

Interactions of mungbean physiology in relation to timing of rainfall and time of sowing—Emerald

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RESEARCH QUESTION: *What impact does the timing of rainfall have on the grain and vegetative yield of early and late-planted mungbeans?*

Key findings

1. In dryland conditions, planting in February increased yield of dryland mungbeans by 475 kg/ha over December planting.
2. Irrigation treatments increased mungbean yields by a maximum of 298 kg/ha and 653 kg/ha (planted in February and December respectively).
3. Application of water during mid pod-fill increased grain yield in the December planting but not the February planting.

Background

Over the past three years the Queensland Pulse Agronomy Initiative project (UQ00067) has been using time of sowing (TOS) trials to measure the impact of weather events on the production and physiology of mungbeans. These trials have highlighted that temperature, humidity, radiation and rainfall all have an impact on the plants' ability to set vegetative and reproductive yield. Previous trial data indicates that grain yield is maximised at a harvest index (HI) of 0.3–0.35 when conditions are ideal; therefore bigger yields require more vegetative production.

Mungbean is categorised as a vegetatively determinant crop, therefore it is surprising that previous TOS trials in Central Queensland (CQ) have recorded significant increases in vegetative dry matter after flowering has begun, although this has not been a consistent anomaly as the early summer TOS tends to be affected to a greater degree than the late summer TOS.

This vegetative growth habit is often linked to poor harvest index in the earlier sowings. It would seem that weather conditions are influencing the accumulation of dry matter prior to flowering and this is then having a negative impact on the resources available for flowering and setting grain yield.

This experiment has attempted to use rainfall timing (imitated by overhead irrigation) to mitigate the negative weather impacts on dry matter production both before and after flowering in an early and late summer TOS. A wide gap between TOS was deliberately used to create the largest contrast in weather conditions that the crop would experience and then monitor how the plant's physiological development changes in relation to changing soil water conditions.

What was done

This trial was located at the Emerald Research Facility. The design of this experiment was as a mixed split-plot/strip-plot structure with Jade-AU[®] mungbeans planted on two sowing dates; 18 December and 13 February and replicated three times. Each TOS block was split into four irrigation treatments. Each of the four irrigation treatments was further split to allow two row spacings and a 'with' and 'without' foliar nitrogen (N) application.

Each plot was a maximum of four metres wide by 24 m long and planted at a rate of 35 seeds/m². A standard rate of Granulock[®] SuPreme Z[™] (30 kg/ha) was applied at planting with the seed. Peat inoculant was delivered by water injection with the seed at planting.

Table 1. Summary of trial treatments.

TOS	In-crop irrigation	Row spacing	Foliar nitrogen*
• 18 December 2017	• Dryland (no irrigation)	• 50 cm	Each row spacing +/-
• 13 February 2018	• Irrigation at bud initiation	• 100 cm	foliar N treatment.
	• Irrigation at bud initiation and first flower		
	• Irrigation at bud initiation, first flower and mid-pod fill		

*Foliar N was applied three times two weeks apart starting at bud initiation at a rate of 10 kg/ha as urea dissolved in 200 L/ha of water.

Table 2. Summary of agronomic information for each TOS.

Time of Sowing	Physiological stage	Date	Days after sowing (DAS)	Growing day degrees (°Cd)	Rainfall (mm)	Starting PAWC (mm)
December	Planting	18/12/2017				80
	First flower	22/1/2018	35	659	40	
	Desiccation [#]	20/2/2018	64	1187	99	
February	Planting	13/2/2018				84
	First flower	23/3/2018	38	660	155	
	Desiccation [#]	28/4/2018	74	1204	162	

[#]Desiccation timing was based on the maturity of the dryland plots.

This trial was planted into old sorghum stubble that was used as a cover crop the previous summer and irrigation was applied in December prior to the first TOS being planted in an effort to get a full profile of stored moisture. Unfortunately, the trial site could not be irrigated twice before planting and as a result the soil profile was not fully wet to one metre.

Irrigation treatments were applied with hand shift aluminium piping and sprinklers. Sprinklers were run for four hours, delivering a minimum of 50 mm per hectare across the treated plots.

Neutron probe tubes were placed in half the plots for each TOS. Plots that had foliar N applied were not monitored. Readings were taken twice weekly at 10 cm increments down to a depth of 120 cm. Tubes were installed just prior to bud initiation and the last reading was taken just after the crop was defoliated. Harvesting was carried out by a two metre wide plot harvester, 10 days after defoliation (which was applied based on an assessment of the maturity of the dryland treatments).

Plants counts, light interception, dry matter cuts, hand harvesting and machine harvest yields were also measured. Weather data was recorded close by the trial site at 15 minute intervals; also measured was starting plant available water content and a full soil analysis at planting.

Results

The key agronomic data (Table 2) shows that neither TOS had a full profile at planting despite site irrigation prior to the first planting. Starting moisture was about two thirds of what would normally be expected for a full profile down to one metre. Nearly all the available moisture was in the top 60-70 cm of the soil profile.

