final report

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Legume Best Management Practice in the Brigalow Belt Bio-region – Stage 1

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Abstract

Pasture legumes have been identified as the best long-term option to increase the productivity and returns from grass pastures through their ability to increase live-weight gains and carrying capacities. Despite impressive results from a number of legumes in trials and some commercial pastures, adoption levels remain very low in the Brigalow Belt. These very low adoption rates mean there is a huge opportunity to increase beef production through the wider successful adoption of pasture legumes in the Brigalow Belt, and provide significantly higher returns for decades to come.

This project aims to increase the productivity of grass pastures in the Brigalow Belt (primarily in southern and central Queensland but also extending into north Queensland) through more reliable and successful adoption of legumes. A coordinated extension program will support landholders to assess and implement on-farm options to successfully adopt legumes; and a coordinated Research and Development program will develop management practices to improve establishment reliability and long term (20+yrs) performance of legumes in grass pastures. This report describes the foundational activities involved in starting the project.

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1 Description

Technical report submitted to MLA in the form of a short report summarising the overall project and the activities to date including:

A. Four grazier groups engaged in learning based extension activities. Eight on-farm research or demonstration sites initiated.
B. Six trial sites selected to test legume persistence on the Darling Downs, Goondiwindi and St George districts. Plans for fallowing and seedbed preparation developed with cooperating landowners.
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F. Existing extension materials reviewed and a plan developed for updating materials where appropriate.
G. Overview describing how the activities conducted in this project contribute to achieving milestones in Stage 2 of the project.

2 Project objectives

The objective of Stage 1 of the project is to conduct preliminary activities to facilitate the timely commencement of Stage 2 undertakings. These include:

- Producer engagement
- Support producers with site preparation
- Summer measurement of legume and grass pastures

The overall aim of this research work is to facilitate widespread and successful (high productivity and persistence) adoption of pasture legumes in the Brigalow Belt Bio-region. It will achieve this aim through developing and extending management practices to improve the ***reliability*** of legumes, especially their establishment into existing grass pastures.
Objectives by the end of the five year period of the project are:

- Develop agronomic management recommendations and package them into extension products to assist graziers and their advisors to:
    - More reliably and effectively establish legumes into existing grass pastures. This will be achieved by identifying and testing practical means of optimising soil moisture and nutrient availability; and minimising competition from existing grass pasture and weeds.
    - Maintain productivity in the longer term.
- Improve available web information pages (such as MLA and FutureBeef) with updated legume establishment and management recommendations.
- Develop legume management plans with 20 groups of producers.
- Facilitate groups of producers and/or individuals to increase successful legume adoption by testing legumes and management practices on their own farms.
- From these groups' successful adoption of legumes, develop case studies and demonstrate the value propositions for other producers to adopt.
- Test the persistence and productivity of commercially available legumes in new areas, specifically desmanthus and Caatinga stylo on the Darling Downs and Border Rivers regions where there are no historical or current trial sites.

- Test the impact of phosphorus fertiliser on the establishment and early growth (up to 3 years growth) of desmanthus, Caatinga stylo and medics.
- Increase the number of producers that are successfully establishing legumes into existing grass pastures. This project aims to work directly with 160 producers to improve the reliability and successful adoption of legumes, thereby improving productivity. Based on property information these producers are likely to have approximately 400,000ha of sown pasture, 450,000ha of native pasture and 180,000 cattle.
- Increase the area successfully planted with pasture legumes in the Brigalow Belt. This project is aiming for participating producers to establish 250ha of legumes using more reliable establishment techniques, which collectively would result in 40,000ha of legume based pastures.

3 Methodology

The methodology of the full research program is outlined below whereas Stage 1 activities are identified in the milestone description in Section 1.

This project proposes an integrated suite of participatory Research, Development and Adoption (RD&A) activities which will bring together the knowledge and experience of scientists, graziers, grazier groups, and their advisers to drive adoption. Development and extension activities will utilise past research to help graziers recognise and understand reduced pasture productivity due to reduced N availability ("rundown" in sown pastures; productivity constraint in native pastures), and to apply current best management practices to establish and manage pasture legumes to increase productivity and resilience on their own farms. At the same time, research with pasture legumes will confirm the most persistent and productive varieties, further develop practical ways to establish them into existing grass-only pastures and increase their productivity through improving nutrition.

There are four main components/activities to this project:

1. Improving understanding and testing legume options with industry.
2. Persistence and comparative productivity of legume varieties.
3. Nutrition of legumes during establishment and early growth.
4. Improving the reliability of establishing legumes in existing grass pastures.

3.1 Improving understanding and testing legume options with industry

The project will use a learning based approach to work with industry (graziers, advisors, seed industry) to better understand the drivers of successful legume establishment and high production in the long term; and to identify, develop and test improved management practices on-farm. This on-farm testing will provide real farm data and practical experiences that can be extended to the wider grazing community. It is anticipated that the project team will work with approximately 20 groups of graziers and their advisors primarily across southern and central Queensland; but extending into northern Queensland (south of Townsville) to improve understanding of legume establishment and management, develop management plans and test options on farm.

In the first year, the team will develop a learning package on *reliable* and *successful* adoption of legumes (i.e. high production and persistence) in the Brigalow Belt. The learning package will evolve but will include both workshop and field based activities. Materials will be developed through reviewing existing materials and incorporating new trial results both from this project, other current projects and previous projects, especially the "Improving productivity of rundown sown grass pastures" project which conducted research trials on a number of aspects of improving the performance and reliability of pasture legumes in the Brigalow Belt. There will be a focus on

improving the reliability of establishing legumes as poor establishment is the most common reason for legumes failing when sown into existing grass pastures, however the learning package will include other aspects of managing legume based pastures for higher productivity. Components of the learning package will involve:

- Understanding nitrogen (N) cycling and the impact of low N availability (e.g. an on-farm activity to demonstrate the impact is to apply N fertiliser to show production potential).
- Understanding the role of legumes in increasing N supply, improving diet quality and their impact on production and economic returns.
- Developing plans for incorporating and managing pasture legumes for participants own situation and farms.
- Testing/implementing legume options on farm. These activities will link with component 4 of the project for trial sites demonstrating the impact of improved practices on legume establishment, as well as participants being supported to conduct trials on their own properties.

A key output from this component of the project will be to develop agronomic management recommendations and package them into extension products to assist graziers and their advisors to:

- More reliably and effectively establish legumes into existing grass pastures. This will be achieved by identifying and testing practical means of optimising soil moisture and nutrient availability; and minimising competition from existing grass pasture and weeds.
- Maintain productivity in the longer term.

Legume establishment extension products will include workshop materials, fact sheets and web pages (on the FutureBeef website).

3.2 Persistence and comparative productivity of legumes

Commercially available legume varieties of Caatinga stylo, desmanthus and leucaena have been demonstrated to be persistent and productive for many, but not all regions of the Brigalow Belt. For example, there is a good network of trial sites across central Queensland, but no legume evaluation or comparative productivity trials for desmanthus and Caatinga stylo have been conducted on the Darling Downs or Border Rivers (Peck *et al.*, 2012). Several landholders have reported that Caatinga stylo and desmanthus have not persisted well on the Darling Downs or Moreton districts, but it has done well further west near Roma. Trials are required to determine if the failure to persist in grazier sowings is due to the adaptation of the varieties to the cooler environment (or perhaps a combination of cooler with more moisture) or another constraint (e.g. grazing management, soil constraints).

This activity proposes to establish trials on the Darling Downs (i.e. from Warwick in the south to around Dalby) and Border Rivers districts (e.g. around Goondiwindi and St George) to test the persistence and productivity of current commercial legume varieties for clay soils. The aim of this activity is to test whether the commercially available legume varieties are well enough adapted to these districts to form a persistent and productive pasture in this environment, or whether new varieties are required (i.e. it is primarily a research question).

The nine legume varieties to be tested are:

- Caatinga stylo cv's. Primar and Unica.
- *Desmanthus virgatus* cv's. Marc, JCU2, JCU3, JCU5.
- *Desmanthus leptophyllus* cv. JCU1.
- *Desmanthus bicornutus* cv. JCU4.
- Leucaena cv. Wondergraze

Where possible, legumes will be established in replicated large plots (>200m^2/plot) to allow a large enough area to cope with grazing and biomass cuts. However, this trial design may have to vary depending on seed availability and the size of the trial paddock (which will be negotiated with landholders). If trial size and/or seed availability limit these trials, a combination of large plots (e.g. smaller number of varieties and/or mixed varieties) and smaller plots (with a greater number of varieties) may be used.

These varieties have been chosen as they represent the persistent summer growing legume varieties adapted to clay soils in the Brigalow Belt. The commercially available legume varieties of other summer growing legume species used on clay soils in the Brigalow Belt have already been demonstrated to not be persistent under grazing in these districts (i.e. Siratro, burgundy bean and butterfly pea) and will therefore not be planted at these trial sites. These short term pasture varieties will be included in some demonstration trials as part of component one of this project.

The key measurement will be legume plant numbers over time. Where appropriate, dry matter (DM) cuts will compare productivity but will depend on grazing periods of cooperating graziers.

3.3 Nutrition of legumes during establishment and early growth

This activity involves testing the impact of phosphorus (P) fertiliser when establishing legumes on low P soils. This activity will establish two research trials (replicated trials) testing the impact of different rates of fertiliser on legume establishment and early growth in the first three years after sowing. Five different rates of P fertiliser will be used (0, 10, 20, 50 and 100 kg P/ha). Legumes to be tested are:

- Barrel medic cv. Caliph
- Button medic cv. Bindaroo Gold
- *Desmanthus leptophyllus* cv. JCU1
- *Desmanthus virgatus* cv. JCU2
- Caatinga stylo cv. Unica

Key measurements for these trials will be the impact of different rates of P fertiliser on:

- Early seedling vigour.
- Plant numbers over time (i.e. survival and recruitment).
- DM yield.

3.4 Improving the reliability of establishing legumes in existing grass pastures

This activity involves continuing trials started in the "Improving productivity of rundown sown grass pastures" project as well as establishing new trials. These trials are comparing a range of legume establishment techniques (both pre and post sowing practices) on short and long term legume population and production.

