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.

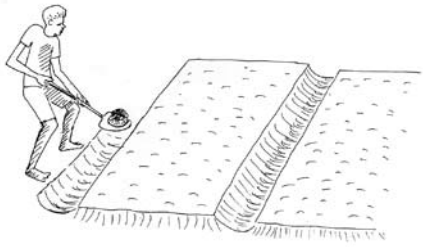

Figure 4 Raised beds are sometimes used if the soil is very wet

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.