Rainfall distribution was quite different for each TOS. The December TOS had small amounts of rainfall both leading up to flowering and at the end of flowering (Figure 1). Maximum temperatures remained above 35 °C for most of the crop’s life with some periods hitting 40 °C prior to flowering (35 days after sowing; DAS).

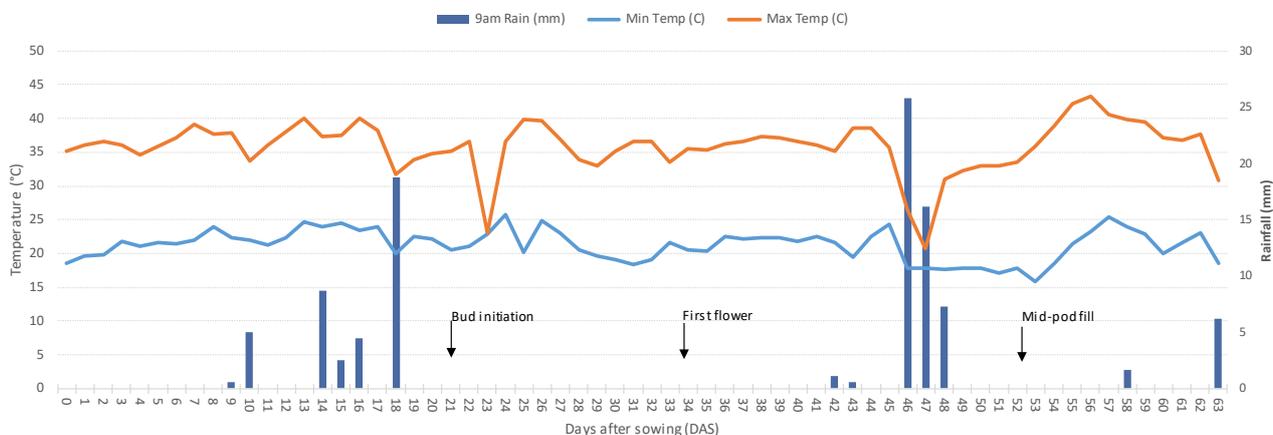


Figure 1. Rainfall and temperature distribution for the December TOS.

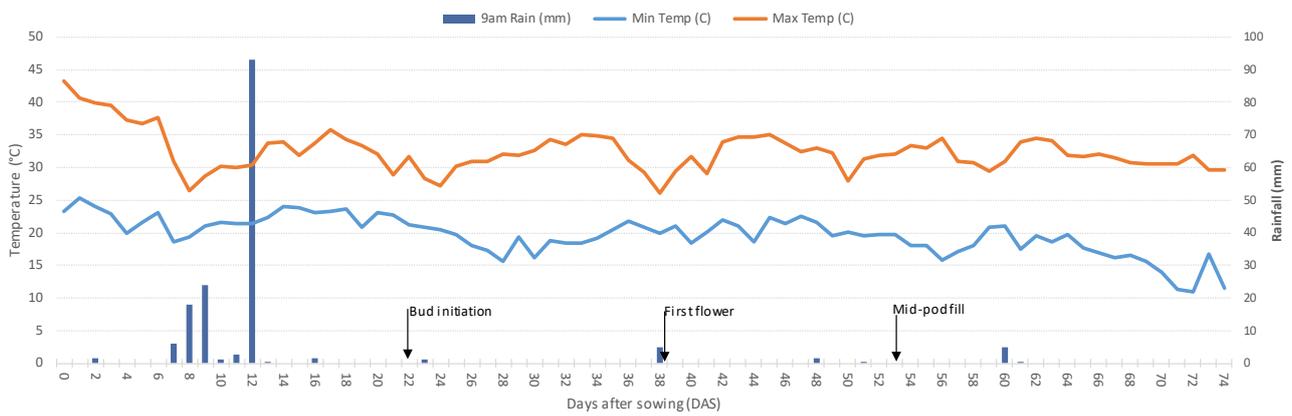


Figure 2. Rainfall and temperature distribution for the February TOS.

The February TOS had most of its rainfall (155 mm) in the first two weeks after planting, causing some early waterlogging issues. Less than 10 mm of rainfall fell for the rest of the crop’s duration (Figure 2). Maximum temperatures were below 35 °C for most of the crop’s life, which meant it took 10 days longer than the earlier TOS to reach maturity.

Overall, the December TOS had to cope with much hotter maximum temperatures and less in-crop rainfall.

Grain yield

The most significant interaction in relation to grain yield was between TOS and irrigation treatments (Figure 3). Although overall plot yields were low, particularly in the early TOS, the differences were obvious. The dryland treatment comparison illustrates the direct benefit of changing TOS with a 475 kg/ha (198% increase) benefit achieved by the February TOS. The differences between the two TOS yields across the increasing water applications remains significant until the last treatment (mid-pod fill).

