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LENTIL

SECTION 6

PLANT AND GROWTH PHYSIOLOGY

KEY POINTS | INTRODUCTION | STAGES OF GROWTH | CROP DEVELOPMENT

Plant and growth physiology

Key points

- The lentil plant is hypogeal, meaning the cotyledons of the germinating seed remain below the ground and inside the seed coat.
- Lentil germination requires a minimum soil temperature of 5°C.
- The lentil plant is a slender, semi-erect, bushy annual with compound leaves with a tendril at each tip.
- Lentil roots are highly sensitive to saline, boron and sodic soils.
- Flowering begins on the lowest branches, gradually moving up the plant and continuing until near maturity.
- Lentil has an indeterminate growth habit, meaning it is possible to find flowers, immature pods and mature pods on a plant at the same time.

FEEDBACK

6.1 Introduction

The lentil plant experiences hypogeal emergence, like field pea (Figure 1), which means the cotyledons of the germinating seed remain below the ground and inside the seed coat. Seedlings with hypogeal emergence are less likely to be killed by frost, wind erosion or insect attack. This is because new stems can develop from buds at nodes at, or below, ground level. Their growth may, however, be slowed considerably.

The lentil plant is a slender, semi-erect, bushy annual with compound leaves (four to seven pairs of leaflets), similar to vetch leaves, with a tendril at each tip. Plants can have single stems or many branches, depending upon the population in the paddock. The many stems of a lentil plant originate from near the ground and are better supported when the crop is sown inter-row, which means between the rows of last season's cereal stubble.

Plants normally range from 30–50 cm in height. Plants generally grow taller when the growing season temperatures are cool, and there is good moisture and soil fertility. Despite their relatively short plant height, many crops lodge late in spring due to their weak stems, particularly if well grown with high crop biomass and high yields.

Flowering begins on the lowest branches, gradually moving up the plant and continuing until harvest. Flowers can be white, lilac or pale blue in colour and are self-pollinated. Lentil plants flower profusely over a short period and set many pods, with each pod containing one or two seeds depending on the growing season conditions. **Due to its indeterminate growth habit it is possible to find flowers, immature pods and mature pods on a plant at the same time.** This means that crop desiccation may be required, as an aid to harvest, in order to create more even maturity.

Seeds are small in comparison with other pulses and are a characteristic lens shape.[1]

1 Pulse Australia (2015) Best Management Guide – Lentil Production: Southern Region. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

FEEDBACK

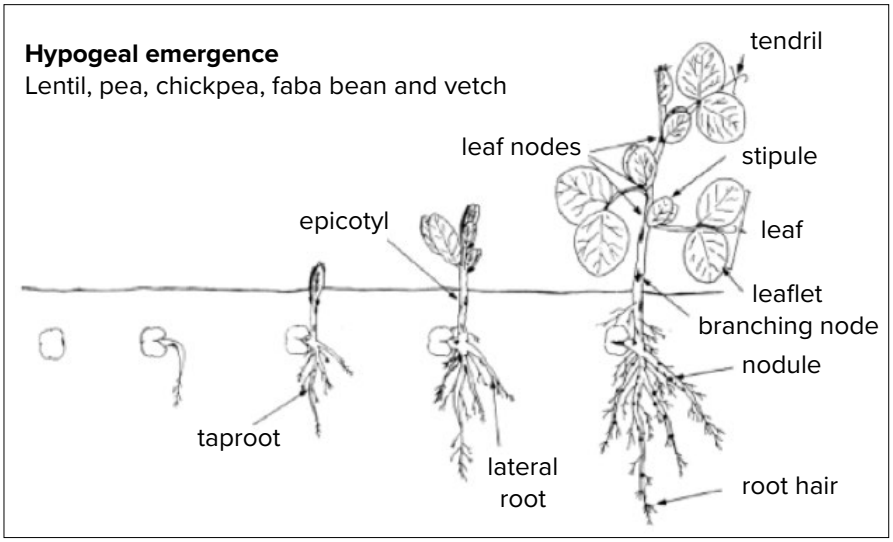

Figure 1: *Seedling development of lentil.*

Source: Best Management Guide –Lentil Production: Southern Region, (2015), Pulse Australia, http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

6.2 Stages of growth

Uniform growth stage descriptions have been developed for the lentil plant (Table 1). These descriptions are universally applicable to all growing environments and divergent cultivars.[2]

Table 1: Growth stages of a lentil plant.

