GRDC Regional Cropping Solutions Network funding
Research Report

Stubble management to reduce the impact of frost to crops in the Albany and Kwinana West Zone of WA – KW/Alb 12/13 JointProj 4

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Introduction

There currently is limited information available to growers surrounding present and emerging farming practices with regards to the impact and severity of frost events.
With a decrease in number of livestock on properties, and subsequent increase in cropping areas, frost is now a significant risk to broadacre grain production and is estimated to cost around $63m annually in lost grain production (Fellowes 2006). Previous agronomic work has shown that management practices can change the ability of the soil to maximise storage of heat during the day or minimise the heat released from the soil at night. Both factors may have an influence on reducing the severity and duration of frost events.
Agronomic practices that have been shown to be effective include things such as delving to increase the amount of water and heat holding capacity of non-wetting sands. While other techniques that reduce canopy density (such as low seeding rates or nutrition) can maximise heat entering the soil, practices such as rolling increase soil compaction and increase heat transfer out of the soil at night. These techniques can reduce severity and duration of frost and its associated damage.
Over the past 10 years as growers increasingly moved to a cropping dominant farm so too did their exposure to frost risk. The actual temperature effect of how they managed their stubble was never measured, but anecdotally many growers were seeing big differences in frost damage where they had retained stubble when compared to areas that had been burnt. This project aimed to quantify the temperature differences between areas that have had their stubble burnt or removed when compared to areas that have had the stubble retained. Paddock demonstrations conducted in 2012 at Wickepin and York demonstrated that high stubble biomass can increase the severity and duration of frost events.
The Albany and Kwinana West Zone Regional Cropping Solutions Networks proposed a research plan to build on previous stubble management work for frost mitigation at two sites prone to frost in York and Nyabing.

Objectives

To quantify the impact of stubble on the severity and duration of frost through canopy temperature and grain yield.

Methodology

Large scale replicated field trials were conducted in wheat paddocks at Nyabing and York during 2013. Paddocks with a known history of frost damage were identified prior to seeding. Trials were sown with farmers' broad acre seeding PA equipment using farmer's standard cultivar, rotation and agronomic management, apart from fungicides which were applied prophylactically to ensure no differences in disease between the standing stubble and the burnt or remove stubble areas. Stubble treatment plot lengths were laid down along the paddocks natural slope for 200m, with a width of 30-48m and replicated three times (Figure 1 and 2).

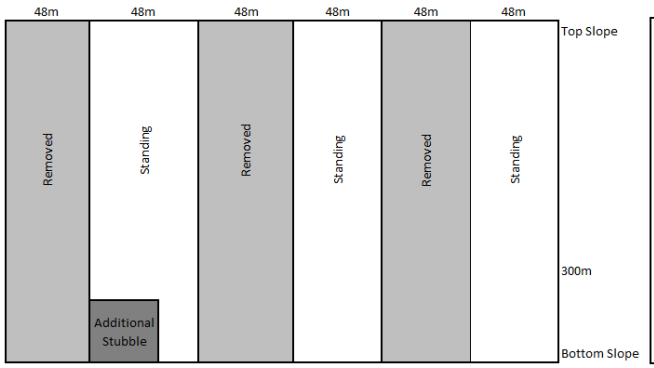

Figure 1: Trial layout at Nyabing

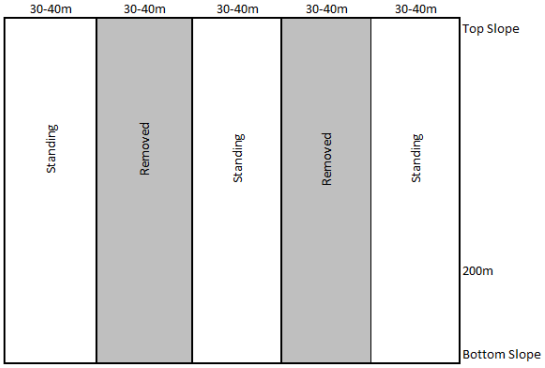

Figure 2: Trial layout at York

The Nyabing site was sown on the 23rd May with Yitpi wheat at 70kg/ha into stubble residue from a canola crop that yielded 0.8t/ha in 2012. There was a gentle slope of 1m in 100m running with the treatments. The trial was replicated 3 times, with three replicates of raked/removed stubble and three replicates of standing stubble.
Given that this trial was located on canola stubble, the Nyabing site was initially thought to be too low in stubble to have an effect on temperature. As a result an additional high stubble load was created in a 30 x 30m area in the lowest part of the landscape by applying the additional canola and barley stubble previously removed from the paddock (Figure 1). This created three distinct stubble loads: 0.5t/ha for removed stubble treatments (approximately 5% ground cover), 2.6t/ha for standing stubble treatments and 3.5t/ha in the additional stubble plot.