Clearly, the irrigation treatments had the largest relative effect in the December TOS where the plants were under stress and made the best use of the extra soil water available despite both TOS starting with almost the same profile of stored soil moisture.

Additional irrigation at first flower showed the greatest increase in yields within both TOS, however an extra irrigation at mid-pod fill had a significant impact in the December TOS only. This was a surprising development as it is widely considered that irrigating the crop at mid-pod fill would be too late to impact on yield. Considering the short maturation of the December TOS (64 days), there was only 12 days between this irrigation and the first desiccation treatment, so the extra pods that formed (Figure 4) did not have long to mature. The first desiccation on 20 February was not effective and there was significant rainfall after this application, potentially allowing immature pods time to mature before the second application.

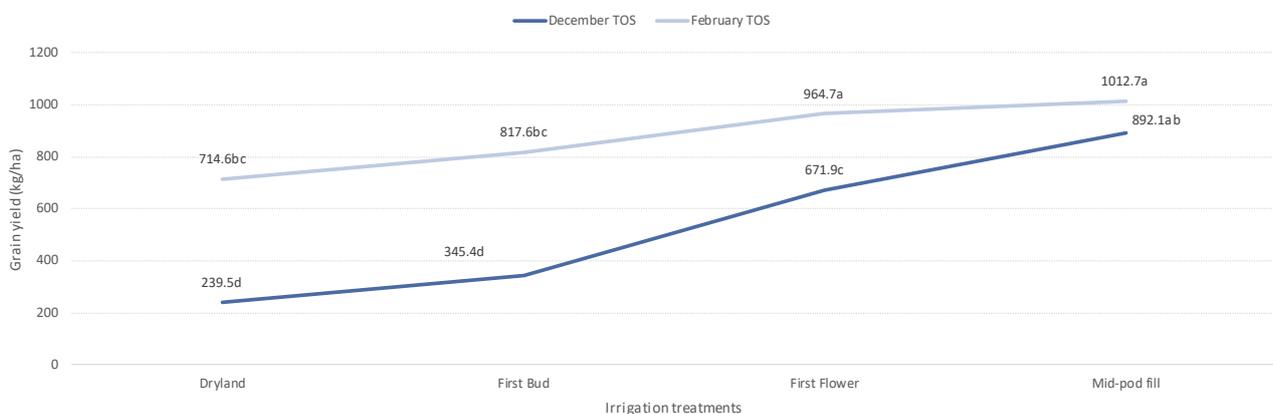


Figure 3. Grain yield comparison for each irrigation treatment across both TOS. Means with the same letters are not significantly different; lsd = 174.

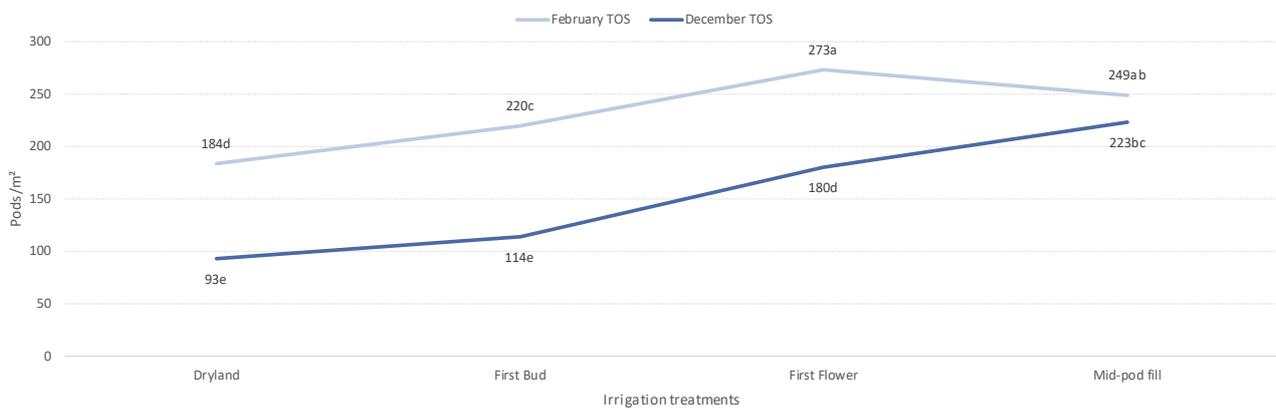


Figure 4. Comparison of hand harvested pods across TOS and irrigation treatments.
Means with the same letters are not significantly different; lsd = 28.65.

Alternatively, the young pods may have already formed and the irrigation at mid-pod fill may have avoided those pods being aborted in the December TOS. The February TOS did not have the same pattern; the later irrigation treatment caused pod numbers to decline but not significantly (Figure 4).

There was no significant differences between wide and narrow row spacing (50 cm, 100 cm) and no significant differences for foliar N application. This is not unexpected given the relatively low yields across the trial as previous trial data suggest there is no real difference between row spacing until yields are above 1.3–1.5 t/ha.

