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CHICKPEA

SECTION 4

PLANT GROWTH AND PHYSIOLOGY

GERMINATION AND EMERGENCE ISSUES (E.G. EFFECT ON SOWING DEPTH, STUBBLE IN THE PADDOCK, CHEMICAL DAMAGE) | EFFECT OF TEMPERATURE, PHOTOPERIOD, CLIMATE EFFECTS ON PLANT GROWTH AND PHYSIOLOGY | PLANT GROWTH STAGES

Plant growth and physiology

Key messages

- Under optimum moisture and temperature conditions, chickpea seeds imbibe water quickly and germinate within a few days, provided temperatures are >0°C.
- Emergence occurs 7–30 days after sowing, depending on soil moisture and temperature conditions and depth of sowing.
- Flowering is invariably delayed under low temperatures but more branching occurs.
- Chickpea in its reproductive stage is sensitive to heat stress (35/20°C or higher as day/night temperatures) with consequent substantial loss of potential yields at high temperatures. In Australia, drought stress often accompanies high temperatures in spring, causing the abortion of flowers, immature pods, and developing seeds.
- Chickpea is a photoperiod-sensitive, long-day plant, where flowering is delayed as day length becomes shorter than a base photoperiod (17 hours).
- Starting soil water can have a strong influence on the yield expectation of chickpea as well as the riskiness of production.

Chickpea, being a legume, belongs to the botanical family of Fabaceae, subfamily Faboideae. It is a semi-erect annual with a deep taproot. Worldwide, two main types of chickpea, Desi and Kabuli are cultivated. Kabuli types, grown in temperate regions, are large-seeded and mainly consumed as a whole seed, whereas Desi types, grown in semiarid tropical and subtropical regions, are mainly consumed as split dhal or turned into flour. Chickpea seed contains about 20% protein, 5% fat and 55% carbohydrates.

The phenology of most crops can be described using nine phases:

1. Sowing to germination
2. Germination to emergence
3. A period of vegetative growth after emergence, called the basic vegetative phase (BVP), during which the plant is unresponsive to photoperiod
4. A photoperiod-induced phase (PIP), which ends at floral initiation
5. A flower development phase (FDP), which ends at 50% flowering
6. A lag phase prior to commencement of grain-filling (in chickpea this period can be very long, up to two months in some cases, under cool temperature conditions (<15°C), which inhibit pod set and pod growth)
7. A linear phase of grain filling
8. A period between the end of grain-filling and physiological maturity
9. A harvest-ripe period prior to grain harvest

These stages of development are generally modelled as functions of temperature (phases 1–8) and photoperiod (phase 4).

Chickpeas are a medium-duration crop, usually beginning flowering within 90–110 days of planting, depending on photoperiod and temperature (Figure 1). Chickpea is a photoperiod sensitive, long-day plant, where flowering is delayed as day length becomes shorter than a base photoperiod (17 hours). [1]

1 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

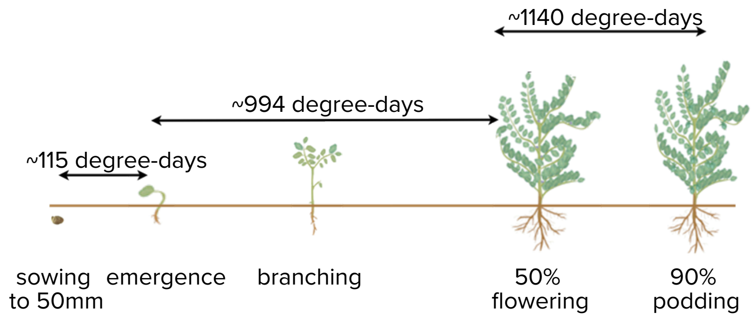

Figure 1: *Key developmental stages of chickpea and their thermal time targets.*

Source: J. Whish, CSIRO

4.1 Germination and emergence issues (e.g. effect on sowing depth, stubble in the paddock, chemical damage)

4.1.1 Germination

Good germination and seedling emergence are important prerequisites for a successful crop and soil and air temperature is one of the key factors affecting seed germination. Under optimum moisture and temperature conditions, chickpea seeds imbibe water quickly and germinate within a few days, provided temperatures are >0°C. Chickpeas will not germinate in soils with temperatures below 0°C. Generally, the longer a germinating seed of a sensitive species is exposed to a chilling temperature, the greater the injury it will sustain. Desi types generally suffer less damage from low temperatures at germination than Kabuli types. Visual symptoms of chilling injury at the seedling stage can include the inhibition of seedling growth, accumulation of anthocyanin pigments, waterlogged appearance with browning of mesocotyls, and the browning and desiccation of coleoptiles and undeveloped leaves. The main effects of chilling range temperatures on the developing seedling are related to membrane injury and include reduced respiration and photosynthesis and loss of turgor, resulting in wilting and cold-induced water stress. Exposure to chilling range temperatures during early growth of established seedlings can exert macroscopic formative effects on leaf shape and size, plant height, root development, and floral initiation. [2]

Chickpea germination is hypogeal, with the cotyledons remaining below the soil surface (Figure 2). This enables it to emerge from sowing as deep as 15 cm. In arid regions, chickpea is sown deep as surface moisture is often inadequate to allow adequate crop establishment (Photo 1). [3]

Note: Chickpea seedlings would not be able to emerge in southern Australia if sown at such depth as in Photo 1 because of low soil temperatures that occur at normal sowing times for chickpea.

2 Croser, J. S., Clarke, H. J., Siddique, K. H. M., & Khan, T. N. (2003). Low-temperature stress: implications for chickpea (*Cicer arietinum* L.) improvement. Critical Reviews in Plant Sciences, 22(2), 185-219.

3 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

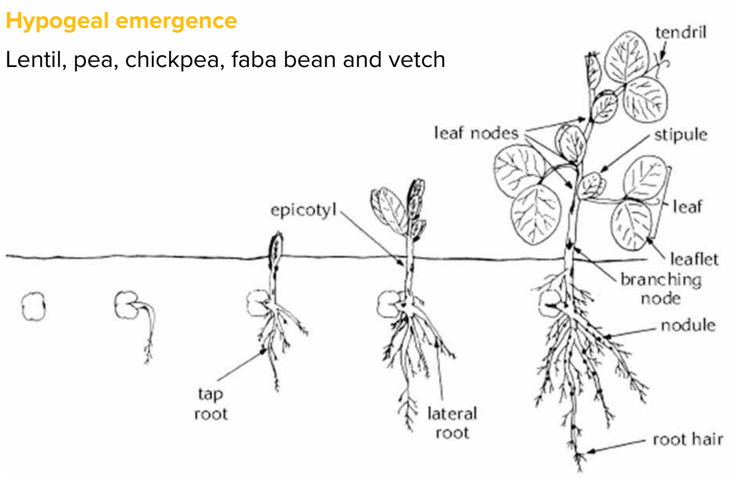

Figure 2: *Hypogeal emergence of chickpea seedlings makes the plant less prone to environmental stress and damage in the early growth stages.*

Source: Pulse Australia.

