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This document provides some background information about different plant species to ensure the best outcome in your cover cropping pursuit. As this document matures, it is intended to add a farmer comment section beneath each plant summary so please let Jenny Stanton know of field learnings whether they are good or bad. As a reminder the following evaluations are based on a species' suitability as a cover crop, rather than for its cash crop performance.

There are a series of tables at the end of this document that summarise the key plant traits.

CHECKLIST:

- Herbicide residues/plantback implications. Please see the table below.

| Crop | Herbicide Residue | | | | | | |
|------------------------------|-------------------|-------------------------|---------------------------|--------------------------------|-------------|-----------------|-------------|
| | SUs | Clopyralid (Lontrel) | Sakura (pyroxasulfone) | Boxer Gold (profluroxycarb) | Atrazine | Imis | Propyzamide |
| Sunflower | No | No | Yes | Yes | No | No ² | Yes |
| Safflower | Yes | No | Yes ³ | Yes | Trace OK | Yes | Yes |
| Corn | No ₁ | Yes | Yes | Yes | Yes | No ² | No |
| Sorghum | No | Yes | Trace OK | Yes | Yes | No | No |
| Millet | No | Yes | No | Yes | Yes | No | No |
| Sunn Hemp | No | No | Yes | Yes | Trace OK | Trace OK | Yes |
| Cowpeas/Lablab/ Mungbeans | No | No | Yes | Yes | Trace OK | Trace OK | Yes |

No¹ – Glean (chlorsulfuron), Logran (triasulfuron), Ally (metsulfuron) etc are SUs (sulfonylureas) and will damage corn. However, others SUs like nicosulfuron are safe and registered on corn outside of Australia.

No² – Clearfield corn and sunflowers will tolerate all Imi (imidazolinone) herbicides at high rates.

Yes³ – Limited trial data suggests safflower can tolerate reasonably high rates of Sakura residues.

Table courtesy of Wayne Smith – Agronomic Acumen August 2018 Newsletter

- What are you hoping to achieve/goals of the paddock?
 - Reduce compaction
 - Boost soil nitrogen levels – slow release N source
 - Hasten stubble break down (maybe a summer legume)
 - Break disease and pest cycle e.g. slugs/snails,
 - Dry out the soil profile to reduce waterlogging (high rainfall zone)
 - Fix non-wetting soil
 - Increase soil rooting depth i.e. grow topsoil down
 - Combat herbicide resistant weed issues and difficult to manage weeds
 - Perhaps get lime at depth via the tillage radish root channels
- Crop rotation and potential disease risk. Don't grow brassicas (e.g. tillage radish/turnip/forage rape) in front of canola due to disease and also aphids. Don't grow corn before wheat due to risk of fusarium head blight
- Ability to sow winter crop through summer cover crop residues and likewise summer crop into winter crop residues. Disc machines better at sowing into living plants but high green bridge risk. High herbage loads from sorghum or millet may present hair pinning issues especially when sowing canola. Discs conserve more moisture when sowing in spring/summer.

Considerations

- Cost effective seed source.
- Seed availability – suppliers and location. Sometimes bird seed suppliers are a good contact for cheap sunflower, millet and corn seed. Leads are Greenpatch Ag <https://www.greenpatch.net.au/>, Yankalilla Seeds <https://yankalillaseeds.com.au/>, AGF Seeds <https://agfseeds.com.au/>, Pasture Genetics <http://pasturegenetics.com/>. *(Suppliers are examples, many others are available. Examples provided are not endorsed)*
- Mixing seed and inoculating the legumes - easier to buy pre-inoculated seed.
- All legumes must be inoculated - freshly inoculated seed whether it be peat or freeze dried needs to be sown inside 24 hours.
- Terminate before seed set so that accumulated nutrients can be recycled for the following crop.
- Sowing - disc vs tyne vs aerial seeding. If sowing by ground, then resources needed (labour, fuel) to sow straight after the winter crop is harvested.
- Sowing – differences in seed size. Small seed will settle to the bottom of the air seeder bin. Aim for sowing depth of 2.8-3cm.
- Green bridge considerations
- Holy Grail – have a self-regenerating cover crop so as to not have to resow annually. Maybe a perennial could fit this criteria especially for pasture. But - does this mean it has become a weed?
- If sowed too early in a weedy paddock e.g. ryegrass, will emerge and run to seed before the cover crop can outcompete the ryegrass.
- Potential weed threats that can compromise sowing a multi species cover crop, e.g. caltrop. However, it is possible that the cover crop could reduce caltrop emergence due to shading.
- Termination and management is important.

Potential Covers

♣ = sow into warming soils ♦ = sow into cooling soils

BRASSICAS

♣ ♦ **Canola (winter types)** (*Brassica napus*) - Requires cold temperatures (vernalisation) to initiate flowering which provides a wide sowing window from early spring through to early autumn mainly for the high rainfall zone. Sowing in early spring requires care in choosing the correct sowing time to avoid accruing part of the crop's requirement for vernalisation in the first spring. Premature vernalisation could lead to early flowering in the following season thereby exposing the crop to severe frost risk. Advantage of being able to be grazed by livestock. Reports of greater build-up of slugs when canola grown for 14 months. Seed costs ~\$25/kg. Open pollinated varieties ~\$10/kg.

♣ ♦ **Forage Brassica/Rape** (*Brassica napus* var. *napus*) – Small seeded, highly palatable to livestock. Residue is low in carbon to nitrogen ratio (C:N) and so doesn't provide long lasting residue but does quickly return its nutrients to the soil. If spring sown, it will not run to flower until the following winter. Most types have a stringent grazing management requirement and must reach maturity before being grazed. Maturity is indicated by a change in leaf colour to a purplish or bronze colour that occurs 10-14 weeks after sowing depending on variety. Grazing prior to this is the major cause of several livestock health problems. As well, livestock must be introduced to forage rape gradually. Vulnerable to diamondback moth attack. Sow at 2-4 kg/ha. ~\$10/kg.