Dry matter and harvest index

Data collected from TOS trials conducted in 2016-17 and 2015-16 showed that the mungbean plant had the capacity to increase vegetative dry matter production after flowering has commenced, particularly in planting dates that experience the highest summer temperatures. This phenomenon goes against the general understanding of plant physiology where mungbean is classed as a vegetatively

determinant crop. Data collected in this TOS trial compliments the vegetative dry matter data collected in past trials where there are significant increases in vegetative dry matter yield after first flowers are set.

When this data is converted into a percentage increase over vegetative dry matter yields at first flower (Figure 5) it shows some stark contrasts between TOS and irrigation treatments. In the February TOS there is an almost linear increase in vegetative dry matter as the access to soil water increases. In the December TOS, the increase is less dramatic except where additional irrigation was applied mid-pod fill and vegetative dry matter doubled after flowering started.

All treatments had extra vegetative growth after flowering, however the dryland treatments in both TOS were the smallest (Figure 5). Weather conditions for the February TOS were milder than the earlier TOS, which may explain some of the differences. When the plant cannot keep up with its evaporative demand it goes into stress mode which then severely restricts growth. When extra water is added the plant can continue normal growth.

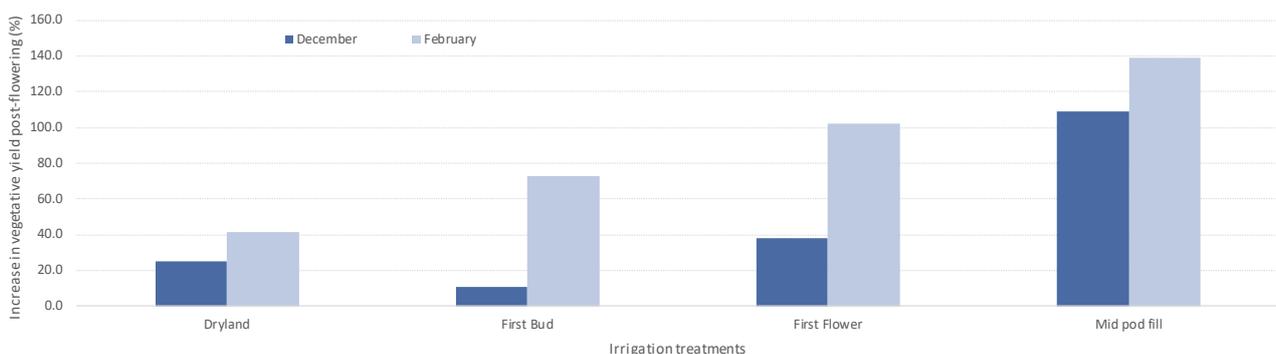


Figure 5. Comparative increase in vegetative dry matter after flowering has started as a percentage of the vegetative yield at first flower.

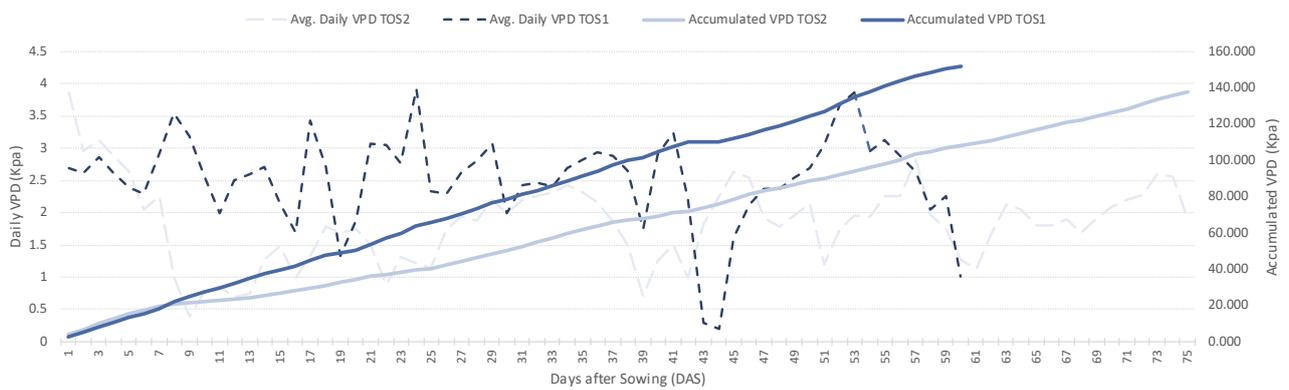


Figure 6. Comparison of daily vapour pressure deficit (VPD) and accumulated daily VPD data across December and February TOS.

In the December TOS, growth was still being suppressed despite increasingly better soil water conditions (first bud, first flower); it was not until the mid-pod fill irrigation that substantial extra vegetative growth occurred. This particular irrigation also had a rainfall event in the same week so soil moisture conditions would have been enhanced even further. This might also indicate that the earlier irrigations within this TOS (50 mm per application) were not substantial enough for the plant to maintain a normal water balance in such high evaporative conditions.