Photo 1: *A chickpea seedling, sown deep for a dry 2016 start.*

Source: Extension hub - Photo Stephen Gibson.

One of the environmental constraints for the germination is the temperature that negatively affects the seed germination. In fact, the optimum temperature for maximum final germination is between 10 and 15°C. Low temperatures are a major constraint for improving the yield of chickpea in numerous regions of the world.

In one study, all chickpea seeds were able to germinate on a wide thermal range (15–35°C). However, the thermal optimum was about 20–25°C with 80 to 100% of seeds germinated within seven days between 10 and 30°C. [4]

Salinity is one of the major stresses especially in arid and semiarid regions, which severely limits crop production. It impairs seed germination, reduces nodule formation, retards plant development and reduce crop yield. Salinity affects germination and physiology of crops due to osmotic potential which prevents water up take and by toxic effect of ions on embryo viability. [5]

One study found that small seeds germinated and grew more rapidly compared to medium and large seeds under salt stress. The study also found that though there was no effect of NaCl treatments on frequency of germination, there was a drastic decrease in early seedling growth under increased NaCl concentrations. [6]

Altered growth hormone balance during germination is another factor resulting in poor germination and seedling growth under salt stress conditions. Application of growth regulators like gibberellic acid and kinetin have been found to increase germination (32%), root (32%) and shoot (153%) dry mass of seedlings under salt stress.

Salt stress is thought to reduce germination either by making less water available for imbibition or by altering enzymatic activity, growth regulator balance or protein metabolism in germinating seeds. One study has found that pre-soaking seeds for 24 hours in normal ground/tap water (0.8 dS m-1) increased germination by 27% compared to direct sowing in saline conditions. Sowing at 4 cm depth also increased seedling growth under saline soils compared with 2 and 6 cm depths. [7]

4.1.2 Emergence

Emergence occurs 7–30 days after sowing, depending on soil moisture and temperature conditions and depth of sowing. Growth of the shoot (plumule) produces an erect shoot and the first leaves are scales. The first true leaf has two or three pairs of leaflets plus a terminal one. Fully formed leaves with 5–8 pairs of leaflets usually develop after the sixth node.

Photo 2: *Inspecting chickpea plants in the early growth stage.*

Source: GRDC.

4 Sleimi, N., Bankaji, I., Touchan, H., & Corbineau, F. (2013). Effects of temperature and water stresses on germination of some varieties of chickpea (*Cicer arietinum*). African Journal of Biotechnology, 12(17).

5 Haileselasie, T. H., & Teferii, G. (2012). The effect of salinity stress on germination of chickpea (*Cicer arietinum* L.) land race of Tigray. Current Research Journal of Biological Sciences, 4(5), 578-583.

6 Kaya, M., Kaya, G., Kaya, M. D., Atak, M., Saglam, S., Khawar, K. M., & Ciftci, C. Y. (2008). Interaction between seed size and NaCl on germination and early seedling growth of some Turkish cultivars of chickpea (*Cicer arietinum* L.). Journal of Zhejiang University SCIENCE B, 9(5), 371-377.

7 Samineni S. (2010). Physiology, genetics and QTL Mapping of Salt Tolerance in Chickpea.

IN FOCUS

Modelling seedling emergence in chickpea as influenced by temperature and sowing depth

Quantitative information about temperature and sowing depth effects on seedling emergence in chickpeas is scarce.

Six physiological days (equivalent to a thermal time of 94°C days) was required from sowing to emergence at a sowing depth of 5 cm. The physiological days requirement increased by 0.9 days for each centimetre increase in sowing depth.

Based on the results from the field and pot experiments, a seedling emergence model was constructed. This model successfully simulated emergence date (range 4–140 days) in spring, winter and 'dormant' sowing dates across Iran. Using an example for north-west Iran, it was shown how this model could be used to optimise sowing management, including the local 'dormant sowing' practice, whereby the crop is sown prior to winter for early emergence in the following spring. [8]

The node from which the first branch arises on the main stem above the soil is counted as node one. In chickpeas, alternate primary branches usually originate from nodes just above ground level (usually one to eight primary branches on the main stem, depending on growing conditions). A node is counted as developed when 6–15 leaflets have unfolded and flattened out (Photo 3). [9]

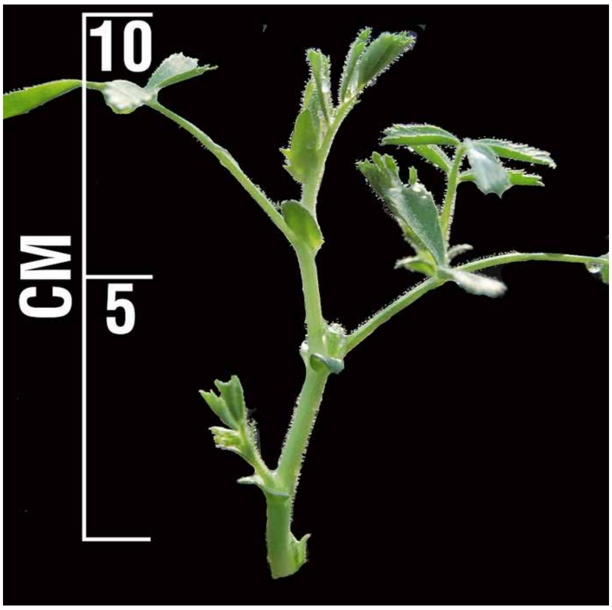

Photo 3: *Chickpea plant with four branches at 8 cm tall.*

Soil water content at sowing is an important determinant of chickpea seed emergence and early growth.

8 Soltani, A., Robertson, M. J., Torabi, B., Yousefi-Daz, M., & Sarparast, R. (2006). Modelling seedling emergence in chickpea as influenced by temperature and sowing depth. Agricultural and Forest Meteorology, 138(1), 156-167.

9 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

IN FOCUS

Effect of Soil Moisture Content on Seedling Emergence and Early Growth of Some Chickpea (*Cicer arietinum* L.) Genotypes.

A controlled glasshouse investigation at day/night temperatures of 22/15 °C was performed (in 2006) to assess the influence of different soil moisture contents (field capacity percentage basis) on emergence, as well as early plant growth in 20 chickpea genotypes.

Significant differences (P < 0.001) regarding plant emergence and early growth were observed among different soil moisture contents (from 100 to 50, then to 25% field capacity) (Figure 3 and Table 1). This brought about a reduction in mean emergence percentage, delayed the first day to emergence and suppressed the early growth in all the chickpea genotypes.

