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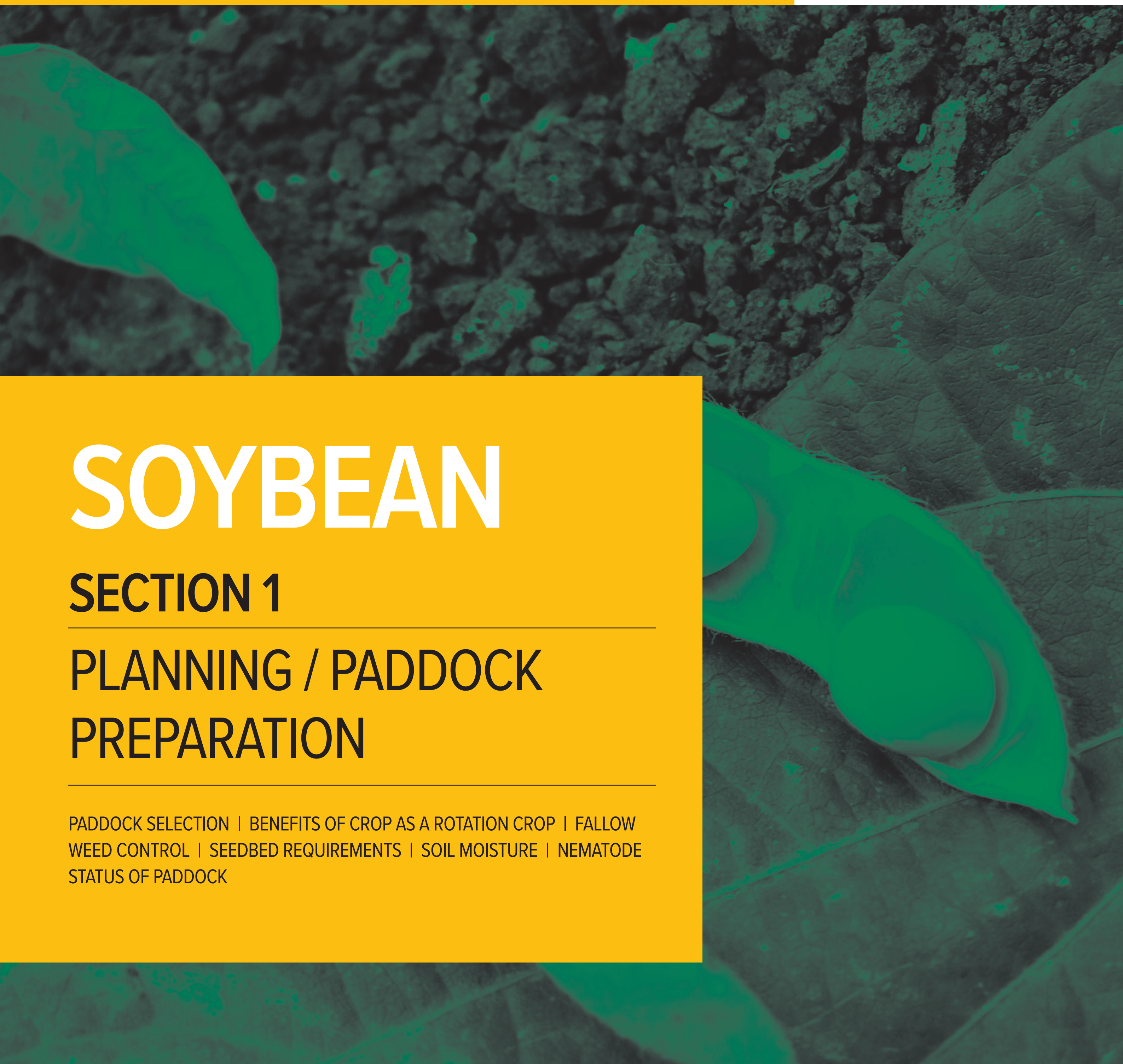

SOYBEAN

SECTION 1

PLANNING / PADDOCK PREPARATION

PADDOCK SELECTION | BENEFITS OF CROP AS A ROTATION CROP | FALLOW WEED CONTROL | SEEDBED REQUIREMENTS | SOIL MOISTURE | NEMATODE STATUS OF PADDOCK