Vapour pressure deficit (VPD) data (Figure 6) would suggest that there were differences in evaporative demand on the plant between the two TOSs. While the daily VPD data was highly variable; when the same data is accumulated over the life of the crop, the overall trend is easier to detect. In this case (Figure 6), the comparison between the December and February TOS shows a clear difference in VPD conditions over the cropping period.

Total dry matter production (Figure 7) shows a similar pattern to grain yield (Figure 3) with a clear significant difference between the December and February TOS of at least 1000 kg/ha for the first three irrigation treatments. Theoretically, this much difference in dry matter should be worth another 300 kg/ha in grain yield if all plant requirements were met (HI of 0.3) to the February TOS, however grain yield results would suggest that some of the differences are actually greater than that between the two planting dates.

There is no significant difference in the dry matter yield in the mid-pod fill irrigation treatment between the two TOS, in both grain yield (Figure 3) and dry matter production (Figure 7). This would suggest that the extra in-crop water benefited the December TOS far more than the February TOS; this is surprising given that the timing of this treatment is quite late in the crop's development and the December TOS had quite short reproductive period (29 days).

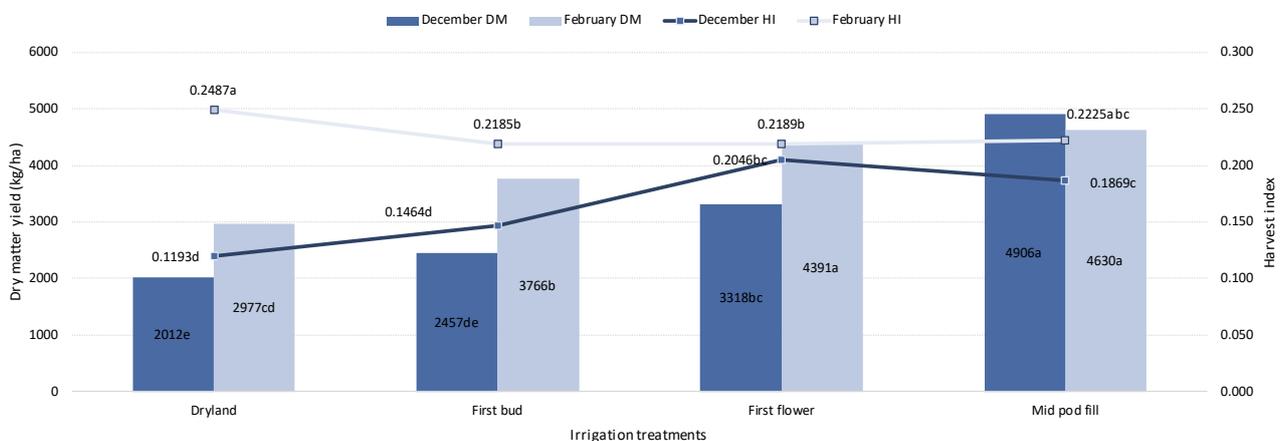


Figure 7. Comparison of total dry matter and harvest index between TOS and irrigation treatments. Means with the same letters are not significantly different; lsd = 579 (TDM), lsd = 0.029 (HI).

The HI data (Figure 7) suggests that there has been some inconsistency in the plants' ability to convert dry matter into grain yield between the two TOS and the four irrigation treatments. Generally HI is quite low with none of the treatments reaching a HI of 0.3. This would indicate that, in general, seasonal conditions have made an impact on reproductive capacity regardless of in-crop soil moisture conditions.

The biggest contrast in HI across TOS is in the dryland treatments, with the February TOS creating the highest HI for the entire trial. Apart from the dryland treatment, the HI for the February TOS is almost a flat line despite dry matter production increasing at almost a linear rate. This means that grain yield increased at the same rate as dry matter production across the increasing irrigation applications. This coincides with the February TOS having a close to linear increase in vegetative growth after flowering has started (Figure 5). This may have split the resources of the plant between vegetative and reproductive processes and therefore the plant did not maximise its grain yield, and HI could not improve.

In the December TOS the total dry matter production increased significantly for the last two irrigation treatments (Figure 7), however HI was similar. Considering vegetative dry matter doubled during the flowering period for this treatment (Figure 5), it would seem that the balance between vegetative growth and reproductive development slightly favoured vegetative growth.

The improvement in soil water supply from consecutive irrigation applications has particularly favoured the December TOS in terms of HI, especially between the irrigations at first bud and first flower. The irrigation at mid-pod fill did not largely improve HI for either TOS; and dry matter production was only enhanced in the December TOS.

Soil water balance

This experiment has largely focused on the response of TOS to changing soil water conditions. Data presented so far shows improved performance for the crop planted in the February TOS but also that the additional in-crop water treatments have favoured stronger improvement in the December TOS.

