CROP SCIENCE SOCIETY
OF SA INCORPORATED

Welcome to the August issue of the Crop Science Society of SA newsletter; issue 348

Dear CSSSA Members,

Welcome to the August issue of the Crop Science Society of SA, issue 348.

In this month's newsletter we explore:

- Member in focus – Judy Rathjen
- 2022 Managing Pulse Disease
- Famous Agronomist by Peter Smith
- Yield response to plant density in faba beans: management and profitability implications

We hope you are keeping well. Please contact us if you have any requests for content of information.

Kind regards,

Dan Petersen
President, Crop Science Society of South Australia

Member in focus – Judy Rathjen

I would like to think that I chose to be in agriculture, but in reality it was already determined for me from a young age.

Growing up I spent a lot of time on our family farm at Birdwood and of course having a dad famous in the agricultural world was the primary influence, but it was with my first casual job at SARDI in 1995 that I really found my interest.

Coming from an urban background I was very much in the minority during my Ag Science studies, but I remember a rich environment of debate, immersion in basic agriculture and a lot of fun with my peers. Interestingly, our Ag Science class has shown profound success in plant breeding, agronomy, consultancy and as leaders in the grower community, which I put down (in part) to the vibrance of our university days.

During these years, my dad (Tony), who was never shy of delegation and recruitment, found a place for me on the CSS committee which led to assistant and eventually sole editor of the newsletter. It is his legacy I hope to continue with the newsletter, even though the publication is much poorer without his interesting contributions and focus on his ever-changing obsessions.

After finishing my PhD in 2006 I have continued in agricultural research and currently work on compatibility of rhizobia with pesticides and fertilisers at Waite. I have a broader interest in the diversity of rhizobia species found in soils around the world as well as finding more effective strains to improve nodulation in legume crops.

In 2015 I was very proud to be awarded a Life Membership of CSS, and it is this photo you see here.

Judy Rathjen.

2022 Managing Pulse Disease

Article source:
Sara Blake, Mohsen Khani; SARDI Pulse Pathology, Plant Research Centre, Waite.
Penny Roberts, Sarah Day; SARDI Clare Pulse Agronomy, Clare.

Managing diseases in pulse crops 2022

Take home messages:

- Botrytis grey mould, chocolate spot and sclerotinia are predicted to be a greater risk this season due in part to the forecast for above average spring rainfall.
- If rain is ongoing, be prepared to apply foliar fungicide sprays 2-3 weeks apart after canopy closure. Ensure fungicide groups are rotated and note that the same fungicide can only be sprayed twice per season in a crop.
- PBA Amberley faba bean has the highest level of chocolate spot resistance (rated MRMS) of all current cultivars, however fungicides are still required to control this disease especially in high rainfall situations.
- If ascochyta blight is present in lentils and faba beans, disease may increase during spring via rain splash. Monitor crops of all commercial cultivars closely, noting that the more aggressive pathotype 2 is commonplace in SA.
- A new lentil ascochyta blight reaction group combining both pathotype 1 (Nipper-virulent) and pathotype 2 (Hurricane-virulent) is becoming established. Implementing integrated disease management best practices, including 3-4 years between lentil rotations, will be important to protect disease resistance in current XT cultivars including PBA Highland XT.
- In field pea crops, fungicides for blackspot are economical if expected yields are above 1.5 tonnes/ha. In higher yielding areas, the more expensive products may be economical.
- All chickpea crops require regular sprays to control ascochyta blight. As pods are highly susceptible to infection, podding sprays are essential to protect the developing seed.

Disease management of Botrytis diseases: botrytis grey mould and chocolate spot

Botrytis grey mould (BGM) in lentil

There are minor changes to BGM ratings in lentil for Nipper, PBA Blitz, PBA Jumbo2 and PBA Hallmark XT and growers are recommended to monitor crops with provisional ratings closely.

When present, BGM is promoted by mild temperatures and high humidity, especially in a wet and humid spring. Dense canopies from early sowing and/or high seeding rates provide ideal conditions for disease. A prophylactic foliar fungicide applied immediately before canopy closure will help to protect the base of the crop and is recommended for all cultivars regardless of the BGM resistance rating. In low rainfall zones and drier seasons, this spray is recommended for any cultivar with less than RMR rating. Follow up sprays are dependent on spring rainfall and growers are encouraged to rotate fungicide groups to reduce the risk of fungicide resistance developing.

Two lentil trials (Hart and Giles Corner) were sown in 2022 to examine the economics of disease management of BGM. The Hart trial is sown at a standard seeding rate of 120 plants/m^2, whilst the Giles Corner trial will also examine the disease infection risk under different crop canopies and is sown with standard seeding rate as well as a higher rate of 150 plants/m^2. Seed of PBA Jumbo2, PBA Bolt and PBA Highland XT were treated with P-Pickel T® prior to sowing the trial. Both trials compare newer fungicide registrations (Veritas®, Aviator® Xpro® and Miravis® Star) with carbendazim, applied at canopy closure. Additional sprays of carbendazim will be applied to plots during spring if warranted. A nil fungicide spray treatment is also included at each site. All plots other than nil will have a chlorothalonil at podding to control ascochyta blight.

Chocolate spot in faba beans
There were no changes to faba bean chocolate spot (CS) ratings in 2022.

PBA Amberley, rated moderately resistant moderately susceptible (MRMS), has the best CS resistance of all the commercially available faba and broad bean cultivars. However, a standard fungicide strategy is still important to control disease in PBA Amberley especially in high rainfall situations (Blake et al 2021). All other cultivars of faba bean are MS or S to CS.

Optimal conditions for CS include mild temperatures and high humidity persisting over 4-5 days during flowering and after canopy closure. Lesions on the flower petals (not sepals) are a distinguishing characteristic of CS as no other faba bean leaf disease causes this symptom. Growers are encouraged to be proactive and apply pre-emptive fungicide sprays at early to mid-flowering before symptoms appear. Follow up sprays may be required in high rainfall regions and seasons, and in high biomass crops especially where there was high seeding and/or early sowing. Areas around trees and under power lines can become hot spots for the disease if spray planes are unable to reach those areas of the crop. A foliar fungicide applied ahead of a rain event will provide around 3 weeks protection and growers are recommended to rotate fungicide groups to reduce the risk of fungicide resistance developing.

One faba bean trial at Giles Corner this year sown to PBA Amberley and PBA Bendoc investigates newer fungicide registrations compared to carbendazim. Treatments are Aviator® Xpro®, Miravis® Star or carbendazim at canopy closure/early flowering, followed by additional carbendazim treatment during the spring if required.

Ascochyta blight in lentil
Some lentil cultivar ascochyta blight (AB) ratings have been downgraded for the 2022 season. This includes PBA Ace, PBA Jumbo2, and GIA Leader. Growers are recommended to focus on the more aggressive Hurricane-virulent pathotype 2 AB rating as this is becoming predominant in SA. Reports of AB in PBA Hurricane XT and PBA Hallmark XT crops were reported on the Yorke Peninsula for the third year in a row. Both cultivars are rated MRMS to pathotype 2.