3.4.1 Existing research trials:

The existing trials that will be continued from the "improving productivity of rundown sown grass pastures" project are:

- Fallowing, post emergence weed control and planting methods impact on legume establishment in existing grass pastures trials. There are five trials across the Wandoan, St George and Goondiwindi districts. These trials are continuing to provide data that is essential to informing industry about improved reliability of legume establishment.
- Rate of legume spread into existing grass pastures when established in strips. There are five trials in the Wandoan, St George and Goondiwindi districts.

3.4.2 New demonstration trials:

New on-farm legume establishment demonstration trials are focussed on adapting the results from research trials (plot trials) initiated as part of the "Improving productivity of rundown sown grass pastures" project to commercial situations at the paddock scale. These trials will be negotiated with the hosting grazier to implement the principles of better agronomic practices developed for establishing legumes in research trials to their own property using their own machinery (although the Department of Agriculture and Fisheries [DAF] pastures team planter may be used to demonstrate some practices e.g. water injection of rhizobia inoculant).

These establishment trial sites will be focus points for engaging with industry (graziers and their advisors) in component 1 of this project and will therefore have a geographic spread across the Brigalow Belt Bio-region. The main point of difference between these sites and the on-farm demonstrations in component 1 of the project is their use in engaging landholders; they will therefore be measured in greater detail and have a number of field days at each site. Proposed locations for these trials will be dependent on engaging with willing co-operators, indicative locations are:

- Central Queensland: east (Lower Dawson e.g. Biloela, Moura); west (southern Central Highlands e.g. Emerald, Rolleston); central (e.g. Middlemount).
- Southern Queensland: north-west (e.g. Roma); East (e.g. Chinchilla, Miles); south-west (e.g. Westmar).
- South-eastern Queensland: Inland Burnett north (e.g. Eidsvold, Munduberra), Inland Burnett south (e.g. Kingaroy, Gayndah).

In addition to the trials listed above, this component of the project will be instrumental in developing legume establishment and management recommendations for developing extension products (described in activity 1).

4 Success in meeting the milestone

4.1 Milestone 2A: Four grazier groups engaged in learning based extension activities. 8 on-farm research or demonstration sites initiated.

Engaging grazier groups and initiating on-farm research or demonstration sites has not occurred as intended. It was decided that it would be more useful to spend more effort on developing the "learning package" in the first six months of the project then in conducting workshops. It is intended that more time spent on developing materials, process and evaluation strategy early will allow more effective and efficient delivery of the learning package over the life of the project.

The project team has been developing workshop materials and processes to facilitate participants to consider the key factors that contribute to legumes succeeding or failing in commercial pastures. Research and development projects have been reviewed for incorporating recent findings into extension materials, especially the recently concluded "Improving productivity of rundown sown grass pastures" project. To further develop the workshop a peer review process of conducting a workshop with the DAF southern Queensland beef team and some external invited guests has been organised for 29 March 2017. The learning package materials, process and evaluation will be updated based on feedback from the peer review workshop. The content is still being finalised, however Table 1 outlines the sections and topics that are expected to be incorporated into the workshop.

Table 1. Topics to be included in action learning workshop

Section	Topic
Welcome	Introductions Expectations and icebreakers Overview of project and workshop
Identify the problem	Current situation: Declining production due to lack of available N in sown pastures Low pasture and animal diet quality for most of year in native pastures
Identify the solutions	Value proposition of legumes: Other N supply options not as profitable as legumes in long term Production, Environmental and Economic benefits of legumes What does success look like
How to establish legumes	Keys to establishment success and critical steps/periods: Planning, fallowing, sowing, early establishment
On-going legume management	Maintaining productivity into the future: Grazing and soil nutrition management, grass: legume ratio
Action plan report back	Finalise individual management action plans; report back to group.
Conclusion	Wrap up, decide on hosts for on-farm demonstrations

It is anticipated that the learning package will be well developed and ready for delivering to grazier groups and their advisors shortly after the peer review workshop. The project team will conduct workshops across the inland Burnett River catchment (south-east Queensland), southern and central Queensland before September. The plan is to conduct three to four workshops in both southern and central Queensland and two workshops in south-east Queensland before September.

4.2 Milestone 2B: Six trial sites selected to test legume persistence on the Darling Downs, Goondiwindi and St George districts. Plans for fallowing and seedbed preparation developed with cooperating landowners.

Six trial sites have been selected at the following locations:

- Two trial sites at Spring Creek near Allora on the southern Darling Downs. One of the trials is located on the valley floor and is expected to experience a high frost incidence. The other trial site is located mid slope and is likely to have less severe frost effects.
- Two trials on "Kioma" north-west of Goondiwindi. One trial is on a poplar box loamy soil (Kandosol) while the other is on a Brigalow/belah clay soil (Vertosol or Sodosol).
- Two trial sites on "Myall Plains" south of St George. One trial is on a poplar box loamy soil (Kandosol) while the other is on a Brigalow/belah clay soil (Vertosol or Sodosol).

Plans for fallowing and seedbed preparation have been discussed with the owners or in the case of Kioma the manager of the properties. These plans will be documented in trial site agreements over the coming months with fallowing due to start in April.

4.3 Milestone 2C: Two low phosphorus trial sites selected for phosphorus fertiliser impacts on legume establishment trials. Plans for fallowing and seedbed preparation developed with cooperating landowners.

Soil sampling has been undertaken, but at the time of writing soil test results have not been received and therefore sites have not been selected.

Two properties with known low phosphorus levels from previous projects conducted by the sown pastures team have had soil samples taken. Both properties have previously hosted trials in conjunction with DAF and both are currently hosting legume establishment trials being continued in this project (Milestone 2D). The two properties are “Kioma” near Goondiwindi and “Juandah Valley” near Wandoan. At Kioma, three locations were sampled for P levels. At Juandah Valley, four locations were sampled for P levels.

4.4 Milestone 2D: Two legume establishment research trials measured

Three legume establishment trials have been measured, two near St George and one near Goondiwindi. These trial sites have been severely impacted by drought over the last two years. The trial sites near St George have had especially low summer rainfall over the last two summers which has resulted in the best treatments having very low legume density and other treatments having either no or negligible amounts of legumes. The trial sites at Kioma near Goondiwindi have also been affected by drought, especially the loam trial site which has therefore not been measured this summer.

4.4.1 Methodology

These trials are investigating the impact of better agronomic practices that are commonly used for grain cropping in the Brigalow Belt Bio-region on establishing small seeded pasture legumes into existing grass pastures. Treatments were a combination of fallow period, seedbed preparation (zero tillage or cultivation), post-emergent weed control and sowing method.

Six trials across three districts (Wandoan, Goondiwindi and St George) and two soil types (grey cracking clays and loamy surfaced soils) were conducted over four years to test the impact of better agronomy on establishing small seeded legumes into existing grass pastures. This array of districts and soil types was selected in order to capture a broad insight into the effectiveness of the treatments applied across a range of geo-climatic environments within the Queensland portion of the Brigalow Belt Bioregion. For instance, it was anticipated that loam and clay soil types would vary in their capacity to store moisture during fallows, form soil crusts after rain and have different weed pressures. It was also expected that localities with lower annual average rainfalls would pose more challenges in achieving fallow moisture storage and plant survival.

4.4.1.1 Trial design and treatment

The trials were designed with 5.5 m wide by 20 m long plots with grass strips (either 4.5 or 2.5 m) left between each plot with two replicates of each treatment. Clay soil trial sites were sown with Progardes desmanthus (a blend of five varieties from three *Desmanthus spp.*). The Wandoan loam soil site was sown with fine-stem stylo (*Stylosanthes guinensis var. intermedia*); Goondiwindi and St George loam sites were sown with Caatinga stylo (*Stylosanthes seabrana cv. Primar* and *Unica*).

A full description of treatments is provided in Table 33. There were 30 treatments in total, with most treatments also having split plots in which seed was either drilled with a single disc opener planter or broadcast. The one-pass cultivation treatments described below did not have split plots, that is seed was broadcast over the whole plot, as graziers would most likely spread seed at the same time as cultivation in a one pass operation as opposed to drilling seed as part of a second operation. Not all treatments were included at each site.

Treatments were a combination of fallow period (i.e. period from first treatment to control the grass until sowing); seedbed preparation (zero tillage or cultivated); and post-emergent weed control as follows:

- No disturbance of the grass pasture.
- Grass pasture disturbed at plant through: slashing; cultivation with a deep ripper, tynes or off-set discs; herbicide spray (glyphosate) with no-post emergence herbicides.
- Short fallows of 2 - 4 months using herbicide (i.e. zero tillage [ZT]), cultivation or both.
- Medium fallow of about 4 - 6 months using either ZT or cultivation.
- Long fallow of about 4 - 6 months using either ZT or cultivation.

Zero-till herbicide applications were conducted primarily using a mix of Roundup® at 2L/ha and LI-700® wetting agent at 250ml/ha. Where broadleaf weeds needed to be controlled 2,4-Dimethylamine (2,4-D) or Starane® (Fluroxypyr) were used. Multiple herbicide applications were used during the fallow period depending on the time period of the particular fallow, rainfall and weed loads.

Cultivated fallows were conducted slightly differently for the different locations as follows:

- Wandoan: The medium fallows were initially cultivated with off-set discs, with subsequent treatments using a chisel plough. Short fallows used a chisel plough only.
- Goondiwindi: All cultivated fallows were initially cultivated with offset discs with longer fallows being treated on two separate occasions. Herbicides were used during the fallow period for the long cultivated fallow treatments once a uniform seed-bed had been created after the second cultivation to try and maintain some ground cover.
- St George: All cultivated fallows were initially worked up using a one way disc plough with the centre of the plots being worked twice due to the width of the grazier's machine. After the initial cultivation treatment, herbicides were used to try and maintain ground cover to maximise soil water storage.

Within the fallow treatments there were also with and without post emergent weed control treatments. The ZT with post-emergent selective herbicide plots were treated as required with either Basagran® at 1L/ha with LI-700® at 200ml/100L for broadleaf weed control and/or Verdict 520® at 100mls/ha with LI-700® at 200ml/100L for control of grass. In the cultivation treatments that received post-emergent herbicide, Spinnaker® was applied at a rate of 50g/ha. Chemical active constituents are summarised for all applied herbicides in **Error! Reference source not found.**2.

Table 2: Active constituents of herbicide chemicals applied in the study.