♣ ♦ **Tillage radish/Daikon radish** (*Raphanus sativus*) – Large tuber taproot that fractures restriction layers and heavy compacted soils, increasing water infiltration, soil tilth and oxygen exchange. Short term fodder option (10-12 weeks) with first grazing in 5-6 weeks, and 2-3 grazings possible prior to maturity. Produces very palatable feed, appropriate for all cattle and sheep. Maximum fodder and tuber development occurs when sown after the longest day (eg Jan/Feb); autumn tuber development also very good. Can also be sown in autumn and spring to provide quick feed options but will mature quickly. Compared to other brassicas, tillage radish is a drought hardy, lower risk option due to the energy reserves available in the tuber, and its ability to access subsoil moisture and nutrients. Tuber is considered high energy food for earthworms. Not hard seeded. Best sown before winter cereals for easy in-crop weed control options. Potential aphid host. Seed ~\$8/kg. Sow at 2-4 kg/ha.

♣ ♦ **Turnips** – (*Brassica rapa* subsp. *Rapa*) - Both leaf and bulbs are utilised by grazing animals. The turnip bulb is a large storage organ that develops in the first year. Turnip feed dry matter is around 60% bulb and 40% leaf, depending on the size/age and variety of turnip. Best grazed once at maturity (10-16 weeks). Regrowth is possible from a light first grazing if the leaf growing points attached to the bulb are not damaged. Turnips suffer less from insect attack compared to the other brassicas however they are not as drought tolerant. Leafy turnips are also an option - faster to maturity than bulb turnip, good quick feed sown in autumn and spring. Seed readily available and cheap - \$5-6/kg. Sowing rate 1 kg/ha.

LEGUMES

◆ **Balansa Clover** (*Trifolium michelianum*) – self regenerating annual legume that grows mainly in spring. Suited to soils of pH_{CaCl2} 4.5-7.0. Tolerates waterlogging. Slow early growth but increases rapidly in late winter and spring as temperatures rise. Produces good quality hay. High proportion of hard seeds. Seed in seed head vulnerable to attack by native budworm. Seeding rate of 2-5kg/ha straight or 0.5-1kg/ha in a mix.

◆ **Biserrula** (*Biserrula pelecinus*) - self-regenerating annual legume. Grows on well-drained but relatively infertile, sandy, acid and alkaline soils. Has a deep root system. Tolerant of heavy grazing, suppresses herbicide resistant weeds such as annual ryegrass and radish in cropping systems. Seed spread by livestock. High hard seed levels (>99%) protect against false breaks and assists long-term persistence. Not suited to heavy textured soils or those prone to waterlogging. Ideal species for ley farming systems (1:1 rotation). Few herbicide options available for broadleaf weed control. Can be used as a longer term pasture in mixtures with perennial or annual grasses, or as a pasture lasting 1 - 5 years as part of a phased pasture crop rotation. Will regenerate from seed after a short cropping period of 1 - 3 years. Biserrula is best suited to regions with 300 - 700 mm annual rainfall with a predominantly autumn-winter-spring distribution and relatively little summer rain.

◆ ◆ **Chickpeas** (*Cicer arietinum*) – winter grain legume/pulse suited as a winter crop to the medium rainfall (350 – 500 mm). Crop growth during winter months is slow but accelerates with warmer weather in spring. Suited to deeper well-drained, neutral and alkaline soils of good water holding capacity. Good drainage is important. Kabuli types are less tolerant than Desi types to dry conditions, as they require more moisture to achieve a satisfactory grain size and yield. Desi types require above 350 mm annual rainfall and kabuli types need more than 400 mm. Spring sowing is a preferred option in high rainfall areas (greater than 550 mm). Chickpeas will tolerate higher temperatures during flowering than peas or lupins. Cool wet conditions at flowering can adversely affect seed set.

◆ **Cowpeas** (*Vigna unguiculata*) – warm season annual legume that are actually a bean not a pea. Fast growing, suitable for grazing, hay/silage, grain or green manure. Very drought tolerant and prefers higher temperatures. Relatively strong taproot. Have the ability to vine and climb so excellent when combined with taller forages like sorghum, sudan or sunflowers. Adapted to a wide range of soils from sands to heavy, well-drained clays, with a preference for lighter soils that favour good root development. Better adapted to strongly acid soils than lablab. Does not tolerate extended flooding or salinity. Soil temp >18°C. Sow at 10-14 kg/ha.

◆ **Faba beans** (*Vicia faba*) – winter grain legume/pulse better suited to loams and clays than light textured soils where moisture stress may occur. One of the highest nitrogen fixing grain legumes. Unlike most legumes, faba beans continue producing nitrogen through grain fill and full maturity. Vegetative plants unpalatable to livestock. Can grow in soils pH 5-9. Nodulation may be impaired if seed is not inoculated in acid soils and sensitive to aluminium and manganese toxicity. Can withstand moderate waterlogging. Easily established, makes rapid growth and quickly shades out inter-row weeds. One downfall is that their larger seed size does not always work well in seed mixtures. Vigorous tap roots that can range up to 1.5 m in depth may be used to open up heavy soils. Seed costs ~35 c/kg.

◆ **Field Peas** (*Pisum sativum*) – winter grain legume/pulse that has a shallow root system making it susceptible to erosion and moisture stress when grown in sandy soils. Susceptible to salinity and also root rot in water logged sites. Can be planted alone or mixed with oats (or less commonly rye) to allow the peas to climb. Cheap seed 30 c/kg

♣ **Guar** (*Cyamopsis tetragonolobus*) – hardy and drought tolerant annual summer grain legumes. Erect, bushy plant, which can grow up to three metres tall. Tolerant of salt and alkaline conditions. Grown as a commercial crop for its beans which are used to give foods a smooth texture. Not palatable to livestock when green. Good for areas that are too dry, too salty or too alkaline for other summer legumes. Requires adequate moisture at seeding but has a large taproot and can access deep sub-soil moisture, so can usually access sufficient moisture at maturity to fill grain. It prefers extremely hot days and high overnight minimum temperatures and will perform well in well-drained, infertile medium textured and sandy soils with a pH of around 7.5-8. Seed could be difficult to source. Requires a special inoculant unique to the species or a cowpea Group E inoculant.

♣ **Lablab** (*Lablab purpureus*)- warm season annual legume. Easy to establish with large seed that can be sown directly into moisture. High yielding with high quality forage, non-bloating. Can be sown with summer grasses (e.g. forage sorghum) to provide a mixed forage system. Drought tolerant once established. Can be grazed, harvested for hay, or used as a green manure. Poor frost tolerance, low salt tolerance, intolerant of prolonged water logging. Wide range of soils from deep sands to heavy clays provided drainage is good. Will grow on acidic to alkaline soils (pH water 5.0 - 7.5). Sowing rate 12-20 kg/ha.