The York site was sown on the 20th May with Mace wheat at 75kg/ha into stubble residue from a 2012 wheat crop that yielded 1.9t/ha. This gave a stubble density of approximately 2.2t/ha. Slope at the York site was more severe than at Nyabing, with a falling slope of 4m in 100m. Three replicates of standing stubble were retained while two replicates of stubble were removed through burning down the slope (Figure 2).

All sites were soil sampled prior to sowing. Data loggers were installed along the slope in each plot. At Nyabing data loggers were placed high and low in the landscape, while York data loggers were placed high, mid and low in the landscape. Canopy temperature readings were collected at a height of 600mm at 3 minute intervals with unshielded Tiny Tag temperature loggers (TGP-4017) from July until harvest. Plant stand counts were conducted at 3 randomly selected locations of each plot to assess crop emergence. From Z 40 (flag leaf sheath extending) onwards plots were assessed weekly for Zadok and NDVI readings. At Z65 (anthesis) 3 x 1m biomass cuts were taken from 3 randomly selected areas of the plot to determine anthesis biomass. Additional cuts were taken at Z89 (hard dough) for frost-induced sterility assessment, harvest index, 1000 grain weight and screenings. At crop maturity harvest cuts were taken using a small plot research header at York. A total of six cuts per plot were taken along the slope. At Nyabing an area of 60m x 288m was divided up into a checkerboard pattern of 6m long x 1.72m wide plots totalling 1656 plots. These were harvested with a small plot combine harvester and the results used to create a detailed spatial yield.

Results

Crop establishment and development

At both York and Wickepin there was no difference in seedling emergence between the two treatments with both removed and standing stubble showing statistically similar emergence at both sites. Standing stubble treatments flowered 1-2 days later than removed stubble treatments ($P<0.05$) across both sites, presumably due to the lower temperatures experienced

in the standing stubble treatments. Crop biomass levels were the same between standing and removed stubble treatments at Nyabing and York. Yield estimates based on tiller numbers and heads/m^2 taken in October indicated a yield potential of 4t/ha at Nyabing. Actual yields achieved were only 2.5t/ha, which can be mainly attributed to frost damage. York yield potential was 5t/ha which was achieved and reflected the low level of frost at this site.

Nyabing

There were 6 frost events (defined here as a canopy temperature below 0°C) at the Nyabing site in September prior to and during flowering (flowering occurred 20th – 25th September). A further 9 frost events were recorded after flowering and during grain development in October. The additional stubble treatment increased the severity of the frost and consistently recorded the lowest minimum temperature (Table 1). On average it was 0.4°C colder than standing stubble and 0.6°C colder than the removed stubble treatments. This trend of stubble increasing the severity of frost is depicted in Figure 3. As well as showing lower minimum temperatures the additional stubble treatment also increased the duration of hours the canopy temperature was below -1 and -2°C (Table 2). At the temperature loggers positioned low in the landscape the standing stubble treatment also recorded lower minimum temperatures than the removed stubble treatment, but did not increase the duration of the frost event.

At Nyabing the differences in temperature between the stubble treatments were greatest at those areas low in the landscape, with data loggers high in the landscape showing no difference in the severity or duration of frost between the treatments (Table 1).

Table 1: Minimum canopy temperature for frost events during September and October in Nyabing, recorded on Tiny Tag (TGP-4017) at 600mm height.

