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Chickpea Disease Management Strategy

Southern Region

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Summary of strategies to minimise disease in chickpea

- **Variety selection** is critical. Ideally grow an ascochyta resistant variety.
- **Paddock isolation** from chickpea stubble is a high priority (greater than 500m).
- **Paddock history.** Aim for a break of at least 4 years between chickpea crops
- **Seed source.** Use seed from a paddock where disease was not detected.
- **Fungicide seed dressing** is effective and should be used, especially in high disease risk situations.
- **Sowing date.** Do not sow too early, even with an ascochyta resistant variety.
- **Sowing depth.** If using an ascochyta susceptible variety, sow deeper than normal.
- **Sowing rate.** Aim for 35-50 plants per square metre, depending on the situation and crop type (kabuli or desi).
- **Hygiene.** Reduce disease sources and prevent spread of disease.
- **Foliar fungicides.** Ascochyta resistant varieties still require foliar fungicide at podding. Success is dependent on monitoring, timeliness of spraying and correct fungicide choice. Early detection and correct disease identification are essential.
- **Manage aphids and virus.** Ground surface cover, healthy plants and crop canopy are important. Control aphids at their source (host) crop.
- **Harvest management**. Harvest early to minimise disease infection of seed. Crop desiccation enables even earlier harvest.

1. Knowing the disease

Disease management of chickpea in southern areas should primarily focus on ascochyta blight (*Ascochyta rabiei*), without ignoring botrytis grey mould (*Botrytis cinerea*), sclerotinia, phoma blight, other seedling root diseases (*Pythium spp, Fusarium spp and Rhizoctonia spp*). Some viruses and pratylenchus root lesion nematode (*Pratylenchus neglectus, P. thornei*) can affect chickpea. Phytophthora root rot is a most damaging disease in northern NSW and Queensland, but is not considered a problem in southern areas.

Ascochyta blight (*Ascochyta rabiei)* can attack the plant at any growth stage. Ascochyta resistance in a variety does not mean immunity, but does delay ascochyta onset and fungicide applications. Ascochyta can be seed-borne, attacking the seedling from emergence. First symptoms are small water-soaked pale spots on younger leaves. With wet conditions the small spots (lesions) enlarge and join with other lesions to blight leaves and buds. Small black spots (pycnidia) can be seen within the lesions. Stem lesions can form which often girdle the stem resulting in stem death above the lesion and breakages. Round, sunken lesions, with pale centres and dark margins can form on pods later in the season. The fungus can penetrate the pod wall and infect the seed. Severe pod infection can result in reduced seed set and discoloured seed. Infected plants will partially recover by re-shooting below stem lesions. Crop losses are worse in wet springs in crops with dense canopies. The fungus can carryover on infected stubble and so crop hygiene is important in removing old chickpea stubbles and avoiding paddocks that had chickpea less than 4 years previously.

Photo: Ascochyta pod and leaf lesions (SARDI).

Strategic fungicide use is needed, even in ascochyta resistant varieties, so it is important to implement an integrated approach to disease management through variety, seed quality, seed dressings, paddock selection and crop management. Varieties like PBA Slasher and Genesis 090 that are resistant to ascochyta blight still require a foliar fungicide application at early podding to protect seeds and ensure high seed quality. A repeat application may be necessary in a prolonged wet spring.

Photo: Stem breakage from ascochyta lesion (SARDI).

Photo: Botrytis grey mould on chickpea leaves (SARDI).

Photo: Ascochyta ;leaf lesions (SARDI).

Varieties like Kalkee, Genesis 114 or Almaz with intermediate resistance (moderately susceptible to moderately resistant) to ascochyta blight will still require 3 to 4 foliar fungicide applications during vegetative stages as well as during podding to protect yield and seed quality. If still growing an ascochyta susceptible variety like Howzat or Kaniva, then 4 to 10 fungicide sprays may be needed throughout the growing season, and timing is critical in this high risk situation. Crop hygiene becomes even more important. Early sowing of that susceptible variety would need to be avoided. Deeper sowing will help reduce emergence of seedlings from infected seed.