An inverse relationship between first day to emergence with plant height (r=-0.87**) and above-ground biomass (r=-0.84**) was observed, indicating that the chickpea genotypes which emerged sooner produced greater plant size. Seed size and density were found to have no relationship with plant size. Kabuli types on average germinated faster and produced larger plants as opposed to the Desi types under the limited soil moisture content. Susceptibility of the genotypes to limited soil moisture condition was shown through relatively longer delays in time to emergence (lower germination rate) and reduction in seedling parameters as compared to the resistant genotypes. Final average above-ground biomass (plant size) and plant height under the limited soil moisture content, as opposed to adequate moisture level (F. C. 25% vs. 100%), were reduced 79–85% in Kabuli and 77–79% in Desi types, respectively. [10]

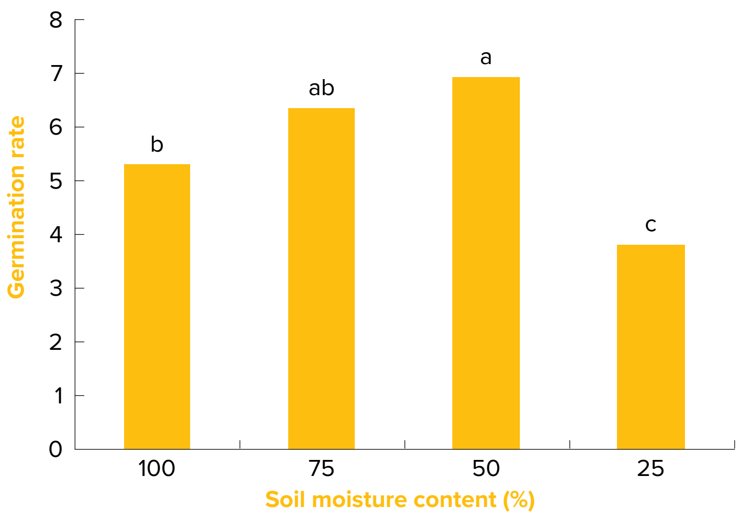

Figure 3: *Effect of soil moisture content (% field capacity basis) on germination rate (averaged over replications and genotypes).* [11]

10 Majnoun Hosseini, N., Siddique, K. H. M., Palta, J. A., & Berger, J. (2009). Effect of soil moisture content on seedling emergence and early growth of some chickpea (*Cicer arietinum* L.) genotypes. Journal of Agricultural Science and Technology, 11, 401-411.

11 Majnoun Hosseini, N., Siddique, K. H. M., Palta, J. A., & Berger, J. (2009). Effect of soil moisture content on seedling emergence and early growth of some chickpea (*Cicer arietinum* L.) genotypes. Journal of Agricultural Science and Technology, 11, 401-411.

Table 1: *Mean soil moisture effects on chickpea genotypes characteristics (averaged over genotypes and replications).* [12]

Soil moisture (%)	Emergence (%)	Time to emergence	Plant height (cm)	Branch no. per plant	Leaf area cm^2	Above-ground biomass (g $plant^{-1}$)	Specific leaf areas (cm^2 g^{-1})
100	78.4	3.8	20.2	4.5	102.6	0.98	178
75	86.4	6.2	19	4.4	81.8	0.83	164.8
50	83.7	7.9	14.4	3.5	41.6	0.54	131.3
25	56.5	13.9	3.7	1	2.5	0.21	37.3
l.s.d. (P = 0.05)	10.8	1.06	2.3	0.4	23.3	0.2	11.4

For more information on the effects of drought stress, see Section 14: Environmental issues.

4.2 Effect of temperature, photoperiod, climate effects on plant growth and physiology

During their growth, crop plants are usually exposed to different environmental stresses which limit their growth and productivity.

Figure 4 shows crop biomass is driven by:

- the capacity of roots to capture water and nutrients, chiefly nitrogen and phosphorus (black arrow in Figure 4);
- the capacity of canopies to capture radiation and carbon dioxide used in photosynthesis (green arrow in Figure 4);
- the efficiency of the crop to transform resources (water, nutrients, radiation, carbon dioxide) into dry matter (red arrow in Figure 4).

Crop growth and yield depends on the ability of crops to capture above ground and soil resources, and on the capacity of crops to transform these resources into biomass. Environmental factors, such as ambient temperature or soil salinity, modulate the rate of capture of resources and the efficiency in the transformation of resources into plant biomass and these are illustrated by the dashed lines in Figure 4. [13]

12 Majnoun Hosseini, N., Siddique, K. H. M., Palta, J. A., & Berger, J. (2009). Effect of soil moisture content on seedling emergence and early growth of some chickpea (*Cicer arietinum* L.) genotypes. Journal of Agricultural Science and Technology, 11, 401-411.

13 V Sandras, G McDonald. GRDC. (2012). Water Use Efficiency of grain crops in Australia: principles, benchmarks and management.

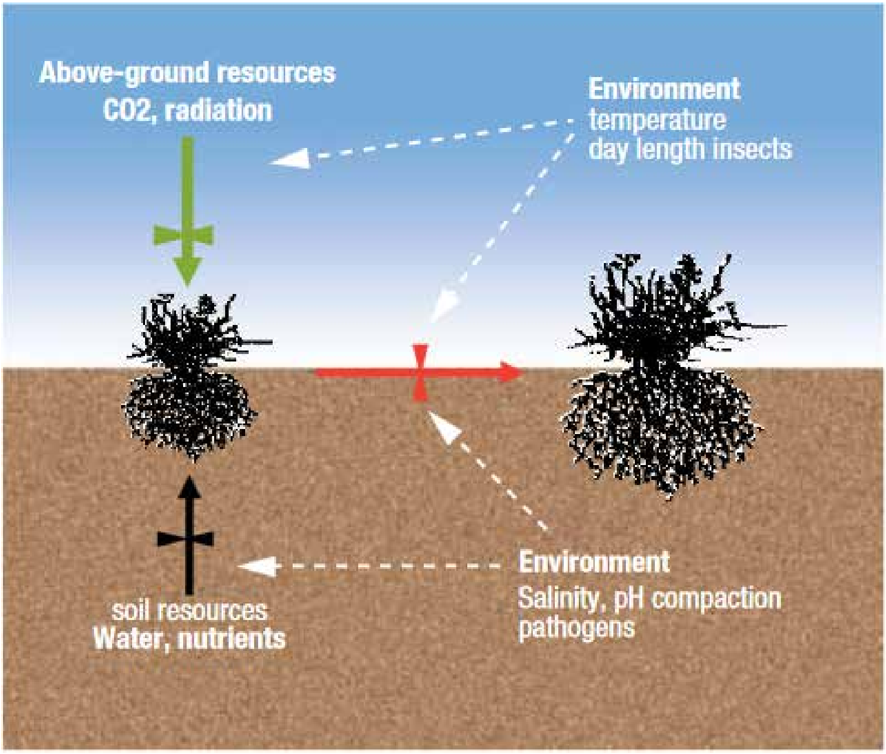

Figure 4: *Factors that drive crop biomass.*

Source: GRDC.

Temperature, day length, and drought are the three major factors affecting flowering in chickpeas. Temperature is generally more important than day length.

4.2.1 Temperature

The timing of flowering is an important trait affecting the adaptation of crops to low-rainfall, Mediterranean-type environments (such as southern Australia), and seed yields of many crops in these areas have been increased by early sowing and the development of early-flowering varieties.

Cold temperatures

Air temperature and photoperiod have a major influence on the timing of reproductive events in chickpeas, with the rate of progress to flowering being a linear function of mean temperature. Flowering is invariably delayed under low temperatures but more branching occurs. [14]

Crop duration is highly correlated with temperature, such that crops will take different times from sowing to maturity under different temperature regimes. Chickpeas, unlike other cool season legumes, are very susceptible to cold conditions, especially at flowering, and any advantage derived from early flowering is often negated by increased flower and pod abortion.