Growers are encouraged to regularly inspect lentil crops to determine if AB infection is severe enough to directly affect yield. If high levels of foliar infection are observed, a mid-season fungicide spray applied ahead of rain events may be required to prevent yield loss. Note that AB disease will not spread during dry periods and fungicides can be held off while there is no rain. If disease is present, a fungicide spray (e.g. chlorothalonil, mancozeb, Aviator® XPro®, Veritas®, Miravis® Star) at podding ahead of rain is recommended to protect seed quality and yield.

Annual pathogenicity testing of Ascochyta lentis on lentil
Twenty-four isolates were collected from South Australian and Victorian lentil field trials and commercial crops in 2021 and were tested in controlled environment conditions in early 2022. All isolates infected PBA Hurricane XT which is currently rated MRMS to pathotype 2. For a second year, testing again found that over half of the isolates tested were able to infect both Nipper and PBA Hurricane XT suggesting a new reaction group combining dual pathotype 1 and 2 virulence may be establishing in the pathogen population. Furthermore, almost two-thirds of these dual virulence isolates also infected PBA Highland XT at a low to moderately high level. PBA Highland XT is currently rated MR to pathotype 2 of AB. This indicates that isolates exist in the pathogen population that can overcome the resistance in PBA Highland XT and may become selected for over time in intensive lentil cropping systems presenting a risk of resistance ratings being downgraded in the future.

Growers should monitor lentil crops of all commercial cultivars closely for AB and are encouraged to observe the recommended three to four year rotation between lentils in the same or neighbouring paddocks.

Ascochyta blight in faba bean

The only change to AB ratings for faba bean cultivars is the provisional downgrade of PBA Marne to MS for pathotype 2. Pathotype 2 of AB is predominant and widespread across both South Australia and Victoria and NVT ratings now reflect this shift. A third reaction group, pathotype 3, that can overcome the resistance source in PBA Samira and Nura is also present in the southern region but at a rate that is not yet cause for concern (Blake et al 2022). Each season there are many reports of AB lesions on resistant cultivars like PBA Samira. However, these are usually crops sown with seed that has been farmer-retained for more than one or two seasons and these disease levels represent 'genetic drift' from outcrossing, not a loss of true AB resistance. Growers are reminded that as open pollinated crops, faba bean seed crops should be sown as least 200 m away from faba bean crops of other cultivars to ensure genetic purity.

AB survives on crop stubble, self-sown volunteers and infected seed. Lesions usually start before flowering. When wet weather persists up to harvest and where AB is present in the crop, there is a risk of stem infection that can cause lodging, and pod infection which can stain seed and downgrade seed quality. Susceptible cultivars will need fungicide application (eg. chlorothalonil, mancozeb, AviatorXPro®, Veritas®, or Miravis® Star) 6-8 weeks after sowing and at early flowering. A podding spray may be necessary in a wet spring if AB is present in the crop taking withholding periods into consideration.

Annual pathogenicity testing of Ascochyta fabae on faba bean

In 2021, 20 *Ascochyta fabae* isolates collected from South Australian faba bean field trials and commercial crops were tested in ambient conditions including on PBA Amberley and PBA Bendoc.

PBA Amberley, rated RMR, showed a resistant reaction to 45% of isolates tested whilst 55% caused a low to moderate level of infection. These are similar levels to last year and affirms the persistence of isolates present in the pathogen population capable of overcoming the resistance in PBA Amberley. For PBA Bendoc, rated MR, all isolates tested were capable of infecting the cultivar again this year and 70% of isolates caused a moderate level of infection (equivalent to a MRMS rating). Testing again utilised 'AR', or ascochyta resistant, lines of Nura and PBA Samira which are selections made within the breeding program that are fixed for the commercial cultivars' AB resistance. Nura AR showed a resistant reaction to 85% of isolates tested. PBA Samira is rated RMR to AB, however in testing, Samira AR showed a resistant reaction to only 40% of isolates tested, whilst 20% of isolates caused a low level of infection. A moderate to moderately high level of infection on Samira AR was caused by 40% of isolates and these are likely members of pathotype 3.

The faba bean AB pathogen sexual reproduces and new genetic variants can be produced in the population that can overcome the current AB resistance sources. Growers should monitor faba bean crops closely for AB and are encouraged to observe the recommended three to four year rotation between faba beans in the same or neighbouring paddocks.

Field pea

Ascochyta blight (AB, synonym blackspot)

Blackspot Manager helps growers predict risk of AB based on the number of spores released from the previous year's stubble and predicted a high risk of disease early in the season this year. Growers were warned to prepare for a high risk of blackspot establishing in crops however actual disease severity is driven by rainfall patterns. Moisture is required for spores to germinate, for plant infection to occur and for disease to spread. Frequent rain events during the season will increase disease severity whilst disease severity will be reduced in drier years.

To protect germinating seedlings and early vegetative growth against infection from airborne spores, P-Pickel T® seed dressing is recommended. Foliar fungicides applied ahead of a rain event will be economic if field pea crops have potential yield of more than 1.5t/ha. An initial foliar fungicide spray is recommended at 4-8 nodes, the earlier timing depends on presence of disease. A second spray at early flowering also reduces disease spread in spring. When applying fungicides, note the label restrictions for chlorothalonil with respect to stock grazing. Mancozeb may reduce disease in some instances but is not always effective. Miravis® Star, Aviator® XPro® and Veritas Opti® are other registered products effective for control of AB in field pea.

Chickpea

Ascochyta blight (AB)

All current commercial cultivars of chickpea are rated moderately susceptible or susceptible and growers are urged to monitors their crops regularly for signs of infection. AB is driven by rainfall and disease will spread and become more severe with each rain event. In chickpea, AB is especially aggressive and disease can progress quickly. To prevent infection and reduce the spread of disease, growers should plan for multiple (3-4) foliar fungicide applications (chlorothalonil, mancozeb, Aviator® XPro®, Veritas®, Miravis® Star) applied ahead of rain events for all cultivars. The use of higher label rates in infected crops will increase the efficacy of disease control. In drier conditions, sprays can be delayed during long dry periods until a rain front is imminent. Crops will require a podding spray to protect the developing seed as pods are highly susceptible to AB infection.

Disease samples of ascochyta blight and sclerotinia sought

Diseased samples of pulses with ascochyta blight or sclerotinia are sought by SARDI for GRDC-funded projects monitoring pathogen populations and changes in cultivar resistance. If you can help, please contact Sara Blake (details below) for a collection kit that includes sample envelopes and a paid return Express Post envelope.

Crop protection products

There are often changes to permits for the use of fungicides in pulse crops. See Pulse Australia's website (www.pulseaus.com.au) for current information on Crop Protection Products including Minor Use Permits, or the APVMA (www.apvma.gov.au).