Chemical Trade Name	Active Constituent
Roundup®	540 g/L glyphosate (present as the potassium salt)
LI-700®	350g/L soyal phospholipids, 350g/L Propionic acid
Basagran®	480 g/L bentazone (present as sodium salt)
Verdict 520®	520 g/L haloxyfop present as the haloxyfop-R methyl ester
Spinnaker®	700 g/kg imazethapyr

Legume plant numbers and pasture biomass were measured for up to three years post sowing. Destructive biomass estimates were taken after a minimum of 12 months after germinating rain. The trial sites were grazed through winter but un-grazed during summer to allow the measurement of plant growth.

Table 3. Description of establishment trial treatments and the districts within which they were applied.

Treatment count	Fallow period	Seedbed treatment	Post plant weed control	Sowing (split plots)	District †
1	No disturbance	None	Nil	Drill and broadcast	W,G,S
2	Disturb at plant	Slash	Nil	Drill and broadcast	W,G,S
3		Deep rip	Nil	Broadcast only	W,G,S
4		Cultivate (tynes)	Nil	Broadcast only	W,G,S
5		Cultivate (discs)	Nil	Broadcast only	G,S
6		Spray	Nil	Drill and broadcast	W,G,S
7	Short (2-4 months)	Zero-till (ZT)	Nil	Drill and broadcast	W,S
8			PEH*	Drill and broadcast	W,S
9		Cultivate	Nil	Drill and broadcast	W,S
10			Spinnaker	Drill and broadcast	W,S
11		Cultivate then spray	Nil	Drill and broadcast	S
12			PEH*	Drill and broadcast	S
13		Spray then cultivate	Nil	Drill and broadcast	W
14	Medium (4-6 months)	Zero-till	Nil	Drill and broadcast	W,G,S
15			PEH*	Drill and broadcast	W,G,S
16		ZT + grass seed	Nil	Drill and broadcast	W
17		Cultivate	Nil	Drill and broadcast	W,G,S
18			Spinnaker	Drill and broadcast	W,G,S
19		Cult. + grass seed	Nil	Drill and broadcast	W
20	Long (9-18 months)	Zero-till	Nil	Drill and broadcast	G,S
21			PEH*	Drill and broadcast	G,S
22			PEH* 2nd summer	Drill and broadcast	G,S
23		Cultivate	Nil	Drill and broadcast	G,S
24			Spinnaker	Drill and broadcast	G,S
25			2 Spinnaker applications	Drill and broadcast	G,S
26		Cult. + grass seed	Nil	Drill and broadcast	G
27	Long + medic	ZT Medic	PEH*	Drill and broadcast	G
28		Cultivate + medic	Spinnaker	Drill and broadcast	G
29		Cultivate + medic + P fert.	Nil	Drill and broadcast	G
30		Cultivate + medic + P fert.	Post emergence herbicide	Drill and broadcast	G

* PEH: post-emergence herbicide; † District: W is Wandoan, G is Goondiwindi, S is St George.

4.4.1.2 Medic treatments

Due to drought conditions at the Goondiwindi trial site sowing was held over by a year. This delay in planting allowed the inclusion of more long fallow treatments including the addition of planting medic in winter prior to sowing summer growing legumes in the following season. These treatments were fallowed for six months via either zero-till herbicide application or cultivation. The seedbed fallow preparations can be summarised as follows:

- Zero-till with post-emergent selective herbicide.
- Cultivation with Spinnaker® post-emergent herbicide.
- Cultivation with phosphorus applied at 20kg/ha.
- Cultivation with phosphorus applied at 20kg/ha and Spinnaker® post-emergent herbicide.

Each plot was divided in half and each half randomly assigned to be sown either by broadcast or drilling in late April 2014. An equally weighted mix of three medic cultivars (barrel medic *Medicago truncatula cv. Jester & cv.Caliph* and button medic *Medicago orbicularis cv. Bindaroo Gold*) was sown at a total seeding rate of 3kg/ha. Drilling was conducted using a single disc opener planter with seeds placed at a shallow depth (<10mm). Broadcasting seed was done by hand. Phosphorus was applied at the time of planting at a rate of 20kg/ha in the form of superphosphate via shallow tines to the relevant plots. Rigid mesh grazing exclosures (2m x 1m) were erected in the centre of each split plot (one in the broadcast end and one in the drilled end). Plots were measured within the grazing exclosures for plant population and total medic dry matter using 1m x 1m quadrats at the end of September 2014.

4.4.1.3 Sowing dates

All trials were sown in the first two weeks of February of their respective years (Wandoan in 2013 and both St George and Goondiwindi in 2015). All sites received below average rainfall during the fallow periods. Sowing in February was to allow as long a fallow period over spring and summer as possible, while still leaving enough time for seedlings to develop into strong plants and produce some seed prior to the onset of winter. This time of year has better prospects of germinating rain with follow up rain and daytime temperatures tending to be cooler than earlier in summer.

4.4.2 Results and discussions

Only the results for the 2016/17 summer growing season are presented in this report, previous results have been described in the final report for the "Improving productivity of rundown sown grass pastures" project. Trial results are shown in Appendix 1. Statistical analysis will be conducted when all establishment trials have been recorded and presented as part of the September milestone report.

4.4.2.1 St George trials

Trial results at St George have been severely impacted by drought. Initially there was a clear trend of higher plant densities with increasing fallow periods. Results from the recent recording are shown in Sections 7.2 and 7.3. Specific points from the recent recording include:

- At both the loam and clay trial sites there has been a severe reduction in legume density across all treatments due to plant deaths during drought (Figs. 6 and 8).
- All treatments have very low legume densities. Unfortunately, the drought conditions and very low legume densities have compromised the value of these trial sites for quantifying the impact of different establishment methods in more average seasons (Figs. 7 and 9).
- There is a trend towards higher legume densities with longer fallow periods (Figs. 7 and 9).
- The loam results show an interesting interaction with competition from medics (Fig. 9). The long cultivated fallows with Spinnaker provided good conditions (i.e. bare ground, lack of grass competition) for very high medic growth when good winter rains were received. Therefore the lack of Caatinga stylo plants in these treatments reflects very high

competition imposed upon the stylo seedlings from the medic as opposed to direct damage from the herbicide.

4.4.2.2 Goondiwindi clay soil trial site

The results at the Goondiwindi clay provide the most complete array of treatments of the six trial sites because the Wandoan trial sites did not include long fallows and the St George sites have been severely impacted by drought. The results from Goondiwindi are shown in Section 5. Specific results from this trial result include:

- A clear trend of increasing legume density and dry matter production with increasing fallow lengths (Figs. 1 and 2).
- Positive results in both legume density and dry matter production from drilling in long fallow zero-till treatments seem to be still present at 24 months after the first germinating rains (Figs. 2 and 5).
- Use of post-emergence herbicides in ZT treatments or Spinnaker in cultivated treatments has increased dry matter production in both the first and second year after emergence in long fallowed treatments (Fig. 4).
- There were dramatically more seedlings in the cultivated long fallow treatments with Spinnaker and the ZT long fallow treatment with post emergence herbicide during the second summer (Fig. 3). These higher seedling numbers are likely to reflect both the higher growth in these treatments in the preceding summer and the lower competition from grass and weeds this summer (Fig. 4).

4.5 Milestone 2E: Six legume establishment demonstration trial sites selected. Plans for fallowing and seedbed preparation developed with cooperating landowners.

Three landholders have agreed to conduct legume establishment demonstration trials in southern Queensland. Several landholders in central Queensland have previously expressed interest in conducting trials on their properties, but have not yet been directly approached as part of this project. Graziers have not yet been approached in the inland Burnett (part of south-east Queensland). Additional landholders will be approached in the coming months to reach the target number of demonstration sites. Plans for the trial sites will be developed in coming months in discussion with participating landholders.

4.6 Milestone 2F: Existing extension materials reviewed and a plan developed for updating materials where appropriate.

A review of extension materials relating to best management practices for legumes in the Brigalow Belt Bio-region has commenced. The review is being conducted in conjunction with the development of the new legume learning package and extension strategy for this project.

4.6.1 Objectives

The main objectives of the review are:

1. The review was to form a gap analyses to identify:
    - Pasture/legume resources that are currently available
    - Pasture/legume topics that are covered well
    - Pasture/legume topics that are poorly covered

2. The review was to identify pathways for the future development and availability of extension materials including:
    - Procurement of extension materials that have become unavailable but remain relevant and up to date.
    - Where applicable, the updating of existing resources.
    - The creation of new materials where gaps exist.
    - The incorporation of useful existing material into the development of the learning package and extension strategy as part of this project.

4.6.2 Methodology

The DAF sown pastures team commenced the review process by brainstorming and listing all of the known published and online extension resources available. The team also sorted through the collective bank of publications in possession of team members. Targeted internet search terms were applied and information sources such as government departments, non-government agencies and commercial company websites were also interrogated and reviewed.
All materials are being categorised into the following forms of extension resources:

- State departmental publications
- Industry partnership publications
- MLA publications
- Factsheets
- Grains Research and Development Corporation publications and resources
- Seed industry guides
- Tropical Grasslands Society publications
- Landcare publications
- Research reports
- Webpages
- Online videos/Webinars
- Workshop training materials

Workshop training materials, such as *LeyGrain*, the Leucaena Network's *Leucaena for profit and sustainability* and the MLA EDGE Network's *Grazing Land Management* package are being reviewed and used to inform the legume BMP learning package being developed as part of this project.
For each catalogued resource, the following information is being collated:

- Title
- Publication type
- Author/Publisher
- Publication date
- ISBN
- Availability of the resource
- Currency of information (have there been new research findings or new species/cultivar releases since publication?)
- Technical soundness
- Overall and additional comments and/or issues of note

The technical soundness component of the review aims to assess whether information contained within the resources is in alignment with current best practice recommendations and the most recent research findings. In particular resources were scrutinised for:

- Appropriateness of species mix recommendations (for environment, timing of sowing and species compatibility).

- Sowing technique recommendations (findings from the recent *Improving productivity of rundown sown grass pastures* report (B.NBP.0639) demonstrated that ground preparation and establishment methods were critical in determining success and failure in legume establishment.

A summary of catalogued resources and nodes of information accounted for to date can be found in Table 4.

4.6.3 Preliminary Findings

To date 72 extension resources have been catalogued as part of the review. The team is currently in the process of identifying further materials and individually reviewing each resource using the criteria described above.