◆ **Lentils** (*Lens culinaris*) – winter grain legume/pulse mainly grown in the medium rainfall zones of Victoria and South Australia with winter dominant rainfall patterns. Shallow root system, combined with short growing season means soil moisture at depth may not be fully extracted. Does not grow well on soils prone to waterlogging, boron toxicity or salinity. Prefers deep, well drained loam-clay soil, >400 mm rainfall, pH_{CaCl2} 6-8.

♣ ◆ **Lucerne** (*Medicago sativa*) - perennial, year round production, deep rooting, extracts water and nutrients from depth, restricts water table recharge, moderate tolerance of soil salinity and sodicity, responds quickly to spring and summer rainfall (or irrigation), dual purpose (grazing and hay), highly productive, high nutritive value. But short-term persistence in some regions (mainly due to disease susceptibility), needs rotational grazing, can cause bloat in cattle. Requires deep, well-drained soils (sands to moderately heavy clays) with a slightly acid to alkaline pH. Intolerant of high levels of exchangeable aluminium and even short periods of waterlogging. Optimum temperatures for dry matter production range from 15 - 25°C in the day and 10 - 20°C during the night. However, this will vary with the winter activity level of the cultivar. Often sown as a pure sward. It is very competitive but if sown at a low rate it will grow with species such as early-flowering sub clover/annual medics, phalaris and Mediterranean types of tall fescue to boost winter production. It can be grown with chicory and a range of tropical grasses.

◆ **Lupins** (*Lupinus angustifolius*) – annual winter legume. Prefer moderate temperatures and rainfall. Not tolerant of frost. Prefer moderate temperatures; too many days over 30°C will also see flowers drop. Deep tap root means it can chase moisture. Adapted to sands and loams pH_{CaCl2} 4-7.5. Will not tolerate free lime >4%. Susceptible to waterlogging or shallow soils. Straight sowing rate of 100 kg/ha.

◆ **Medics** (*Medicago spp.*) – winter, self regenerating annual legume. Well adapted to neutral to alkaline clay and clay-loam soils across rainfall zones 250-700mm. Have high levels of hard seed, allowing them to self-regenerate from soil seed reserves after cropping (ley farming system). More productive and persistent in low rainfall areas than subclover. Sow at 4-6kg/ha and allow to set seed in the initial year.

♣ **Mungbeans** (*Vigna radiata*) - warm season grain legume. Relatively drought tolerant, quick maturing (80-110 days) and requires minimal fertiliser input. Mung bean has a shorter growing

season than cowpea and may be better adapted to dryland conditions. Relatively strong taproot. As a cover crop addition, current mung bean varieties often produce seed, something growers prefer to avoid. Later maturing varieties would alleviate this problem. One of the most water efficient summer crops available. Mungbeans do best on fertile sandy, loam soils with good internal drainage. They do poorly on heavy clay soils with poor drainage. Performance is best on soils with a pH between 6.2 and 7.2 and plants can show severe iron chlorosis symptoms and certain micronutrient deficiencies on more alkaline soils.

◆ **Vetch** (*Vicia sativa*) – annual winter legume. Will grow on a wide range of soil types and rainfall zones. Versatile - can be used for grain (species dependent), forage or as a green/brown manure crop. On light, sandy soils the Common and Woolly pod varieties perform well. All perform well on loam clay soils but the best production comes from soils with good fertility. Vetch prefers more alkaline soils (pH 5.2–8.2) but the variety Benatas, for example, has been found to perform well on slightly more acidic soils. Common vetch will not survive prolonged waterlogging. Conversely, the vetch subspecies Purple vetch and Woolly pod will tolerate waterlogging. Potential for weed issues in legume crops eg beans or lentils if allowed to set seed. Persistence after autumn/winter grazing not fantastic, but will set seed well in spring if ungrazed in autumn/winter. Good hay option with cereal as well.

◆ **Serradella** (*Ornithopus sativus*) - winter-growing annual pasture legume. Adapted to sandy soils with pH range 4 to 6.5. Not well adapted to shallow or hard setting sands, loams, clays, or soils that waterlog. Seed will regenerate each year, germinating in mid to late autumn after rain. With early rain, it can produce a large quantity of forage before winter. It grows slowly during winter, making its best growth after spring rain, when it flowers and seeds before dying in the heat of summer. In the first year, stock should be removed when flowering begins to ensure a heavy seed set. Performs best with regular or continuous grazing at a lower stocking rate. Compatible with summer growing grasses. Deep-rooting behaviour on deep sandy soils (deeper than subclover) can extend the length of the growing season.

◆ **Soybeans** (*Glycine max*) - warm season grain legume crop. Adapted to a wide range of soils from sands to heavy clays. Prefers a pH_{CaCl} in the range of 5.2-6.5. Sow when soil temperature is above 12°C. Has gained popularity as a fallow/green manure option in the sugar industry on Queensland's wet tropical coast, replacing more traditional green manure crops such as cowpea and lablab because it produces more dry matter with a higher nitrogen concentration (3.0-3.5% N compared with 2.0-2.5% for cowpeas). Not very drought tolerant. Soybean crops are also suitable for both greenchop and hay and silage production, particularly in the sheep, beef and dairy production systems of northern NSW. The best forage yields can be expected from early-planted, long-season varieties, cut around the mid-pod fill stage. The high protein content of the hay is good to be used in supplementary feeding rations, or fed to livestock as a source of high quality fibre and protein. Sow at 50 kg/ha

◆ **Stylo** (*Stylosanthes guianensis* var. *guianensis*) - Warm season sub-tropical legume. Highly palatable and persistent pasture legume mostly used for permanent pastures. Produces an abundance of seed. Suited to >400 mm rainfall and cooler arid region of the tropics. Tolerant of heavy grazing. pH 5.4 - 8. No record of toxicity. Best sown at the end of the dry season or early in the wet season to allow plants to develop sufficiently before the next dry season or the onset of frost. Sowing rate 2-5 kg/ha. Suggest variety Amiga.

