Summer cropping and rotational effects on following winter crops in western Victoria

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Abstract
Opportunistic summer cropping with adapted legume species such as Mungbean and Soybean may be an option for some sub-regions within southern Australia.. However, soil water depletion and effects on soil nitrogen are likely to influence the performance of subsequent winter crops. The rotational effects of up to 8 different summer crop species on the following winter wheat crop was assessed with remote sensing tools used to monitor growth across three agroecological zones in western Victoria (low, medium, and high rainfall zones). The preceding summer crops (legumes and sorghum) caused variation in the subsequent wheat response, for example., sorghum caused a reduction in wheat yield in the medium and low rainfall zones, however, it was associated with an increase within the high rainfall zone. Where mungbean and cowpea were grown as summer crops, these had an equivalent effect on the wheat as that observed for a summer fallow. The comparative performance of each species at anthesis could be detected with in-season multispectral imagery for the low and medium rainfall sites using the Normalized Difference Red-Edge (NDRE) index, where no remote sensing or agronomic differences were detected in the high rainfall zone. Understanding the rotational effects of potential summer crop species, will enable growers to make informed decisions on when summer legume crops may best fit into crop sequences depending on agroecological region across southern Australia.

Keywords
mungbean, soybean, legumes, remote sensing, crop health, UAV

Introduction

Summer crops have long been an important component of cropping systems in the summer dominant rainfall regions of northern Australia. An opportunity to broaden the legume crop options grown in southern Australia exists through a combination of expanding the suitability of crops and introducing alternative legumes crops as summer adapted species. The expansion of crop options could improve the efficiency and profitability of farming systems through access to higher-value legumes, increased break crop and fodder options. Summer adapted species also provide the opportunity to maximise resource capture within the system by utilising episodic summer rainfall. This rainfall can potentially contribute up to 1.0 t/ha or 33% of water limited attainable yield for winter cereals (Hunt and Kirkegaard, 2012). The probability of summer rainfall varies across each of these sites as outlined by Christy et al, 2021. In higher rainfall regions, such as south west Victoria, summer cropping may improve the performance of the following winter cereals, where the reliable growing season rainfall and duplex soils often result in waterlogging and runoff (Harris et al, 2016). It is therefore important in the evaluation of summer cropping options to consider any carry over effects to the winter growing season. This paper assesses the remote detection and agronomic effect of a broad range of summer crops on the growth and yield of the following wheat crop across three key agroecological zones within Victoria.

Methods

Summer Cropping Program

To assess the agronomic suitability of alternative legume species across a range of southern agroecological zones (low, medium, and high rainfall zones) an extensive summer field program was established in 2019/2020. Crop species tested were largely legumes and included commercial varieties of adzuki bean, burgundy bean, cowpea, fenugreek, kidney bean, lab lab, messina, mungbean, pigeon pea, soybean and a non-legume comparison, sorghum. All plots were irrigated at sowing, vegetation, and early reproductive stages, receiving 198mm, 196mm and 163mm of growing season rainfall (GSR) and irrigation at Ouyen, Horsham and Hamilton, respectively. Throughout the season, whole trial site images were acquired on an unmanned aerial vehicle (UAV) platform with an integrated, high resolution RGB (red, green, blue) camera (Zenmuse 3, DJI, Shenzhen, China). Images were stitched and georeferenced to ground control points (GCP's). Guided by maturity, plots were harvested and processed between March and May 2020. Species and varieties were selected from a larger pool for legacy monitoring based upon a range of growth behaviours and overall performance during the season, including plots with no establishment, to form a fallow control (Table 1). The location of each harvest cut was georeferenced using an RTK (real-time kinematic) corrected GPS at 5 cm or greater accuracy.

Winter wheat as a bioassay

Wheat was sown during autumn 2020 by the host growers across the summer trial sites; Ouyen (low rainfall), Horsham (medium rainfall) and Hamilton (high rainfall). GSR ranged from 277mm at Ouyen, to 288mm and 509mm at Horsham and Hamilton, respectively. The digital perimeter of each summer trial plot was determined from the high-definition base map, corroborated with the plant and soil sample locations, and subsequently pegged. Quadrat cuts (*ca.* 1 m^2) were taken from each plot at wheat anthesis and harvest to determine biomass and yield components.

At anthesis, RGB and multispectral imagery (AIRPHEN camera, Hiphen, Avignon France) were collected at 40 metres above ground level, stitched, calibrated to reflectance and georeferenced. The Normalised Difference Vegetation, and Red Edge indices (NDVI, NDRE), and Photochemical Response Index (PRI) were calculated using the 6 available bands of the multispectral camera and extracted by the plot's extent in QGIS (QGIS.org, 2021). Variance in the agronomic and remote sensing values were analysed in GenStat (VSNI, 2021).