Experiments have shown that the average day/night temperature is critical for flowering and pod set, rather than any specific effects of maximum or minimum temperatures. Pods at a later stage of development are generally more resistant to frost than flowers and small pods, but may suffer some mottled darkening of the seed coat.

The critical mean or average daily temperature for abortion of flowers in most current varieties is <15°C. Abortion occurs below this temperature because the pollen

14 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

becomes sterile and reproductive structures do not develop. Flowers may develop below this temperature but they contain infertile pollen. [15]

In many chickpea crops, it is not until temperatures rise in late August and September that pod set and seed-filling commence. When temperatures rise, true flowers develop within 3–4 days. Even after the production of true flowers, periods of low temperature may result in further flower and pod abortion at intermittent nodes on the stems.

Pollen germination and vigour is also affected by chilling range temperatures. [16]

Sub-zero temperatures in winter and spring can damage leaves and stems of the plant. Frosts can cause bleaching of leaves, especially on the margins, and a characteristic 'hockey-stick' bend in the stem (Photo 4). However, chickpeas have an excellent ability to recover from this superficial damage and is able to regenerate new branches in severe cases.

Photo 4: *Frost can cause bends like a hockey stick in chickpea stems.*

Photo S. Loss, DAFWA.

Late frosts also cause flower, pod, and seed abortion (Photo 5). Pods at a later stage of development are generally more resistant to frost than flowers and small pods, but may suffer some mottled darkening of the seed coat. Empty pods appear bleached and are known as "ballons". They pop when squeezed.

15 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

16 Croser, J. S., Clarke, H. J., Siddique, K. H. M., & Khan, T. N. (2003). Low-temperature stress: implications for chickpea (*5.6* L.) improvement. Critical Reviews in Plant Sciences, 22(2), 185-219.

Photo 5: *Frost can cause pod abortion (usually low on the stem) but the plant may set many pods late in the season if conditions are favourable.*

Photo: T. Knights, NSW DPI.

NOTE: The impacts of low air temperatures will be moderated by topography and altitude, i.e. there will be warmer and cooler areas in undulating country.

For more information, see Section 14: Environmental issues.

Heat stress

Chickpea in its reproductive stage is sensitive to heat stress (32/20°C or higher as day/night temperatures) with consequent substantial loss of potential yields at high temperatures. Temperatures >35°C in spring may also reduce yield in chickpea, causing flower abortion and a reduction in the time available for seed filling. Chickpea, however, is considered more heat-tolerant than many other cool-season grain legumes. The anthers of heat sensitive genotypes have been found to have reduced synthesis of sugars due to inhibition of the appropriate enzymes. Consequently, affected plant pollen can have considerably lower sucrose levels resulting in reduced pollen function, impaired fertilisation, and poor pod set in the heat sensitive genotypes. [17]

In Australia, drought stress often accompanies high temperatures in spring, causing the abortion of flowers, immature pods, and developing seeds. On the other hand, high levels of humidity and low light also prevent pod set.

Chickpea pollen grains are more sensitive to heat stress than the stigma. High temperatures have been found to reduce pollen production per flower, amount of pollen germination, pod set, and seed number. [18]

High air temperatures during the period from flowering to maturity have also been found to reduce the time to maturity of late-sown chickpea and lead to reduced seed size and lower yields. [19]

Chickpea can tolerate high temperature if there is adequate soil moisture, and it is usually one of the last grain legume crops to mature in Mediterranean-type environments.

For more information, see Section 14: Environmental issues.

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17 Kaushal, N., Awasthi, R., Gupta, K., Gaur, P., Siddique, K. H., & Nayyar, H. (2013). Heat-stress-induced reproductive failures in chickpea (*Cicer arietinum*) are associated with impaired sucrose metabolism in leaves and anthers. Functional Plant Biology, 40(12), 1334-1349.

18 Devasirvatham, V., Gaur, P. M., Mallikarjuna, N., Tokachichu, R. N., Trethowan, R. M., & Tan, D. K. (2012). Effect of high temperature on the reproductive development of chickpea genotypes under controlled environments. Functional Plant Biology, 39(12), 1009-1018.

19 Sivakumar, M. V. K., & Singh, P. (1987). Response of chickpea cultivars to water stress in a semi-arid environment. Experimental agriculture, 23(01), 53-61.

4.2.2 Photoperiod

Photoperiod is one of the major environmental factors determining time to flower initiation and first flower appearance in plants. In chickpea, photoperiod sensitivity (expressed as delayed to flower under short days (SD) as compared to long days (LD)) may change with the growth stage of the crop. Chickpea is a photoperiod sensitive, long-day plant, where flowering is delayed as day length becomes shorter than a base photoperiod (17 h). Progress towards flowering is rapid during long days (17+ h) and flowering is delayed but never prevented under short day (<17 h) conditions. [20]

IN FOCUS

Determination of Photoperiod-Sensitive Phase in Chickpea (*Cicer arietinum* L.).

For one day-neutral cultivar, there was no significant difference in the number of days to flowering of the plants grown under SD and LD as well as subsequent transfers. In photoperiod-sensitive cultivars, three different phenological phases were identified: a photoperiod-insensitive pre-inductive phase, a photoperiod-sensitive inductive phase, and a photoperiod-insensitive post-inductive phase.

The photoperiod-sensitive phase extends after flower initiation to full flower development. Results from this research will help to develop cultivars with shorter pre-inductive photoperiod-insensitive and photoperiod-sensitive phases to fit to regions with short growing seasons. [21]

4.2.3 Water and moisture

About 90% of chickpeas in the world are grown under rainfed conditions where drought is one the major constraints, limiting its production. Drought affects various morphological and physiological processes, resulting in reduced growth, development and economic yield of crop. Water stress has prominent effect on leaf number, total leaf area, and secondary branches, causing invariable reduction under rainfed conditions. Several studies have shown that optimum yield can be obtained by irrigation at branching, flowering, and pod formation stages.

The reactions of plants to water stress vary depending upon intensity and duration of stress, as well as plant species and its stage of growth. Stress during vegetative phase reduce grain yield through reducing plant size, restricting leaf area, dry matter accumulation and limiting number of pods. However, water deficits at the flowering and the post flowering stages have been found to have greater adverse impact than at the vegetative stage. [22]

Starting soil water can have a strong influence on the yield expectation of chickpea as well as the riskiness of production.

Yields are best in areas with reliable winter rainfall for crop growth and mild spring conditions during seed filling. Chickpea is well suited to well-drained, non-acidic soils with medium to heavy clay texture. [23]

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20 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

21 Daba, K., Warkentin, T. D., Bueckert, R., Todd, C. D., & Tar'an, B. (2016). Determination of Photoperiod-Sensitive Phase in Chickpea (*Cicer arietinum* L.). Frontiers in plant science, 7.

22 Randhawa, N., Kaur, J., Singh, S., & Singh, I. (2014). Growth and yield in chickpea (*Cicer arietinum* L.) genotypes in response to water stress. African Journal of Agricultural Research, 9(11), 982-992.