◆ **Subterranean Clover** (*Trifolium subterraneum* ssp) - Grazing tolerant, annual pasture legume with prostrate growth habit. Annual life cycle, growing from autumn to spring coinciding with seasonal rainfall. Regenerates naturally from seed set in previous seasons, without the need for re-sowing. Maintains a seed bank of 'hard' seeds, in which some seeds remain dormant for germination in later years, enabling regeneration after cropping or a year of little or no seed-set. Buries its burrs to protect seeds from being eaten by stock and native budworm. Tolerant of low soil pH and waterlogging (spp. *yannicum*). Red-legged earth mite are a major threat to establishment. Sowing rate of 10 kg/ha straight or 2-5 kg/ha in a mix.

◆ **Sulla** (*Hedysarum coronarium*) - biennial forage legume suited to neutral to alkaline soils with a pH_{CaCl} range of 5.5 - 8.5. While an individual plant can live for up to two years, sulla can easily regenerate from seed which allows for a paddock of sulla to continue to produce for a number of years. Ideal for short pasture rotations in both mixed farming and livestock production systems. Sulla has a high yield potential and is highly palatable, with excellent forage and fodder qualities leading to outstanding animal performance. Sulla is non bloating and has qualities which may reduce worm burdens. Water logging will result in plant death and therefore reduce the life of a sulla stand.

◆ **Sunn Hemp** (*Crotalaria juncea*) – tropical warm season legume that fixes large amounts of nitrogen. Typically a very long season plant that may produce flowers but unlikely to produce viable seed as it requires warm overnight temperatures. Grows extremely fast in the heat sometimes reaching heights of 1.8-2 m in 60 days. Seed supply and inoculation are issues. Requires warm soil to germinate. Can provide grazeable biomass or conserved fodder or be green/brown manured.

◆ ◆ **Tedera** (*Bituminaria bituminosa*) - perennial forage legume aimed at filling the summer-autumn feed gap. Drought and heat tolerant with minimal leaf shedding during summer and autumn. High nutritional value and has the ability to recruit seedlings in autumn, contributing to the perenniality of the sward. Most productive in medium to high rainfall environments (>350 mm of annual rainfall) and is best suited to well drained soils, but tolerates short periods of transient waterlogging. Performs best with soil pH_{CaCl} ≥4.8 and is suited to a range of soil textures from sands to clays. Tedera is a traditional forage native to the Canary Islands, Spain. Lanza was bred by the Department of Primary Industries and Regional Development (WA) and is well adapted to Mediterranean-like climates with a dry summer and autumn. Lanza tedera is better suited to landscapes/regions with minor frost risks. Temperatures of <-2°C will burn foliage, but perennial plants will re-grow. Regions with continuous cold temperatures during winter will reduce Lanza growth rates. Regions with multiple severe frosts can kill plants and significantly reduce plant populations. Tedera has the ability to survive on 150 mm of rainfall and can exist without rainfall for up to five months.

OTHER BROADLEAVES

◆ **Buckwheat** (*Fagopyrum esculentum*) – not a wheat. Related to dock and rhubarb. Grows on well drained acidic and neutral pH soils. Does not like soils with excess nitrogen. Adapted to cool moist through to warm growing conditions, though will wilt in hot weather. Must have adequate stored soil moisture and rainfall to perform satisfactorily. Fast growing but shallow root system so not very drought tolerant. However, its short growing season may allow it to avoid droughts. Terminate at 20% flowering (6-8 weeks after sowing) with a flail mower or mulcher - it won't reshoot. Weed potential if allowed to set seed. Quick breakdown of residues. Good at scavenging and accumulating nutrients to re-release later. Source of nectar and pollen for beneficial insects especially bees. Sow in spring into a clean seedbed at 2-4 cm deep, with sowing rates from 40 kg/ha (drilled) – 70 kg/ha

(broadcasted). 2-4 kg/ha in a mix. Germinates at soil temperatures above 7°C, seeds will emerge in 7-10 days and flowering commences about 30-40 days after seeding. There are issues with buckwheat allergies in parts of Asia.

◆ ◆ **Chicory** (*Cichorium intybus*) - Usually grown as a pasture species in high rainfall environments. Its strong penetrating tap root will access water from deep in the profile, so care must be taken that water use is not excessive. Chicory requires deep well drained fertile soil with a pH above 5.5 to grow well. It also has a high nitrogen requirement. Chicory may be sown in autumn but needs to be well established by winter. Alternatively it is sown in early spring into a firm cultivated seed bed followed by a roller or press wheels to improve seed to soil contact. The recommended seeding rate is 4-6 kg/ha and seeding depth no greater than 10 mm. Individual plants will last for 2-3 years, so allowing plants to set seed in some years will be necessary. Sow at 1 kg/ha in a mix. Seed costs \$20/kg.

◆ **Coriander** (*Coriandrum sativum*) - a non-hardy annual native to southern Europe and North Africa. Its major drawback - it will run to seed at the slightest hint of neglect. Soil needs to remain damp but never waterlogged. Coriander prefers cooler weather and will quickly go to flower (bolt) when the weather warms above 30°C. Initial results show the crop fitting in reasonably well with a conventional broadacre cropping rotation, although the extremely light seed makes it difficult to harvest. The flowers attract a number of pollinators. Seed has the potential to taint the meat of livestock grazing on the residues and there is also a risk of tainting grain that is trucked after coriander. Strongly photosensitive with flowering triggered by increasing day length. Although the crop is heat loving, it has an optimum growing temperature of 18°C. Competes poorly with weeds during early growth. Hot, dry winds during flowering can lead to the dropping of flowers, resulting in substantial yield reduction. If the soil is too dry, the herbs will not grow to their potential, they may flower too early, reducing foliage production, or they may fail completely. Sowing rate of 6-8kg/ha.

◆ ◆ **Linseed** (*Linum usitatissimum*) – Excellent companion crop next to other species in an early season mixture especially due to its strong mycorrhizal fungi association. Can be utilized as a green manure if terminated early enough but take caution if attempting to cut too late as lignin/cellulose content increases with maturity and would hamper decomposition. Decreases slug numbers through drying the soil profile reducing suitable habitat and breeding potential. Extracts more water from depth than faba beans and dried the profile the most over three years of monitoring despite a decile 10 winter on Kangaroo Island (SAGIT 2016 report). Attracts beneficial insects. Not very competitive especially with ryegrass. Being a broadleaf, most disease associated with it will not transfer over and cause infection to cereals with the exception of powdery mildew and rhizoctonia. Very susceptible to native budworms. Sow at 40 kg/ha straight or 5 kg/ha.