Useful resources

Crop Watch SA e-newletter and Twitter account (@CropWatchSA) – subscribe for seasonal disease reports: http://pir.sa.gov.au/research/services/reports_and_newsletters/crop_watch

2022 South Australian Pulse Variety Disease Guide:
https://www.pir.sa.gov.au/__data/assets/pdf_file/0020/386102/pulse_variety_disease_guide_2022.pdf

GRDC GrowNotes: https://grdc.com.au/resources-and-publications/grownotes

2022 SA Sowing Guide: https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide

2022 Pulse Australia fungicide guide: https://www.pulseaus.com.au/blog/post/2022-fungicide-guide
https://grdc.com.au/resources-and-publications/all-publications/publications/2020/2021-south-australian-crop-sowing-guide

Diagnostic plant samples can be sent by Express Post to SARDI Pulse Pathology Diagnostics, Locked Bag 100, Glen Osmond, SA 5064. Dig up whole symptomatic and asymptomatic plants and send with roots wrapped in damp (not wet) paper towel. Send at the beginning of the week, so the parcel does not get held up in the post. Please send an email to PIRSA.SARDIPulsepathology@sa.gov.au to notify the team that the plants are coming. Photos via email also accepted.

Acknowledgements

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FAMOUS AGRONOMISTS by Peter Smith

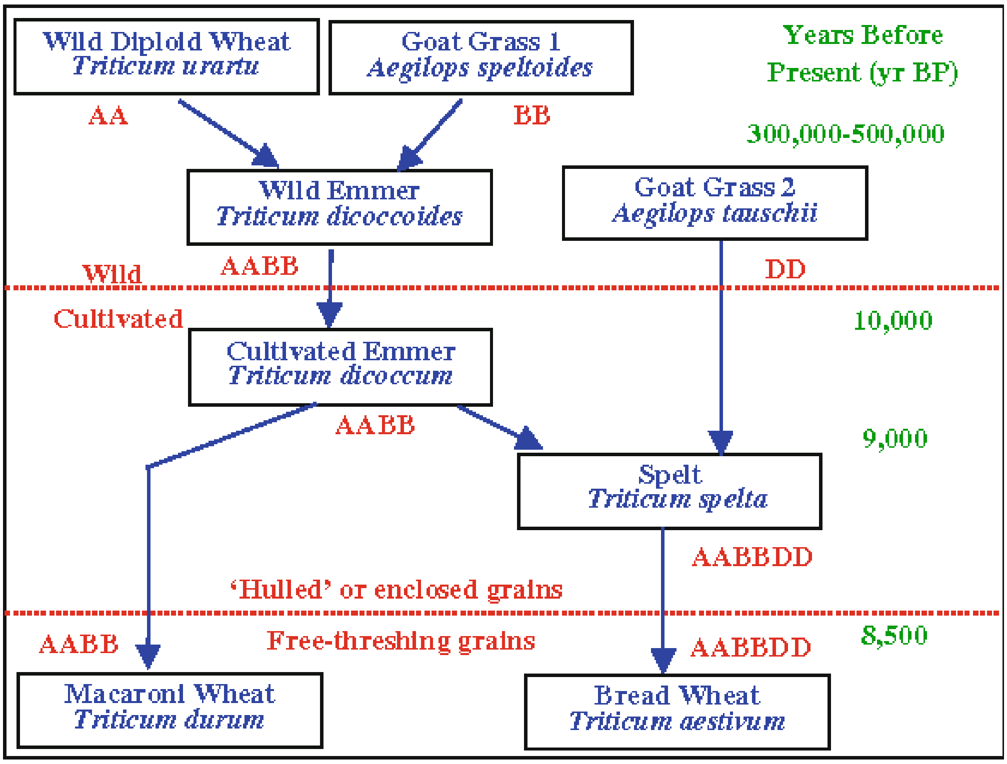
AARON AARONSOHN

Aaron Aaronsohn was born in Bacau, Romania in 1876, and in 1878 the Russo-Turkish war led to Romania's independence from the Ottoman Empire. But soon the Jewish population existence became intolerable under a Christian democracy, so at age 6 he was brought with his parents to Zikhron Ya'akov in northern Palestine near Haifa – then part of the Turkish Ottoman Empire. His parents were among the founders of one of the pioneer Jewish agricultural settlements. He had two sisters, Sarah and Rivka, one of which played a big part in his life during WWI. At home he spoke Yiddish and Hebrew but he also spoke English, Arabic, Turkish, French, German and some Italian. The establishment of this and other agricultural settlements was sponsored by Baron Abraham Edmond Benjamin James de Rothschild

de Rothschild was a French member of the Rothschild banking family and a strong supporter of Zionism. His large donations lent significant support to the movement during its early years, which helped lead to the establishment of the State of Israel, where he is simply known as "the baron Rothschild" or the generous one.

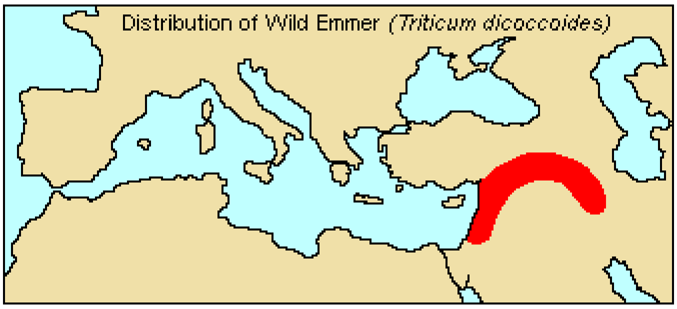
In 1903 he was sponsored by de Rothschild to study agriculture in France and on returning he worked in Metulla, then a new colony in the north of the country. A year later he left to establish an organisation for agricultural technology and together with a member of the German Templer community (a Pietist movement of the Lutheran Church) launched a business importing and selling agricultural machinery such as reapers, harrows and combine harvesters along with fertilisers and different varieties of seeds and vines.

He botanically mapped Palestine and its surroundings and became a leading expert on the subject. On a field trip in 1906 in the Upper Galilee (an area that is now in Lebanon), he was geographically mapping the distribution of wild wheats. It was here he discovered *Triticum dicoccoides,* a weather resistant variety also known as Wild Emmer wheat.



Wild Einkorn hybridised with a Goat Grass at least 30,000 years ago to produce Wild Emmer. About 10,000 years ago, when this began to be cultivated by hunter-gatherers for food, their subconscious plant selection slowly created Cultivated Emmer with larger grains. Later, as this became more widely cultivated, it spread into the natural habitat of another wild Goat Grass. Random hybridisations between the Cultivated Emmer and the Goat Grass produced some early forms of hard shelled Spelt.

Another similar hybridisation occurred later but with a mutation that changed the ears from having the grain enclosed within a hard shell to an ear that would release the grain more easily. The hunter-gatherers would naturally have selected this easier threshing form to collect so that, assisted by this human selection, it slowly evolved into free-threshing Bread Wheat. Over time, Emmer Wheat also mutated and evolved to create Durum Wheat.



Wild Emmer (Triticum dicoccoides) is a hybrid created when a Goat Grass was pollinated by pollen from Wild Einkorn at least 30,000 years ago. The two parents, Wild Einkorn and the Goat Grass are both diploids, each with 14 chromosomes in their cells. After natural pollination and amphiploidy (chromosome doubling), a tetraploid wheat with cells containing 28 chromosomes, genome 'AABB' was produced. Hybridisation probably occurred many times over several millennia in areas of the Fertile Crescent where the two parent plants grew together.