Development phase	Growth stage (GS)	Description
Germination and emergence	VE	Seedling emergence, cotyledonary node visible
Vegetative	V1 V2 V3 V4 V5 NV	First simple leaf has unfolded at the first node Second simple leaf has unfolded at the second node First bifoliate leaf has unfolded at the third node Second bifoliate leaf has unfolded at the fourth node First multifoliate leaf has unfolded at the fifth node Nth multifoliate leaf has unfolded at the nth node
Reproductive Flowering in lentil is indeterminate, occurring from axillary buds on the main stem and branches. It proceeds acropetally from lower to higher nodes.	R1 R2 R3 R4 R5 R6	Early bloom, one open flower at any node Full bloom, flower open or has opened on nodes 10–13 of the basal Primary branch Early pod, pod on nodes 10–13 of the basal primary branch visible Flat pod, pod on nodes 10–13 has reached its full length and is largely flat Early seed, seed in any single pod on nodes 10–13 fill the pod cavity Full seed, seed on nodes 10–13 fill the pod cavities
Physiological maturity	R7 R8	Leaves start yellowing and 50% of the pods have turned yellow 90% of pods on the plant are golden-brown

Source: Stages of Development in Lentil (1990), https://www.researchgate.net/publication/231803378_Stages_of_Development_in_Lentil

2 W Erskine, F Muehlbauer, R Short (1990) Stages of Development in Lentil. Exp. Agric. 26:297-302, https://www.researchgate.net/publication/231803378_Stages_of_Development_in_Lentil

FEEDBACK

6.2.1 Germination and emergence

Germination occurs with the root developing out of the seed first. This is followed by the shoot emerging upward towards the soil surface.

The shoot emerges through the soil with the first leaves pointing downwards. Upon reaching the soil surface the shoot extends upwards.

6.2.2 Vegetative

The vegetative stage is determined by counting the number of developed nodes on the main stem, above ground level.

Vegetative nodes are counted from the point at which the first true leaves are attached to the stem. The last node counted must have its leaves unfolded.

The node at which the first leaflet arises from the main stem above the soil is counted as vegetative node one (Figure 2). A node is counted as developed when leaves are unfolded and flattened out. Scale leaves at the base of the plant and close to the ground are not counted but are classified as 'true nodes'.

Leaves that develop above the 5th or 6th node are about 5 cm long with 9–15 leaflets.

MORE INFORMATION

Cotyledtons

Cotyledons and first node are with the seed piece. Second and third nodes usually stay below the ground and act as axillary buds. The first true leaf actually is the third or fourth node. However, it is called the first vegetative node.

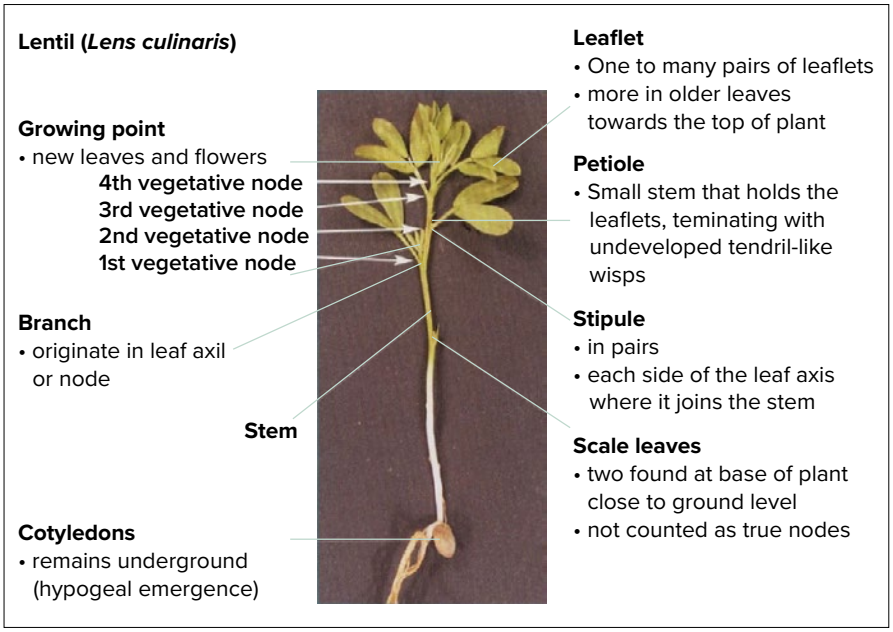

Figure 2: *Lentil early growth stages.*

Source: Image is modified from: Weeds in Winter Pulses (2004), CRC for Australian Weed Management, http://trove.nla.gov.au/work/11851108?selectedversion=NBD41255510

6.2.3 Reproductive

The reproductive stage begin when the plant begins to flower at any node. Flowering in lentil is indeterminate, occurring from axillary buds on the main stem and branches. It proceeds acropetally from lower to higher nodes.