◆ **Okra** (*Abelmoschus esculentus*) - warm season broadleaf vegetable in the cotton family that is extremely deep-rooted and has excellent heat and drought tolerance. Okra's massive taproot is an excellent compaction breaker. Grows best in light soils ranging from sandy loam to loam. Can tolerate slightly acidic soil. It is a crop of tropical and sub-tropical climates requiring a long warm and humid growing season. It is susceptible to frost and cannot thrive well in cold. Fast growing plant provides a large canopy, long lasting residue. Livestock will graze okra, as the pods are high in vitamin A, C, and K, along with other minerals and vitamins that help strengthen the immune system and bones. Seed may be difficult to source.

◆ **Phacelia** (*Phacelia tanacetifolia*) - Fast establishing flowering annual. The purple flowers are attractive to beneficial insects especially hoverflies, the larvae of which are voracious predators of aphids. The sweetly scented flowers are nectar-rich and will also attract honey bees and other insect pollinator species. Grows up to 1 m tall and is fast growing which makes it a great cover or green-

manure crop. The root system, although not particularly extensive has a beneficial effect on soil structure and is useful in breaking up clay soils. Can flower for up to 6 weeks as long as there are 12 or more hours of sunlight. High drought tolerance, low biomass production, poor forage quality. Leaves an easy to work and dark fine stemmed mulch layer promoting soil warming in winter. Will grow and flower well in a wide range of soils providing they're sufficiently free-draining. Seeds need darkness to germinate. Sow seeds 5 mm deep.

◆ **Plantain** (*Plantago lanceolata*) - Perennial. Fast establishing, tolerant of drought and low fertility, excellent feeding value including summer, susceptible to broadleaf herbicides, slow growth in winter. Tolerates a broad range of soil types, fertility and pH, wide climate adaption; tolerant of frost; relatively heat tolerant. Sow at 1 kg/ha.

◆ **Safflower** (*Carthamus tinctorius*) – Drought tolerant, warm season, annual broadleaf that can be sown into cool soils (>4°C but 15°C optimal). Has an exceptionally deep taproot that can reach depths of 2.4-3 m breaking hardpans, encouraging air and water movement into the soil profile and scavenging nutrients from depths unavailable to most agronomic crops. Provides excellent forage but becomes very prickly with maturity, rendering plants unpalatable to livestock. Big tap root will help drain/aerate the profile. Sowing rate 5-10 kg/ha.

◆ **Sunflower** (*Helianthus*) - warm season broadleaf with an extensive and prolific root system that is able to soak up residual nutrients out of reach of other plants. Sunflowers work very well in cover crop cocktails/mixtures due to their rapid early season establishment, allowing other species under the canopy that normally don't grow in hot conditions to take advantage of cooler and favourable environment. Attracts pollinators and beneficial insects. Can add significant biomass production in just a short growing season, they can also serve as additional forage or silage for livestock feed. Can sow early provided soil temperature >10°C. Strong mycorrhizal association. Sowing rate 2-5 kg/ha. Certified hybrid seed ~\$25/kg. Birdseed or off the header \$3/kg. Common sunflowers stocked by seed companies at \$3-4/kg.

GRASSES

◆ **Barley** (*Hordeum vulgare*) – annual cereal grain. Germinates at any time of the year after rain. Moderate tolerance of salinity. A 40% loss in grain production can be expected on soils with a soil conductivity of 15 mS/cm and a 10% loss at 9 mS/cm. Fibrous root system. Fast to set and fill seed compared with other cereal grains. Ill tolerant of low pH. Should be $pH_{CaCl} > 5$.

◆ **Cereal rye/Ryecorn** (*Secale cereale*) – tolerates soils of pH_{CaCl} 4.5-8. Rye is a cold tolerant grain crop and produces more growth during winter than any other crop but is the first to get stemmy and unpalatable in spring. Grows well in dry situations and is suited to marginal, infertile sandy soils, where it may produce better growth than other cereals, but responds well to fertility. Does not like very wet soil. Has an extensive fibrous root system that makes it good for improving soil structure. In areas of low frost risk, cereal rye can be left to hay off naturally and form a straw windbreak to reduce wind and sand blast. Very tolerant of drought. Hard to control volunteers in wheat. Fantastic weed suppression. Cheap seed ~20 c/kg sow at 40-50 kg/ha up to 70 kg/ha in the high rainfall zone.

◆ **Corn (grazing)** (*Zea mays*) - otherwise known as brown mid-rib (BMR) corn bred specifically for grazing. Extremely palatable and digestible for cattle, it is the first species to be eaten in a cover crop mix. Corn tolerates cooler temperatures and soils than sorghum but does not regrow like sorghum. Sow when soil temperature >16°C. Medium drought tolerance, heavy feeder. Seed and small plants very attractive to cockatoos - significant risk of crop damage.

◆ **Millet (Proso – eg French White)** (*Panicum miliaceum*) - Grain only. Not suited to grazing or hay due to hairy leaves, being both unproductive and unpalatable. However it is one of the most water efficient grain crops and is used to provide animal feed in areas too dry for corn or sorghum. It is also used as a rapid maturity (as little as 60 days to maturity) grain crop when the growing season is too short for a full season crop. Very drought tolerant. Open, drooping heads. More suited to lighter, loamier soils, and able to cope with hot, dry conditions better than the other millets. Tends to ripen unevenly and very prone to shattering. Very good tolerance to atrazine residues in the soil. Very tolerant of soils that are sodic and saline at depth. Sow at 2-5 kg/ha in a mix or 5-10 kg/ha individual.

◆ **Millet (Japanese – eg Rebound/Shirohie)** (*Echinochloa esculenta*) Dual purpose – grain and graze. More suited to grazing compared with French White but less resilient when subjected to drought. Sow when soil temperature is 14°C and rising. All crops like growing after it, but due to the risk of Fusarium head blight (scab), grow canola or legume instead. Shirohie is a larger, white seeded selection of the variety Japanese. Exceptionally tolerant of wet soil and will even grow in standing water. Does not grow well in sandy soil. Suited to medium and heavy clay soils provided establishment conditions are satisfactory (non-crusting soils). Can tolerate moderate levels of soil salinity and prefers high fertility. Sow at 2-5 kg/ha as a mix or 5-10 kg/ha individual.