23 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

Soon after the development of pods and seed-filling, senescence of subtending leaves begins. If there is plenty of soil moisture and maximum temperatures are favourable for chickpea growth, flowering and podding will continue on the upper nodes. However, as soil moisture is depleted, flowering ceases and eventually the whole plant matures. This is typical of grain legumes and annual plants in general.

Research has indicated that unlike other winter pulses under mild moisture stress, chickpeas are capable of accumulating solutes (sugar, proteins, and other compounds) in their cells, thereby maintaining stomatal conductance and low levels of photosynthesis. This process is known as osmoregulation.

Chickpeas can access moisture to 90 cm depth provided there is no compaction or saline/sodic layers or boron in the soil profile.

IN FOCUS

Growth and yield in chickpea (*Cicer arietinum* L.) genotypes in response to water stress.

Twenty chickpea genotypes were grown under rainout shelter to investigate the influence of water stress treatments imposed at varied growth stages.

The maximum reduction in height and branches was observed when irrigation was restricted at T2 stage. Restricted irrigation decreased the biomass of stem, leaves and roots leading to reduced leaf area and leaf area index as well. The yield traits viz. 100 seed weight, total number of pods, percentage filled pods were reduced significantly under stress. The grain yield under restricted conditions was reduced by 40.50 to 55.91% over irrigated control in T4 to T2, respectively. [24]

4.2.4 Drought stress

Chickpea has been shown to be one of a number of pulses that is suited to the fine textured, neutral-to-alkaline soils of the eastern cropping zone of southern Australia. Pulses are subjected to terminal drought in this environment. Studies have shown that pollination and pod development are inhibited by low temperatures in chickpea, thus under the winter conditions present in southern Australia, pod set and seed filling are delayed until spring when leaf photosynthetic rates are low as a consequence of soil water depletion.

One of the major consequences of this is that terminal drought reduces the size of the seed, particularly in late-formed seeds. As seed size and uniformity are important in determining the market price, particularly in Kabuli chickpeas, any variation among genotypes in maintaining seed size under conditions of terminal drought will be important in breeding for improved yield and quality in chickpeas for drought-prone environments.

24 Randhawa, N., Kaur, J., Singh, S., & Singh, I. (2014). Growth and yield in chickpea (*Cicer arietinum* L.) genotypes in response to water stress. African Journal of Agricultural Research, 9(11), 982-992.

IN FOCUS

Seed growth of Desi and Kabuli chickpea in a short-season Mediterranean-type environment

The influence of terminal drought on the seed growth of three chickpea genotypes was examined in a field experiment in south-western Australia. Tyson, a small-seeded Desi cultivar, ICCV88201, a Desi breeding line (sister line to the recently released Sona cultivar) with medium-sized seed, and Kaniva, a Kabuli cultivar with large seed, were grown under rainfed and irrigated conditions.

Genotypic differences in the maximum rate of seed fill were found to exist in chickpea. Both the rate and duration of seed growth were reduced in the rainfed plants, regardless of genotype. Reductions in the dry weight of the pod shell suggest that the remobilisation of dry matter from the pod may contribute 9–15% of the seed weight in rainfed chickpea. [25]

For more information about factors affecting chickpea growth, see Section 14: Environmental Issues.

4.3 Plant growth stages

Photo 6: *Newly established chickpea plant.*

ABC Rural, Jodie Gunders.

The chickpea crop germinates, matures, senesces, and dies within 100–225 days from sowing, depending on environmental conditions before and after flowering, the magnitude of seed yield, and the rate and synchrony of seed filling (Photo 6). [26]

25 Davies, S. L., Turner, N. C., Siddique, K. H. M., Leport, L., & Plummer, J. A. (1999). Seed growth of desi and kabuli chickpea (*Cicer arietinum* L.) in a short-season Mediterranean-type environment. Animal Production Science, 39(2), 181-188.

26 Croser, J. S., Clarke, H. J., Siddique, K. H. M., & Khan, T. N. (2003). Low-temperature stress: implications for chickpea (*Cicer arietinum* L.) improvement. Critical Reviews in Plant Sciences, 22(2), 185-219.

Photo 7: *Chickpea growth and development from germination to two months. Plants may vary according to variety and environment.*

Photo: H. Clarke, UWA.

The chickpea plant is erect and freestanding, usually 15–60 cm in height, although well-grown plants may grow to 80 cm. The plants have a fibrous taproot system, a number of woody stems forming from the base, upper secondary branches and fine, frond-like leaves. Chickpeas are considered very indeterminate in their growth habit; i.e. their terminal bud is always vegetative and keeps growing, even after the plant switches to reproductive mode and flowering begins. [27]

Early research indicates that chickpea seed yield can be reduced by 81% and straw yields by 63% when fields remained weed infested until harvest, compared with weed-free conditions throughout the growing season. The critical period of weed interference has been suggested to be between 35 and 49 days after emergence in chickpea. [28]

Another study expanded on this research and found that chickpea must be kept weed-free between the five-leaf and full flowering stages (24–48 DAE) and from the four-leaf to beginning of flowering stages (17–49 DAE) in order to prevent >10% seed yield loss. [29]

The chickpea growth stages key is based on counting the number of nodes on the main stem (Table 2). Uniform growth stage descriptions were developed for the chickpea plant based on visually observable vegetative (V) and reproductive (R) events. The V stage was determined by counting the number of developed nodes on the main stem, above ground level. The last (uppermost) node counted must have its leaves unfolded. The R stages proposed begin when the plant begins to flower at any node.

27 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

28 Al-Thahabi, S. A., Yasin, J. Z., Abu-Irmaileh, B. E., Haddad, N. I., & Saxena, M. C. (1994). Effect of weed removal on productivity of chickpea (*Cicer arietinum* L.) and lentil (Lens culinaris Med.) in a Mediterranean environment. Journal of Agronomy and Crop Science, 172(5), 333-341.

29 Mohammadi, G., Javanshir, A., Khooie, F. R., Mohammadi, S. A., & Zehtab Salmasi, S. (2005). Critical period of weed interference in chickpea. Weed research, 45(1), 57-63.