SECTION 1

Planning/Paddock preparation

1.1 Paddock selection

1.1.1 Land management

Probably the hardest part about growing a good soybean crop is to get good crop establishment. In most areas 200,000–300,000 plants per hectare are required to get maximum yields. Soybean is very sensitive to soil water during the establishment stage up until the four leaf stage. If the soil is too wet seed will rot and if too dry it will fail to germinate and/or die before emergence. Soybeans are intolerant of soil salinity and need soil with 2dS/m ECs and irrigation water needs to be less than 1.5 dS/m ECw. Thus land preparation is a very important consideration when planting soybean. A range of options can be employed. These are detailed below.[1]

1.1.2 Conventional tillage

With conventional tillage the whole paddock is prepared prior to planting. Initial cultivations are usually done with discs, chisels or heavy scarifiers. The aim is to have 20 to 25 cm of loose soil allowing the formation of raised hills or beds. However, land preparation will vary according to the particular soil type. Where soybean is grown in rotation with sugarcane, the cane can be sprayed out prior to cultivations or disced out during the land preparation. On light sandy soils, cultivation should not be excessive while heavier soils may require more working to obtain a satisfactory seedbed.[2] Avoid leaving seed bed with large clods as they will harbor weed seeds that will not be controlled by pre emergents and reduce seedling population as seedlings emerge.

1.1.3 Controlled traffic and permanent beds

Controlled traffic farming is becoming more popular for many cropping enterprises as increased knowledge is gained of its benefits. Soybean is no exception. Controlled traffic farming involves having permanent traffic zones and permanent crop zones to avoid the adverse effects on crop growth of compaction caused by heavy machinery. A system that controls traffic separates wheel tracks and the cropping zone.

Where in conventional farming the whole soil surface area of the field is worked to make it suitable for cropping, with controlled traffic only the cropping area is worked and not the wheel tracks. These remain permanent across crop cycles. With controlled traffic, compaction caused by the passage of heavy machinery is isolated from the cropping zone. Soil compaction has an adverse effect on crop yield through limiting water and nutrient supply to the crop.

Controlled traffic requires equipment to be modified so all wheel widths match, allowing tyres to run on the same permanent wheel tracks with every operation. This can be done very cheaply by using guide arms to mark the rows. However, natural driver error

[1] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[2] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

limits the success of guide arms. The most effective way is to move to satellite guided systems, or auto steer systems, that remove driver error.

Whether by design or not, controlled traffic systems will result in planting on beds. These beds can be either flat (drier areas) or raised to improve drainage in wet conditions.

Over time, as the permanent traffic lanes become more consolidated, it becomes easier to drive the machinery down the compacted tramlines, using less fuel and allowing earlier field access after rain. At the same time, in the planting zone, the soil profile develops an improved structure and better moisture holding capacity. The establishment of permanent traffic lanes facilitates a movement towards, initially, zonal tillage (tilling only the crop area) and eventually, in some situations, the move to zero tillage can occur.

Increasingly, controlled traffic and GPS guided systems are also moving toward the incorporation of permanent raised beds or hills. In the wet tropics and coastal areas it is advisable to sow soybeans on raised beds or hills to allow for better drainage during the wet summer months. Hill or bed formation can be done prior to sowing though some planters can be fitted with hill/bed forming equipment to allow planting and bed formation to be carried out in a single operation. In areas with lower rainfall, soybeans can be planted without forming beds.[3]

1.1.4 Zonal tillage

As the name implies, tillage is carried out in zones. This concept is based on the premise that cultivation should only be carried out when absolutely necessary and that crop-growth zones and traffic zones should be separated on a permanent basis. Thus zonal tillage is an integral part of a controlled traffic system and is important in maintaining the compacted traffic lanes and non compacted cropping lanes.

Other advantages include:

- being able to use smaller tractors;
- savings in time and fuel;
- non compaction of the cropping zone benefiting root growth and drainage;
- compaction of traffic zone allowing quicker access onto the paddock following rainfall;
- and provision of a friable seedbed to facilitate crop establishment.