	Low in the landscape			High in the landscape	
Dates	Additional	Stubble	Removed	Stubble	Removed
5th Sept	-1.4	-1.1	-0.9	-0.2	-0.2
6th	-2.9	-3.1	-2.9	-2.2	-2.5
9th	-0.7	-0.2	-0.4	0.1	0
27th	-1.9	-1.2	-0.9	-0.7	-0.8
28th	-0.4	0.3	0.6	1.3	0.8
1st Oct	-2.4	-2.3	-2.1	-1.5	-1.7
10th	-3.1	-2.7	-2.6	-1.6	-2.0
12th	-1.8	-1.8	-1.3	-0.5	-0.6
13th	-5.0	-4.8	-4.4	-4.0	-4.3
14th	-4.4	-4.0	-3.8	-3.1	-3.4
15th	-2.5	-1.8	-1.5	-0.9	-0.9
17th	-2.7	-2.0	-1.8	-1.3	-1.3
18th	-1.2	-0.8	-0.8	0.6	0.4
21st	-3.5	-2.7	-2.6	-2.1	-2.2
22nd	-2.4	-1.9	-1.9	-0.7	-0.9
LSD (0.17) **AVG**	**-2.4**	**-2.0**	**-1.8**	**-1.1**	**-1.3**

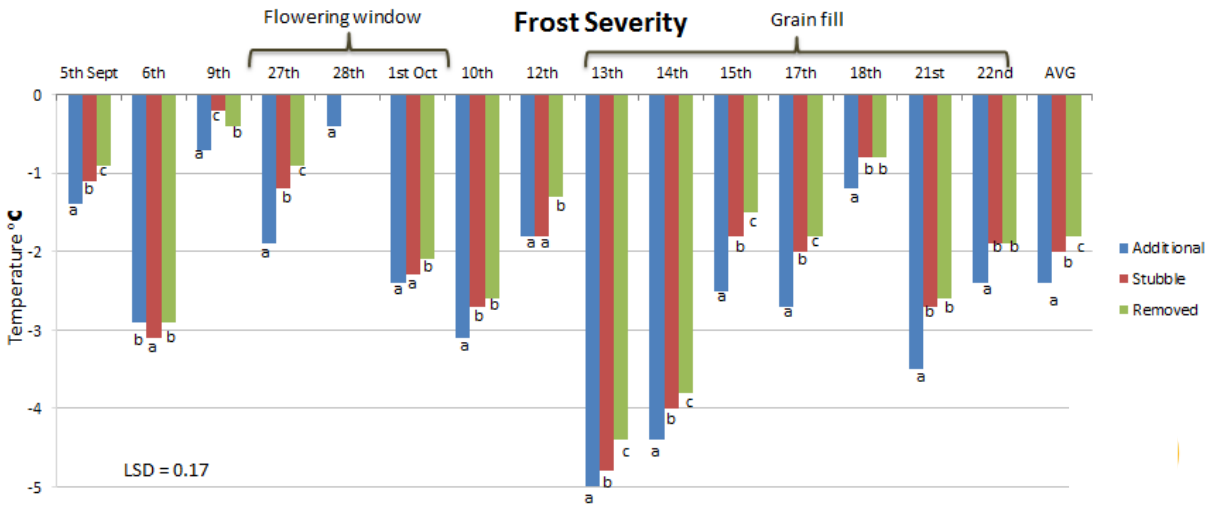

Figure 3: Minimum canopy temperature for frost events during September and October in Nyabing, recorded on Tiny Tag (TGP-4017) at 600mm height from low in the landscape.

Table 2: Number of hours below different temperature thresholds for frost events during September and October in Nyabing, recorded on Tiny Tag (TGP-4017) at 600mm height.

Temp. threshold below	Low in the landscape			High in the landscape	
	Additional	Standing	Removed	Standing	Removed
0°C	58 *a*	52 *b*	58 *a*	48 *b*	50 *b*
-1°C	45 *a*	33 *b*	32 *b*	22 *c*	24 *c*
-2°C	27 *a*	18 *b*	16 *b*	11 *c*	11 *c*
-3°C	10 *a*	8 *a*	7 *a*	2 *b*	3 *b*
-4°C	2 *a*	1 *a*	1 *a*	0 *a*	0 *a*

