. Crop rotation is the best way to manage these soil-borne diseases.

Symptoms include irregular, light green patches near the edges of leaves, which turn brown and die in dry weather (Photo 41). Reddish-brown streaks occur in the roots, stem, pegs and pods. Plants are often stunted and wilt in dry weather. Small black microsclerotes (resting stage of fungus) can develop on the pegs and pods.

Photo 41 *Verticillium* **wilt (Photo: L. Kuniata, Ramu Agri-Industries Ltd)**

Photo 42 Severe peanut mild mottle virus (Photo: L.Kuniata, Ramu Agri-Industries Ltd)

Photo 43 White mould (Photo: L. Kuniata, Ramu Agri-Industries Ltd)

Photo 44 Leaf showing leaf spot symptoms (Photo: DPI&F)

Photo 45 Leaf spot on peanut plants (Photo: L. Kuniata, Ramu Agri-Industries Ltd)

7.5.3 Peanut mild mottle virus

PMMV is very common. It is transmitted through infected seed, and by insect vectors such as aphids. Symptoms are wrinkling between the leaf veins, downward curling of the leaf margins and a chlorotic mottle (Photo 42). PMMV is generally considered to have little effect on yield. However, pulling out affected plants may help to reduce the sources of infection.

7.5.4 White mould

White mould is found across all peanut growing regions, but may be worse in some years and fields. The fungus prefers to live on dead plant matter and grows well in warm, humid conditions. It produces fluffy, white mycelium at or near the base of the plant (Photo 43). Affected stems turn yellow and die, and may look shredded. The affected tissues may also be lined with small, white sclerotes (which then turn dark brown). Infected pegs frequently rot.

To control white mould, practise good crop rotation, and do not throw soil around the crown of the plant or plant into soil containing fresh or undecomposed organic matter.

7.5.5 Early and late leaf spot

Early and late leaf spot are leaf diseases that significantly affect peanut crops. These diseases, which are found in all peanut-growing areas, can defoliate the crop and severely reduce yields. Leaf spot is worse when peanut crops are planted in succession, or in fields where peanut crops of different ages are growing at the same time. Leaf spot spores may carry over on dead peanut plants following harvest and infect the new crop. They are also blown by the wind.

The symptoms of early and late leaf spot are small, yellow spots, usually first found on the lower older leaves around the base of the plant, which change to brown and black on both sides of the leaf (Photos 44 and 45). Stems and leaf stalks may have dark, shallow spots with a distinct edge. The spots may grow up to 10 mm wide, and are often surrounded by a yellow halo. As the disease increases in severity, it can cause premature leaf drop. Late leaf spot tends to be a darker colour and have a more obvious spore mass on the underside of the leaf. However, to accurately tell the two diseases apart, samples must be studied under a microscope.

7.5.6 Rust

Rust is the other leaf disease that significantly affects peanut crops. Rust needs live plants for survival. Rust spores from infected plants are spread on the wind; therefore, all volunteer peanut plants in sites previously planted with peanut crops must be eradicated before planting the new crop.

Rust affects leaves, leaf stalks and stems. Initial small, yellow spots quickly erupt into a mass of dark orange spores that turn brown as they age (Photo 46). Both sides of the leaf are affected, but generally, more spores are produced on the underside. The leaf tissue around the rust spots dies, and the leaves curl, become brown and brittle, and drop.

7.5.7 Leaf disease detection and control

Peanut crops must be regularly inspected for early disease detection. From the time a plant is infected, it takes 7–10 days until lesions are easily seen; therefore, this period is critical in managing leaf spot and rust infections.

Photo 46 Plant showing peanut leaf rust symptoms (Photo: Trukai Industries Ltd)

Box 3 Managing leaf spot diseases

A three-part program is needed to manage early and late leaf spot diseases.

1. Rotate crops using non-peanut crops for at least 4–6 months.
2. Apply fungicide early.
3. Remove infected leaves and stems by deep-ploughing or burning.

Fungicides can control these foliar diseases effectively. When high disease pressure is expected, fungicide programs need to start before the first sign of disease, and may involve multiple fungicide applications. Application of chlorothalonil fungicide (e.g. Bravo) can reduce rust and late leaf spot infections, and these products are readily available. Chlorothalonil is a good, all-round protectant fungicide and can be applied at a rate of 2 L/ha on a fortnightly basis, starting 30–35 days after planting (check label first, as rates may vary with some products). It is a broad-spectrum fungicide with excellent weathering properties, and is currently used in the PNG potato industry.