Soybean can be planted in the cultivated zones (beds) with row crop planters. It is important to ultimately match wheel spacings of planters, harvesters, tractors and spray rigs to preserve the structural integrity of the beds and retain controlled traffic zones.[4]

Zonal tillage can also be used between the rows of soybean stubble once the crop has been harvested to create a planting zone for the following crop, for example, sugar cane as illustrated in Figures 1 and 2 below.

3 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

4 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Figure 1: Zonal or strip tillage applied to the inter-row of soybean crop stubble using a 'Soil Soldier'. The objective is to encourage better rainfall penetration and create a zone that is conducive to rapid germination of cane sets planted in a dual row between the three soybean rows on the bed, whilst causing minimal disturbance to the structure of the beds and maintaining controlled traffic zones. (Photos: Alan Munro, Woodford Dale, NSW)

Figure 2: Zonal tillage using a power harrow and crumbler roller was applied to the top of these beds. In this example, different depths of zonal tillage (50 mm and 125 mm) were applied at variable times prior to planting cane in September. The overall objective is to incorporate soybean crop stubble and create a zone conducive to growth of the cane sets whilst retaining the bed structure and controlled traffic zones. (Photos: Alan Munro, Woodford Dale, NSW)

1.1.5 Zero tillage

Zero tillage is the ultimate for developing a sustainable farming system. It is the next step up from zonal tillage. After the permanent cropping and traffic lanes are firmly established the cropping lanes should remain friable enough to be able to be directly seeded into the undisturbed soil. However, friability may vary with soil type. Trash or stubble management will be an issue. This is addressed below.

There are a number of advantages to this system in addition to those captured with zonal tillage:

- more time and fuel savings
- less capital involved in cultivation machinery
- can be done on slopes not suitable for conventional tillage due to erosion hazards
- maintains a better soil structure
- planting moisture is not lost through tillage
- Increased water retention and reduced runoff

In coastal farming systems, zero-till systems have been developed in rotations with sugarcane where soybean is sown on either side of the cane row and cane is planted into the soybean residue. Volunteer cane can be controlled with grass selective herbicides while the soybean can be controlled with a broadleaf selective herbicide. However, in most cases the soybean will be allowed to grow. It will be easily outcompeted by the cane.

A system now being practised in many cane areas is the development of 1.8 m controlled traffic beds onto which three soybean rows are planted. At the end of the soybean crop, two rows of cane are directly planted into the beds through the soybean residue.

Cane farms using this system involving soybean breaks have reported 20% yield increases in the following cane crop.

When sowing soybean into sugar cane trash several issues must be considered. Soybean does not grow well in compacted soil and a ripper tine along the cane stools will loosen the area where soybean is planted without disturbing the trash on the surface.[5] The use of covering chains will improve plant stand population, by reducing air pockets in seed trench and stopping trench baking from the sun which will dry out moisture around seed.

1.1.6 Managing grass (cane, wheat) residue to facilitate soybean planting

Both grass and legume trash require careful management if the most is to be gained from a zonal/zero tillage system. However, if a few simple rules are followed, good establishment of either crop will be achieved. Both contribute a substantial amount of organic matter to the system and the legume contributes nitrogen.

Fresh cane trash in a green cane trash blanket system contains organic acids and other chemicals that can adversely affect soybean germination. To offset against poor germination and thus poor soybean establishment the fresh cane trash needs to be either raked away from the line where the soybean is to be planted or the soybean planting should be delayed for 4-6 weeks after cane harvest.