Botrytis grey mould *(Botrytis cinerea)* can attack the plant at any growth stage. It can be seed-borne, attacking the seedling during emergence and causing root rot on the upper taproot and collar. Affected areas develop a soft rot and a fluffy grey mould. Botrytis grey mould (BGM) as a seedling blight can reduce seedling establishment significantly if infected seed is sown without a fungicide dressing. Later in the season significant crop losses can occur during wet spring conditions particularly in crops with dense canopies. Control grey mould by using seed from disease free crops, applying a seed dressing and using foliar fungicides. Fungicides such as chlorothalonil or mancozeb applied to control ascochyta may give some protection against BGM, but better control will be achieved by using more effective products for BGM and applications during flowering to protect flowers and subsequent pods.

Photo: Botrytis grey mould on basal stem (SARDI).

Sclerotinia has occasionally caused significant crop losses in chickpea in eastern Australia, but tends to be sporadic. It may first appear during very wet conditions in July. The disease is readily identified as white mycelial growth on infected plant tissue, which later produces small, black survival bodies called sclerotia. It is favoured by cool, wet conditions in winter and spring. Control is by using disease free seed and by crop rotation with cereals and other non-host crops.

Phoma blight causes foot rot and brown-black lesions on the lower stem and leaves. The pathogen can survive in soil, on infected seed and on crop residue. This disease has potential to be a serious disease in a wet growing season. Pod infection can occur, and the pathogen can then penetrate the pod wall and infect developing seeds. Phoma blight is managed through use of disease free seed and crop rotation with non-host crops such as cereals and oilseeds. Fungicide seed dressings can help reduce the disease but may not eliminate it.

Root Lesion Nematode (either *Pratylenchus thornei* or *P. neglectus)* is considered a disease, but is a nematode that multiplies on the roots of chickpea plants causing stunting of roots. They may reduce the growth and yield of chickpea and the following cereal crop. Newer chickpea variety releases are considered to be far less susceptible to root lesion nematode than old varieties like Desavic that contributed to a poor reputation for chickpea and root lesion nematode multiplication. Chickpeas are however generally considered more susceptible to multiplying root lesion nematodes than are field peas, beans, lentils and lupins, but less than wheat.

Photo: Phoma blackening of basal stem (SARDI).

Root rots and damping off are caused by fungi living in the soil, such as *Pythium* spp. They can reduce emergence and grain yield, particularly in kabuli varieties. These diseases are managed with seed dressings.

Viruses most prevalent in chickpea are beet western yellows (BWYV), which is not seed transmitted, and cucumber mosaic virus (CMV) which is seed transmitted. Both are spread by aphids. A healthy crop with a closed canopy or adequate early ground cover will reduce aphid numbers landing in the crop and so reduce virus infection. Where possible, aphids must be controlled at their source before they enter the chickpea crop.

2. Disease carry-over and on–farm hygiene (post harvest - pre sowing)

Seed retained on-farm should be as free of ascochyta as possible. Protect seed crops with fungicides at podding.

Ascochyta and botrytis grey mould carry from one season to the next on infected chickpea stubble, infected seed, or volunteer plants. Control volunteer chickpeas pre seeding to limit build-up of disease inoculum for the new crop.

Particularly with ascochyta susceptible varieties, undertake a program of stubble reduction where this will not create an erosion risk (eg chop, bury, destroy, graze or burn infected crop residue).

Photo: Root lesion nematode effects (J. Thompson QDPI).

Infected stubble may also be carried by wind, water and machinery at harvest. Clean all machinery, transport equipment and storage silos with compressed air before moving to the next paddock.

3. Paddock selection

Close proximity to chickpea stubble and volunteer chickpea plants should be avoided. Do not sow adjacent to chickpea stubble, particularly downwind. Aim to separate by a distance of at least 500 m.

Be aware that self-sown chickpeas or early sown chickpea crops may be a source of ascochyta spread into adjacent, later sown chickpea crops.

A break of at least 4 years between chickpea crops is usually required to minimise soil inoculum. In paddocks that grew faba bean, chickpea, vetch, lathyrus, field pea, medic or clover pastures two years previously, there is a slight risk of phoma *(Phoma medicaginis var pinodella)*, sclerotinia or botrytis grey mould attacking chickpea.

There is a greater risk of Grey Mould in chickpea if sown downwind from a crop or infected stubble of lentils or faba beans.

Observe the maximum plant-back period for sulphonylurea herbicides (eg Glean®, Logran®), Lontrel®, triazines and imidazolinones (eg Spinnaker®). Herbicide residues may increase susceptibility to virus and disease.