◆ **Oats** (*Avena sativa*) – annual cereal crop grown for hay or grain. Compared with other cereals, oats are adapted to a wider range of environments, generally better-adapted to cooler and wetter environments and more tolerant of poor soil conditions. Good early vigour. Often sown with a legume (clovers, medic or vetch) to produce a mixed species hay that has higher protein levels. Can be grown as a dual purpose crop where the standing crop provides quality forage for livestock for a short period early in the growing season, and then the crop is grown out to produce hay or grain. Oats prefer soil pH that is slightly acid to neutral but will grow in a range of pH 4.5–8.6. Not as tolerant of alkaline soil (pH >7) as other cereals, however, growing oats for hay production is generally on alkaline soils. Of all the cereals, oats are the least tolerant of soil salinity, with levels of 6 dS/m reducing production. Most frost tolerant of cereal crops sown in Australia.

◆ **Panic (Gatton)** (*Panicum maximum*) - summer growing perennial grass. Leafy plant producing high quality palatable forage when green, with good production on fertile soils, responds quickly after rain, drought tolerant. Demonstrated very good persistence and biomass production on sandy soils, including deep pale sands in both the northern agricultural region and south coast of Western Australia (WA), but does not tolerate waterlogging or flooding. >400 mm annual rainfall. Plants frosted in winter but shoot in early spring when moisture is available. Heavy frosting can cause plant mortality after heavy grazing in the late summer and autumn. Examples: Megamax™ 049 or 059.

◆ **Teff** (*Eragrostis tef*) – fast growing summer annual grass with dense shallow fibrous roots, fine stems and palatable leaves. Provides high quality feed and hay for dairy, beef and sheep. Hardy but difficult to establish. High production potential. Originated in the highlands of Ethiopia where it has been consumed for thousands of years. Self-pollinated, grows 40–80 cm tall. Preferred growing temperature is 10–27°C with 12 hours of sunlight, although experience in Tasmania (<https://www.agrifutures.com.au/farm-diversity/teff/>) suggests the crop may not be day length sensitive as long as the temperature range is appropriate. Optimum rainfall is 450–550 mm a year, primarily during summer. In some areas where the summer conditions are hot and dry, irrigation is essential. Sow at 3-6k g/ha. Firm seedbed and very shallow sowing absolutely critical for establishment, due to the extremely small seed size.

◆ **Triticale** (*×Triticosecale*) – annual cereal grain developed by human intervention from crosses between wheat and rye. Developed to incorporate the high yield potential and quality of wheat and the adaptability of rye and is adapted to a wide range of soil types and environments. Has an aggressive root system that binds light soils better than wheat, barley or oats. Of the cereals available, triticale has the best adaptation to water logged soils and those of high pH. Triticale is also

tolerant of low $\text{pH}_{\text{CaCl}_2} > 4$, grows well on sodic soils and tolerates soils high in boron. In nutrient deficient soils, triticale appears to respond better to applied fertilisers than other cereals. Triticale has the capacity to survive utilising trace elements in soils which would be considered nutrient deficient for any other type of crop. Has poor tillering capacity and good tolerance to shattering making it a useful cereal as a cover crop to establish undersown lucerne or medic.

◆ **Ryegrass** (*Lolium rigidum*) - self-regenerating vigorous annual, biannual or perennial grass. Varieties highly variable regarding time of flowering, tillering; habit varies from prostrate to erect. Fibrous dense root system that can support animals and vehicles in wet weather. A productive, nutritious feed, well suited to a short term pasture phase in the wheat sheep zone. Useful for hay and for improving the productivity of saline land. Reasonable winter growth, good spring growth. Drought tolerant. Tolerant of continuous grazing, heavy stocking, low soil fertility and some insect pests. Suits a wide range of soils and thrives on high fertility soil. Tolerates wetter soils better than any of the cereal grains. Maintains palatability and nutritional value later in the season compared with cereal rye.

◆ **Saia Oats** (*Avena strigosa*) – annual winter cereal. Tall black seeded grazing oat with fine stems making it a good cover crop, forage or hay option. Fast to establish. Allelopathic chemicals from plant decomposition can impede germination of broadleaf species (i.e. don't sow in front of a broadleaf cash crop). They make an excellent crop for those just getting started with covers because it can be easily terminated with an array of methods. Excellent tillering potential to get the ground covered quicker. Less prone to insect problems than either wheat or barley may reduce take-all of wheat. Grows in a wide range of soil types and has a good tolerance of acid soils. Nematode reduction (*pratylenchus*) is particularly important in light sandy soils. If taken to harvest, best to windrow as they shake out and ripen unevenly. All-purpose partner for cover crop blends sow at 20 kg/ha.

◆ **Sorghum (forage)** (*Sorghum spp.*) are coarse stemmed, long maturity sorghum that are higher in sugar. Forage types are generally all hybrids. They have poor regrowth but high yield potential if allowed to grow to maturity. Sowing rate 1-3 kg/ha as a mix or 5-10 kg/ha alone. Need 16°C and rising soil temperature. Potential prussic acid toxicity. Potential host of cereal aphids e.g. Russian Wheat Aphid especially in early sown cereals - ensure sorghum has been brown for two weeks prior to sowing cereals. Example - Mega Sweet from Pioneer Seeds.

◆ **Sorghum x Sudan** (*Sorghum spp.*) is a hybrid between sudangrass and forage sorghum. Exhibits hybrid vigour and thus has excellent yield and regrowth potential. Needs >300 mm rainfall. Potential host of cereal aphids especially in early sown cereals - ensure sorghum has been brown for two weeks prior to sowing cereals. Examples BMR Fuel from Stephen Pasture Seeds or Betta Graze from Pioneer Seeds. Can be sown slightly earlier than forage sorghum at 15°C.

◆ **Sudangrass** (*Sorghum x drummondii*) - warm season forage, closely related to sorghum that is fine stemmed and regrows rapidly after grazing. Poses a lower risk of prussic acid toxicity than sorghum type forages. Drought tolerant grass as it has many secondary roots allowing it to absorb more water. The leaves are smaller which helps it conserve water by not allowing as much loss to transpiration. Livestock can graze directly, or it can be cut several times during the season for hay. Because the grass thrives in warm temperatures and is resistant to drought, it's an excellent forage grass when other grasses are heat stressed and recovering. Sow when soil temperature is 15°C and rising. Examples: Super Sweet Sudan (SSS) from Pioneer Seeds or FeedEx from Stephen Pasture Seeds.