Results and Discussion

Agronomic response of wheat after summer crops

At Ouyen, anthesis biomass of wheat was equivalent when comparing summer fallow to plots where the summer legume species (cowpea, burgundy bean, mungbean, lab lab and pigeon pea) were grown. However, biomass was significantly lower in plots where wheat followed sorghum (Table 1). This same pattern occurred for grain yield where wheat after fallow yielded 2.5 t/ha and sorghum caused a 47% reduction. In contrast, where cowpea, burgundy bean, mungbean, lab lab and pigeon pea were grown, subsequent wheat grain yield averaged 2.2t/ha which was equivalent to wheat after fallow. This indicates that for a low rainfall environment (Mallee), growing a legume summer crop did not impact the subsequent wheat yield in the 2020 season.

At Horsham, wheat biomass at anthesis was greatest after either a summer fallow or where mungbean was grown; 15.6 and 14.2 t/ha, respectively. In contrast, where cowpea, lab lab, sorghum, adzuki bean, soybean or pigeon pea were grown, a significant reduction in biomass at anthesis occurred (average 1.26 t/ha) when compared with wheat after fallow. At crop maturity the pattern of response changed, where wheat yield after cowpea, mungbean and fallow was highest, and significantly greater than where pigeon pea and sorghum were grown prior. Similarly, the wheat response at Ouyen, the effect of a summer legume crop on subsequent wheat yields was not significant compared with a summer fallow, the only exception being the negative effect of pigeon pea as a summer crop at Horsham.

At Hamilton, there was no significant effect of summer crop on subsequent winter wheat growth to anthesis, where average biomass was 12.6 t/ha. At crop maturity, wheat yield was significantly higher following sorghum compared with summer-sown lab lab, mungbean, soybean, adzuki bean or fallow. In contrast with Ouyen (low rainfall zone) and Horsham (medium rainfall zone), sorghum induced a positive crop response in wheat at Hamilton (high rainfall zone), which may be due to sorghum effectively extracting stored soil water, thus reducing potential negative effects of water logging of winter crops. For all sites, there was no evidence that any nitrogen fixed by the summer legume crops translated to a positive response in the winter wheat crop compared with a preceding fallow.

Table 1. The effect of summer crop species on subsequent winter crop (wheat) growth and yield across three different agroecological regions within Victoria. Wheat biomass at anthesis and yield are in kg/ha.

Ouyen			Horsham			Hamilton		
Summer option	Anthesis biomass	Yield	Summer option	Anthesis biomass	Yield	Summer option	Anthesis biomass	Yield
Fallow	3524	2502	Cowpea	13235	8034	Sorghum	11975	10921
Cowpea	3645	2384	Mungbean	14198	7768	Cowpea	10873	10065
Burgundy Bean	3478	2316	Fallow	15563	7605	Pigeon Pea	13964	9339
Mungbean	3809	2255	Lab lab	12974	6978	Lab lab	11900	8618
Lab lab	3508	2106	Adzuki bean	12445	6840	Mungbean	12547	8519
Pigeon Pea	3392	2061	Soybean	12259	6723	Soybean	15143	8445
Sorghum	2365	1333	Sorghum	12809	6188	Fallow	12225	8383
			Pigeon Pea	11864	6102	Adzuki	13542	8299
						Soybean*	11195	7643
LSD(P<0.01)	826	512		2209	1443		ns	2173

*Soybean breeding lines

Remote sensing

At Ouyen, significant differences in NDRE existed between summer crop species (P=0.029), with plots previously sown to sorghum and lab lab averaging a comparable NDRE of 0.13 and 0.12, respectively (Figure 1a). The remaining crop species and fallow plots investigated were not significant from each other, ranging between an NDRE value of 0.19 to 0.16. Excluding the significant reduction in the index value of wheat following lab lab, these results agree with the observed agronomic response, where anthesis biomass and yield kg/ha were equivalent between the summer legume crops and significantly less for the sorghum. High variability in the NDVI data likely due to issues of reflectance calibration of the red band meant it was and removed from further analysis.