At Nyabing the additional stubble treatment had significantly more visible signs of head frost such as aborted florets, rat-tailed heads as well as stained heads and stems from mid-October onwards (Figure 4). Yield data supported the visual differences, with the additional stubble treatment yielding an average of 0.6t/ha, the standing stubble plots yielding an average of 1t/ha and the removed stubble plots averaging 1.8t/ha When comparing just the standing stubble and the removed stubble there were statistically similar differences in yield regardless of whether it was high or low in the landscape, with removed stubble yielding between 0.6-0.8t/ha more than the retained stubble treatment (Table 3). Assessment of frost induced sterility and harvest index correlated with yield and demonstrated higher sterility in the additional stubble plot (87%) when compared to the standing stubble (33%) and removed stubble treatments (35%) (Table 3). 1000 grain weights were very low (16mg/1000 grains) and screenings high (~60%) in the severely frosted additional stubble, and compared to 9% in the removed stubble. Yield maps created from harvesting the area in a checker-board pattern demonstrate the significance of the yield differences observed at the Nyabing site (Figure 5).

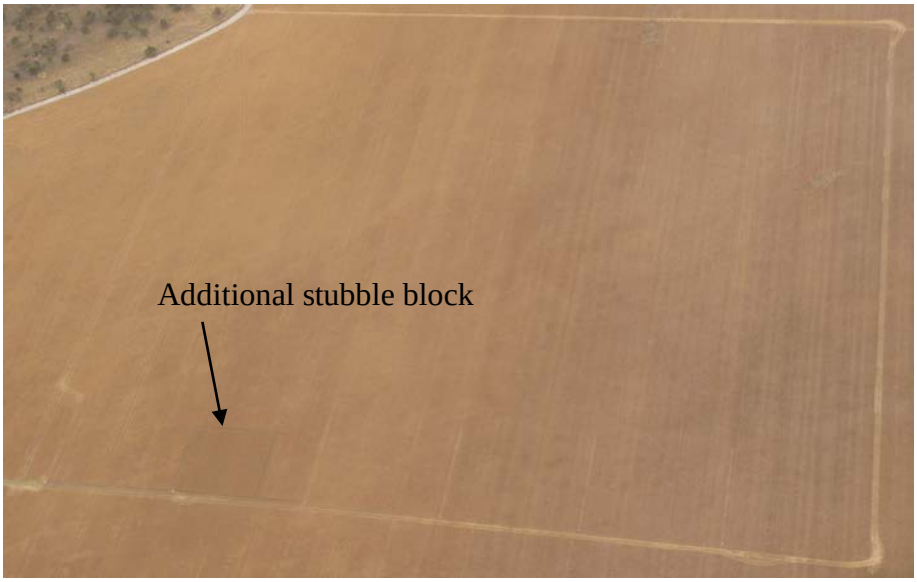

Figure 4: Visual effects of frost damage on additional stubble plot from aerial photograph taken late October (Courtesy Steve Curtin)

Table 3: Yield and yield component data for Nyabing. Where frost induced sterility (FIS), harvest index (HI) 100 grain weight (100GW) and screening <2mm were measured. Values are the predicted means, n=3, estimated using linear mixed models.

Position	Low landscape			High landscape		
Stubble	Additional*	Standing	Removed	Standing	Removed	$LSD_{0.05}$
Yield (t/ha)**				1.9	2.5	0.40
Yield (t/ha) –map***	0.6	1.0	1.8			0.30
FIS (%)	87	33	35	20	13	4.0
HI	0.02	0.26	0.24	0.28	0.32	0.10
1000GW (mg)	16	46	45	43	44	3.0
Screenings (%) <2mm	56	9	9	13	13	5.5

*Additional stubble plot was un-replicated and was only located low in the landscape
**Yield estimated from small plot trial harvester cuts with 2 replicates per plot.
***Yield estimated from small plot trials harvester with 276 replicates per plot.