There were a number of resources produced by the Queensland Government and its co-funders from the mid-1980s to the mid-1990s. At the time, a number of these represented excellent resources that were both comprehensive and technically sound in regards to species selection, establishment and post-sowing management. However, since 2000 only a handful of publications have been produced, all of which provide either species specific information or particular aspects of managing long term pastures in the Brigalow Belt Bio-region:

- Bowen, M., Buck, S. & Chudleigh, F. (2015) Feeding forages in the Fitzroy: A guide to profitable beef production I the Fitzroy River catchment. Queensland Department of Agriculture and Fisheries.
- Partridge, I., Cook, S., Paton, C., Johnson, B. & Lambert, G. (2009). Pastures for Protection & Production on marginal cropping lands. Queensland Department of Agriculture and Fisheries.
- Dalzell, S., Shelton, M., Mullen, B., Larsen, P., McLaughlin K. (2006). Leucaena: A guide to establishment and management. Sydney: Meat and Livestock Australia Ltd.
- Bullen, K. (2002) The Lucerne management handbook 4th Edition. Queensland Department of Agriculture and Fisheries.
- Conway, M., Grundy, P., Collins, R. (2005) The butterfly pea book: A guide to establishing and managing butterfly pea pastures in central Queensland. Queensland Department of Agriculture and Fisheries.
- Drew, E., Herridge, D., Ballard, R., O'Hara, G., Deaker, R., Denton, M., Yates, R., Gemell, G., Hartley, E., Phillips, L., Seymour, N., Howieson, J & Ballard, N. (2002) Inoculating legumes: A practical guide. Grains Research and Development Corporation.

Each of the above, while being useful and technically sound, cover only a specific component topic resource as part of the broader picture of best management practice for legumes in the region. There has not been a comprehensive publication addressing overall management practices grasses and legumes within the Brigalow Belt Bio-region since 1996 (Lambert & Graham, *Sown pasture notes: Central Queensland*).

A small number of other minor resources have been produced since 2000, however all of them lack detailed information regarding ground and seed preparation, fertiliser considerations, establishment techniques and species adaptation and selection. Many of these resources are also now both out of print and no longer current. In recent years there have been several research developments in regards to legume establishment methods, fertiliser responses and species persistence. There have also been new commercial entity entries to the northern Australian legume market and the release of several new varieties.

There are a growing number of online resources available to producers and extension staff, however it is difficult to gauge how much of industry is engaging with these. Many of these online resources

are not hosted centrally, making access difficult and there are also several large gaps in information (such as species suitability and fertiliser considerations). Tropical Forages, FutureBeef, MLA and DAF provide several online resources of varying applicability and technical soundness. Private seed companies also provide a limited amount of establishment information however the quality and technical soundness of this advice is often questionable. For example, there are numerous examples of inappropriate species mixes, incorrect species suitability recommendations and establishment method advice.

Overall, there appears to be a lack of comprehensive publications with regionally relevant, up to date and technically sound information that are able to guide producers through species suitability and selection, ground preparation and the sowing and management of legumes and grasses.

4.6.4 Preliminary Recommendations and Actions

With a very strong and growing industry interest improving pasture productivity as demonstrated through the extension component of the recently completed *Improving productivity of rundown sown grass pastures* report (B.NBP.0639) (over 2000 producers and industry professionals engaged over five years), now more than ever there is both a great need and a great opportunity to provide quality, accurate, accessible and reliable extension resources on pasture legumes.

At this stage of the review, it is apparent that MLA, DAF and their collaborators need to work in a concerted manner to build more centralised and readily accessible nodes of quality, sound and current information on pastures and legumes on a platform such as the FutureBeef website. Information on legumes needs to be easily found using typical search engines such as Google. The pastures team plans to work with the FutureBeef and DAF website administrators to update older resources, remove obsolete and incorrect information and to better collate and organise relevant resources on the webpage.

With the limited number of professionals trained in sown pasture establishment within the region, it is important that farm advisors such as other DAF staff and the private sector receive training and knowledge on where to locate useful information, in order for the extension of best practice methods for the region to be augmented.

The up-skilling and training of producers and advisors will be paramount in combatting the persistence of incomplete or poor information sources. The better equipped producers are with accurate information, the better they will be able to critique and challenge substandard sources of extension or sales information. With this in mind the project team is working towards finalising the review in order to produce an effective project extension package and to identify new extension products for development.

4.7 Milestone 2G: Overview describing how the activities conducted in this project contribute to achieving milestones in Stage 2 of the project.

The activities in the Stage 1 project have been critical as the foundation work that has allowed the Stage 2 project to commence. Specific examples of how Stage 1 has contributed to the more timely delivery of the full project include:

- Retaining skilled staff. Without the Stage 1 project there was a high likelihood that staff working on the project would have been made redundant which would have meant recruitment of replacement staff would have had to occur before project activities could fully commence.
- Timely selection of trial and demonstration sites. Site selection would not have occurred, therefore delaying the start of research and demonstration trials. Based on previous

research results, greater than nine month fallows are required to provide reliable establishment of legumes into existing grass pastures. Starting the project early has meant that trial sites could be selected in time to allow fallowing in 2017 and thus planting in the 2017/18 summer (depending on seasonal conditions). By contrast, if the project started later, fallows would not have commenced until mid-calendar year which would compromise the likelihood of getting good establishment of trials in the first year of the project.

- Measurement of the existing legume establishment research trials would not have occurred. Measuring the existing establishment trials provides the information required to create the management recommendations that underpin the project.
- Review current knowledge on legume best management practices in the sub-tropics and development of key management recommendations. The management recommendations will be used to develop extension products that are recommended from the review (Milestone 2F) and for developing workshop materials as part of the “learning package”.

5 Appendix 1 – Legume establishment trial results

5.1 Goondiwindi clay

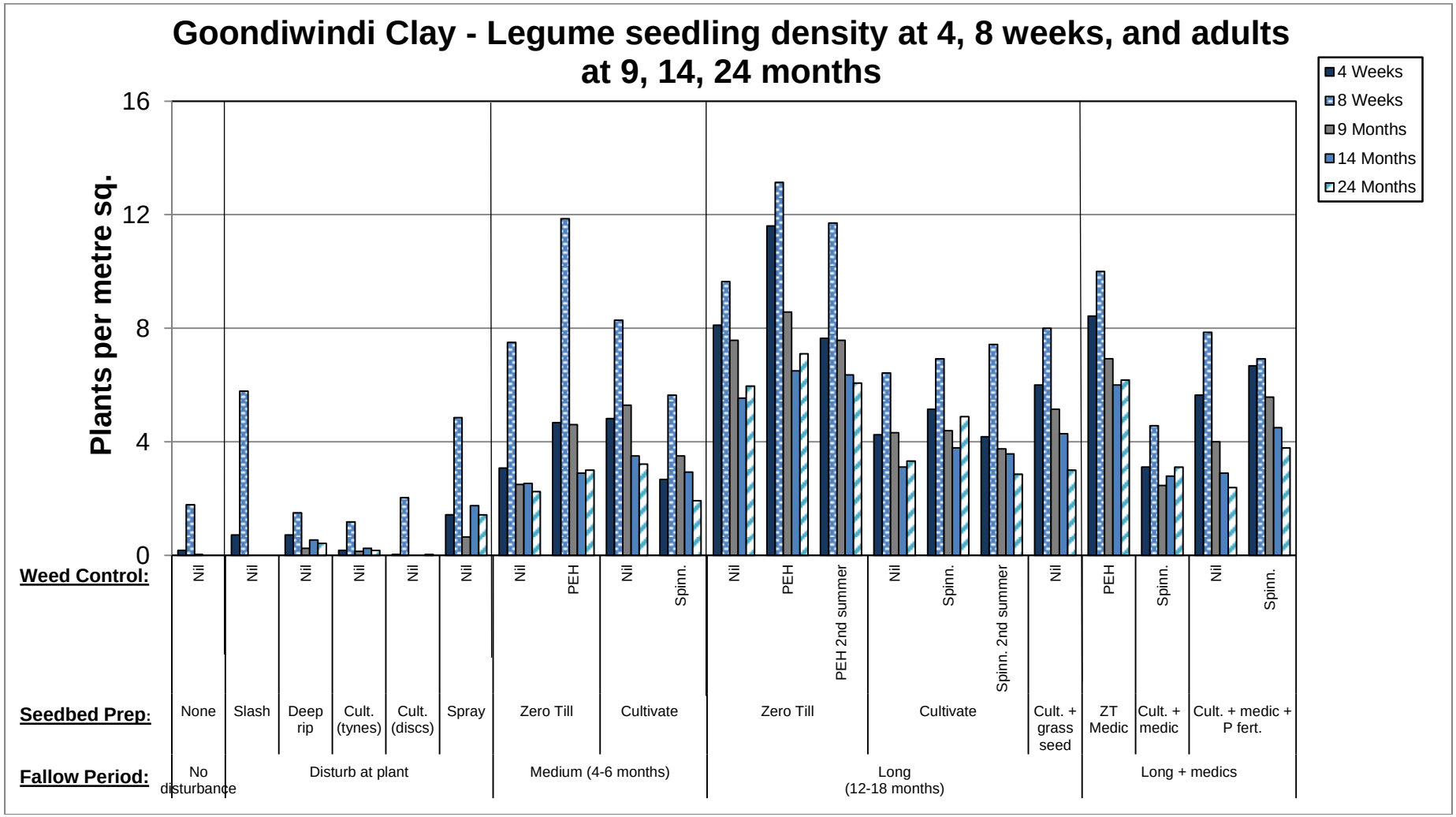

Fig. 1: Legume plant density (plants/m2) at the Goondiwindi clay soil legume establishment site 4 & 8 weeks, 9, 14 & 24 months after germinating rain. (PEH: post-emergence herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