Wild Emmer has grains that are larger than those of Wild Einkorn but they are still enclosed in ears with the characteristic hard shell or 'hull'. Although the ears fragment into single spikelets when ripe, this did not prevent their collection as a food source.

Aaronsohn found that Wild Emmer would endure well over a wide range of altitudes and geographies and he called it the “mother of wheat”. This was a very significant find for agronomists and historians of human civilisation. It is probable that Wild Emmer originated in SE Turkey and emmer wheat has been found in archaeological excavations and ancient tombs and dated at 17000 BC. Emmer was collected from the wild and eaten by hunter gatherers for thousands of years before its domestication. Around the Mediterranean emmer, einkorn durum and barley became the mainstay cereals.

This discovery made Aaronsohn world- famous and, on a trip to the United States to talk with American scientists about his discovery, he was able to secure financial backing for a research station which he established in1909 at Athlit. He continued his field trips and built up a large collection of geological and botanical samples and established a library.

Aaronsohn was a committed Zionist and his stature in American agricultural circles led to him being appointed to distribute relief funds in 1914 as the First World War began to impact. He also had very good relations with the Turkish administration in Palestine and was in regular contact on agricultural matters. His prestige with the Turks rose even higher when he served as scientific consultant and reduced the impact of a massive desert locust invasion in 1915.

During 1915 Aaronsohn and his team fighting the locusts were given permission to move around Palestine and southern Syria and they made detailed maps of the area as they surveyed. In addition he collected strategic information about Ottoman camps and troop deployments. Conditions for Jewish settlers and Christians became very difficult as Germany began to dominate Turkey. Aaronsohn could see that the best future lay with alignment to the British and so began his life as a spy.

He continued work as an agronomist but with close members of his team and his sister, he set up a spy centre at Athlit. Information was passed to the British by small boats on the Palestine coastline. However there were many difficulties and the British were unsure of the reliability of his information. In 1916 when Aaronsohn became aware of a second plan by the Turks to take the Suez Canal, he decided he needed to get to England to convince the British of the value of his intelligence. To do so he went to Constantinople to convince authorities about his scheme to produce oil from sesame, explaining of his need to go to Sweden to an experimental station to finalise his research. On arriving in Germany he took a boat sailing for America via Denmark. The ship docked in Kirkwall in the Orkneys, and having previously arranged with the British he was “arrested”, taken off the vessel and whisked to Scotland Yard where he was interviewed to ascertain his authenticity.

Eventually he convinced them and he was taken to Cairo to assist with the plans for the invasion of Palestine. In February he crossed paths with T.E. Lawence (Lawrence of Arabia) and found him to be ”knowledgeable but conceited.” Of course Lawrence was quietly backing the Arabs in the war with the Turks at this time while Aaronsohn had his sites set on the British gaining control and assisting with a Jewish homeland.

Aaronsohn recommended the plan of attack through Beersheba that General Edmund Allenby ultimately used to take Jerusalem in December 1917 as part of the Sinai and Palestine Campaign. Owing to information his group supplied to the British Army concerning the locations of oases in the desert, General Allenby was able to mount a surprise attack on Beersheba, bypassing strong Ottoman defences in Gaza. Unfortunately his sister Sarah and members of his group were killed during this time.

After the war, he was called upon to work on the Versailles Peace Conference. On 15th of May 1919, under unclear circumstances, Aaronsohn was killed in an airplane crash over the English Channel while on his way to France.

Aaronsohn died a bachelor and had no children. His research on Palestine and Transjordan flora, as well as part of his exploration diaries, were published posthumously.

After Aaronsohn's death, the director of British Military Intelligence, confirmed that Allenby's victory would not have been possible without the information supplied by the Aaronsohn group.

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Lawrence and Aaronsohn

T. E. LAWRENCE, AARON AARONSOHN, AND THE SEEDS OF THE ARAB-ISRAELI CONFLICT
By ***FLORENCE, RONALD***

Spy, agronomist, entrepreneur: The Israeli Legacy of Aaron Aaronsohn, Haaretz

The evolution of wheat from the prehistoric Stone Age grasses to modern macaroni wheat and bread wheat (reproduced from http://www.newhallmill.org.uk/wht-evol.htm)

Lawrence in Arabia, Scott Anderson

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Yield response to plant density in faba beans: management and profitability implications

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Take home messages

- Analysis of data from 76 Australian experiments showed that faba bean grain yield was maximised by a plant density from 13 plants/m^2 in high yield environments, through to 57 plants/m^2 in low yield environments.
- Faba bean grain yield is highly responsive to plant densities from 10 to 30 plants/m^2 so the sowing rate should be regarded as an important management tool.
- Yield constraints such as weeds, diseases and frost changed the plant density required to maximise grain yield.
- To increase grain yield in the presence of constraints, growers can: 1) increase plant density, 2) ameliorate other constraints to improve the yield at lower plant densities, or 3) find compromises between 1) and 2) .
- For all environments measured, an increase from 20 to 25 plants/m^2 (130 to 160 kg seed/ha) increased profitability with a range of -$22/ha to +$254/ha depending on grain price and yield.
- Increasing plant density may lead to a requirement for additional protective fungicide applications and windrowing of tall crops, but the need for these measures will depend on the season.

Background

Three components determine the grain yield of a crop:

- how long the crop grows for
- how quickly it grows
- how much of the accumulated resources ends up in the grain.

Growers can manipulate these components through various agronomic levers, for example, ameliorating soil constraints or varying the sowing date, variety (maturity type) or plant density. Here we will focus on plant density because it has a significant impact on faba bean grain yield. Increasing plant density could increase crop growth, at least during the early part of the season. However, this can potentially cause a greater depletion of soil moisture, leading to earlier maturity. Individual plant size decreases with increasing plant density which can affect how much growth is allocated to the grain. The net effect of these changes is addressed in this paper.

Increasing plant density causes earlier canopy closure that increases competitive ability with weeds but also favours Ascochyta blight and chocolate spot, and taller crops with higher risk of lodging. Therefore, changes in plant density have multiple effects and involve trade-offs with implications for profitability and risk.

Industry guidelines usually recommend 15–25 plants/m^2 produce optimal yields but individual experimental results are inconsistent. Here we compile a large data set and synthesise the results to clarify the interaction of plant density with the environment, using yield as a proxy for environmental conditions.

Method

We retrieved plant density and grain yield data for each unique combination of variety, row spacing and sowing date from 76 experiments conducted across the Australian grain belt from 1982 to 2021, which totalled 123 density-yield datasets.

Asymptotic curves (a curve that rises rapidly to approach a maximum and then plateaus) were fitted to each experiment. The median R^2 for these curves was 0.95 indicating that the mathematical model fit the data extremely well. From the curves, we calculated the plant density required to reach 95% of peak yield, and the yield at 10, 15, 20, 25 and 30 plants/m^2.

In the discussion below, we outline the steps taken to estimate the effect of plant density on profitability.