Paddocks with low soil fertility or nutrient status can lead to stress, predisposing the chickpeas to disease.

4. Varieties

Yield and marketability, along with disease resistance, are the major factors to consider in variety choice (table 2). Varieties resistant to ascochyta are not immune to that disease, and may suffer some production losses or grain quality damage under high disease pressure.

5. Seed

Select seed of the highest possible purity, germination and disease free status. For ascochyta susceptible varieties, use seed with nil disease infection because ascochyta epidemics can be

initiated by very low levels of seed infection. Ascochyta infected seed will often fail to emerge, but can act as a source of disease when transported to new districts.

Botrytis grey mould can occur on seed and significantly affect establishment if not treated with a fungicide seed dressing.

Seed retained on-farm should be from the 'cleanest' paddock or section. Select the area early, apply fungicides at podding and harvest it before any other chickpeas to prevent contamination from other diseased chickpea crops.

If seed is more than one year old, frosted, weather damaged or diseased, its germination and vigour may have deteriorated. This may increase its susceptibility to disease attack.

Re-test seed for germination percentage before sowing if retained in silos for more than one year.

6. Seed dressing

No chickpea variety is resistant to seed infection by ascochyta or botrytis grey mould. Kabuli types and all ascochyta susceptible varieties should be treated with a seed dressing. All ascochyta resistant varieties, desi or kabuli, will benefit from a seed dressing to protect against botrytis and other seedling rots (table 3 and fungicide section). Seed dressings may have a deleterious effect upon rhizobia, particularly under acid soil conditions, so minimize the contact time between these. Check the inoculum label. Either apply seed dressing first, then separately mix the inoculum and apply it to the seed immediately before sowing, or consider using granular or liquid injection inoculums.

7. Sowing date

Sow within optimum times for the region (table 1)

With ascochyta resistant varieties, sow at traditional sowing dates (table 2). Delayed sowing for ascochyta reduction is not necessary in those varieties.

With ascochyta susceptible varieties, delayed sowing has been a most important strategy for ascochyta management. It reduces the duration of exposure of chickpea seedlings to ascochyta spores. It will not help though if self-sown chickpeas are nearby. Be aware though that delayed sowings can result in lower yields due to increased risks of dry finishes and high temperatures during podding.

In all varieties, sowing too early can lead to poor early pod set or seed fill if flowering in a colder period (less than 15^0 C mean daily temperature).

Early sowing can produce increased vegetative growth and may increase lodging, which will increase the risk of grey mould incidence particularly in the larger plant types.

In a disease prone area or higher risk situation, sow at the later end of the recommended optimum for the district.

Table 1. Sowing times for ascochyta resistant chickpea varieties[A].

Region (annual rainfall)	Month	May				June				July			
	Week	1	2	3	4	1	2	3	4	1	2	3	4
Less than 400 mm – SA/Vic													
Less than 400 mm – southern NSW													
400-450 mm – SA/Vic													
400-450 mm – southern NSW													
450-500 mm – SA/Vic													
450-500 mm – southern NSW													
500–600 mm[B] – SA/Vic													
500–600 mm[B] - southern NSW													

Marginal areas or low disease risk areas

Preferred planting time for ascochyta resistant varieties.

For high disease risk areas or ascochyta susceptible varieties

[A] Sowing time varies with the variety flowering date and maturity rating.

[B] Preferred sowing time for spring-sown chickpea in south-eastern Australia is August-September

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Photo: Ascochyta susceptible (R) vs resistant variety (L) (Pulse Australia).

Photo: Ascochyta susceptible variety with stem lesion (Pulse Australia).

Table 2: Disease resistance rating[A] of current chickpea varieties.