Table 2: *Growth stages of a chickpea plant (Nolan 2001).*

Designation	Growth stage	Description
Vegetative growth stage (V-stage) in chickpeas		
VG	Germination	Cotyledons remain underground inside the seed coat and provide energy for rapidly growing primary roots (radicle) and shoots
VE	Emergence	The plumule emerges and the first two leaves are scales. The first true leaf has two or three pairs of leaflets plus a terminal leaflet
V1	First node	Imparipinnate (terminal unpaired) leaves attached to the first node are fully expanded and flat while the 1st imparipinnate leaf attached to the upper node starts to unroll
V2	Second node	1st imparipinnate leaf attached to the second node is fully expanded and flat while the 2nd imparipinnate leaf on the upper node starts to unroll
V3	Third node	2nd imparipinnate leaf attached to the third node is fully expanded and flat while the 3rd imparipinnate leaf on the upper node starts to unroll. The bulk of the yield is found on the branches stemming from the first three nodes
V(n)	N-node	A node is counted when its imparipinnate leaf is unfolded and its leaflets are flat
Reproductive growth stage (R-stage) in chickpea		
R0	False flowering	In the transition from vegetative to include reproductive growth, a number of false flowers (called pseudo flowers) may develop from the axillary buds. These flower buds lack fully developed petals and typically appear if flowering is triggered before mean temperatures are high enough for true flowers to develop, especially if soil has high moisture content coinciding with flowering, which enables it develop a bigger canopy
R1	Start flowering	One flower bud at any node on the main stem (see p. 5 in 'The chickpea book', Loss *et al.* 1988)
R2	Calyx opening	Bud grows but is still sterile, sepals begin to form
R3	Anthesis	Pollination occurs before the bud opens
R4	Wings extend	Flower petals extend to form a flower
R5	Corolla collapses	Flower collapses and petals senesce and peduncle reflexes so that the developing pod usually hangs below its subtending leaf
R6	Pod initiation	One pod is found on any node on the main stem
R7	Full pod	One fully expanded pod is present that satisfies the dimensions characteristic of the cultivar
R8	Beginning seed	One fully expanded pod is present in which seed cotyledon growth is visible when the fruit is cut in cross-section with a razor blade. (Following the liquid endosperm stage)
R9	Full seed	One pod with cavity apparently filled by the seeds when fresh
R10	Beginning maturity	One pod on the main stem turns to a light golden-yellow in colour

Designation	Growth stage	Description
R11	50% golden pod	50% of pods on the plant mature
R12	90% golden pod	90% of pods physiologically mature (golden yellow), usually about 140–200 days after planting depending on season and cultivar

For populations, vegetative stages can be averaged if desired. Reproductive stages should not be averaged.

A reproductive stage should remain unchanged until the date when 50% of the plants in the sample demonstrate the desired trait of the next reproductive (R) stage. The timing of a reproductive stage for a given plant is set by the first occurrence of the specific trait on the plant, without regard to position on the plant (Photo 8). [30]

Photo 8: *Growth habit of a chickpea plant.*

4.3.1 Leaves

Leaves in chickpeas are alternate along the branch (Photo 9). The first true leaf has two or three pairs of leaflets plus a terminal one. Fully formed leaves, with 5–8 pairs of serrated leaflets (10–16 leaflets), usually develop after the sixth branch (node) stage. Leaflets can fold slightly in dry conditions to minimise transpiration. Despite having more leaves and branches than other legume crops such as faba beans, canopy development in chickpeas is slow, especially during the cool winter months.

30 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited

Photo 9: *Alternate leaves along the branch, with multiple leaflets on each leaf.*

Photo: G. Cumming, Pulse Australia

The entire surface of the plant shoot, except the flower, has a thick covering of glandular hairs (trichomes) that secrete a strong acid (mostly malic acid), particularly during pod-set (Photo 10). The malic secretions from all vegetative surfaces of the plant seem to play a role in protecting the plant against pests such as red-legged earth mite, lucerne flea, aphids, and pod borers. Similar substances are also secreted from the root system and can solubilise soil-bound phosphate and other nutrients. The acid also corrodes leather boots.

Photo 10: *Green pods covered in glandular hairs excreting acid.*

Source: LloydslistAus.

4.3.2 Roots

Chickpea root systems are usually deep and strong, and contribute to the ability to withstand dry conditions. The plant has a taproot with few lateral roots. Root growth is most rapid before flowering but will continue until maturity under favourable conditions. Although rare, in deep well-structured soils, roots can penetrate more than 1 m deep (Photo 11); however, subsoil constraints such as soil chloride >800 mg/kg soil in the top 60 cm will restrict root growth and water availability.

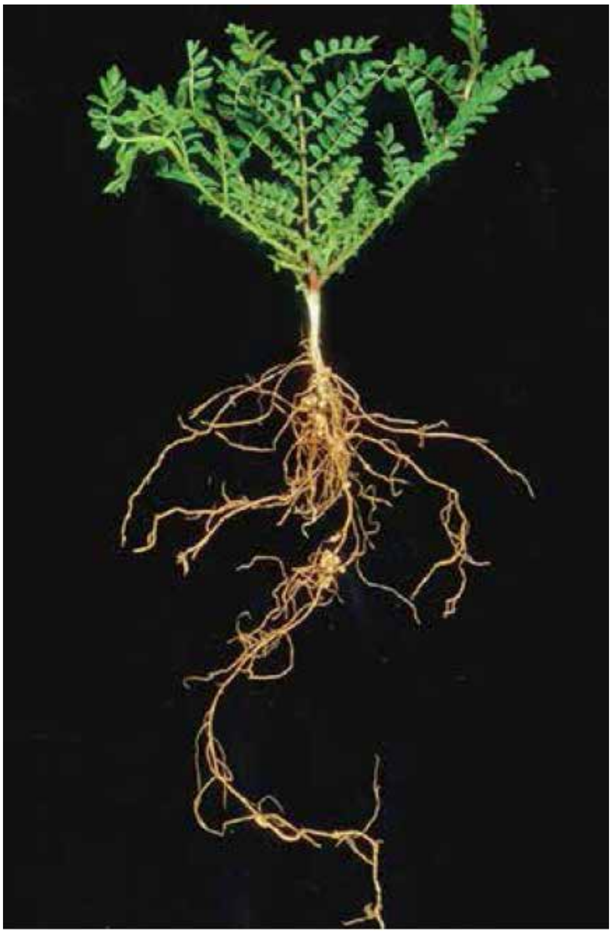

Photo 11: *Chickpea usually has a deep tap root system.*

Photo: P. Maloney, DAFWA.

As well as their role in water and nutrient uptake, chickpea roots develop symbiotic nodules with the Rhizobium bacteria, capable of fixing atmospheric nitrogen. The plant provides carbohydrates for the bacteria in return for nitrogen fixed inside the nodules. Chickpea plants can derive more than 70% of their nitrogen requirement from symbiotic nitrogen fixation.

These nodules are visible within about a month of plant emergence, and eventually form slightly flattened, fan-like lobes (Photo 12). Practically all nodules are confined to the top 30 cm of soil and 90% are within the top 15 cm of the profile. When cut open, nodules actively fixing nitrogen have a pink centre. Nitrogen fixation is highly sensitive to waterlogging so it is essential that chickpea crops are grown on well-aerated and drained soils. [31]

31 Pulse Australia. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

Photo 12: *Well-nodulated chickpea plants.*

Photo: G. Cumming, Pulse Australia

4.3.3 Branches

Primary branches, starting from ground level, grow from buds at the lowest nodes of the plumular shoot as well as the lateral branches of the seedling. These branches are thick, strong, and woody, and they determine the general appearance of the plant (Figure 5). The main stem and branches can attain a height of about 40–100 cm. Kabuli varieties are generally taller than Desi varieties.