◆ ◆ **Wheat (winter/spring)** (*Triticum aestivum*) - potential to be sown in spring or autumn in the high rainfall zone. In the low and medium rainfall zones, April sowing is ideal with May being too late

as the winter types flower too late resulting in a yield penalty. Can be used for both grazing and grain. Grazing either has no effect, or a small negative effect on grain yield which is cultivar dependent. Grazing needs to be performed prior to GS30, or there are large negative effects, especially to the slower growing winter wheats. Different winter wheats required for different environments. Flowering time cannot be manipulated with sowing date in winter wheats such as spring wheat. 10 mm of rainfall was needed for establishment on sands, 25 mm on clays - more was not better. Be wary of Russian Wheat Aphid when sowing early. Suits wide range of soil types – $\text{pH}_{\text{CaCl}_2} > 4.5-9$

Australian Natives

Considerations:

- 1) Cost and sourcing the seed. Seed is pricey and normally need to give a year's lead time to be able to bulk up. Most cost around > \$100/kg.
- 2) Their poor germination and early vigour relative to competing exotic species means they can be difficult to establish. .

Weeping Ricegrass (*microlaena*) Hard to source and seed very pricey. Perennial grass. Prefers cooler moist climates. Prostrate ground cover. Softer leaf and palatable. Slight wool contamination issue.

Queensland Bluegrass (*Dicanthium sericeum*) - Distributed across much of Australia, this C4 perennial grass is adapted to a broad range of soil types and climates. It may have a role in those regions where summer rainfall occurs regularly and soil moisture is often in excess. It can be sown with wallaby grass to create a year round perennial native sward. Queensland bluegrass grows best on clay soil with a pH from 6.0 to 7.5. An attractive summer active perennial native grass which can be sown as a sole species or in a species mix, it will add floral diversity to the cover crop sward in areas receiving summer rainfall. The seed awns bind together making it impossible to sow through a conventional seeder. The seed can be purchased in a pelletised form, or the seed sown through a specialized planter. It is planted from spring to summer, sown shallowly (5-10 mm) and preferably immediately prior to a significant rainfall event. Mowing and grazing (if appropriate) are management options to control weeds and moisture uptake. As individual plants last about 3-4 years, allowing seed set will be required to maintain the stand in the long term. Seed costs \$45/kg. Seed rate 5-10 kg/ha. >400 mm rainfall.

Wallaby Grass (*Rytidosperma spp.*) A native grass for medium rainfall environments. It is a winter active grass, but with adequate soil moisture it will continue to grow through the spring and summer months with up to two periods of seed production during this time. Not all of the 35 species of wallaby grass are grown commercially, but there are numerous varieties available providing a range of growth habits. Sowing a mix of species adapted to particular environments enhances the likelihood of a successful establishment and increases the diversity of the sward. While seed costs for establishment are expensive, the cost may be amortised over 10 or so years, and with low management costs it becomes a cheaper option than annual cover crops. Soil preferences vary between species of wallaby grass. Source from your local area for best results. Perennial clumpy grass. Poor nutrient profile. Need to give advance notice if you wish to sow large areas to allow growers to bulk up seed. Seed costs ~\$100/kg roughly. May be outcompeted by volunteer weeds in highly fertile soils. No wool contamination issue.

Winter Grass

| Species | Tolerances | | | pH | Sowing | | | | | Suitable Rainfall Zone | | |
|-----------------|------------|---------|----------|---------|--------|---------------|----------|------------------|---------|------------------------|-----|-----|
| | Heat | Drought | Low Fert | | Pref | Straight Rate | Mix Rate | Min Soil Temp °C | Cost/kg | Seed Size | Low | Med |
| Annual ryegrass | ** | ***** | *** | 5-8 | 15-20 | 2 | 4 | \$2.5 | S | | ● | ● |
| Barley | **** | **** | ***** | 6-8.5 | 50-100 | 15 | 3 | \$0.25 | M | ● | ● | ● |
| Cereal Rye | *** | **** | ***** | 5-7 | 60-120 | 20-40 | 1 | \$0.2 | M | ● | ● | ● |
| Oats | *** | ** | *** | 4.5-7.5 | 80-110 | 15 | 3 | \$0.25 | M | ● | ● | ● |
| Triticale | **** | *** | **** | 4-9 | 80-150 | 20 | 3 | \$0.25 | M | ● | ● | ● |
| Wheat | **** | *** | *** | 4.5-9 | 60-120 | 15 | 3 | \$0.3 | M | ● | ● | ● |
| Winter Wheat | **** | *** | ** | 4.5-9 | 60-120 | 15 | 3 | \$0.5-1.5 | M | | ● | ● |
| Saia/Black/Oats | *** | ** | *** | 4.5-7.5 | 50-70 | 15-50 | 3 | \$0.75 | S | ● | ● | ● |

* Poor; ** Fair; *** Good; **** Very Good; ***** Excellent

Rainfall Zone: Low <350mm, Medium 350-500mm, High >500mm

Winter Broadleaf

| Species | Tolerances | | | pH | Sowing | | | | | Rainfall Zone | | |
|------------------|------------|---------|----------|-------|--------|---------------|------------|------------------|---------|---------------|-----|-----|
| | Heat | Drought | Low Fert | | Pref | Straight Rate | Mix Rate | Min Soil Temp °C | Cost/kg | Seed Size | Low | Med |
| Balansa Clover | **** | *** | ** | 4.5-9 | 5 | 1 | 6 | \$6 | S | | • | • |
| Biserrula | | **** | ***** | 4.2-7 | 7-10 | 1-4 | 6 | ??supply | VS | | • | • |
| Canola (Win&Spr) | ** | *** | ** | 5-8 | 5 | 0.5 | 5 | \$0.5-\$6 | S | | • | • |
| Chickpeas | **** | *** | ** | 6-8 | 60 | | 5 | \$1 | M | | • | •% |
| Chicory# | **** | *** | ** | >5.5 | 4-6 | 1 | 6 | \$18-22 | S | | • | • |
| Faba Beans | * | ** | * | >5 | 150 | | 6 | \$0.4 | L | | • | • |
| Field Peas | *** | *** | ** | 6-7 | 80-120 | | 5 | \$0.3 | M | • | • | • |
| Lentils | **** | **** | *** | 6-8 | 50-60 | | 5 | \$0.5 | M | • | • | • |
| Linseed | ** | *** | ** | 5-7 | 30-50 | 2 | 7 | \$2 | S | | • | • |
| Lupins | ** | **** | **** | 4-7 | 70-100 | | | \$0.4 | M | • | • | • |
| Lucerne# | **** | *** | ** | 6.5-8 | 2-12 | 0.25-1 | Aut or Spr | \$6-13 | S | • | • | • |