Reproductive stages R1 and R2 are based on flowering, and R3 to R6 are based on pod and seed development.

6.2.4 Physiological Maturity

Physiological maturity is when the seed can develop no further dry matter (R7 and R8).

FEEDBACK

6.3 Crop development

6.3.1 Sowing to germination

Lentil germination requires a minimum soil temperature of 5°C, slightly warmer than that required for field pea.[3]

Under optimum moisture and temperature conditions, lentil seeds absorb water relatively quickly and germinate within a few days providing temperatures are above 0°C. Unlike lupin, lentil seedlings have hypogeal emergence, that is, their cotyledons (embryonic leaves) remain underground inside the seed coat whilst providing energy to the rapidly growing roots and shoots.

6.3.2 Germination to emergence

Emergence occurs 10–21 days after sowing, depending on soil moisture, temperature conditions and depth of sowing.

Depending on soil temperature, the number of days to emergence for lentil are:

- 5°C–7.2°C ➔ 17–21 days;
- 7.2°C–10°C ➔ 14–17 days; and
- 10°C–12.8°C ➔ 10–14 days.

Growth of the shoot (plumule) produces an erect shoot and the first leaves are 'scales.' The first true leaves have a single pair of leaflets (i.e. two leaflets), and from the 5th to 8th node leaves have two or three pairs of leaflets. The development of multiple pairs of leaflets per leaf generally corresponds with development of the first flower bud.

Approximate times to reach leaf stages are:

- 1st node/leaf stage: usually 14 days (depending on soil temperature); and
- 2nd node/leaf stage and after: every 4–5 days.

6.3.3 Roots

Lentil has a slender taproot with a mass of lateral fibrous roots. Plant roots are important in the capture of moisture and inorganic nutrients, particularly on soils with low fertility or low water-holding capacity.

Positive associations have been reported between rate, and amount of, root surface development with grain yield.[4,5]

Lentil varieties, that are adapted to differing soil types, have either shallow, intermediate or deep root systems (Figure 3). Soil texture, depth, and whether the soil cracks or not, can determine which variety suits a particular soil.

3 K McKay (undated) Growing Peas and Lentils: Key Growth Stages. Unpublished, https://www.ag.ndsu.edu/NorthCentralREC/crop-production-extension/Pea%20Growth_Stages_Considerations.pdf

4 T Gahoonia, O Ali, A Sarker, M Rahman, W Erskine (2005) Root traits, nutrient uptake, multi-location grain yield and benefit-cost ratio of two lentil (Lens culinaris, Medikus) varieties. Plant and Soil, 272(1/2), 153-161, https://repository.uwa.edu.au/R/-?func=dbin-jump-full&object_id=18937&local_base=GEN01-INS01

5 A Sarker, W Erskine, M Singh (2005) Variation in shoot and root characteristics and their association with drought tolerance in lentil landraces. Genetic Resources and Crop Evolution 52(1): 89-97, http://link.springer.com/article/10.1007%2Fs10722-005-0289-x

FEEDBACK

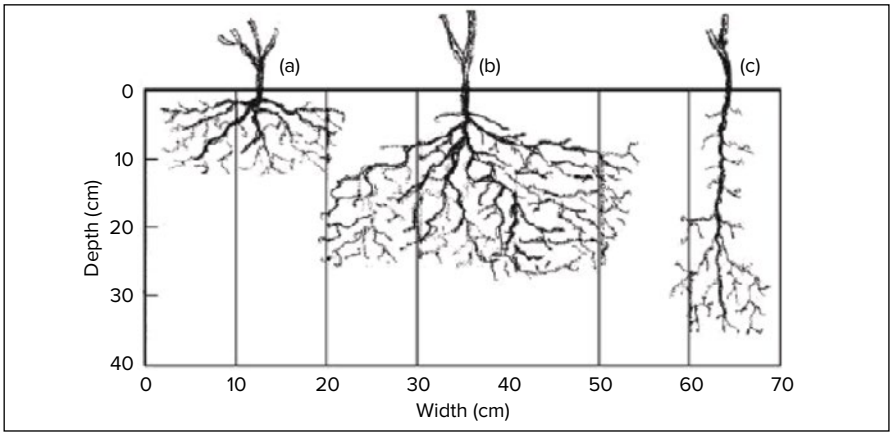

Figure 3: *Root systems in lentil.*

Source: The Lentil: Botany, Production and Uses. Centre for Legumes in Mediterranean Agriculture (2009), http://www.cabi.org/cabebooks/ebook/20093211138