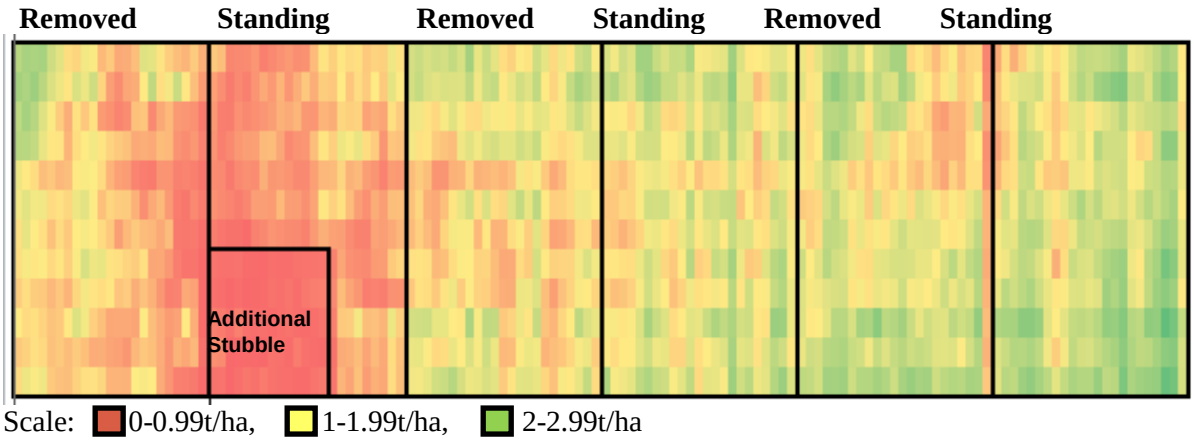

Figure 5: Yield map of bottom 60 metres of treatments at Nyabing site.

York

There were 12 frost events (canopy temperature below 0°C) at the York site between August and October. Data loggers positioned low in the landscape showed that the standing stubble treatment consistently recorded the lowest minimum temperature (Table 4). On average it was 0.5°C colder than the removed stubble treatment. These differences are depicted graphically in Figure 6. Position in the landscape (high, medium or low) also had a significant effect on the severity of the frost, with temperatures high in the landscape higher than temperatures recorded low in the landscape. Regardless of position in the landscape, standing stubble had

significantly lower temperatures than the removed stubble treatments. At York, stubble treatment generally did not increase the duration of hours the canopy temperature was below 0°C, -1°C and -2°C (Table 5). High in the landscape the standing stubble treatment recorded significantly more hours below 0°C than the removed stubble treatment; however this result did not continue further down the slope.

Although there were 12 frost events at the York site, no sterility or yield damage was recorded. This is because all frosts events fell outside the flowering and grain fill window of the crop.

Table 4: Minimum canopy temperature for frost events during August, September and October in York, recorded on Tiny Tags (TGP-4017) at 600mm height.

	Low landscape		Mid landscape		High landscape	
Date	Standing	Removed	Standing	Removed	Standing	Removed
16th Aug	-0.9	-0.6	-0.7	-0.6	-0.8	-0.9
20th	0.0	0.3	0.5	0.8	0.9	0.6
23rd	-1.6	-1.3	-1.2	-0.9	-0.8	-0.8
24th	-1.3	-0.9	-1.0	-0.7	-0.5	-0.7
6th Sep	-1	-0.6	-0.7	-0.9	-0.9	-0.6
27th	-0.4	0.1	0.4	-0.1	-0.2	0.2
28th	-0.9	-0.2	0.0	-0.5	-0.6	-0.1
1st Oct	-2.3	-1.6	-1.2	-1.6	-1.4	-1.0
10th	-0.2	0.4	1.0	0.6	0.5	1.1
13th	-1.3	-0.8	-0.1	-0.3	-0.1	0.2
14th	-1.3	-1.1	0.5	0.2	0.4	0.6
15th	-1.5	-0.8	-0.1	-0.3	-0.2	0.2
LSD (0.16) Ave	-1.1	-0.6	-0.2	-0.4	-0.3	-0.1