Although the two TOS started with similar starting soil moisture at planting (Table 2), the neutron data recorded in each of the dryland treatments (Figure 8) would suggest the February TOS had a much higher soil moisture content by 20 DAS. This was due mainly to a week of wet weather where 150 mm of rain fell between 7 and 14 DAS. This extra 25mm of stored moisture may have made a significant contribution to the large yield difference between the two TOS in the dryland treatment; although daily draw down would seem to be quite similar between the two TOS until 40 DAS.

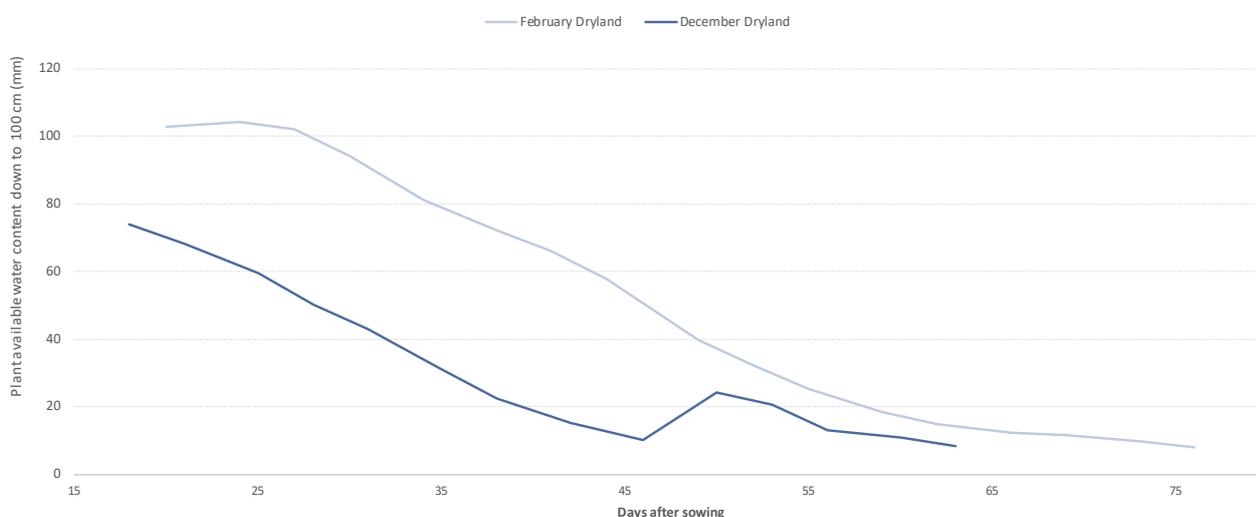


Figure 8. Comparison of PAW between the dryland treatments for the December and February TOS.

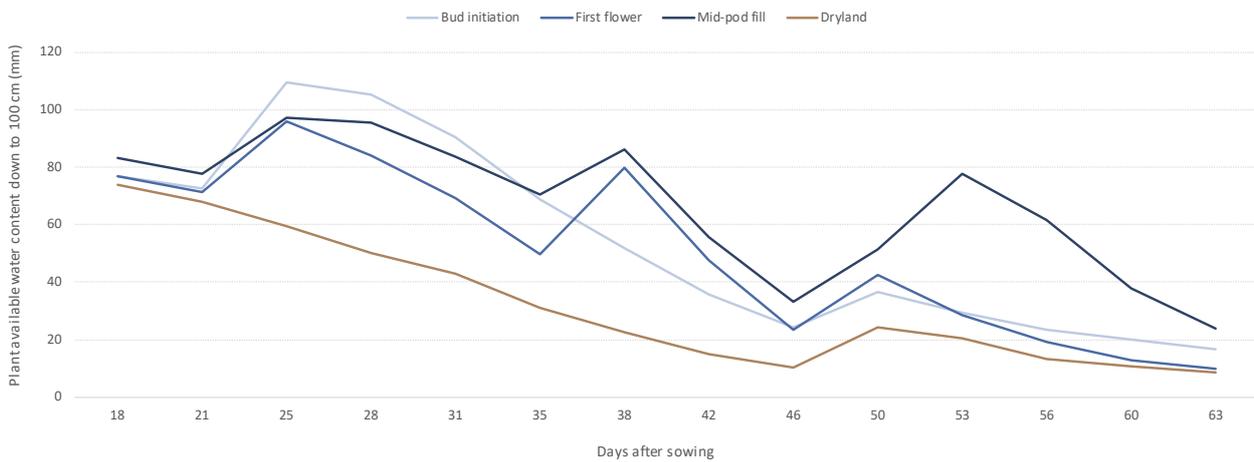


Figure 9. Comparison of PAW between irrigation treatments in the December TOS.