At Horsham, the NDRE (Figure 1b) and NDVI were both significant (P<0.001) in distinguishing between wheat crops following the different summer crop species. Significant differences were observed between wheat sown after sorghum and pigeon pea, with the lowest average NDRE values of 0.32 and 0.34, respectively. Summer fallow plots exhibited the greatest average NDRE value of 0.42 and were significantly greater than all other species. As reflected in the agronomic biomass and yield response of wheat, cowpea and mungbean effect were not significantly different from each other (NDRE = 0.40, 0.38) and were comparable to wheat grown after long fallow.

For Hamilton, there were no significant vegetation index value differences for wheat across any of the preceding summer crop species (Figure 1c). Agronomic data also supports there being no difference, primarily due to a lack of significant difference in wheat growth at anthesis.

At all three sites, the photochemical response index (PRI) was unable to detect any differences in wheat growth because of summer species. While PRI has commonly been used as a non-chlorophyll sensitive substitution, capable of detecting changes in photosystem I due to stressors, such as drought. While differences in plant performance were observed and attributed to differing soil water content, adequate GSR meant that plants were likely water-limited, however not to the point of being drought stressed, causing a reduction in photosynthetic activity.

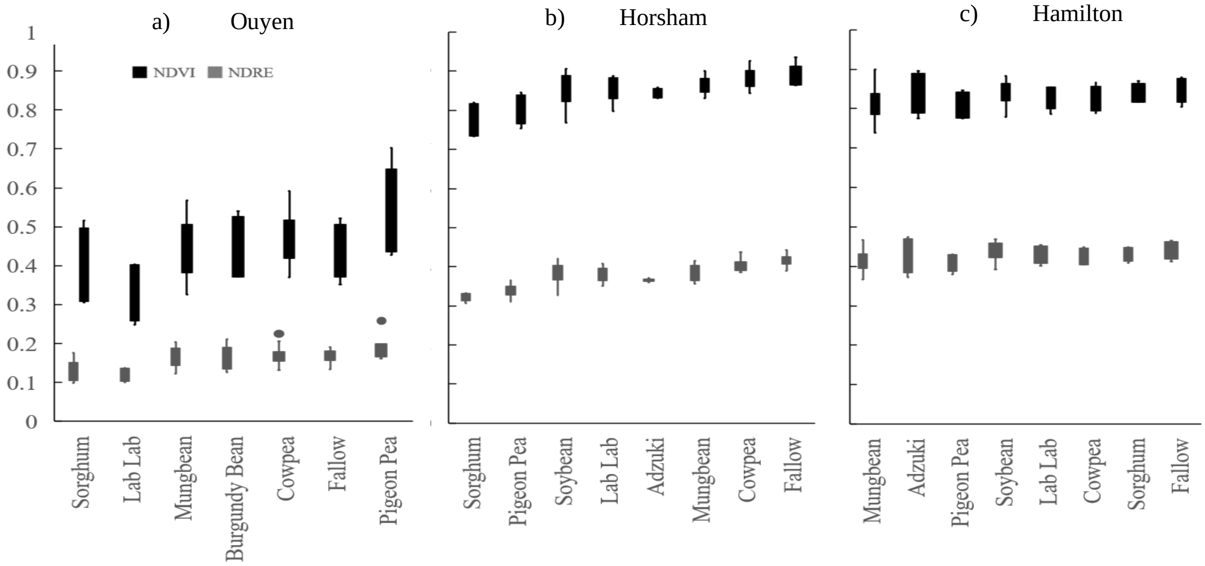

Figure 1. Distribution and range of plot mean NDVI and NDRE index values for each species at Ouyen (a), Horsham (b) and Hamilton (c).

Conclusion

Across the three agroecological zones investigated in the 2020 season, the growth of wheat following summer cropping was dependent on plant species, which may be due to the variable water depletion across the summer crop species. For Horsham and Ouyen, this hypothesized depletion by sorghum and pigeon pea may have a negative impact on wheat growth, while in the high rainfall zone of Hamilton, may decrease the chances of waterlogging and have a net beneficial effect. For the low and medium rainfall regions, it is suggested that most of the summer legume species (e.g., cowpea and mungbean) had no negative impact on subsequent winter crop yields. Further investigations are necessary to determine the response of wheat in relation to the soil water balance as well as the establishment and growth of the summer crops. The differences in legacy effects of summer crops can be detected using remote sensing tools, such as vegetation indices, NDVI and NDRE, derived from multispectral imaging.

Acknowledgments

The '*Alternative legume crops for the southern region*' project is supported by Agriculture Victoria and the Grains Research & Development Corporation (GRDC) through the Victorian Grains Innovation Partnership. The authors would like to thank Tim Rethus and Scott Anderson, for hosting both the summer and winter studies, as well as the Alternative legumes technical team.

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