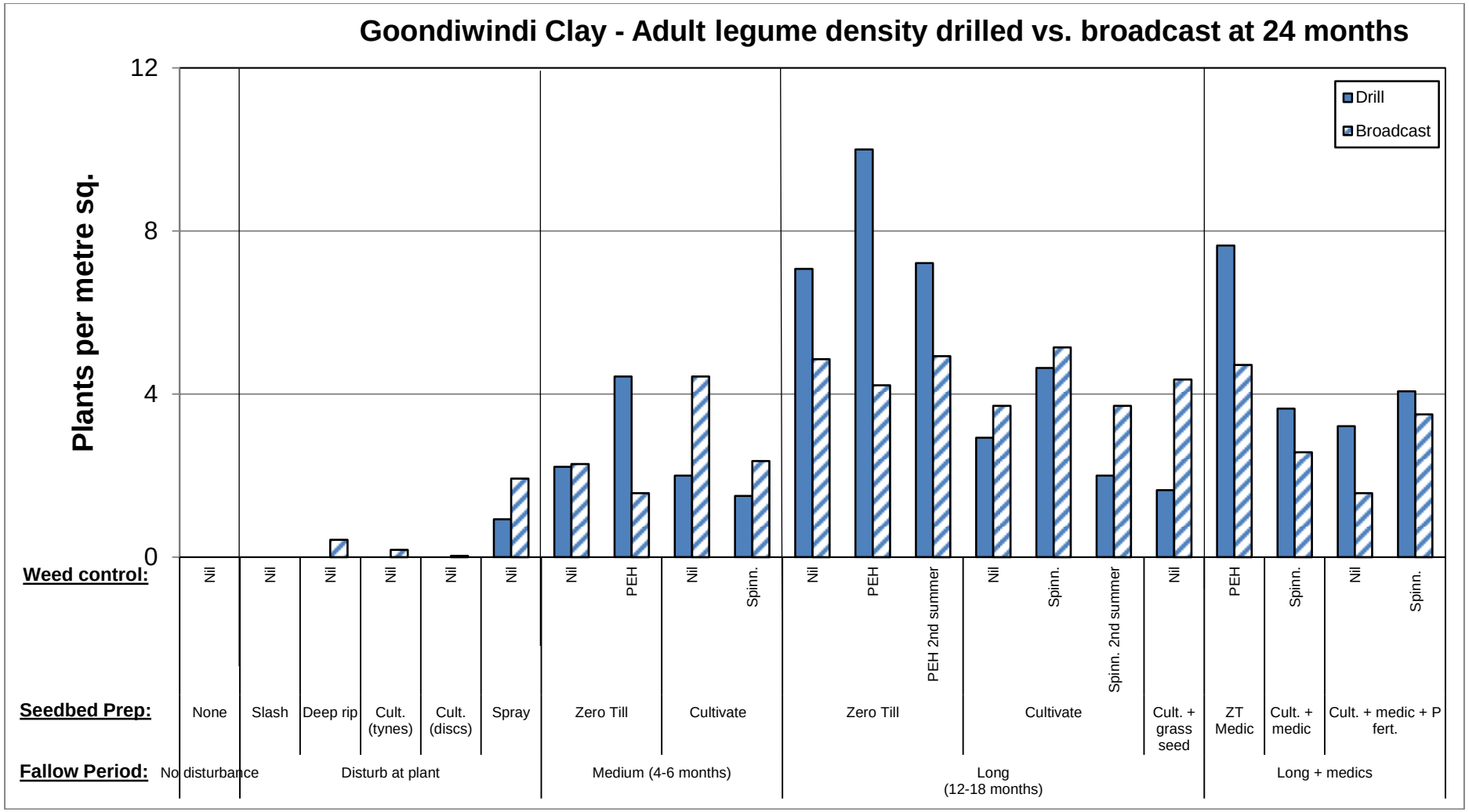

Fig. 2: Legume plant density (plants/m2) at the Goondiwindi clay soil legume establishment site for drill and broadcast sowing methods, 24 months after germinating rain. (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

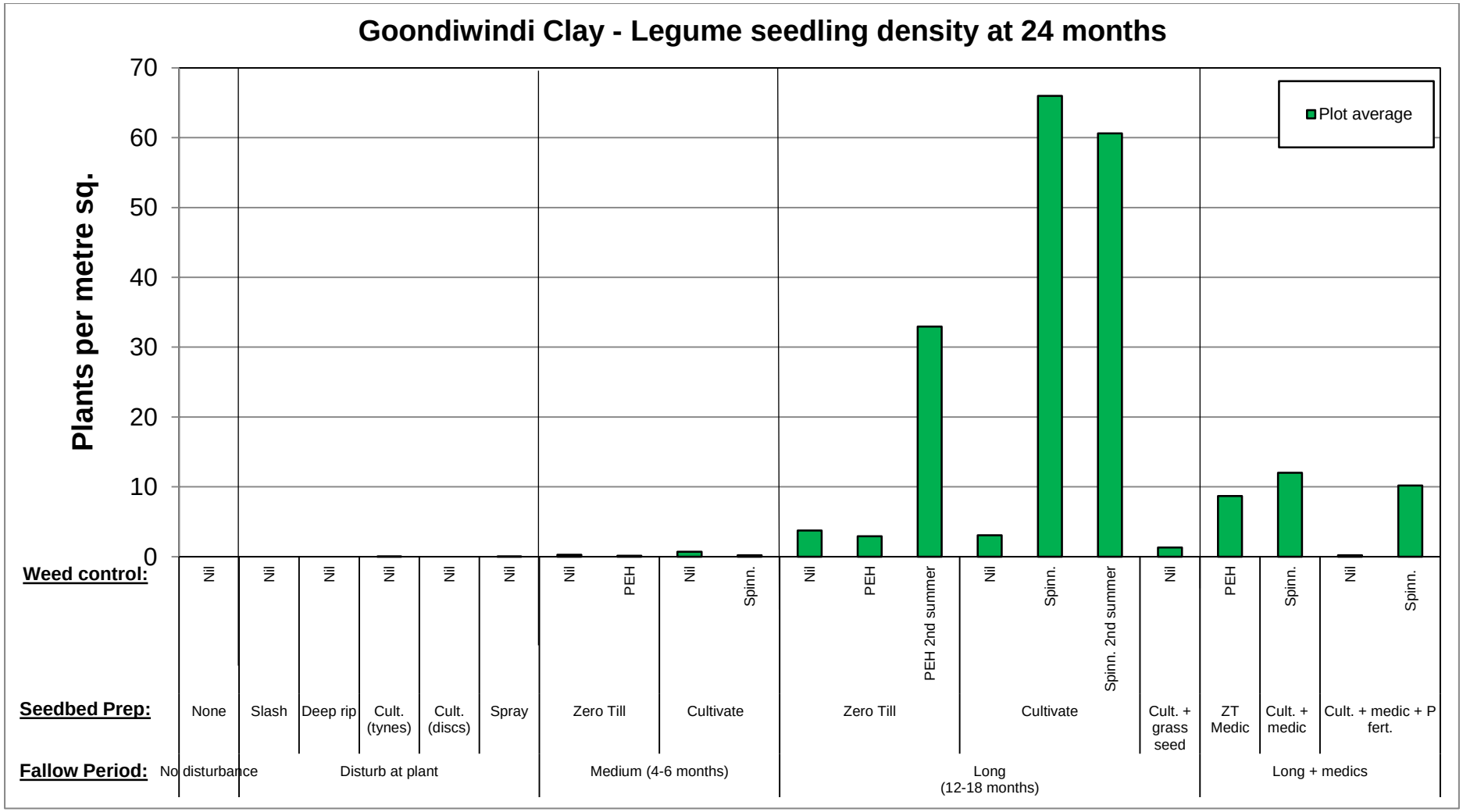

Fig. 3: Legume seedling density (plants/m2) at the Goondiwindi clay soil legume establishment site, 24 months after germinating rain. (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

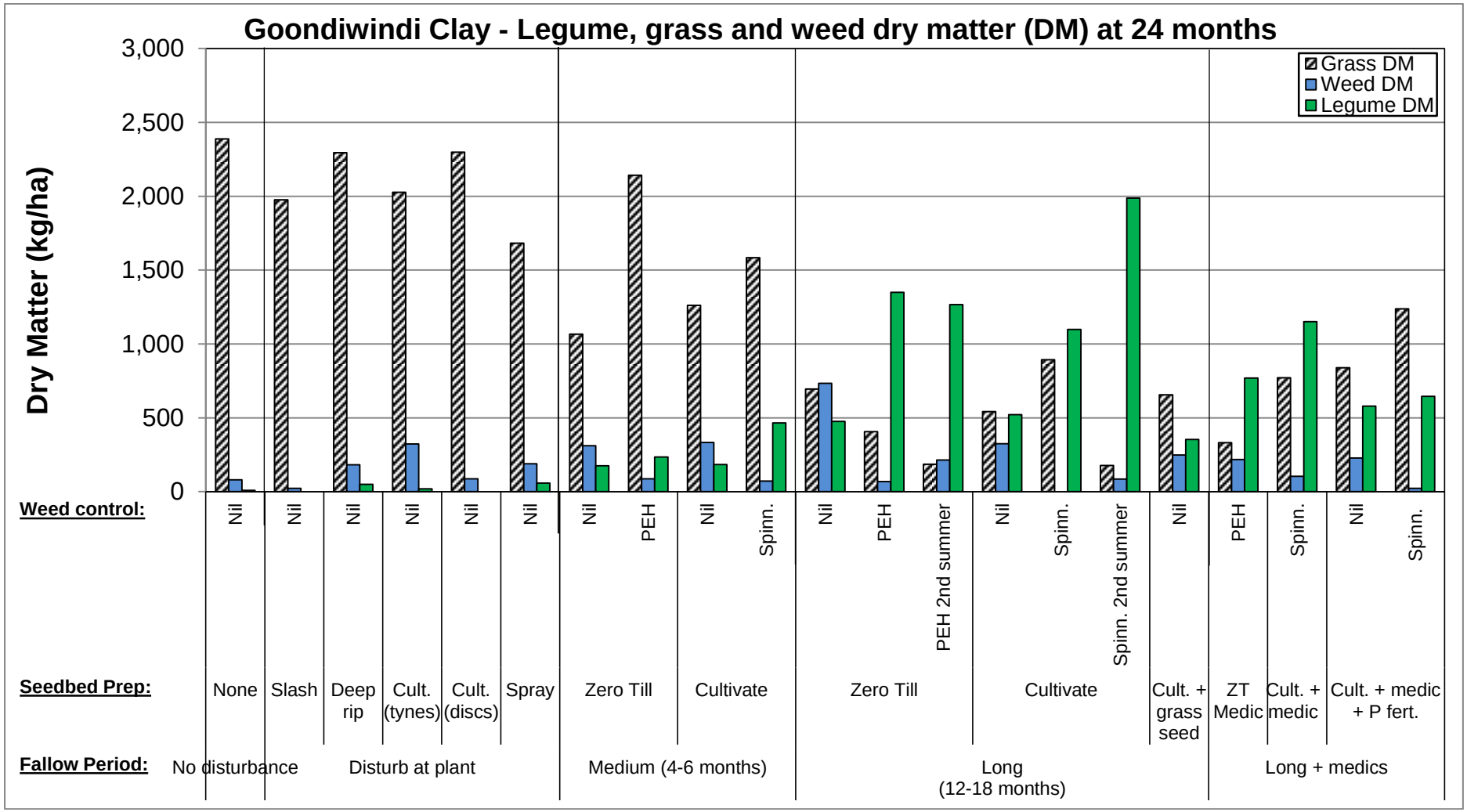

Fig. 4: Grass, legume and weed dry matter at the Goondiwindi clay soil legume establishment site, 24 months after germinating rain. (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