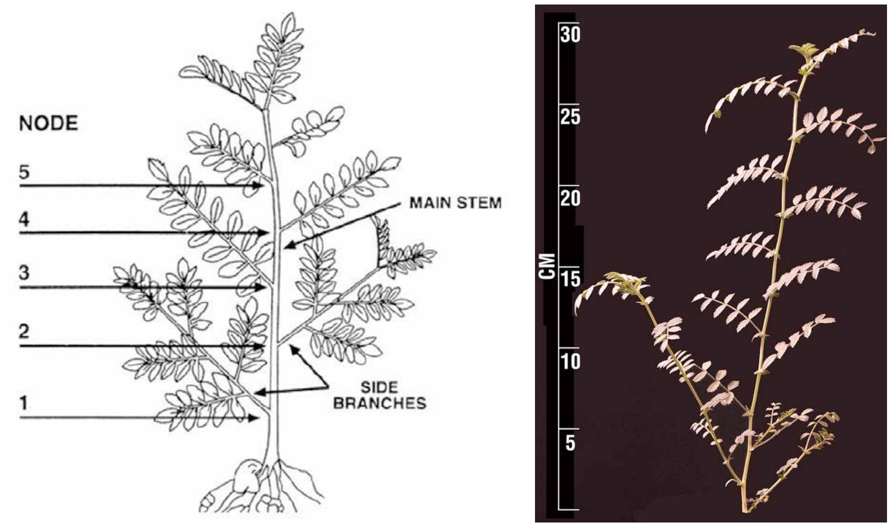

Figure 5: *Chickpea at the 5–7-node stage of development, prior to flowering.*

Secondary branches are produced by buds on the primary branches. They are less vigorous but contribute to a major proportion of the plant yield. Tertiary branches growing from buds on secondary branches are more leafy and carry fewer pods. The number of primary branches can vary from one to eight depending upon the variety and growing conditions. In chickpeas, five branching habits based on angle of branches from the vertical are classified: erect, semi-erect, semi-spreading, spreading, and prostate. Most modern varieties are erect or semi-erect, to enable mechanical harvesting. The final height of the plant is highly dependent on environmental conditions and the variety being grown, but in general, can range from 50 to 100 cm. [32]

4.3.4 Flowering

Growth in chickpeas is often described as 'indeterminate'. This means that branch and leaf (or vegetative) growth continues as the plant switches to a reproductive mode and initiates flowering. Hence, there is often a sequence of leaf, flower bud, flower and pod development along each branch (Photo 13).

The onset and duration of flowering in chickpea are functions of genotype, photoperiod, and temperature. Flowering is indeterminate and can extend for up to 60 days with leaf initiation and stem elongation continuing into the reproductive period. [33]

Photo 13: *Different stages of flower development on the same chickpea branch.*

Photo K. Siddique, DAFWA.

Chickpea is peculiar among pulses in that a number of pseudo-flowers or false flower buds develop during the changeover from leaf buds to flower buds on the stem. Therefore, there could be a period of ineffective flowering when pod set does not occur.

In warmer tropical and subtropical environments, this period is minimal but in cooler temperate–subtropical environments, it can be as long as 50 days. Flowering commences on the main stem and lower branches and proceeds acropetally at intervals averaging 1.5–2 days between successive nodes along each branch. The bulk of the yield is found on the branches stemming from the first three nodes.

The fruit develops in an inflated pod containing 2–4 ovules, of which one or two usually develop into seeds. At any location, seasonal variations in temperature can bring about a significant shift in flowering times (i.e.±10 days from the figures quoted

32 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

33 Croser, J. S., Clarke, H. J., Siddique, K. H. M., & Khan, T. N. (2003). Low-temperature stress: implications for chickpea (*Cicer arietinum* L.) improvement. Critical Reviews in Plant Sciences, 22(2), 185-219.

below). In general, warmer temperatures hasten development. Chickpeas will tolerate higher temperatures during flowering than peas or lupins. Cool wet conditions at flowering can adversely affect seed set.

Petals are generally purple in the Desi type and white-to-cream in the Kabuli type (Photo 14). Purple-flowered Desi types generally contain high amounts of the red pigment anthocyanin, and their leaves, stems and seed coats are generally dark. By contrast, the white-flowered Kabuli types lack anthocyanin, have light green leaves and stems, and pale seeds. Increased pigmentation is evident following environmental stresses such as low temperature, salinity, waterlogging, drought, and virus infection, especially in Desi types.

Photo 14: *Desi chickpea purple flower (left) and Kabuli chickpea flower (right). Kabuli chickpeas lack anthocyanin, hence their white flowers.*

Photos: G. Cumming, Pulse Australia.

Pollination takes place before the flower bud opens in chickpea, when the pollen and the receptive female organ are still enclosed within a fused petal, called the keel (Table 3 and Photo 15). Natural crosspollination has been reported; however, most studies indicate 100% self-pollination.

Table 3: *Stages of pollen development in chickpea grown at 25/18°C day/night temperatures (12 hour daylength).* [34]

Description of bud	Time before anthesis (days)	Stage of pollen development
Microscopic bud (<0.5 mm)	9	Pre-meiotic microspore mother cells
Very small bud (0.75 mm)	7-8	Early stages of first division meiosis
Small bud (1 mm)	6	Late first division, second division meiosis and early tetrads
Small bud (1.5 mm)	4-5	Late tetrads and microspore release
Sepals much larger than petals	3	Vacuoles appear and mitosis occurs; generative and vegetative nuclei and sperm cells visible
Sepals slightly larger than petals (petal visible)	2	Maturation, starch accumulation
Sepals same length at petals	1	Mature pollen, vacuoles disappear
Hooded flower	Anthesis	Mature dry pollen

34 Clarke, H. J., & Siddique, K. H. M. (2004). Response of chickpea genotypes to low temperature stress during reproductive development. Field Crops Research, 90(2), 323-334.