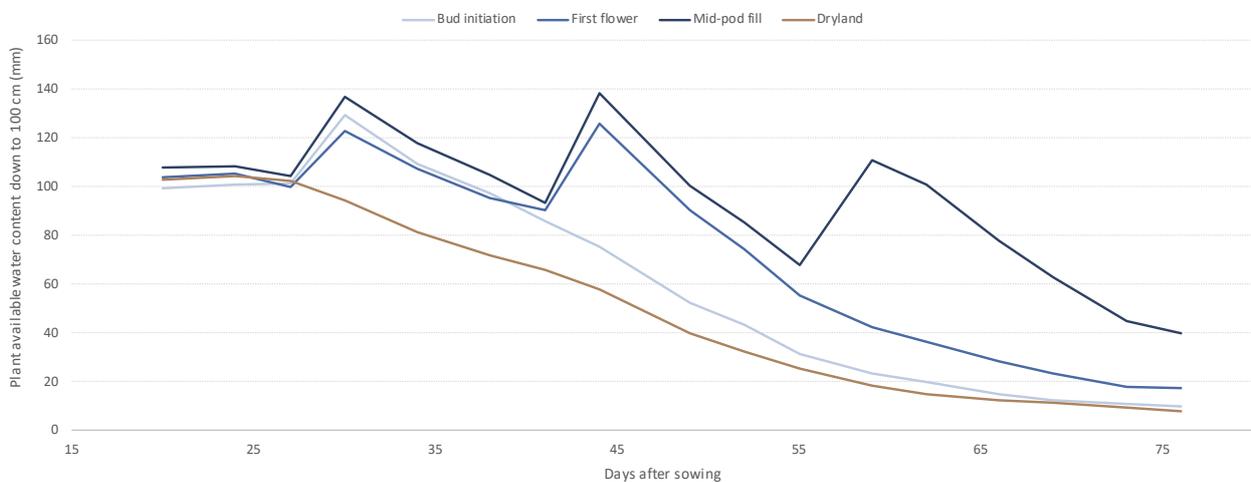


Figure 10. Comparison of PAW between irrigation treatments in the February TOS.

In contrast to the dryland treatments, it is clear that the plant is capable of much faster draw down of water on a daily basis (Figure 9). After each irrigation application in the December TOS, the slope of the draw down is much steeper compared to the dryland treatment particularly around the flowering period (40 DAS). This may indicate that the dryland treatment is constantly under stress in regards to the water balance of the plant and this may then flow through into reduced biomass production.

It is worth noting in the mid-pod fill treatment that despite the relatively late application of irrigation in the crop cycle, the plant has still managed to utilise nearly all the available water (Figure 9). This lines up with the fact that this treatment produced a lot of vegetative biomass and grain yield in comparison to the irrigation treatment at first flower (Figure 3 and Figure 7).

Despite the February TOS (Figure 10) starting with a fuller profile, the draw down during the flowering period is still much steeper than the dryland treatment. Draw down (slope) between the irrigation treatments and the dryland treatment are similar in the first period between first bud and first flower, which may indicate easier growing conditions and evaporative demand is being met by all treatments. This changes from flowering to pod fill, and even into the later pod fill period, where drawn down by the plant after irrigation is much steeper than the other treatments.

The mid-pod fill treatment for the February TOS (Figure 10) has not utilised all the soil moisture before defoliation, which would indicate that general crop demand has slowed. Based on the yield and dry matter production, this last irrigation did not add any significant increase in grain or biomass.

A comparison of daily evapotranspiration (ET_o) data (Figure 11) shows a clear difference in the relative evaporative pressure that each TOS experienced. This data, taken in conjunction with the vapour pressure deficit data (Figure 6), would indicate that the plants in the December TOS had to work much harder to maintain the appropriate water balance for the plant to continue to function normally and have a normal growth pattern. The difference in water uptake by these plants in dryland conditions (Figure 8) and after irrigation (Figure 9) would indicate that the plants in the dryland treatment were constantly under stress and hence normal dry matter accumulation could not occur.

Increasing the amount of soil water available in the top 20 cm (by rainfall /irrigation) has allowed the plant to access moisture easily and quickly. This has helped the plant to maintain its water balance and continue normal dry matter production. When dry matter production is suppressed prior to flowering it would seem the plant can compensate by continuing to build vegetative dry matter after flowering has started (Figure 5). This may, however interfere with the plant being able to set its true yield potential in relation to HI.

The HI data (Figure 7), particularly for the February TOS, indicates that while vegetative production and grain yield was enhanced by increasing applications of water, the HI was not maximised. High temperatures and evapotranspiration demands continued through the flowering period for the December TOS and this may have suppressed flower set and also any compensatory vegetative dry matter accumulation. In both TOS cases the fact that vegetative potential was not fulfilled by early flowering meant that HI was always

going to be compromised; even though the mechanism of that compromise was slightly different for each TOS. Overall, the later TOS had the best performance mainly due to milder environmental conditions.