For the best results, fungicides need to be used as a preventive treatment. Farmers should consider using up to three fungicide sprays to assist leaf disease control; as a minimum, chlorothalonil should be applied as soon as the first lesions are seen, and again 2–3 weeks later. This will extend the effective growing season and result in a significant yield increase. Table 10 lists fungicides that can be used in PNG.

Leaf spot spores carry over on stubble, infecting new crops. Removing plants from the field when harvesting will therefore reduce the number of infected leaves that would maintain the infestation. Deep-ploughing to bury remaining leaves and stems, or raking and burning the residues, also helps to reduce early infection of the next crop. Returning stems to the fields as compost or mulch will increase the risk of infection. Box 3 outlines the program needed to manage leaf spot.

7.5.8 Fungicide control of peanut diseases

There are a number of fungicides available for control of both soil and leaf-borne peanut diseases. Care needs to be taken when using these to ensure that resistance does not build up. A list of fungicides and the diseases they control are shown in Table 10.

Table 10 Fungicides registered in Australia for peanut-foliar and soil-borne diseases that can be used in Papua New Guinea

Chemical[a]	Concentration of active ingredient	Trade name example[b]	Target fungi Common name (scientific name)
Azoxystrobin	500 g/kg	Amistar 500 WG	Stem rot/white mould (*Sclerotium rolfsii*) *Rhizoctonia* peg and pod rot (*Rhizoctonia solani*)
Azoxystrobin + cyproconazole	200 g/L azoxystrobin + 80 g/L cyproconazole	Amistar Xtra	Early leaf spot (*Cercospora arachidicola*) Late leaf spot (*Cercosporidium personatum*) Net blotch (*Phoma arachidicola*) Rust (*Puccinia arachidis*)
Chlorothalonil	500 g/L	Chlorothalonil 500 SC	Early leaf spot (*Cercospora arachidicola*) Late leaf spot (*Cercosporidium personatum*) Net blotch (*Phoma arachidicola*) Rust (*Puccinia arachidis*) Peppery leaf spot (*Leptosphaerulina trifolii*)
Cyproconazole	100 g/L	Alto 100 SL	Early leaf spot (*Cercospora arachidicola*) Late leaf spot (*Cercosporidium personatum*) Rust (*Puccinia arachidis*)
Iprodione	500 g/L	Rovral Aquaflo	*Sclerotinia* rot (*Sclerotinia sclerotiorum, Sclerotinia minor*)
Mancozeb	750 g/kg	Dithane DF	Early leaf spot (*Cercospora arachidicola*) Rust (*Puccinia arachidicola*)
Quintozene	750 g/kg	Quintozene 750	Crown rot (*Sclerotium rolfsii*)
Tebuconazole	430 g/L	Folicur 430 SC	Early leaf spot (*Cercospora arachidicola*) Late leaf spot spot (*Cercosporidium personatum*) Rust (*Puccinia arachidis*) Net blotch (*Phoma arachidicola*)

g = gram; kg = kilogram; L = litre

[a] Consult labels for information on application rates and safety; always use fungicides according to the label. Check for withholding periods before using a fungicide. Always use appropriate safety equipment when handling chemicals. Refer to Appendix 1 for safe handling of chemicals and Appendix 2 for calibrating a knapsack sprayer.

[b] While an example of a trade name is provided, this is not a specific recommendation for the named product. There may be other similar products available.

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)

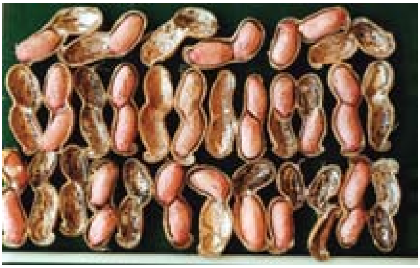

Photo 49 100% pod maturity shown by the shell-out method (Photo: R. Rachaputi, DPI&F)

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) =

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

Example:

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

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

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

(2) Spray volume per hectare =

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

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 =

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

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) =

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

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.

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

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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