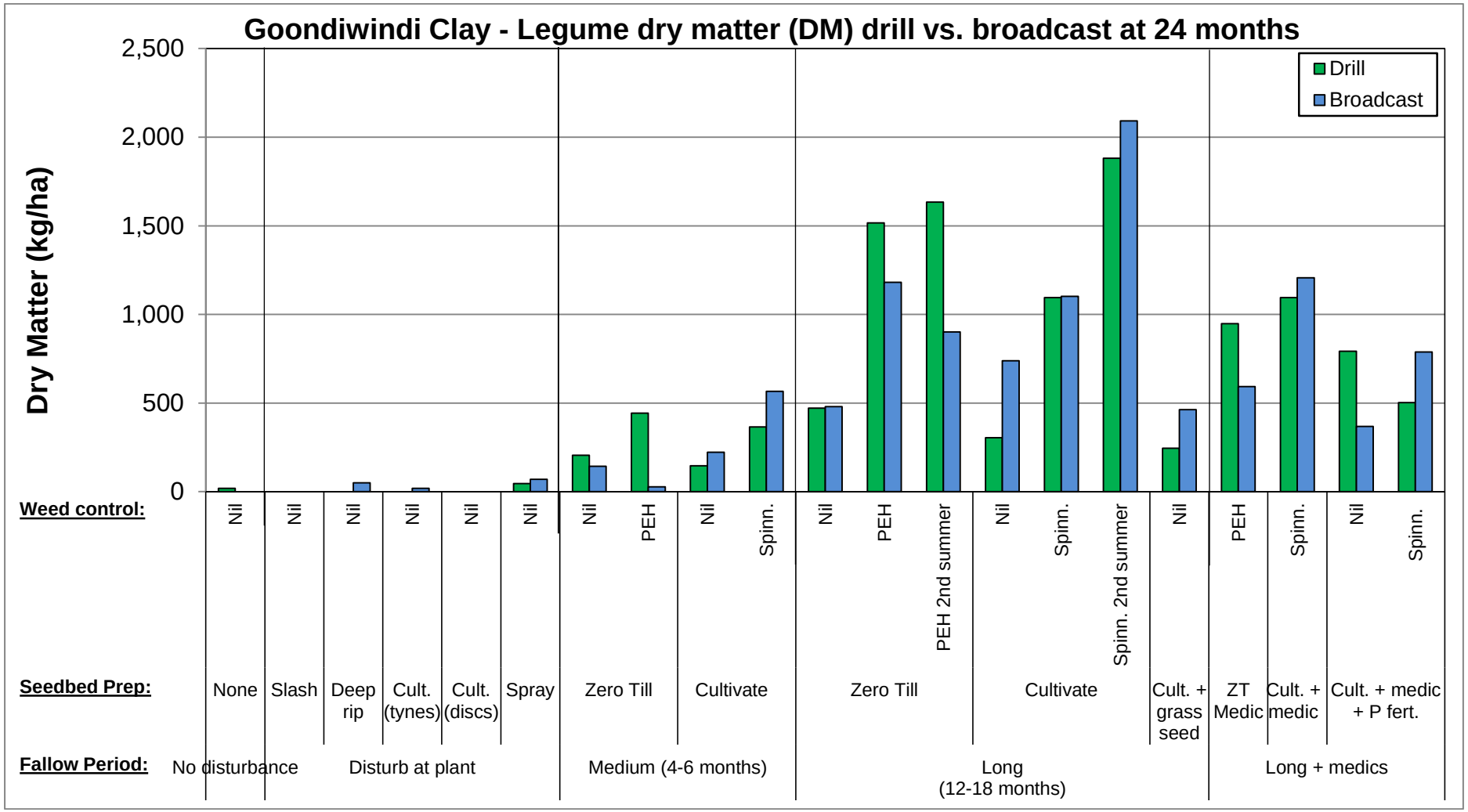

Fig. 5: Legume dry matter at the Goondiwindi clay soil legume establishment site for drill and broadcast sowing methods, 24 months after germinating rain. (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

5.2 St George clay

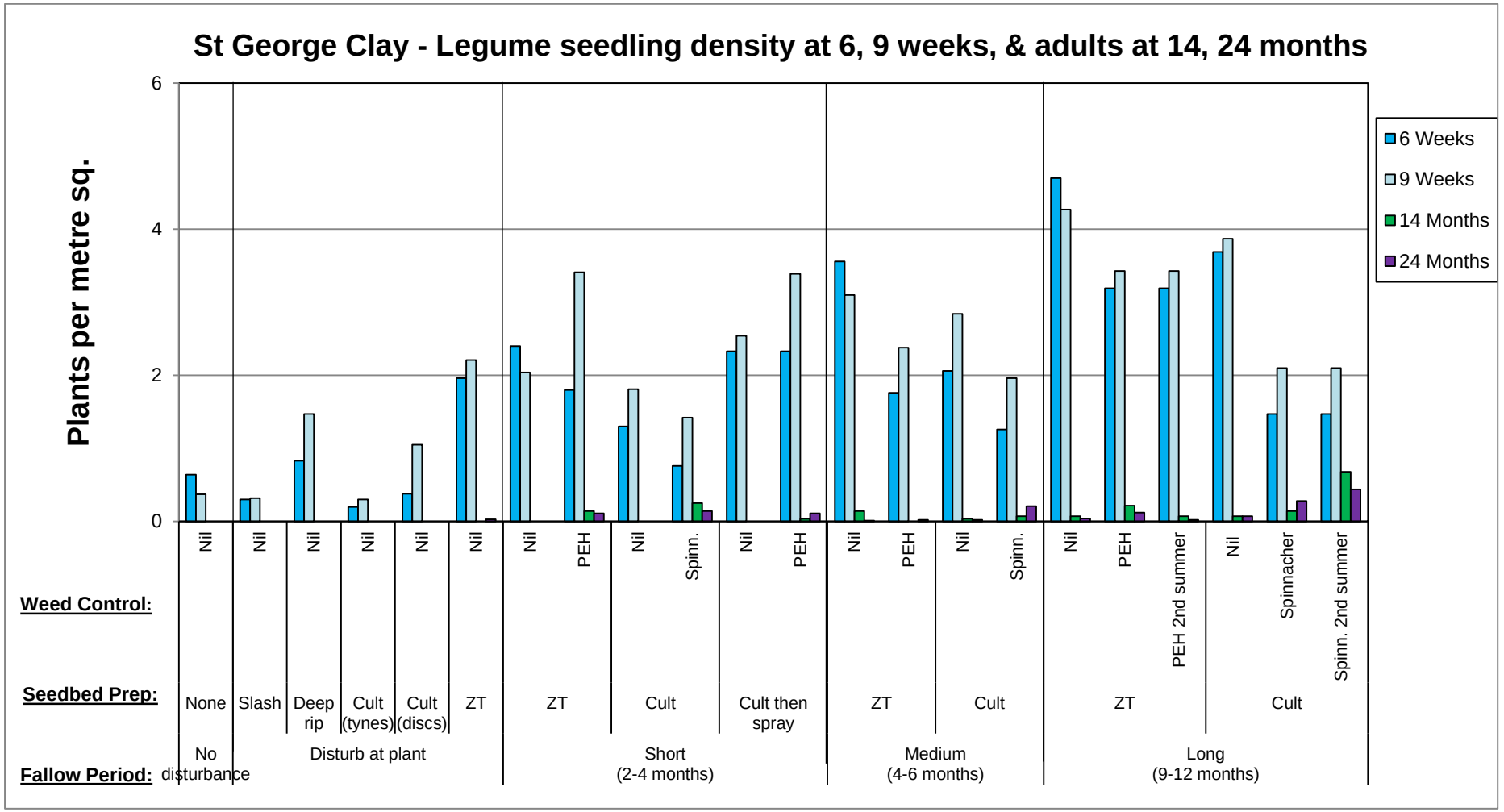

Fig. 6: Legume plant density (plants/m2) at the St George clay soil legume establishment site 6 & 9 weeks, 14 & 24months after germinating rain (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