Results and discussion

Plant density to maximise grain yield decreases in high yielding environments

Figure 1 shows that the plant density required to achieve 95% of the maximum grain yield was at least 30 plants/m^2 in low-yield environments (1 t/ha or less), decreased to approximately 20 plants/m^2 in medium-yield environments (3 t/ha), and to approximately 15 plants/m^2 in high-yield experiments (5 t/ha or greater). There was no relationship between growing season rainfall and the yield-maximising plant density. This means that favourable conditions, incorporating multiple factors and not just rainfall, allow low density stands to fully capture resources (water, radiation, nutrients) and maximise yield. On the other hand, more plants are required to compensate for adverse conditions.

In 90% of the experiments, at least 19 plants/m^2 were required to maximise grain yield. This plant density would require 130 kg/ha of seed if the seed size was 65 g per 100 seeds. Growers who are near or below this sowing rate should be aware that plant numbers may be limiting their grain yield, especially in lower yielding sites and seasons. It should be noted that maximising profit may require a different plant density to that which maximises grain yield, and this is discussed below.

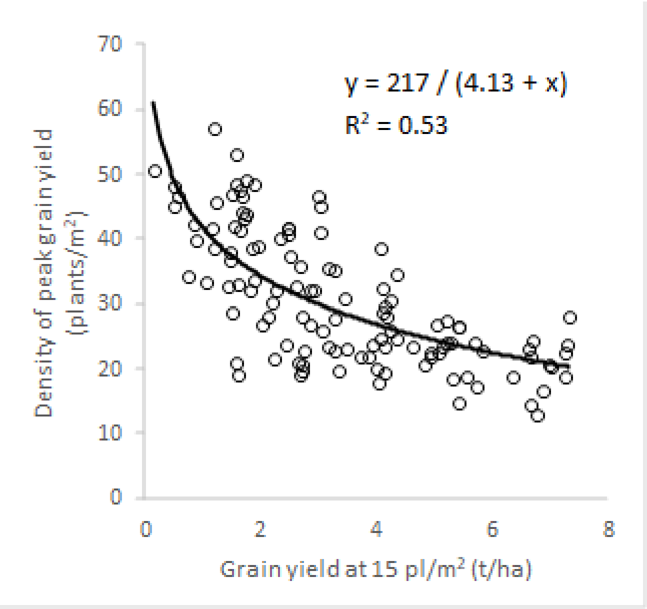


Figure 1. The plant density required to achieve 95% of maximum grain yield as a function of grain yield at 15 plants/m^2. The data is calculated from 123 plant density response curves retrieved from 76 experiments conducted in Australia between 1982 and 2021.

Growers can accommodate plant density to growing conditions

We explored the variation between the points in Figure 1 to understand how plant density interacts with other yield-limiting factors.

Figure 2a shows that irrigated crops generally required a lower plant density to maximise grain yield. Irrigation is not an option available to dryland growers, but the comparison indicates that moisture supply shifts the density-yield relationship. Data on soil type and moisture could inform adjustments to plant densities between paddocks or zones of paddocks.

Figure 2b indicates that higher plant densities are higher yielding in the presence of weeds. The history of a paddock and the expected weed pressure could be factored into decisions about plant density with the understanding that a higher plant density could favour both crop competition with weeds and grain yield.

Figure 2c highlights three datapoints of severely frosted crops in northern New South Wales in 2015. These crops reached 95% of the maximum grain yield at around 20 plants/m^2, whereas 25–30 plants/m^2 were required in other trials with environments of a similar yield. This indicates that some stresses, such as severe frosts, can override potential effects of plant density. Increasing plant density to maximise grain yield may not be appropriate in frost-prone areas, or frost could be avoided with a later sowing but compensated for with a higher plant density.

These findings indicate that growers have three ways to accommodate plant density to constraints: 1) increase the sowing rate, 2) address other yield constraints to improve the performance of lower plant densities, or 3) find compromises between options 1) and 2) on a paddock-by-paddock basis.

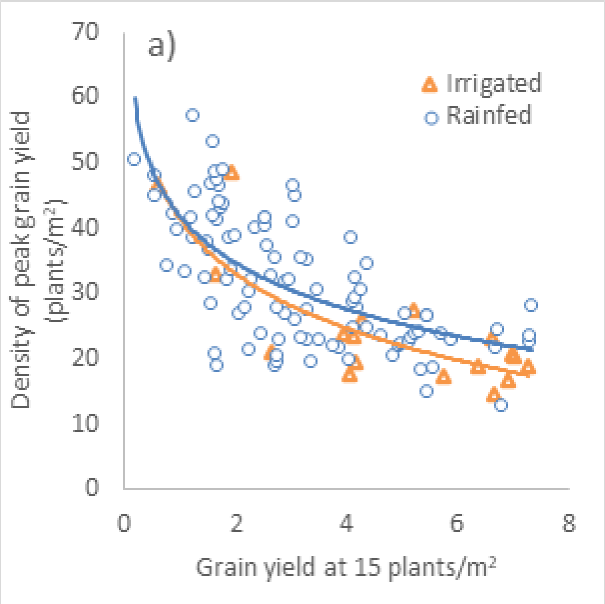
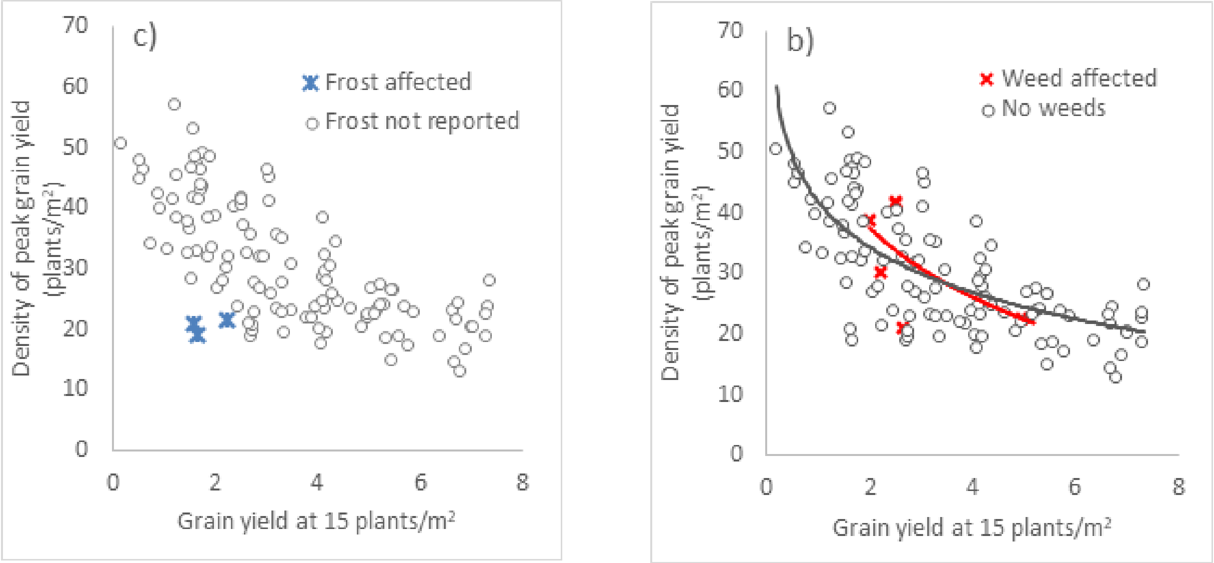


Figure 2. The plant density required to achieve 95% of maximum grain yield as a function of grain yield at 15 plants/m^2 in experiments a) with or without irrigation, b) with or without weeds reported, and c) with or without frost reported.