Implications for growers

Time of sowing can have a big impact on mungbean yields and it is not simply just a matter of too much heat at flowering. The period leading up to flowering is just as important as it essentially sets the level of vegetative biomass which in turn sets the potential yield of the crop. Warm temperatures, long day length and high levels of radiation all promote strong vegetative growth conditions, however if that growth is interrupted by stress then that potential growth is not met. This stress seems to be based around the plant's inability to utilise stored soil moisture to maintain its water balance in high evaporative conditions (high heat and low humidity). When extra water is added (either rainfall or irrigation) the plant can utilise this moisture quite quickly and increase both vegetative and reproductive yield, but the timing of that rainfall will impact on whether the true potential of the plant is met in relation to HI.

It is evident that irrigation can minimise the impacts of environmental conditions, so much so that there was no significant difference between the highest irrigation treatments in both TOS. This then creates a contrast between an irrigated farming system and a dryland farming system. The highest potential biomass accumulation occurs in the earlier TOS, however this is dependent on the plant being able to maintain its water balance all through the vegetative period.

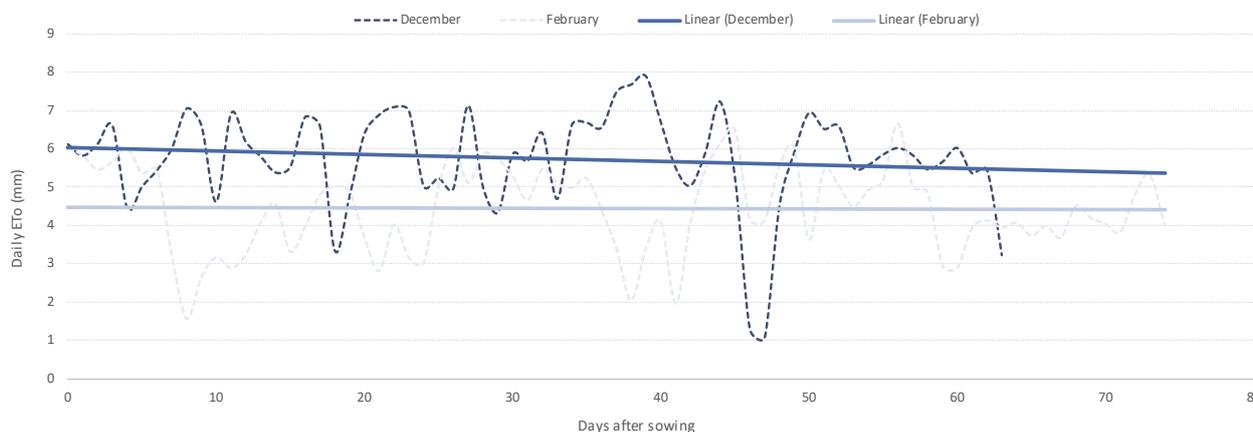


Figure 11. Comparison of daily evapotranspiration between December TOS and February TOS.

The plant cannot maintain its water balance on stored moisture under normal environmental conditions of a CQ summer; it has far more success when evaporative stresses are much lower. This means in a dryland scenario a later TOS has a far more reliable yield as it can produce more grain for the same amount of stored moisture. For an irrigator, an earlier planting window can produce more yield as long as evaporative demand can be met without waterlogging the plant.

This contrast in the plant may well be a direct attribute of the plant's tap root structure which has a low surface area. When evaporative conditions are high, the root system cannot supply enough water fast enough for the plant to maintain full turgor pressure in its cells and therefore transitions into stress mode. It is possible that the plant is stressing before visual symptoms are apparent and consequently normal biomass production is constantly being interrupted.

Based on these findings it would be expected that mungbeans would be more suited to situations where evaporative pressure is lower (lower temperature and/or higher humidity); which means planting later (February-March) in the summer for CQ regions. Irrigated systems can offset the impacts of high evaporative demand to some extent and can therefore benefit from an earlier summer TOS (December-January) which has longer day length and higher radiation levels, which in turn can promote bigger vegetative yields. High maximum temperatures can still affect the length and intensity of flowering regardless of soil water conditions, so early summer plantings always have a higher risk factor in achieving optimum yields.

Acknowledgements

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Trial details

Location: Emerald Research Facility
 Crop: Mungbeans
 Soil type: Black / Grey cracking Vertosol
 In-crop rainfall: 99 to 162 mm
 Fertiliser: Granulock® SuPreme Z™ at planting (30 kg/ha)

Selected soil fertility characteristics of the trial site:

Depth (cm)	Nitrate nitrogen	Phosphorus Colwell	Sulfur (KCl-40)	Exc. potassium	Phosphorus BSES	CEC
0-10	10	14	7	0.65	21	32
10-30	8	6	3	0.49	11	33
30-60	5	<2	9	0.38	5	33



Drone image of December TOS on 18 January.



December TOS (left, 51 DAS) and February TOS (right, 64 DAS), bud initiation irrigation treatments on 1 m rows.