Another problem likely to arise will be nitrogen deficiency early in the life of the soybean crop. This is caused by the large amount of high carbon cane trash (often between 7-10 t/ha dry matter) immobilizing soil nitrogen. The addition of some starter N (20-30 kg/ha) will address this issue during the time prior to symbiotic nitrogen fixation commencing.[6]

1.1.7 Managing soybean residue to facilitate grass (cane, wheat) planting and to maximize the benefits of soybean

The amount of nitrogen contributed to the system by a soybean crop will depend on how the crop is managed–green manure or harvested for grain. With the latter, around 66% of the nitrogen in the crop will be removed with the grain. For example, a soybean crop producing 8 t/ha total dry matter at 3.5% nitrogen concentration will contain 280 kg/ha N. If the crop is harvested for grain 185 kg/ha will be removed with the grain leaving less that 100 kg/ha contributed to the soil. However, there will be a certain amount of nitrogen associated with the root system and rhizosphere. General assessments suggest this will be approximately 30% of what is contained in the above ground biomass. Thus, if the tops contain 280 kg/ha the amount in the rhizosphere and roots will be around 80 kg/ha, making a total for a harvested soybean crop in the order of 180 kg/ha. These figures, of course, will vary with the situation and the vigour of the soybean crop so they should only be treated as a guide.

How the soybean residue is managed will also have an important impact on nitrogen availability to the following crop. If the residue is incorporated, the nitrogen is mineralized very rapidly. Although this is generally accepted as a positive outcome, it can have negative effects with long-term crops such a sugarcane in high rainfall areas

5 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

6 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

where leaching can rapidly move nitrogen out of the root zone on permeable soils and de-nitrification can become a major source of N loss on heavier clay soils.

Surface managing the legume residue can slow the mineralization process and conserve the legume nitrogen later into the growing period of the following crop. Such a strategy fits very well into a zero tillage system. It can also have positive effects on the maintenance of soil water for the establishment of the following crop.[7]

1.2 Benefits of crop as a rotation crop

1.2.1 Soybean and their use in crop rotation

Crop rotation plays an important role in spreading risks associated with seasons and markets. As knowledge of the agronomic value of rotations increases – reducing disease severity, lowering the risks of herbicide resistance, controlling hard to kill weeds, reducing insect pressure, positively affecting soil physical properties, maintaining arbuscular mycorrhizae levels – their importance in sustainable cropping systems is more appreciated. Further, if the rotation crop is a legume the provision of symbiotically fixed nitrogen is an added bonus. Thus the ideal crop rotations involve broadleaf (legumes, canola, sunflower) and grass crops (maize, wheat, sugarcane). Being a broadleaf crop and legume, soybean is ideally suited for rotation with grass crops.

It is also important to consider both summer and winter crops when looking for rotation species. With major winter crops being the cereals, particularly wheat and barley, and soybean being a summer crop, it ideally suits as a rotation crop in many cropping areas. Further, a 'double-crop' rotation of soybean and wheat, for example, on an annual basis will improve cash flow and reduce overhead costs. Even if it is not possible to grow both crops on the same land in any one year, the growing of a summer and winter crop will spread the work load and better utilise machinery and labour resources.

Soybean offers a wide diversity in its use as a rotation crop. It can be used for forage, hay or silage, incorporated as a green manure or harvested for grain. Further, there are a number of market options for soybean grain. [8]

The introduction of soybean as a rotation crop in a sugarcane enterprise enables farmers to gain all the benefits of a green-manure legume crop in wet areas where only failures have occurred in the past. Economic modelling shows that a system including soybean fallows can produce improved gross margins over 100% cane throughout the whole crop cycle as well as improving soil health. There are also environmental benefits through reduced use of nitrogenous fertiliser due to the slower release of nitrogen from soybean residues and the reduced tillage after a soybean crop avoiding erosion losses following excessive aggressive tillage. [9]

Growing soybean as a rotation crop in sugarcane can help boost cane yields because there is a range of registered herbicide options which are available for weed control in soybean crops that are not suitable for use in sugarcane crops. Using these different herbicides gives cane growers a chance to reduce weed-seed populations by tackling some of the problem weeds in their paddocks, including volunteer cane. [10]

1.3 Fallow weed control

Don't let summer weeds seed for two years before planting summer crops. Ensure no residual chemicals are applied that will endanger soybean germination and production.