The lentil varieties grown in Australia have profusely branched secondary roots that increase in size near the soil surface as the season develops. Their root systems are relatively strong, but do not penetrate to the same depths as cereal roots, especially when there are subsoil constraints.

Lentil roots are highly sensitive to saline, boron and sodic soils. Implications of this include limited root growth, root depth and moisture extraction capabilities. Yield can be severely reduced on wet, poorly drained soils, and root diseases will increase as well.

Lentil roots can 'leave' moisture at depth late in the season and this can contribute to their relatively lesser ability to withstand dry conditions. Root growth is most rapid before flowering and will continue until maturity under favourable conditions.

Lentil is susceptible to hard-pans, which are compacted layers of soil that physically restrict root growth. Lentil prefers deep, well-structured soils so that roots can penetrate deeply. Subsoil constraints, such as soil chloride in excess of about 800 milligrams per kilogram (mg/kg) soil in the top 60 cm will likely restrict root growth and water availability.

With chloride levels at over 1,000 mg/kg in the top 100 cm there is likely to be a significant negative relationship between yield and salt tolerance in lentil.

As well as their role in water and nutrient uptake, lentil roots develop symbiotic nodules with the rhizobium bacteria *Rhizobium leguminosarum*, which are capable of fixing atmospheric nitrogen. The plant provides carbohydrates for the bacteria in return for nitrogen 'fixed' inside the nodules (Photo 1).

MORE INFORMATION

For more information on soil types suited to lentil refer to Section 2: Paddock selection and preparation

FEEDBACK

Photo 1: *Nodulated roots.*

Photo: G. Cumming, formerly Pulse Australia

IN FOCUS

Root mass and penetration

Root growth of lentil is often most rapid until pod development, when seeds begin to fill. After, roots continue to grow at a much slower rate until close to crop maturity. The total root length beneath pulse crops is about 10 times smaller than in cereal crops. Root length density of pulse crops seldom exceeds 1 cm of root/cm^3 of soil, even in the surface layers. This restricted rooting density has consequences for the uptake of water by the lentil plant.[6]

Lentil roots do not produce as much biomass as chickpea or wheat plant roots.

MORE INFORMATION

The GRDC has produced fact sheets on nitrogen fixation and micronutrients. Please see: https://grdc.com.au/GRDC-FS-NFixation-Legumes

6 P Gregory (1988) Root growth of chickpea, faba bean, lentil, and pea and effects of water and salt stresses. In 'World crops: Cool season food legumes. Current Plant Science and Biotechnology in Agriculture Volume 5, 1988, pp 857-867, http://link.springer.com/chapter/10.1007/978-94-009-2764-3_68

FEEDBACK

6.3.4 Nodulation

Nodules might start appearing as early as 15 days after emergence. The taproot and lateral roots near the soil surface carry the small round or oblong shaped nodules, if the correct strain of rhizobia is present.

Nodulation by nitrogen-fixing bacteria begins at the 3rd and 4th node stage.

Peak nodule growth and development occurs at peak vegetative production, and starts to decline at the commencement of flowering, or later if adequate soil moisture is available.

Nodules eventually form slightly flattened, fan-like lobes and are nearly all confined to the top 30 cm of soil, with 90% being within 15 cm of the surface. When cut open, healthy nodules that are actively fixing nitrogen have a pink centre (Figure 5). Nitrogen fixation is highly sensitive to waterlogging so lentil needs well aerated soils.[7]