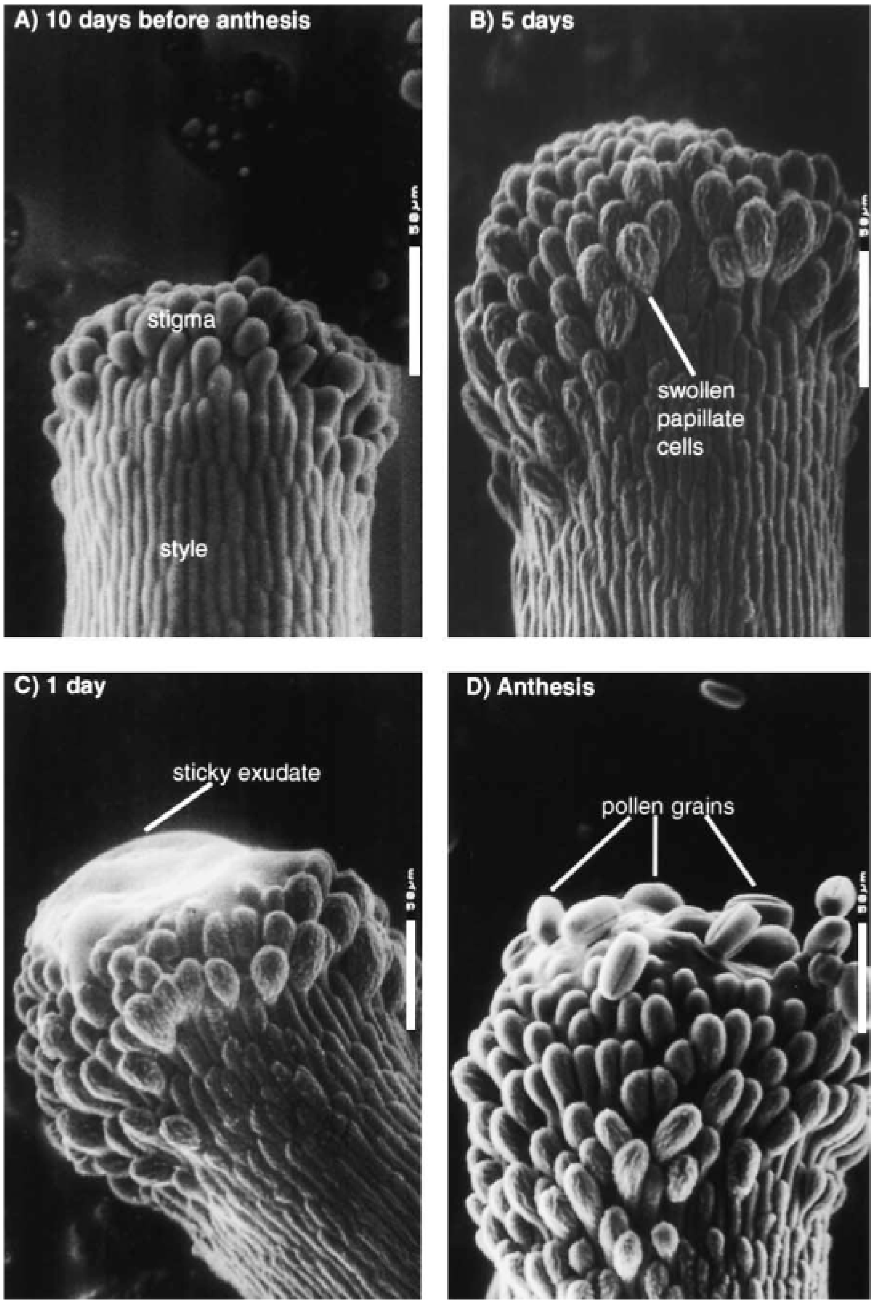

Photo 15: *Development of the style and stigma in chickpea buds from 10 days before anthesis to the fully reflexed flower when plants were grown at 25/18°C, 12 hour daylength. A low temperature regime of 12/7°C increased the time for the same development from 10 to 20 days.* [35]

Flower terminals normally develop from the axillary bud at the base of each node. Flowers are borne on a jointed peduncle that arises from nodes. Flowers are primarily self-pollinated, with most reports measuring 100% self-pollination.

Chickpea plants generally produce many flowers. However, ~30% do not develop into pods, depending upon the variety, sowing date and other environmental conditions.

35 Clarke, H. J., & Siddique, K. H. M. (2004). Response of chickpea genotypes to low temperature stress during reproductive development. Field Crops Research, 90(2), 323-334.

4.3.5 Podding

Initial stages of seed development involve the pod wall expanding rapidly—in chickpea achieving its maximum dry weight while the embryo is very small and is in a phase of cell division. Seed growth is then characterised by a high rate of metabolic activity associated with the rapid, linear accumulation of dry matter, principally as starch and storage protein. At the end of this phase, a period of dehydration and maturation follows, by which time there is little endosperm left, with the embryo filling the seed coat. The maximum potential size of a seed is a function of the rate and duration of embryo growth. Environmental factors such as temperature and water availability affect seed growth rate and final seed size. [36]

Under favourable temperature and soil moisture conditions, the time taken from fertilisation of the ovule (egg) to the first appearance of a pod (pod set) is about six days (Figure 6). The seed then fills over the next 3–4 weeks (Figure 7). Once a pod has set, the jointed peduncle of the senescing petals reflexes, so that the developing pod hangs beneath its subtending leaf. After pod set, the pod wall grows rapidly for the first 10–15 days, and seed growth mainly occurs later.

Figure 6: *Chickpea podding (left) and chickpea plant seven weeks before harvest (right).*

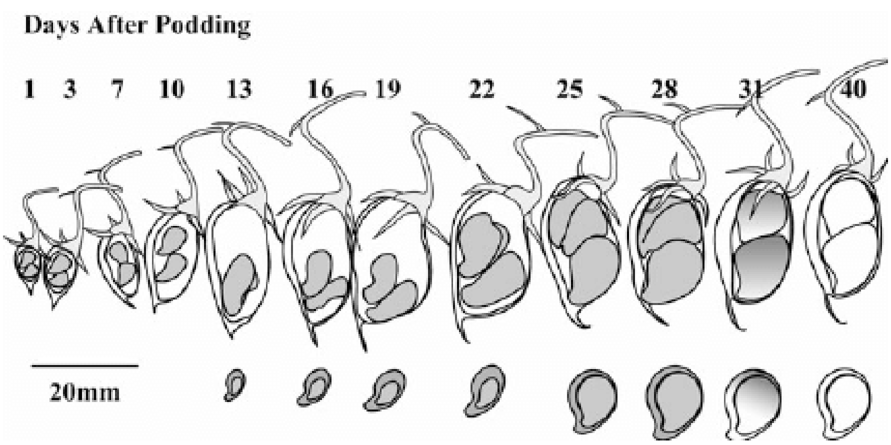

Figure 7: *Seed and pod development in chickpeas, showing the relative sizes of the pod, seed coat, embryo, and the internal pod gas volume.* [37]

36 Davies, S. L., Turner, N. C., Siddique, K. H. M., Leport, L., & Plummer, J. A. (1999). Seed growth of desi and kabuli chickpea (*Cicer arietinum* L.) in a short-season Mediterranean-type environment. Animal Production Science, 39(2), 181-188.

37 Furbank, R. T., White, R., Palta, J. A., & Turner, N. C. (2004). Internal recycling of respiratory CO_2 in pods of chickpea (*Cicer arietinum* L.): the role of pod wall, seed coat, and embryo. Journal of Experimental Botany, 55(403), 1687-1696.

Chickpea pods vary greatly in size between varieties. Pod size is largely unaffected by the environment. By contrast, seed filling and subsequent seed size are highly dependent on variety and weather conditions.

Seeds are characteristically 'beaked', sometimes angular, with a ridged or smooth seed coat. Seed colour varies between varieties from chalky white to burgundy and brown, to black, and is determined by the colour and thickness of the seed coat and the colour of the cotyledons inside. Seeds vary from one to three per pod.

In southern Australia, chickpea crops can reach maturity 140–200 days after sowing, depending on the sowing date, variety, and a range of environmental factors including temperature. Chickpeas become ready to harvest when 90% of the stems and pods lose their green colour and become light golden-yellow. At this point, the seeds are usually hard and rattle when the plant is shaken (Photo 16). [38]

Photo 16: *Physiologically mature grains 'rattle pod'.*

Photo: G. Cumming, Pulse Australia.

38 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.