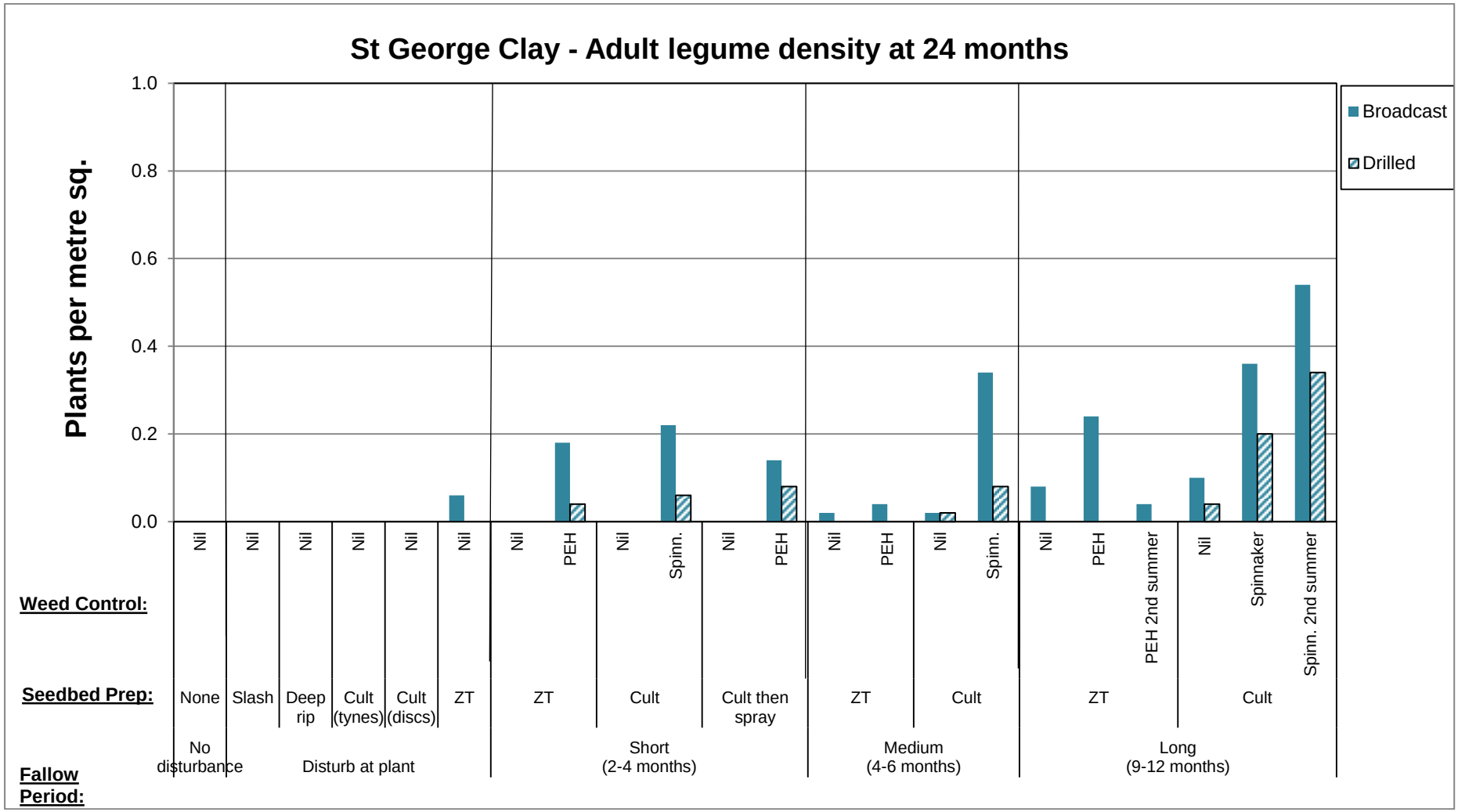

Fig. 7: Legume plant density (plants/m2) at the St George clay soil legume establishment site for drill and broadcast sowing methods, 24 months after germinating rain. (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

5.3 St George loam

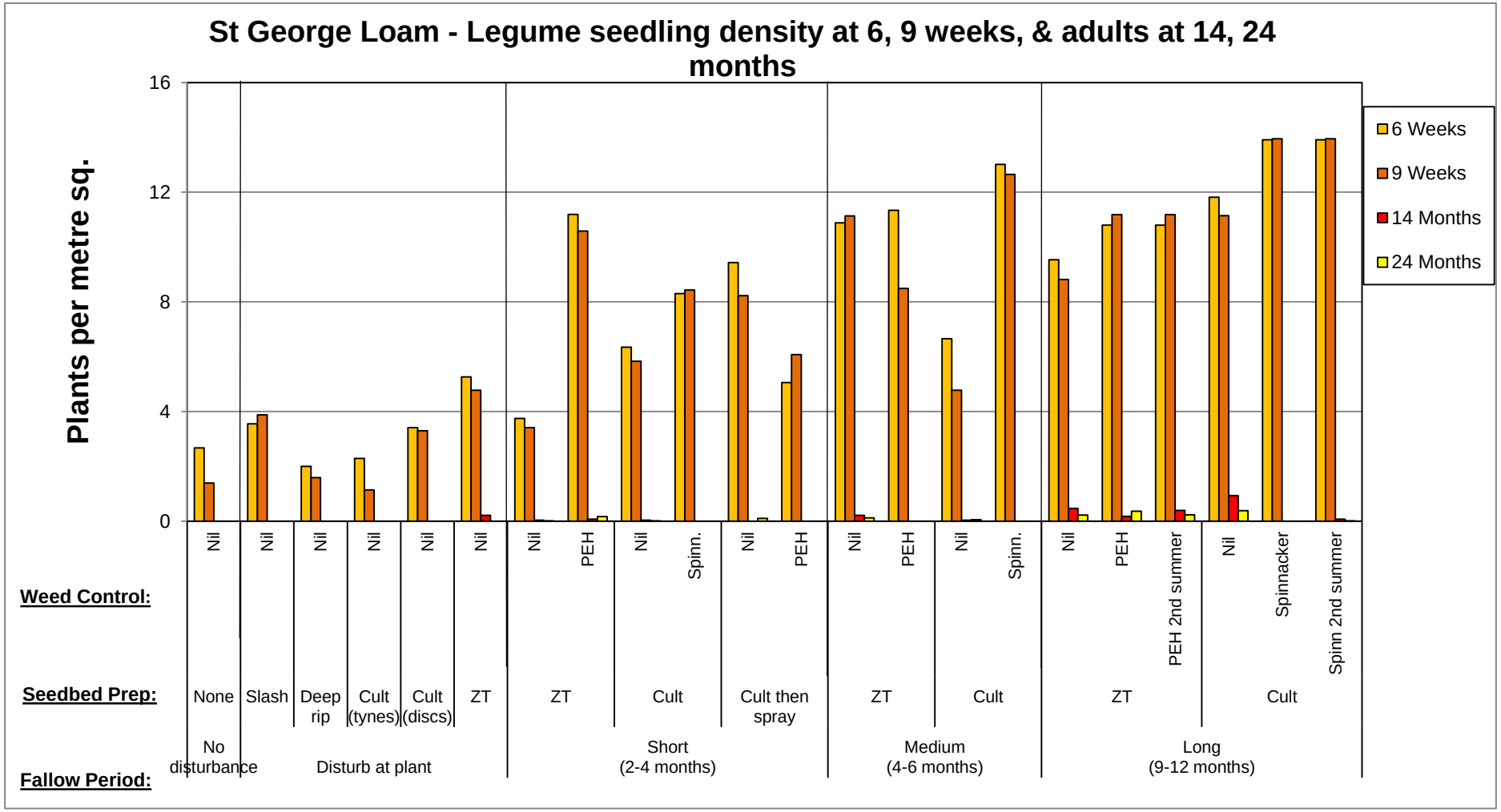

Fig. 8: Legume plant density (plants/m2) at the St George loam soil legume establishment site 6 and 9 weeks and 14 months after germinating rain (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

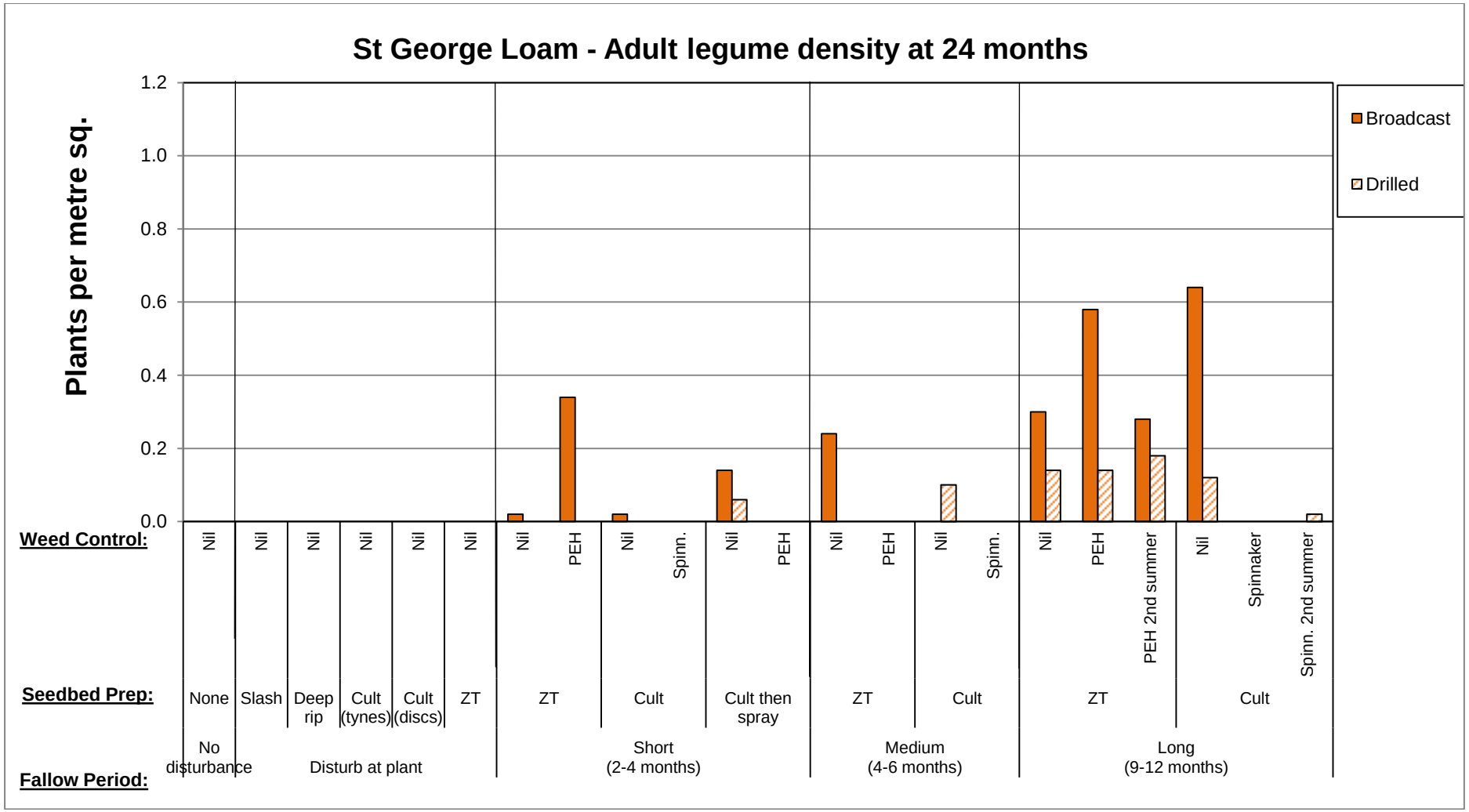

Fig. 9: Legume plant density (plants/m2) at the St George loam soil legume establishment site for drill and broadcast sowing methods, 24 months after germinating rain. (PEH: post-emergent herbicide, using Verdict for grass control and Basagran for broad-leaf weeds; Spinn.: Spinnaker residual herbicide).