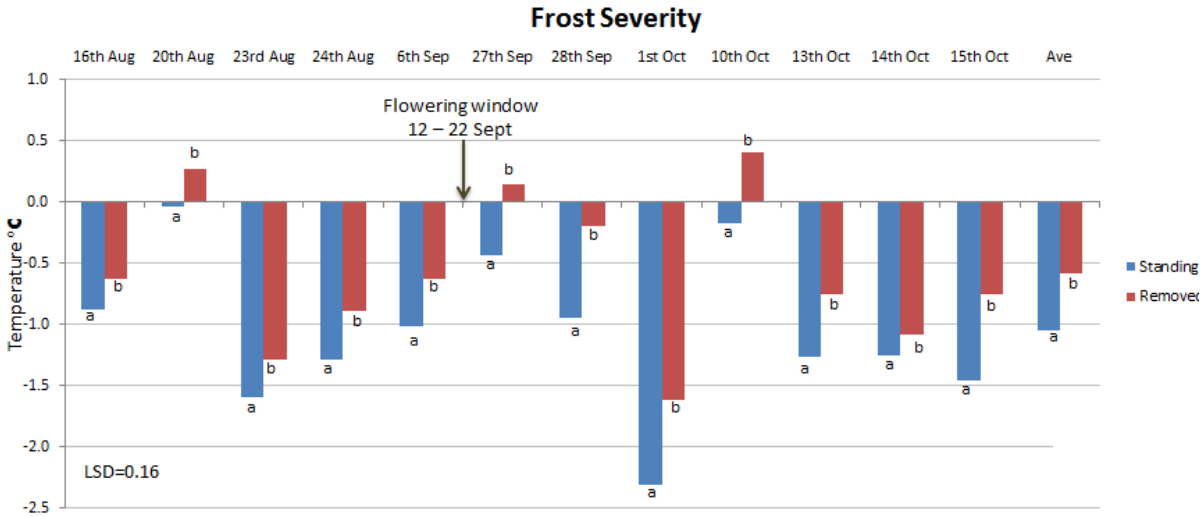

Figure 6: Minimum canopy temperature for frost events during August, September and October in York, recorded on Tiny Tags (TGP-4017) at 600mm height low in the landscape.

Table 5: Number of hours below different temperature thresholds for frost events between August and October in York, recorded on Tiny Tags (TGP-4017) at 600mm height.

Temp threshold below	Low landscape		Mid landscape		High landscape	
	Standing	Removed	Standing	Removed	Standing	Removed
0°C	36 *bc*	29 *c*	17 *b*	23 *b*	17 *b*	11 *a*
-1°C	8 *a*	5 *a*	3 *a*	3 *a*	2 *a*	1 *a*
-2°C	1 *a*	0 *a*	0 *a*	0 *a*	0 *a*	0 *a*

Due to frost events falling outside the typical area of crop sensitivity the York site did not receive yield limiting frost induced sterility or yield penalties. Frost-induced sterility for the site was <5% indicating minor levels of frost damage. The average yield of the York site was 4.6t/ha, which achieved its predicted yield potential. Parts of this trial had a low to moderate grass weed burden, which meant that some of the yield and screenings differences were more likely to be attributed to weed competition than temperature differences in the treatments. Screenings were higher lower in the landscape however there was no influence of stubble treatments (Table 6).

Table 6: Yield and yield component data for York. Where frost induced sterility (FIS), harvest index (HI) 1000 grain weight (1000GW) and screenings <2mm were measured. Values are the predicted means, n=3, estimated using linear mixed models

Position	**Low landscape**		**Mid landscape**		**High landscape**		
Stubble	Standing	Removed	Standing	Removed	Standing	Removed	$LSD_{0.05}$
Yield (t/ha)	4.5	3.4	4.8	5.1	5.0	4.8	0.75
FIS (%)	4	3	5	4	4	4	1.0
HI	0.36	0.35	0.37	0.39	0.38	0.38	0.015
1000GW (mg)	33	32	35	35	35	34	2.4
Screenings (%) <2mm	50	50	36	35	35	40	10.3
Frosted grain (%)	1.0	0.6	0.3	0.2	0.2	0.3	0.46

Discussion of Results

These trials have provided preliminary information regarding the influence of stubble load/density on the severity and duration of frost throughout the Western Australian Wheatbelt. These trials have demonstrated that the retention of stubble in a cropping system can increase the severity of frost by up to 0.6°C in low areas of the landscape. The retention of stubble can also increase the number of hours the crop canopy is below 0°C. It is hypothesised that this is because the removal of stubble allows more heat to penetrate the soil during the day, and then takes longer to dissipate at night. Further to this it is hypothesised that areas with retained stubble actually act like an insulation layer, stopping sunlight from penetrating the soil during the day and then leading to lower minimums at night.

Reducing stubble loads (to <0.5t/ha) in these two trials has been shown to decrease frost damage and provide a yield advantage of 0.6 to 0.8t/ha. This response is greatest in frost prone areas low in the landscape.