Disease rating[A]	Ascochyta		Grey mould	Phytophthora	Root lesion nematode *P. Neglectus*		Root lesion nematode *P thornei*	
	Foliage / stem	Pod			Tol[A]	Res[A]	Tol[A]	Res[A]
R	**PBA Slasher,** Genesis 079, **Genesis 090,** Genesis 425, **Genesis 509**, Genesis 510	-	-	-	Yorker	-		Kyabra
				PBA HatTrick, Yorker				
MR	**PBA Boundary[B], PBA HatTrick[B]**	-	-		Howzat, Kaniva	-	Kaniva, Yorker	Jimbour
MR-MS	Flipper[B]	-	-	Jimbour	-	-	Howzat	Howzat
MS	Genesis 836, Sonali, Yorker **Kalkee[B], Genesis 114[B],** Nafice[B], **Almaz[B]**	-	Howzat, Genesis 509 Jimbour	**PBA Boundary,** Kyabra, Flipper, Howzat	Jimbour,	-	Jimbour, Kyabra	Kaniva
S	Howzat[B] Jimbour, Kyabra, Kaniva	-	Genesis 836	Nafice, Almaz	-	-	-	Yorker
		All current varieties	**Genesis 090**, Yorker, Flipper, Nafice, **Almaz**	Genesis 090, Genesis 836	-	-	-	-
			Kaniva	Kaniva	-	-	-	-

[A] National ratings as supplied by Pulse Breeding Australia (PBA) 2012: R = Resistant, MR = moderately resistant, MS = moderately susceptible, S = Susceptible, Tol = tolerance (no yield loss), Res = resistance (no increase in nematode population).
[B] Note ascochyta blight ratings revised for these varieties 2012.

Table 3. Chickpea fungicide seed treatments and the diseases they control.

	Seed treatment			
Active ingredient	Thiram	Thiram + Thiabendazole (TBZ)	Metalaxyl-M	Metalaxyl
Fungicide group	2	M3 & 1	4	4
Example products	Thiragranz®, Thiram®600, Thiraflo®, Thiram®	P-Pickel T®, Fairgro®, Reaper® TT	ApronXL®	Mantle®, Mantle® flowable, Rampart®
Active ingredient	Thiram 800 g/kg or 600 g/L	Thiram 360 g/L + TBZ 200 g/L	Metalaxyl-M 350 g/L	Metalaxyl 350 g/kg or 322 g/L
Rate (per 100kg seed)	125-150 g or 170 to 200 ml	200 ml	75 ml	150 g
Disease controlled				
Botrytis grey mould	√	√	-	-
Ascochyta	√ **(NAP)**	√	-	-
Phytophthora	-	-	√	√
Seedling root rot	√	√	-	-
Always read the label. ® = registered trademark. **NAP** = not all products registered for this disease,				

8. Sowing rate

Aim for 35-50 plants per square metre, depending on the situation and crop type (kabuli or desi). Higher seeding rates lead to greater canopy vigour, increased lodging and higher humidity, and under ideal growing conditions can increase the risk of botrytis grey mould.

Avoid double sowing headlands. A denser crop can be more prone to disease establishment and lodging.

Seeding at rates below the minimum recommended plant population will have minimal impact on fungal disease incidence, but reduce potential yield and increase harvest losses. A lower seeding rate may increase aphid landing, hence virus infection.

See your local regional production guidelines for seeding rate recommendations.

9. Row spacing

Wider row spacing does not reduce ascochyta incidence in chickpea, but could reduce the occurrence of grey mould. It may also allow better fungicide penetration and cover.

Use of wider row spacing with chickpea sown into standing stubble is part of an overall farming system targeting water use efficiency, weed control and harvestability rather than specifically disease control.

10. Chickpea virus

Chickpea crops in South Australia and Victoria are prone to Beet western yellows virus (BWYV) which on occasions has been devastating. It is not seed-borne. Cucumber mosaic virus (CMV) has also been present, and it can occasionally express as a major problem. It is seed-borne. Where chickpea crops have experienced heavy losses from viral infection, it has mostly been in association with prolonged, high levels of aphids that arrived early from nearby. There is often an association between virus susceptibility and: thin plant populations; bare ground; or plants that were stressed by factors such as herbicide damage, transient wet conditions, phoma; or/and slow growth from cold conditions. Lack of virus under cold conditions is most likely associated with low aphid numbers.

Important factors that predispose pulse crops to severe virus infection are:

- Close proximity to a substantial build up of aphids or resevoir (eg in lentil, canola, lucerne, summer weeds).
- High summer-autumn rainfall and the subsequent uncontrolled multiplication of aphids on host species nearby. Aphids do not colonise chickpea, but fly in and out, spreading virus as they probe.
- Infected chickpea seed.
- Early aphid flights to newly emerged crops cause early infection and economic loss as infected plants act as a reservoir for further spread of infection within the crop.
- Thin plant populations with bare ground.