Plant density, biomass and lodging

Figure 3 shows grain yield increased with total biomass at maturity, which was in turn related to plant density in a low-yield environment of Western Australia (1.7 t/ha at 15 plants/m^2) and a higher yielding environment in Victoria (5.4 t/ha at 15 plants/m^2). There was no lodging in the low-yield environment, and moderate lodging occurred in all treatments of the high-yield environment. This illustrates how the relationships between plant density, biomass and the risk of lodging are highly dependent on the growing environment.

Comparing the data points to the 60% harvest index line in Figure 3 shows that the relationship between yield and biomass levelled off with total biomass >12 t DM/ha, that is, they were 'decoupled' in high-yielding environments. High biomass with relatively less grain may return more nitrogen to soil fertility and compensate for this loss of production efficiency.

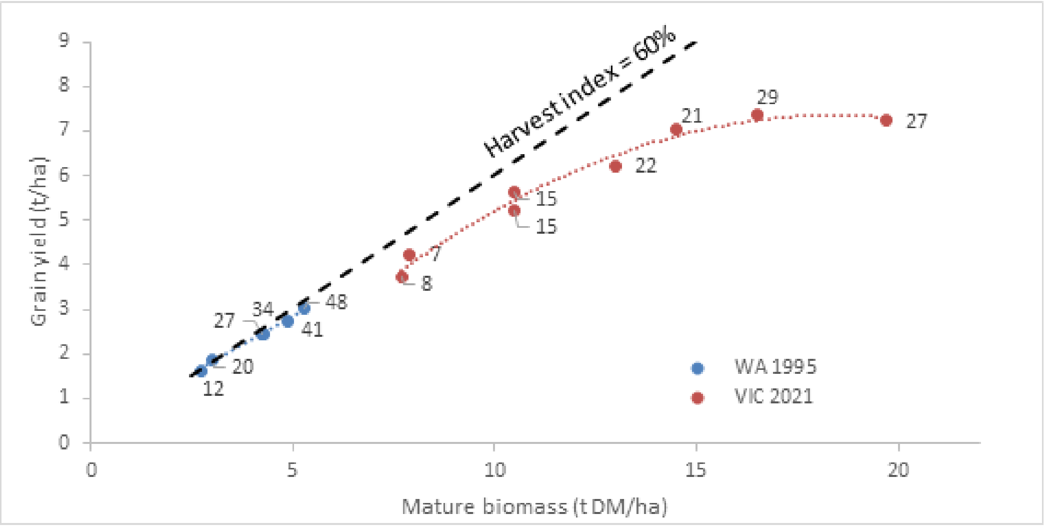


Figure 3. The relationship between grain yield and total above ground biomass at maturity in two experiments with plant density treatments. The data are labelled with the established plant density (plants/m^2) and the dashed line represents a harvest index (the ratio of grain biomass to total mature biomass) of 60%.

Plant density and disease management

Crops with visual symptoms of disease generally required higher plant densities to maximise grain yield than asymptomatic crops (Figure 4). This is despite the higher disease severity that occurred in these treatments (data not presented).

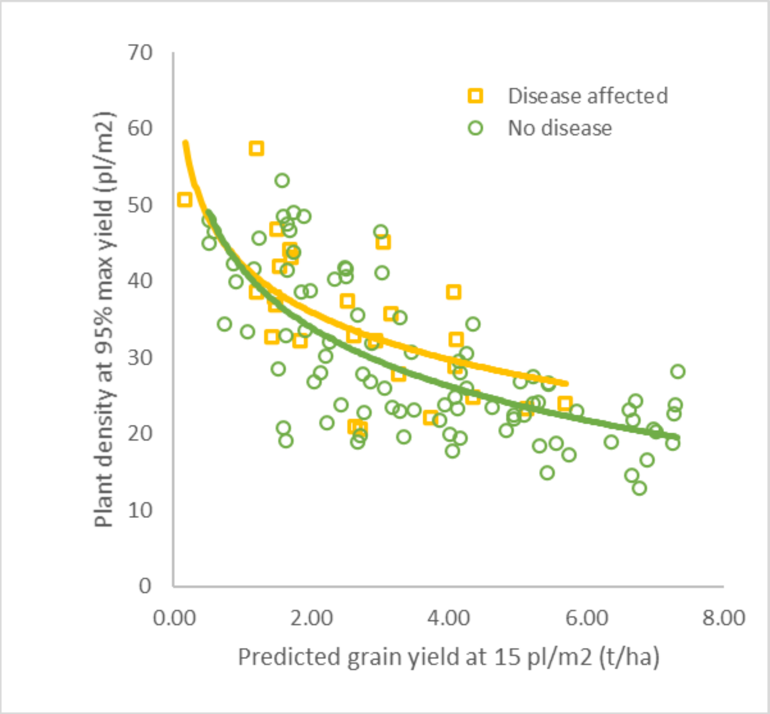


Figure 4. The plant density required to achieve 95% of maximum grain yield as a function of grain yield potential (defined as the grain yield achieved by 15 plants/m^2 in the experiment), in experiments that were disease affected or had no disease.

Figure 5 shows three experiments contrasting in the onset and final severity of chocolate spot disease. Despite the use of fungicides, chocolate spot infected all treatments due to the ability of the disease to spread from an unsprayed plot to a sprayed plot. In each experiment, chocolate spot caused substantial yield losses, so prevention of disease onset should be the first priority for disease management.

With no fungicides (open symbols in Figure 5), a variety with disease rating MRMS to chocolate spot (PBA Amberley ⓟ) outyielded a variety rated S (PBA Bendoc ⓟ). However, when fungicides were applied (closed symbols in Figure 5), the two varieties were similar in the less severe experiments (Figures 5a and 5b, compare with Figure 5c).

Therefore, assuming growers intend to use fungicides, the value of a higher disease resistance rating may reside more in preventing disease with fungicides than in tolerating an established disease. Interestingly, there are no treatments where 20 plants/m^2 yielded less than 10 plants/m^2, even though the disease infection was more severe.

In these experiments, the weather was the primary factor driving the onset of disease, which occurred at approximately the same time in both plant density treatments. Therefore, these results do not account for the possibility that a higher plant density could lead to an earlier infection in some seasons compared to a lower plant density, or that fungicide control may be more effective with lower plant density stands.