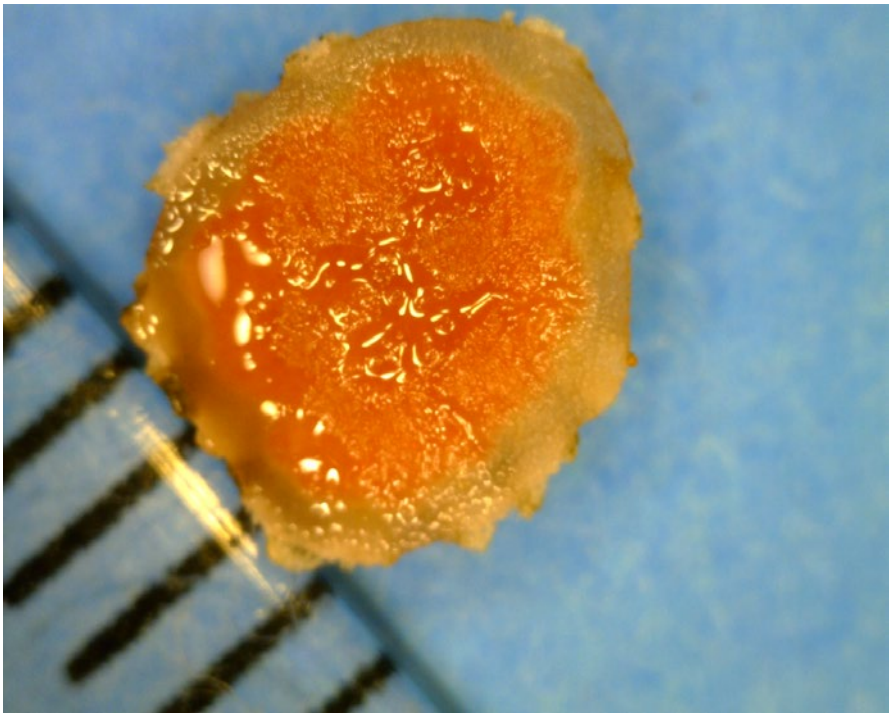

Photo 2: *Active nodules have a pink centre.*

Photo: G. Cumming, formerly Pulse Australia

7 AH Gibson (1971) Factors in the physical and biological environment affecting nodulation and nitrogen fixation by legumes. Plant and Soil. Aust J. Sci. 20 1087-1104, https://link.springer.com/article/10.1007/BF02661847

FEEDBACK

6.3.5 Nodes and leaves

The first node of the lentil plant is found below the soil surface, and sometimes the second is found below or at the ground surface. A scale or scale leaf will form at these nodes.

At the third and fourth nodes, a bifoliate leaf (two-leaflet compound leaf) will unfold.

From the fifth node on of the vegetative stages, a multifoliate leaf will unfold at each node. These multifoliate compound leaves will be made up of 9–15 leaflets.

Leaflets are not serrated. Unlike most other members of the *Lens* genus, lentil is without tendrils or rudimentary tendrils. Just prior to flowering, new leaves develop a short tendril at the leaf tip.

6.3.6 Stem and branches

Primary branches, starting from ground level, grow from buds at the lowest nodes, or plumular shoot, as well as the lateral branches of the seedling. These branches are relatively thin, and determine the general appearance and erectness of the plant. Height achieved by the main stem and branches depends on soil moisture or rainfall conditions, length of growing season, and variety.

Unlike lupin and some other pulses like chickpea, lentil does not have secondary or tertiary branches that develop from the main stem or branches.

Australian lentil varieties are indeterminate, which means vegetative growth continues initially after the plant switches to reproductive mode and flowering begins, but can terminate before moisture becomes limiting. Current Australian green lentil varieties are later maturing than red lentil varieties.

Plants normally range from 30–50 cm tall; the taller plants are a result of cool growing season temperatures, good moisture and good fertility. Plants can have single stems or many branches depending upon the population in the field.

Photo 3: *Lentil plant structure. Note basal branches, branch and then pod development as the plant grows. Note also leaves along the branch, with multiple leaflets on each leaf.*

Photo: Wayne Hawthorne, formerly Pulse Australia

FEEDBACK

Photo 4: *Lentil plant structure.*

Photo: Wayne Hawthorne, formerly Pulse Australia

6.3.7 Flowering and pod development

The beginning of the reproductive stage is marked by flowers opening at any node. In early maturing varieties, flowers will open at about the 10th to 11th nodes, while flowers of later-maturing varieties will open at the 13th or 14th nodes.[8]

Flowering begins on the lowest branches, gradually moving up the plant, and continuing until desiccation or harvest.

The node of the first flower, and the interval between successive nodes, vary depending on the month, season, variety and sowing time. Duration between nodes is particularly slow during vegetative and early reproductive stages during winter, but shorter during spring.