6 Appendix 2 – Catalogued existing extension materials

Table 4: Extension resources catalogued to date within the review of existing extension materials.

Title	Publication Type	Author/ Publisher	Public-ation Date	Available?	Current?	Technical Soundness
Feeding forages in the Fitzroy: A guide to profitable beef production in the Fitzroy River catchment	DAF Publication	Bowen, M., Buck, S. & Chudleigh, F.	2015	Yes	Yes	Sound
Pasture management for south east Queensland	DAF Publication	O'Sullivan, D.	2013	Yes	Under review	Under review
Pasture varieties used in New South Wales 2012–13	NSW Department	Edited by Lattimore, M. & McCormick, L.	2012	Yes	Under review	Under review
Grazing land management	MLA Publication	MLA	2012	Yes	No	Update/ Revise
Inoculating legumes: A practical guide	GRDC Publication	GRDC: Drew, E., Herridge, D., Ballard, R., O'Hara, G., Deaker, R., Denton, M., Yates, R., Gemell, G., Hartley, E., Phillips, L., Seymour, N., Howieson, J & Ballard, N.	2012	Yes	Under review	Sound
Best-bet practices for managing the grazing lands of the Maranoa Balonne: A technical guide of options for optimising animal production, profitability and land condition.	DAF Publication	Paton, C., Hamilton, J & Emery, T	2011	Under review	No	Under review
Tropical and perennial grasses in northern inland NSW	NSW Department	NSW Department: Harris, C., McCormick, L., Boschma, S & Lodge, G.	2010	Under review	No	Under review
Enhancing native pastures	Industry Partnership Publication	MLA, DAF, Australian Government	2010	Yes	No	Update/ Revise
Establishing sown pastures	DAF Webpage	DAF	2010	Yes	Yes	Sound

Title	Publication Type	Author/ Publisher	Public-ation Date	Available?	Current?	Technical Soundness
Pastures for protection and production	DAF Publication	Tropical Grasslands/QMDC/DAF: Partridge, I., Cook, S., Paton, C., Johnson, B. & Lambert, G.	2009	No	Under review	Under review
Pastures for production, soil health and carbon sequestration (Proceedings of 8th Australian Tropical Pastures Conference, Goondiwindi 18-19 March 2009)	Tropical Grasslands Publication	Partridge, I.	2009	No	Under review	Under review
Pasture management in the inland Burnett	DAF Publication	O'Sullivan, D.	2009	Under review	Under review	Under review
Grain and Graze Final Report: Ley Pastures and their establishment in the western downs and Maranoa of southern inland Queensland	Report	Sibson, K.	2008	No	No	Under review
LeyGrain Workshop Material	Department & GRDC	DAF/GRDC	2007	No	No	Sound
Pastures: Mackay Whitsunday Region	DAF Publication	DAF	2007	Under review	Under review	Under review
Pastures for protection and production on the marginal cropping lands (Proceedings of the 7th Australian Tropical Pastures Conference, Dalby 11-12 April 2007)	Tropical Grasslands Publication	Partridge	2007	No	No	Under review
Making better fertiliser decision on grazed pastures in Australia	Victorian Department of Primary Industries	Gourley, C., Melland, A., Waller, R., Awty, I., Smith, A., Peverill, K. & Hannah, M.	2007	Under review	Under review	Under review
Leucaena: A guide to establishment and management	MLA Publication	MLA	2006	Yes	Under review	Under review
Grazing land management EDGE workshop notes	MLA Publication	MLA	2006	Yes	Under review	Update/ Revise

Title	Publication Type	Author/ Publisher	Public-ation Date	Available?	Current?	Technical Soundness
Pasture tools for a profitable beef enterprise	MLA Publication	MLA	2006	Under review	Under review	Under review
The butterfly pea book: A guide to establishing and managing butterfly pea pastures in central Queensland	DAF Publication	Conway, M., Grundy, P., Collins, R.	2005	Under review	Under review	Under review
Pasture management for weed control: A grazier's guide to controlling annual weeds in Southern Australian improved pastures	Industry Partnership Publication	Burton, J. & Dowling, P.	2004	Under review	Under review	Under review
Lucerne Management Handbook, 4th Edition	DAF Publication	Bullen, K.	2002	Under review	Under review	Under review
Buffel grass symposium (proceedings of workshop held at Theodore on 21-23rd of February, 2000)	DAF Publication	Kyte, J., Loxton, I., Lees H.	2000	No	No	Under review
Pastures for beef cattle in southern Queensland	DAF Publication	Clarke, R. & Mills, B.	1998	No	No	Update/ Revise
Beef cattle production on the Darling Downs	DAF Publication	Clarke, R. & Mills, B.	1997	No	No	Update/ Revise
Sown pasture notes: Central Queensland	DAF Publication	Lambert, G., & Graham, G.	1996	No	No	Update/ Revise /
Tropical pasture seed production - a training manual	DAF Publication	Partridge, I.	1996	No	No	Under review
A guide to better pastures in temperate climates	Seed Industry Guide	PGG Wrightsons/ NSW Department	1994	No	No	Under review
Waggamba pastures	Landcare	Cockfield, G.	1994	No	No	Update/ Revise
Sown pastures for the brigalow lands	DAF Publication	Partridge, I., Burrows, B. & Weston, E.	1994	No	No	Update/ Revise
Saleable stock from stable pastures	NSW Department	Watson, R., McDonald, W. & Freebairn B.	1994	No	No	Update/ Revise

Title	Publication Type	Author/ Publisher	Public-ation Date	Available?	Current?	Technical Soundness
Sown pasture management notes	DAF Publication	DAF	1992	No	No	Update/ Revise
Pastures of northern Australia	Tropical Grasslands Publication	Tropical Grasslands	1992	No	No	Update/ Revise
The Buffel Book	DAF Publication	Caveye, J.	1991	No	No	Update/ Revise
Native Pastures in QLD: Their resources and management	DAF Publication	DAF	1988	No	No	Update/ Revise
Improving livestock profitability with pasture and forage crops	Industry Partnership Publication	Thompson, P.	1988	No	No	Update/ Revise
Tropical pastures and fodder crops		Humphries Longman Scientific Group	1987	No	No	Update/ Revise
Better pastures for the tropics	Seed Industry Guide	Yates & Cheetham Salts	1985	No	No	Update/ Revise
Brigalow farm management handbook	DAF Publication	DAF	1976	No	No	Update/ Revise
Stylos for Better Beef	DAF Publication	DAF		No	No	Update/ Revise
Legumes for long-term pastures on high fertility soils in Queensland	Webpage	DAF		Under review	Under review	Under review
Managing Southern Speargrass		Partridge, I., et al.		Under review	Under review	Under review
Establishing small seeded pasture legumes into existing grass pastures	Webinar	Peck, G., Johnson, B., & Buck, S.		Under review	Under review	Under review
The lowdown on pasture rundown	Webpage	Peck, G., Johnson, B., & Buck, S.		Under review	Under review	Under review

Title	Publication Type	Author/ Publisher	Public-ation Date	Available?	Current?	Technical Soundness
Managing grazing in the semi-arid woodlands: a graziers guide	DAF Publication	DAF		Under review	Under review	Under review
Getting legumes into pastures	DAF Publication	Peck, G., Johnson, B., & Buck, S.		Under review	Under review	Under review
Land types factsheets (two-pagers including recommended legume spp.)	DAF Publication	DAF		Under review	Under review	Under review
Stylo info on DAF Online	DAF Webpage	DAF		Under review	Under review	Under review
Using sown pastures for grazing	Webpage	Business Queensland (www.business.qld.gov.au)		Under review	Under review	Under review
Selecting the right pasture species	Webpage	Business Queensland (www.business.qld.gov.au)		Under review	Under review	Under review
MLA Tips and Tools	Webpage	MLA		Under review	Under review	Under review
The Leucaena Network: Workshop & Notes	Industry Partnership Publication	The Leucaena Network		Under review	Under review	Under review
Tropical Forages Pages	Industry partnership publication	Tropical Forages		Under review	Under review	Under review
An introduction to grasses and legumes	Factsheet	D Lloyd & Conservation Farmers Inc.		No	No	Under review
David Illing Seeds	Seed Industry Guide	Illing Seeds		Under review	Under review	Under review
6 easy steps for applying Phosphorus	MLA Publication	MLA	2009	Yes	Yes	Sound

Title	Publication Type	Author/ Publisher	Publication Date	Available?	Current?	Technical Soundness
Establishing Pastures	NSW Department	NSW Department	1997	Yes	Under review	Under review
Pasture Genetics Webpage	Webpage	Pasture Genetics	2017	Yes	Yes	Update/ Revise
Envirogro® tropical seed from PGG Wrightson Seeds	Video/YouTube/Vimeo	PGG Wrightson	2012	Yes	Under review	Update/ Revise
Envirogro® tropical seed from PGG Wrightson Seeds	Webpage	PGG Wrightson		Yes	Yes	Update/ Revise
Envirogro® tropical seed from PGG Wrightson Seeds	Webpage	PGG Wrightson		Yes	Yes	Update/ Revise
Product Webpage: Caatinga Stylo	Webpage	PGG Wrightson		Yes	No	Update/ Revise
Caatinga Stylo Mix (Envirogro) PDF "an in-depth look at Caatinga"	Seed Industry Guide	PGG Wrightson		Yes	Yes	Update/ Revise
Progardes Website: Establishment Guide	Webpage	Agrimix	2016	Under review	Under review	Under review
DAF Website: Desmanthus	Webpage	DAF	2014	Under review	Under review	Under review
Tropic Forages Website: *Stylosanthes seabrana*	Webpage	Tropical Forages		Under review	Under review	Under review
Tropical Grasslands Website	Webpage	Tropical Grasslands		Under review	Under review	Under review
Pastures Australia	Webpage	Tropical Grasslands		Under review	Under review	Under review
Pasture Picker	Industry Partnership Publication	Tropical Grasslands		Under review	Under review	Under review
Case Study: Sam Morris: Caatinga stylo and desmanthus	MLA Publication	MLA		Yes	No	N/A
DAF Webpage: Growing Leucaena	DAF Publication	DAF	2011	Yes	No	Sound

Sound: Technically sound. Update/revise: At least some aspects of the content is not technically sound and needs to be updated with more recent R&D findings.
Under review: Resource has not been fully reviewed.