[7] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[8] Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

[9] DR Sparkes and C Charleston, Adoption of Soybeans as a Rotation Crop in Far North Queensland: http://www.australianoilseeds.com/__data/assets/file/0013/1192/Catherine_Charleston-Adoption_of_Soybeans_as_a_Rotation_Crop_in_Far_North_Queensland.pdf

[10] Weed control in soybean crops can be a valuable investment in your cane crop: http://www.sugarresearch.com.au/icms_docs/157925_Bulletin_Edition_36_2013_Weed_control_in_soybean_crops.pdf

1.4 Seedbed requirements

The preparation of a weed-free seedbed to allow rapid emergence is most critical.

To facilitate harvesting, the land should be free of sticks, stones and other obstacles. As soybeans set their lowest pods close to the ground, it is essential that the header front operates close enough to the ground to maximise grain yield without damaging the header. [11]

Figure 3: A weed-free seedbed to allow rapid emergence is critical for good soybean establishment.

1.4.1 Soil pH, acidity and liming

Soybean is adapted to a wide range of soils from sands to heavy clays. The plant prefers a $pHCaCl_2$ in the range of 5.2-6.55. As pH levels drop below 5, increasing amounts of toxic aluminium and manganese can enter the soil solution. This effect is common in the coastal soils of NSW and is greatest in soils that are low in organic matter as indicated by an organic carbon soil test. For soybean, keep aluminium saturation levels less than 15% and manganese less than 20 mg/kg. If barley is also grown, depending on variety, keep aluminium saturation levels below 5% and manganese less than 50mg/kg. Soils with a $pHCaCl_2$ of 4.5 or less are unsuitable for growing soybean.

For example, many soils on the wet tropical coast of Queensland are marginal for soybean without the application of lime. However, most Burdekin district soils are primarily in the range of pH 6-8 while those in the Mackay district range from pH 5-6.5. Where the soil is acidic liming is an important consideration. However, it should only be carried out after a soil test indicates lime is needed. In sugarcane areas mill mud can be a valuable source of calcium and other nutrients. [12]

11 M Bennett (2008), Soybean Production Recommendations for the NT: http://www.nt.gov.au/d/Content/File/p/Crop/659.pdf

12 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

1.4.2 Soil Salinity

Soybeans are intolerant of salt. Yield reductions occur at soil salinities greater than 2.0 dS/m and irrigation waters greater than 1.5 dS/m. Nodulation is impaired and plant growth is affected. Paddocks with known salinity problems should be avoided. Numerous Burdekin Delta farms in Queensland may have issues with soil salinity from saline irrigation (bore) water. This is usually less of an issue for summer crops (which are primarily rain grown), however, may be a significant issue for winter crops that are usually 100% irrigated.[13]

1.5 Soil moisture

1.5.1 Dryland

Soybeans must be sown into good soil moisture to ensure inoculant and seed survival. Soybean is a tropical legume so it requires adequate soil moisture especially in the establishment phase. The worst situation is when the seed is sown and starts to germinate but does not have adequate moisture to complete the process and establish a primary root down into moist soil. Seedlings direct drilled into stubble or sprayed out pasture cope better with hot dry conditions during establishment, which would be due to the moisture conservation aspects of the stubble coverage (compared with bare worked ground) and not varietal differences.

1.5.2 Irrigation

Soybeans are suited to a range of irrigation systems including raised beds, furrow, full flood and sprinkler irrigation. Regardless of the type of irrigation system, soybeans have a peak water demand during flowering and early pod filling.

In the subtropical and tropical coastal production regions, summer grown soybeans are usually grown on rainfall alone, however, irrigation (if available) is also used to supplement growth. Winter grown soybeans in the tropical north (e.g. Burdekin) rely almost fully on irrigation. High yielding soybeans receiving little or no rain typically use 6-8 ML of irrigation water/ha depending upon soil type, variety, paddock/irrigation layout and seasonal conditions.

In irrigated cropping systems (e.g. southern and central Queensland, northern inland and southern New South Wales and northern Victoria), the quantity of irrigations applied will vary depending on season, soil type and target yield. Implementing a scheduling system to help identify when the crop is approaching water stress is recommended.

Pre-irrigating fields one to three weeks prior to planting is recommended. This allows accurate planning of planting time, consolidation of the beds, planting into moisture and controlling weeds prior to planting. Watering up is possible but requires more care to ensure soils do not crust and weeds do not germinate at the same time as the crop. If watering up, particularly on heavy soils, plant at as shallow a depth as possible and only plant as much area as can be irrigated in a set.