Virus control

Virus risks can be managed by combining a number of different control measures:

Suppress the virus source within the crop by sowing seed with less than 0.1% seed infection.

Control volunteer weeds during summer and autumn in and nearby where chickpea is to be sown.

Ensure chickpea plants are less attractive to aphids by minimising seedling diseases, herbicide damage or poor nutrition.

Decrease aphid landing rates through having stubble cover and/or a dense early canopy. Note that high seeding rates and narrow row spacing to provide early canopy closure assists in aphid control, but conflicts with other fungal disease and crop moisture management systems.

Note that seed treatment of imidacloprid is not registered in chickpea for early aphid protection.

Control aphids in nearby host crops to prevent an aphid population build up before they enter the chickpea crop. Only apply insecticide for virus control in the chickpea crop if it is considered to be at high risk. Insecticide aimed at controlling damage from aphid feeding are normally applied too late to control virus spread.

Photo: Beet Western Yellows Virus (Pulse Australia).

Photo: Chickpeas in wide rows are less vulnerable to aphids if sufficient stubble is present (Pulse Australia).

Photo: BWYV virus in chickpeas in wide rows where previous herbicide damage and minimal stubble (Pulse Australia).

11. Disease monitoring and control periods

Disease impact is greatly reduced when a fully integrated disease management program is initiated before seeding and maintained through the growing season. A crop is considered to be at high risk if a susceptible variety is grown, crop rotation is tight, it is sown adjacent to chickpea stubble, sown early or where all integrated management strategies cannot be followed. Potentially critical periods for disease development in chickpea are in the early vegetative stages (for ascochyta susceptible varieties), flowering and during seed fill. The decision to spray or not will

depend on the variety resistance and the disease risk for the individual crop. Disease monitoring should start at 6-8 weeks after emergence if a susceptible crop since regular fungicide applications will be necessary in these varieties.

Ascochyta *(Ascochyta rabiei)*
A seed treatment containing thiram (Thiragranz® or Thiraflo ST®) or thiram plus thiabendazole (P-Pickel T®) is essential to control seed-borne infection.
Chlorothalonil is the more effective foliar fungicide for ascochyta, and only Unite® 720 and Barrack® 720 are registered for this use. Mancozeb and metiram can also provide some protection from ascochyta if timeliness of application is observed; eg mancozeb might give protection for a fortnight compared to chlorothalonil which could protect for 21 days. Efficacy differences between products can arise if ascochyta is present. Protective fungicide sprays should be applied 1-3 days ahead of rainfall to prevent infection spreading during the rainy period. No new ascochyta infection will occur during dry periods, so fungicide application can be held off until rain (>5mm) is forecast. Do not wait until after the rain.

With ascochyta resistant varieties like PBA Slasher, Genesis 090 or Genesis 079, spraying for ascochyta before the podding stage is unlikely to be needed, especially if no ascochyta lesions are present. A single application of chlorothalonil at podding may be sufficient for grain protection in these more resistant cultivars. A repeat application should only be necessary in severe and extended disease pressure situations (rainfall during spring combined with presence of disease in the crop).

Photo: Ascochyta leaf lesions (Pulse Australia).

Photo: Botrytis grey mould (L) on chickpea seed (SARDI).

Botrytis grey mould *(Botrytis cinerea)*
If infected seeds are sown, botrytis seedling blight can reduce plant establishment throughout the growing season. Seed treatment containing thiram (Thiragranz®, Thiraflo ST® , Thiraflo FF® or Thiram®) or thiram plus thiabendazole (P-Pickel T®, Fairgro®, or Reaper®TT) will control seed-borne infection.

Warm, humid conditions under a dense crop canopy in spring are ideal for the spread of grey mould. Carbendazim or procymidone are most effective against a botrytis grey mould (BGM) epidemic. Use of chlorothalonil, mancozeb or metiram as a foliar spray for control of ascochyta has the added benefit of providing some protection and control of grey mould. Applications targeted at ascochyta during podding might however be too late for BGM protection of flowers.

Phytophthora root rot
(Phytophthora megasperma)
Unlike northern Australia, phytophthora is not usually an issue in the southern region. The disease can be reduced by seed treatments containing metalaxyl (Apron XL® , Rampart® or Mantle®).