From the original objectives of this project it has been shown that stubble does have an effect on the extent, severity and duration of frost. It has been found that retention of standing stubble decreases canopy temperatures during frost conditions. If these frost conditions fall within the crops flowering window it can result in decreased yield where standing stubble is retained. In these trials, the removal of stubble to <0.5t/ha through burning or raking was shown to increase canopy temperature and decrease yield loss due to frost.

Implications

The implications of this research could assist growers in implementing new management strategies in frost prone areas of their cropping landscape. The benefits of stubble removal in frost prone areas include;

- Increased canopy temperature during frost events
- Decreased duration of time canopy temperature spends below 0°C
- Decrease in financial risk from yield loss

- Removal of stubble (burning) can be a cost effective management strategy for frost

Recommendations

Preliminary results have shown that the removal of stubble can reduce frost severity and duration. However, this does not advocate the complete removal of all stubble on farming properties. The removal of stubble may be beneficial in low lying frost prone areas of paddocks.

This research was an investigative look at the potential to manipulate temperatures at crop canopy height to lessen the severity and duration of frost. Further research needs to be conducted to validate the results found in 2013 and determine the effect of density, composition and orientation of stubble on the severity and duration of frost.

Extension

- 2014 Perth Agribusiness Crop Updates (150 people attended talk)
- Living Farm Grower Group post-harvest meeting (30 people attended)
- Facey Group Crop Updates
- Southern Dirt Crop Updates
- WANTFA Crop Updates
- RAIN Crop Updates
- Consult Ag pre-seeding frost workshops at Lake Grace, Nyabing, Yealering, Lake King, Hyden, Narembeen and Doodlakine

Plain English Summary

Project Title:	Stubble management to reduce the impact of frost to crops in the Albany and Kwinana West Zone of WA
GRDC Project No.:	KW/Alb 12/13 JointProj 4
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Objectives	To quantify the impact of stubble on the severity and duration of frost through canopy temperature and grain yield
Background	There currently is limited information available to growers surrounding present and emerging farming practices with regards to the impact and severity of frost events. With a decrease in number of livestock on properties, and subsequent increase in cropping areas, frost is now a significant risk to broad acre grain production and is estimated to cost around $63m annually in lost grain production (Fellowes 2006). Previous agronomic work has shown that management practices can change the ability of the soil to maximise storage of heat during the day or maximise the heat released from the soil at night. Both factors which may have an influence on reducing the severity and duration of frost events.
Research	Large scale replicated field trials were conducted in wheat paddocks at Nyabing and York during 2013. Paddocks with a known history of frost damage were identified prior to seeding. Trials were sown with farmer's broad acre seeding equipment, using framers standard cultivar, rotation and agronomic management. Stubble treatment plot lengths were laid down along the paddocks natural slope for 200m, with a width of 30-48m and replicated three times. Temperature loggers were placed within each treatment along the landscape and recorded temperatures at a height of 600m at 3 minute intervals. These trials were harvested to determine whether the stubble treatments influenced final yield following frost events.
Outcomes	From the original objectives of this project it has been shown that stubble does have an effect on the extent, severity and duration of frost. It has been found that retention of standing stubble decreases canopy temperatures during frost conditions. If these frost conditions fall within the crops flowering window it can result in decreased yield where standing stubble is retained. In these trials, the removal of stubble to <0.5t/ha through burning or raking was shown to increase canopy temperature and decreased yield loss due to frost. Preliminary results have shown that the removal of stubble can reduce frost severity and duration. However, this does not advocate the complete removal of all stubble on farming properties. The removal of stubble may be beneficial in low lying frost prone areas of paddocks. This research was an investigative look at the potential to manipulate temperatures at crop canopy height to lessen the severity and duration of frost. Further research needs to be conducted to validate the results found in 2013 and determine the effect of density, composition and orientation of stubble on the severity and duration of frost.
Implications	The implications of this research could assist growers in implementing new management strategies in frost prone areas of their cropping landscape. The benefits of stubble removal in frost prone areas include; • Increased canopy temperature during frost events • Decreased duration of time canopy temperature spends below 0°C • Decrease in financial risk from yield loss • Removal of stubble (burning) a cost effective management strategy for frost
Publications	2014 Perth Agribusiness Crop Updates