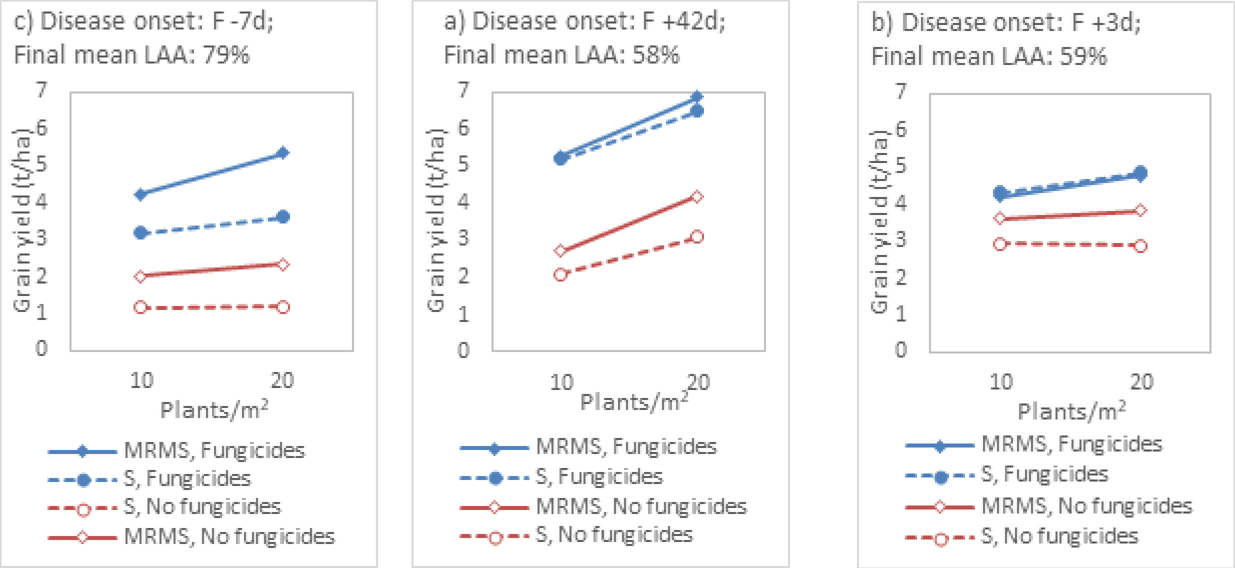


Figure 5. The effects of plant density, cultivar disease rating to chocolate spot (MRMS "Moderately Resistant Moderately Susceptible", PBA Amberley ⅆ, or S "Susceptible", PBA Bendoc ⅆ) and the use of fungicides on faba bean grain yield in three experiments contrasting in the onset of disease (Flowering "F" + number of days) and the mean final severity of disease (LAA "Leaf area affected"). a) Vite Vite North, VIC, 2021, b) Lake Bolac, VIC, 2020, c) Tarrington, VIC, 2020.

Sowing rate and profitability

Here we outline a method to predict the effect of plant density on profitability. Growers can follow the process and adjust the values for their own businesses.

Predicted yield changes from the plant density-yield response curves

The plant density-yield response curves were used to predict the change in yield associated with an increase or decrease in plant density around 20 plants/m^2 (Figure 6). Then, the average effect was predicted from the slope of the trendline for each plant density (boxes in Figure 6).

The differences in grain yield between plant densities increased proportionally as yield increased. The yield losses from decreasing plant density below 20 plants/m^2 were greater than the yield increases above this threshold.

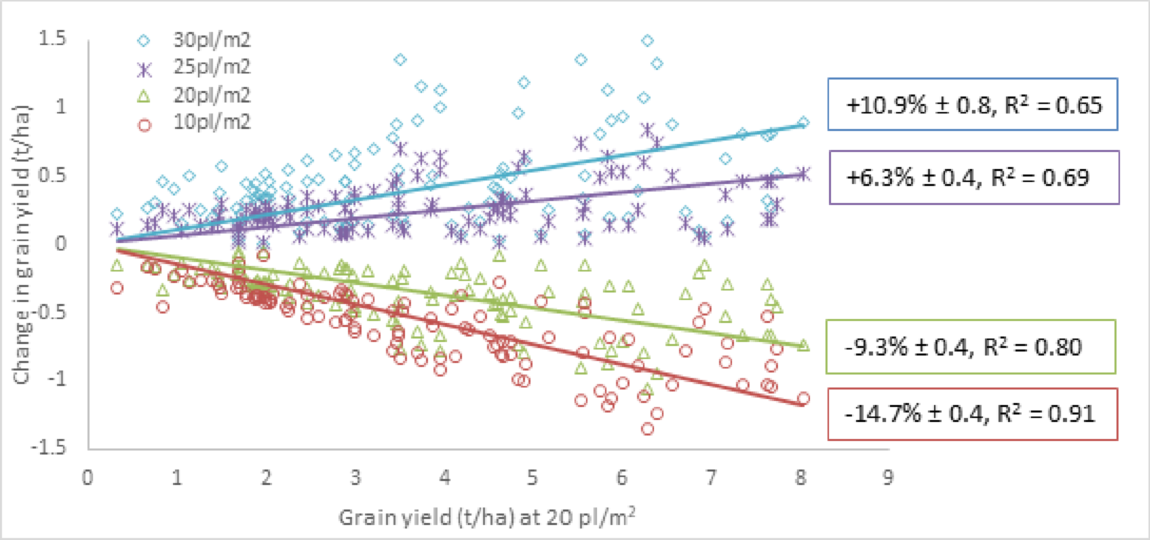


Figure 6. The change in grain yield relative to plant density compared with grain yield at 20 plants/m^2. The slope of each line is presented as a percent of the grain yield at 20 plants/m^2, ± the standard error.

Predicted changes to profitability

Change in costs

The change in sowing rate to achieve a given plant density is a function of the seed size. For example, for a seed size of 65 g per 100 seeds, every increase of 5 plants/m^2 requires an increase in sowing rate of 32.5 kg/ha. The capacity of the seeder may limit the maximum sowing rate that can be achieved.

The model for predicting the change in costs accounted for the effect of plant density on sowing and harvest operation costs, the number of fungicide inputs and the cost of sowing seed. It accounted for the effect of grain yield on freight cost and end point royalties. The costs were estimated from recent PIRSA Gross Margin and Enterprise Planning Guides, and the predicted changes were based on discussions with agronomists. See Table 1 for a summary.

Table 1: Estimated changes in costs associated with changing the sowing rate.

Cause of change	**Variable cost**	**Estimated cost**	**Predicted change**
Plant density	Sowing seed	\$0.60/kg	+\$19.5 per 5 plants/m^2
	Sowing operational costs (labour and machinery)	\$50/ha	+10% per 5 plants/m^2
	Fungicide applications	\$20/application	0.5 applications per 5 plants/m^2
	Harvest operational costs (labour and machinery)	\$100/ha	+10% per 5 plants/m^2
Grain yield	Freight cost	\$25/t harvested grain	Function of change in yield
	End point royalties	\$4/t harvested grain	Function of change in yield

Change in income

The trendlines in Figure 6 were used to create an index of predicted grain yields for each plant density from 5 to 25 plants/m^2, this is available in the Appendix, Table A1.

The change in income is the product of the change in yield and the grain price. The median grain price for faba beans at Adelaide is \$350/t. Partial budgets were calculated with grain prices of \$200, \$300, \$400 and \$500 per tonne of harvested grain to test price sensitivity.