| | | | | | | | | | | | | |
|---------------------------------|-------|-------|------|---------|---------------|---|---|---------|----|---|---|---|
| Medic | ***** | **** | *** | 4.8-8.5 | 8 | | 7 | \$6-8 | S | • | • | • |
| Plantain# | **** | *** | ** | 4.5-9 | 5-6 | 1 | 6 | \$13-16 | VS | | | • |
| Serradella (French & Yellow) | *** | **** | **** | 4-7 | 5-8 podded | | 7 | \$3.5-4 | S | | • | • |
| Sub clover | *** | **** | *** | 4-8 | 10 | 2 | 3 | \$5-9 | S | | • | • |
| Sulla# | ** | ***** | * | 6.5-8.5 | | | | \$13-15 | | | • | |
| Tedera# | ***** | **** | ** | >4.8 | 10 | | 7 | ? | | • | • | • |
| Tillage Radish | *** | ** | ** | 6-7.5 | 5 | 1 | 7 | \$8 | S | | • | • |
| Vetch - Common | **** | *** | ** | 5.5-7.5 | 15-20 | 5 | 5 | \$2-3 | | • | • | • |

* Poor; ** Fair; *** Good; **** Very Good; ***** Excellent

Low <350mm, Medium 350-500mm, High >500mm #Perennial %Spring sowing preferred

Summer Grass

| Species | Tolerances | | | pH | Sowing | | | | | Suitable Rainfall Zone | | |
|---------------------|------------|---------|----------|---------|--------|---------------|----------|------------------|----------|------------------------|-----|-----|
| | Heat | Drought | Low Fert | | Pref | Straight Rate | Mix Rate | Min Soil Temp °C | Cost/ kg | Seed Size | Low | Med |
| Corn/Maize | **** | ** | * | 5.5-7 | 30,000 | | 16 | \$1.50 | M | | | ● |
| Gatton Panic# | **** | **** | *** | >4.3 | 2-4 | 0.75 | Spring | \$20 | VS | | ● | ● |
| French White Millet | ***** | ***** | *** | 4.5-9 | 5-10 | 2-5 | 14 | \$2.5 | S | ● | ● | ● |
| Shirohie Millet | ** | *** | **** | 4.6-7.4 | 5-10 | 2-5 | 14 | \$3 | S | | ● | ● |
| Sudangrass | ***** | ***** | *** | >4.8 | 2-5 | | 15 | \$7-12 | | ● | ● | ● |
| Sorghum | **** | *** | ** | >4.8 | 5-10 | 1-3 | 16 | \$2-5 | M | | ● | ● |
| Sorghum x Sudan | ***** | ***** | ** | >4.8 | 2-10 | | 16 | | | | ● | ● |
| Teff | ** | **** | | >4.8 | 3-4 | 1 | 18 | \$8 | VS | | ● | ● |

* Poor; ** Fair; *** Good; **** Very Good; ***** Excellent #Perennial

Summer Broadleaf

| Species | Tolerances | | | pH | Sowing | | | | | Rainfall Zone | | |
|-----------------|------------|------------------|----------|---------|--------|---------------|----------|------------------|---------|---------------|-----|-----|
| | Heat | Drought | Low Fert | | Pref | Straight Rate | Mix Rate | Min Soil Temp °C | Cost/kg | Seed Size | Low | Med |
| Buckwheat | *** | ** | ** | 5-7 | 30-70 | | 10 | \$3-5 | M | | | ● |
| Cowpeas | ***** | **** | ***** | 5.5-6.5 | 10-15 | 5-7.5 | 18 | \$4 | M | | ● | ● |
| Forage Brassica | *** | ** | ** | 6-7.5 | 2-4 | 1 | 7 | \$10 | S | | ● | ● |
| Guar | ***** | ***** | **** | 7.5-8 | 8-10 | 1-2 | 20 | | M | ● | ● | ● |
| Lablab | ***** | **** once est | *** | 5-7.5 | 15-20 | 5-8 | 18 | \$3.50 | L | | | ● |
| Mungbeans | ***** | **** | **** | 4.5-7.5 | 20-25 | 5 | 18 | | M | | ● | ● |
| Okra | ***** | **** | ** | 6.5-7.6 | 8-10 | 1 | 20 | | M | | | ● |
| Phacelia | | **** | *** | | 10-12 | 2 | 18 | | S | | ● | ● |
| Tillage Radish | *** | ** | ** | 6-7.5 | 5 | 1 | 7 | \$8-10 | S | | ● | ● |
| Turnips | **** | ** | ** | 5.5-7.5 | 1 | 0.25-0.5 | 5 | \$6 | S | | ● | ● |
| Safflower | ***** | ***** | **** | 5-8 | 15-20 | 5-10 | 4 | \$2 | M | ● | ● | ● |
| Soybeans | *** | ** | ** | 5.5-7.5 | 5-12 | | 4 | \$2 | M | | | ● |

| | | | | | | | | | | | | |
|------------|-------|------|------|---------|-------|---|----|----------|---|--|---|---|
| Sunn Hemp | ***** | **** | *** | 5.5-7.5 | 18-20 | | 18 | \$7-9 | M | | • | • |
| Sunflowers | **** | *** | **** | 5.5-8 | 5-10 | 2 | 8 | \$3-\$25 | L | | • | • |
| Stylo | | *** | | | 1-5 | | | \$18 | S | | • | • |

* Poor; ** Fair; *** Good; **** Very Good; ***** Excellent # Perennial

Project Proponents



Project Funders



Government of South Australia
Department for Environment
and Water