Each flower produces a short pod containing one or two lens-shaped seeds. Flowers can be white, lilac or pale blue in colour and are self-pollinated. At maturity, plants tend to lodge because of their weak stems.

Flowers are self-pollinated. Pods are less than 2.5 cm in length and contain one or two seeds. Most of the seed is produced on branches that form on the middle and lower nodes of the main stem, depending on variety and growing conditions.

If moisture and temperature conditions are favourable, additional crop growth, node production, flowering and, therefore, crop height occurs until flowering ceases. It is hot conditions (maximum temperatures >30°C) or lack of moisture that causes flowering and consequently, additional crop growth to cease.

If the crop is able to continue to grow taller as it flowers, it will use more soil water. Water-use efficiencies will decline under such circumstances.

8 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

FEEDBACK

Photo 5: *Lentil flowers.*

Photo: M. Raynes, formerly Pulse Australia

Photo 6: *Lentil with poor podset.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 7: *Lentil with excellent podset.*

Photo: M. Raynes, formerly Pulse Australia

Photo 8: *Well-podded lentil plants showing their basal branching habit and multiple podding nodes.*

Photo: W. Hawthorne, formerly Pulse Australia

6.3.8 Maturity

Soon after the development of pods and seed filling, senescence (drying-off) of leaves begins. If there is plenty of soil moisture, and maximum temperatures are favourable for lentil growth, flowering and podding will continue on the upper nodes. However, as soil moisture is depleted, or if temperatures increase, flowering ceases and eventually the whole plant matures. Flowering can recommence if rain follows high temperatures. This is typical of pulse crops and annual plants in general.

In warmer environments, flowering might cease and plants start to ripen in response to high temperatures, even though there could be adequate soil moisture present.

FEEDBACK

Lentil is unlike chickpea, and cannot tolerate high temperatures even if there is adequate soil moisture. Chickpea is normally one of the last pulse crops to mature in Mediterranean-type environments.[9]

Green lentil varieties in Australia are generally later maturing than red lentil varieties, although both types have a range of maturities. These large green lentil varieties will only produce to their genetic potential for seed size if they are grown in a long, cool growing season.

As leaves begin to senesce, there is a rapid re-translocation of dry matter from leaves and stems into the seeds.

In southern Australia, lentil crops can reach maturity 180 to 220 days after sowing, depending on the sowing date, variety, and a range of environmental factors including rainfall and temperature. Lentil is ready to harvest when more than 90% of the pods lose their green colour. Stems may still show some 'green-ness', however, seeds are usually hard and rattle when the plant is shaken.

Windrowing, or desiccation, of lentil crops can commence when the majority of seeds are physiologically mature. This is assessed as being when at least 50% of the seeds in the pods present in the top third of the canopy are displaying some colour change (yellow-buff) and the remaining seeds are firm to touch and a deep green colour.

As an indicator this will coincide with 60% of the pods in the top third of the canopy appearing yellow-buff.

At this stage, at least 85% of the pods should be yellow to ripe, and the top pods should have turned from a dark green colour to a lighter green to yellow colour. Cotyledons of the top-most pods change from a green colour to yellow or red, depending on the lentil type. There is still yellow to green leaf present. Lowest pods start to turn light brown and have seeds with completely normal cotyledon colour for the variety.

Photo 9: *Lentil that has matured.*

Photo: W. Hawthorne, formerly Pulse Australia

9 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

FEEDBACK

Photo 10: *Mature, well-podded lentil before their pods and stems dry for harvest.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 11: *A view from a harvester front of erect, well-podded lentil plants.*

Photo: W. Hawthorne, formerly Pulse Australia

FEEDBACK

Photo 12: *Mature lentils are a golden, light brown colour, and in this photo have been harvested (left). Note the erectness at harvest after being sown inter-row into standing cereal stubble.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 13: *This lentil grain is not yet considered physiologically mature. Note that the leaf colour has yellowed on the dry down, but pods have not yet started to dry down. Note also the small brown aborted pods in this crop.*

Photo: M. Raynes, formerly Pulse Australia

FEEDBACK

Photo 14: *Lentil pods starting to change colour from the tip as they commence to dry down towards maturity.*

Photo: M. Raynes, formerly Pulse Australia

Photo 15: *Lentil during pod-fill and before dry down.*

Photo: W. Hawthorne, formerly Pulse Australia

FEEDBACK

Photo 16: *Lentil during pod fill and starting to dry down.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 17: *Lentil drying down.*

Photo: W. Hawthorne, formerly Pulse Australia