Effect on profitability

The effect of plant density on profitability was calculated for yield from 1 to 6t/ha. See the appendix for the equation. The results were divided into low (1–3t/ha), medium (2–4t/ha), high (3–5t/ha) and very high (4–6t/ha) yield, at the three grain prices described above. See Table 2.

The only situation in which it was profitable to reduce plant density below 20 plants/m^2 was for low yields and the very low grain price of \$200/t. When grain price was \$300/t or higher, it was more profitable to increase the sowing rate above 20 plants/m^2. The change in profit for an increase from 20 to 25 plants/m^2 (130 to 160kg/ha) was -\$22/ha to \$254/ha, depending on grain price and yield.

Some variability is masked by making these estimations with the average yield response to plant density (the slopes in Figure 6).

Table 2: The effect of changing the plant density above or below 20 plants (pl)/m^2 on profitability ($/ha) as a function of grain price, yield and extra costs. The cell shading indicates negative, neutral or positive effects on profitability.

Grain price	10 pl/m^2 (70kg/ha)	15 pl/m^2 (100kg/ha)	Yield range at 20 pl/m^2 (130kg/ha)	25 pl/m^2 (160kg/ha)	30 pl/m^2 (190kg/ha)
$200/t	42 to -8	19 to -13	1-3t/ha	-22 to 0	-45 to -8
	17 to -33	3 to -28	2-4t/ha	-11 to 10	-27 to 11
	-8 to -59	-13 to -44	3-5t/ha	0 to 21	-8 to 29
	-33 to -84	-28 to -60	4-6t/ha	10 to 32	11 to 48
$300/t	22 to -43	7 to -34	1-3t/ha	-13 to 15	-25 to 34
	-10 to -75	-14 to -55	2-4t/ha	1 to 28	5 to 64
	-43 to -108	-34 to -76	3-5t/ha	15 to 42	34 to 93
	-75 to -140	-55 to -96	4-6t/ha	28 to 56	64 to 123
$400/t	0 to -109	-7 to -76	1-3t/ha	-4 to 43	-14 to 67
	-55 to -164	-42 to -111	2-4t/ha	19 to 66	26 to 107
	-109 to -218	-76 to -145	3-5t/ha	43 to 90	67 to 148
	-164 to -273	-111 to -180	4-6t/ha	66 to 113	107 to 188
$500/t	-15 to -153	-17 to -104	1-3t/ha	2 to 62	-3 to 100
	-84 to -222	-60 to -148	2-4t/ha	32 to 91	48 to 151
	-153 to -292	-104 to -192	3-5t/ha	62 to 121	100 to 202
	-222 to -361	-148 to -236	4-6t/ha	91 to 151	151 to 254

Conclusion

In 76 Australian experiments, where yield ranged from 0.2 to 7.3t/ha, the plant density that maximised grain yield ranged from 13 plants/m^2 in a high yield environment through to 57 plants/m^2 in a low yield environment. In most cases, grain yield and profitability were highly sensitive to a change in plant density from 10 to 30 plants/m^2. A modest increase of sowing rate from 130kg/ha to 160kg/ha, which changed the plant density from 20 plants/m^2 to 25 plants/m^2, increased profitability with a range of - $22/ha to + $254/ha depending on yield and grain price.

These results support a minimum plant density of 15 to 25 plants/m^2 in most Australian conditions, and the upper end of this range should be considered in most environments. However, there was variation in the plant density required to maximise grain yield. As a result of this variation, growers can accommodate the plant density to their assessment of the productive potential of a paddock. A key message is that the target plant density should not be ignored or standardised for all situations.

This study has successfully defined the optimal plant density for faba beans for target grain yield. All data in this study is based on experiments, hence results need confirmation at paddock scale. Collaboration between growers and local research organisations to collect data from commercial fields would be beneficial to the industry. Future experiments could explore the interactions of density with other factors such as soil type, row spacing or disease management, but simple density-yield response experiments would have a low return on investment.

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Appendix

Calculating the effect of plant density on profitability

Step 1. Use the index of predicted grain yields to estimate the change in income

The trendlines fitted to the data in Figure 6 were used to create a look-up table of predicted grain yields for each plant density from 5 to 25 plants/m^2 in Table A1. This can be used to predict the yield change associated with a change in plant density. For example, if the predicted grain yield for 10 plants/m^2 is 2.54t/ha (Row number 6), then the predicted grain yield is 3t/ha for 15 plants/m^2 (+0.46t/ha) and 3.28t/ha (+0.72t/ha) for 20 plants/m^2.

The change in yield predicted from Table A1 is multiplied by the grain price to estimate the change in income for a given change in plant density.

Table A1: A look-up table of grain yields for plant densities from 5 to 30 plants (plants/m^2, predicted from the slopes of yield responses to plant density in Figure 6. Compare yields in the same row to predict yield responses to plant density.

Row number	**5 pl/m^2**	**10 pl/m^2**	**15 pl/m^2**	**20 pl/m^2**	**25 pl/m^2**	**30 pl/m^2**
1	0.25	0.43	0.45	0.50	0.53	0.55
2	0.51	0.85	0.91	1.00	1.06	1.11
3	0.76	1.28	1.36	1.50	1.59	1.66
4	1.01	1.71	1.81	2.00	2.13	2.22
5	1.27	2.13	2.27	2.50	2.66	2.77
6	1.52	2.56	2.72	3.00	3.19	3.33
7	1.77	2.99	3.17	3.50	3.72	3.88
8	2.03	3.41	3.63	4.00	4.25	4.44
9	2.28	3.84	4.08	4.50	4.78	4.99
10	2.54	4.27	4.54	5.00	5.32	5.55
11	2.79	4.69	4.99	5.50	5.85	6.10
12	3.04	5.12	5.44	6.00	6.38	6.65
13	3.30	5.54	5.90	6.50	6.91	7.21
14	3.55	5.97	6.35	7.00	7.44	7.76
15	3.80	6.40	6.80	7.50	7.97	8.32
Slope	-0.493	-0.147	-0.093		0.063	0.109
s.e.	0.0106	0.0043	0.0043		0.004	0.0075
R^2	0.95	0.9116	0.8007		0.6921	0.6546

Step 2. Estimate the change in variable costs

The change in sowing rate needed to achieve a given plant density is a function of the seed size. For example, for an average seed size of 65g per 100 seeds, every increase of 5 plants/m^2 requires an increase in sowing rate of 32.5kg/ha. The capacity of the seeder may limit the maximum sowing rate that can be achieved.

The costs used in this paper are reported in Table 2 above.

Step 3. Predict the change in profitability with a partial budget

The equation used to calculate the change in profitability is as follows:

Change in profitability = (Change in grain yield * grain price) – (change in sowing rate * $0.6/kg) – (sowing operational costs * 10% per 5 pl/m^2) – (fungicide cost * 1 application per 5 pl/m^2) – (harvest cost * 10% per 5 pl/m^2) – (change in grain yield * freight cost) – (change in grain yield * EPR)