Foliar Fungicide Application Guide: – all environments
Consider the variety grown, potential crop yields, rainfall zone and disease risk when deciding on fungicide use.

Treat chickpea seed with a seed dressing, particularly kabuli varieties, to protect against seedling root rots as well as to provide early protection against ascochyta blight. Where there is a high risk of ascochyta (ie adjacent chickpea stubbles, early sown, close rotations), treat seed for ascochyta protection, irrespective of variety.

With ascochyta resistant varieties (PBA Slasher, Genesis 090, Genesis 509), only consider applying an early foliar fungicide for ascochyta if the disease is present. A foliar fungicide applied ahead of rain during podding will likely be required to protect grain quality. Varieties with resistance to ascochyta require less and later fungicide applications for ascochyta control. This reduction in fungicide use may expose the crop to a higher risk of grey mould infection etc.

With varieties that are intermediate in ascochyta resistance (eg Kalkee, Genesis 114, Almaz, Genesis 836), three to four strategic foliar fungicide applications for ascochyta control will be necessary in many areas. Apply a fungicide early, before the disease is detected pre-flowering. Strategic applications will likely be needed at the commencement of flowering, early podding and late podding. Timing of the protective application is critical, as control is less effective if the fungicide is applied after the disease has taken hold.

Table 4. Foliar fungicides registered for chickpea and the diseases they control.

Product	Active ingredient and (Group)	Rate	Disease	
			Botrytis grey mould	***Ascochyta blight***
Barrack®, Barrack® Betterstick, Unite® 720	Chlorothalonil 720 g/L….**(M5)**	1.1-2.0L/ha	**R**	√
Dithane Rainshield® Neo Tec, Manfil® Manzate® DF, Manzeb®, Unizeb® Penncozeb750DF®,various Mancozeb	Mancozeb 750 g/kg **(M3)**	1.0-2.2 kg/ha*	√	√
Penncozeb 420SC®	Mancozeb 420g/L…….. **(M3)**	1.8-3.95 L/ha	-	√
Many	Mancozeb 750 or 800g/kg **(M3)**	Not Registered	-	-
All others, including Bravo® - Weather Stik®, various Chlorothalonil	Chlorothalonil 720 g/L, 900 g/kg or 500 g/L **(M5)**	Not Registered	-	-
Howzat®, Spinflo®, Boomer®, Carazim®, Motac®, Shincar®, Goldazim®, Various Carbendazim	Carbendazim 500 g/L **(1)**	500 mL/ha	√	-

With ascochyta susceptible varieties (eg Howzat, Kaniva, Sonali), regular foliar fungicide applications for ascochyta control will be necessary in all areas. Apply a fungicide before the disease is detected, from emergence through flowering until 4 weeks before maturity. Starting early with protective applications is critical. Control is often ineffective if fungicide is applied after the disease has taken hold.

A fungicide program needs to account for:
Disease risk categories, based on:

- Varietal susceptibility or resistance
- Source of seed and treatment of seed
- Planting proximity to chickpea crops in the previous season
- Level of ascochyta inoculum present from crop residue or volunteer plants
- Climatic conditions in relation to disease infection.

Registration status: The product must be registered or have a permit for the disease and use.

Withholding period: All products and timings used in the fungicide program must meet Australian withholding periods and export slaughter intervals.

Fungicide resistance management: Adhere to the maximum number of sprays of a product to minimise the risk of fungicide resistance developing.

Mode of action: To further reduce the chance of fungicide resistance development and to improve efficacy, use products with a range of mode of actions. Fungicides are also recommended at times of the disease life cycle where they will be most effective according to their mode of action.

and cost effective.

12. Early harvest

Harvest at maturity to minimise ascochyta seed infection and potential down grading. Seed damage from ascochyta is usually more severe when crops are harvested late. Moisture content allowable on delivery is 14%. Harvest losses, seed splitting and downgrading in quality can be substantial if chickpea is harvested at below 12% moisture.

Chickpea crop desiccation assists in early harvest. Care is needed in desiccating because of the late maturity of chickpea. Do not crop-top or prematurely desiccate as it can affect grain quality, particularly kernel or seed coat colour.

Early harvest will give the best chance of achieving number 1 grade chickpea receival standard, in which there is a maximum of 1% poor colour (due to disease, water staining, weathering or frost).

13. References

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