13 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

Figure 4: Young soybeans established in rice stubble on beds in bankless irrigation bays.

Grain yield and protein content are dependent on timely irrigations throughout the life of the crop, and avoiding moisture stresses. Mild moisture stress in the early vegetative stage has little impact on grain yield and can encourage the plant to seek moisture with a deeper root system. Intermittent moisture stress should be avoided as it may reduce grain protein content. When soybean plants start to become moisture stressed, they will firstly shutdown the nodules in the root system and will not activate them again until they receive adequate moisture. However, the delay between crop irrigation and fully functional rhizobia can be several days. The cumulative effect over the season can have a negative impact on the total nitrogen content within the plant and ultimately grain protein content.

As soybeans are often flowering and filling pods during the hottest part of the year, moisture stress can reduce yield by reducing the number of retained pods and by reducing seed weights.

It is critical that the plants do not experience moisture stress from the start of flowering, through pod development and filling to physiological maturity. For a crop planted in late November-early December in southern NSW, this means the peak water demand is from mid January to late March. This equates to 50–110 days after emergence. For a crop planted in mid-late December in north Queensland, the peak water demand is from mid February to early April. This equates to 50–110 days after emergence.

In terms of irrigation scheduling, it is not possible to make a definitive statement that will be appropriate for all soil types. Ideally some form of irrigation monitoring equipment (evaporation pans, enviroscans, etc) should be used to support irrigation decisions. Seek advice from an experienced local agronomist if in doubt.

The timing of the final irrigation is also critical, as it needs to be timed to ensure adequate water until physiological maturity yet not allow the field to remain too wet for harvest. Many growers stop irrigation too soon and lose valuable yield. As a very general guide, apply the final irrigation when the first maturing (pale yellow) leaves appear in the crop. Consider choosing a shorter-season (fast maturing) variety if one is available for your region as this may reduce the number of irrigations required for the crop.[14]

1.5.3 Double crop options

Double cropping after soybeans is a common practice in the northern tablelands of NSW. Generally soybeans are planted early November and harvested in April which will allow enough time to crop back into a winter cereal crop in June. Double cropping from a cereal into a soybean crop is very risky, due to low moisture profile after winter crop cereal.

1.6 Nematode status of paddock

1.6.1 Effects of cropping history on nematode status

A field trial of three cropping histories (sugarcane, maize and soybean) and two tillage practices (conventional tillage and direct drill) on plantparasitic and free-living nematodes in the following sugarcane crop was conducted at Bundaberg, Queensland, in 2010. Soybean reduced populations of lesion nematode (*Pratylenchus zeae*) and root-knot nematode (*Meloidogyne javanica*) in comparison to previous crops of sugarcane or maize but increased populations of spiral nematode (*Helicotylenchus dihystera*) and maintained populations of dagger nematode (*Xiphinema elongatum*). However the effect of soybean on *P. zeae* and *M. javanica* was no longer apparent 15 weeks after planting sugarcane, while later in the season, populations of these nematodes following soybean were as high as or higher than maize or sugarcane. Populations of *P. zeae* were initially reduced by cultivation but due to strong resurgence tended to be higher in conventionally tilled than direct drilled plots at the end of the plant crop. Even greater tillage effects were observed with *M. javanica* and *X. elongatum*, as nematode populations were significantly higher in conventionally tilled than direct drilled plots late in the season. Populations of free-living nematodes in the upper 10 cm of soil were initially highest following soybean, but after 15, 35 and 59 weeks were lower than after sugarcane and contained fewer omnivorous and predatory nematodes. [15] See Section 8–Nematodes for more information.

14 Australian Oilseeds Federation (2013), Better Soybeans manual http://www.australianoilseeds.com/soy_australia/Soybean_Production

15 GR Stirling, NV Halpin, MJ Bell and PW Moody (2010), Impact of tillage and residues from rotation crops on the nematode community in soil and surface mulch during the following sugarcane crop: http://www.assct.com.au/media/pdfs/Ag%206%20Stirling.pdf