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The dirt on on-farm lime: Comparison of on-farm sources and limesand under different cultivation strategies in the paddock and utilising iLime over two years (2019/20)

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Key messages

- Quality of on-farm lime and distance from coastal limesand sources are important factors in determining economic advantage over coastal limesand
- Cultivation of sources resulted in higher net present values after the 20-year iLime simulation, and improved return on investments at five and 10 years compared to when uncultivated
- In 2019 cultivation consistently improved yield and the high rates of local dolerite and limesand improved yield by 0.55t/ha and 0.57t/ha respectively.
- Due to the 2020 season and in-season challenges there were no significant differences in yield between sources and cultivation

Aims

To investigate the cost-effectiveness of on-farm lime for ameliorating soil acidity in Kwinana East port zone and to validate the iLime application (developed by DPIRD and Desiree Futures, with funding from GRDC) by comparing simulations with field trial results.

Background:

On-farm lime sources with potential to ameliorate soil acidity have been identified throughout the low rainfall zone of the Kwinana East port zone (KE) landscape. Growers located in the KE have highly variable yields and large distances to coastal lime sources, resulting in increased costs of freight. This can pose a barrier to using coastal limesand as an ameliorant for soil acidity. An issue with on-farm sources is the significant variation in quality (Peek et al. 2019). Sources over the landscape have inconsistent particle size distributions and neutralising values (NV), which influences the source quality. Thus understanding the economic interaction between effective neutralising values (ENV), particle size, quantity and freight distances are critical when evaluating these on-farm sources (Donnison et al. 2020).

Method

A field trial was established south of Moorine Rock, Western Australia, located approximately 458km from the nearest limesand pit in Lancelin. The soil at the trial site was an acidic sandy earth with pH below the recommended threshold of 5.5 at 0−10cm and 4.8 in the subsoil (Van Gool 2016) (Table 1 and 2). The entire trial site was deep ripped to 50cm in 2018.

The 2019 and 2020 growing season rainfall is detailed in Table 1. 2019 had a very hot and dry September (3.4mm) and, while 2020 temperatures were milder (no days over

30°C), the rainfall was still low with only 2mm falling after the first week. 2020 also experienced a poor start of the season and, due to this, the canola was re-sown on 3 June. The trial also had substantial bird and wind damage in 2020 and required hand cuts and collection of pods that had fallen on the ground to determine yield.

Table 1. Site details for 2019 season

Location		Moorine Rock Western Australia (31°33' S, 119°11'E)
2018, 2019 & 2020		Canola, Wheat (Scepter), Canola (Bonito)
2019 Rainfall (DPIRD weather station)	Summer Rainfall (December 2018 – March 2019)	80.4mm
	GSR 2019 (April – September)	220mm
2020 Rainfall (DPIRD weather station)	Summer Rainfall (December 2019 – March 2020)	79.8mm
	GSR 2020 (April – October)	168mm
Seeding date 2019		12/05/2019
Seeding date 2020		12/4/2020, reseeded 3/6/20

Table 2. 2019 Moorine Rock trial site soil properties.

Depth (cm)	Average Phosphorus Colwell (mg/kg)	Average Potassium Colwell (mg/kg)	Average Conductivity (dS/m)	Average pH Level ($CaCl_2$)	Average Aluminium $CaCl_2$ (mg/kg)
0-10	19.6	55.2	0.04	4.3	7.7
10-20	4.6	37.8	0.04	4.2	13.1
20-30	3.3	31.4	0.03	4.4	7.1
30-50	4.3	32.4	0.03	4.8	0.9

Treatments were a factorial arrangement of lime sources (nil lime and three different lime sources at low, medium and high rates) and cultivation (nil and cultivated with an offset disc to 20cm with a second pass in the opposite direction) (Table 5). Lime sources included coastal limesand, higher ENV dolerite on-farm lime sourced from an area associated with doleritic rocks and a lower ENV depositional Morrel on-farm lime. All three samples were analysed using at wet sieve analysis for NV and particle size. ENVs were calculated based on research by Scott et al (NSW Agriculture lime comparison calculator 2003) and the WA Soil Quality "Lime benefit Calculator" (Table 3 and 4). The NSW method was used to calculate the trial application rates using lime quality information provided by the owners of the lime sources.

Table 3. Lime source neutralising values using the NSW Agriculture lime comparison calculator (2003) and the WA Soil Quality "Lime Benefit Calculator" (2017).

Lime Source	Wet sieve ENV% (NSW)	Wet sieve ENV% (WA)	Total NV%
Limesand	43	79.6	86.6
Local depositional Morrel	12.8	17.9	47.9
Local dolerite	19.6	21.0	23.6

The local depositional source has a higher overall NV but a lower ENV. A large proportion of the particles from this source (47% weight) were >2mm, which are not very effective at reacting with soil acidity. This coarse fraction of the source also had a high NV which contributed to the overall high NV. The ENV gives a better representation of how the source will react in the soil, as it takes into account the effectiveness of the particle size in neutralising acidity. Comparatively, the local dolerite had a lower overall NV; however, it had a larger proportion (50.4% weight) of material in the fine fraction (<0.075mm). This fine fraction is highly effective in reacting with soil acidity, as it is a smaller particle and has a larger surface area. Due to this the ENV for the dolerite was higher even though the NV was lower (Table 4a and 4b).

Table 4. a) Depositional Morrel source particle size distribution (%) and neutralising values, b) Dolerite source particle size distribution (%) and neutralising values and c) Limesand source particle size distribution (%) and neutralising values.

a) Local depositional Morrel source

Sieve Range (mm)	% Weight	NV
<0.075	21.4	27.2
0.075-0.150	5.8	24.7
0.150-0.250	7.0	21.1
0.250-0.500	9.2	15.7
0.500-1.00	4.6	14.9
1.00-2.00	3.9	4.6
>2.00	47.0	75.5

b) Local dolerite source

Sieve Range (mm)	% Weight	NV
<0.075	50.4	35.5
0.075-0.150	11.5	8.2
0.150-0.250	9.5	8.4
0.250-0.500	8.2	7.5
0.500-1.00	7.1	6.1
1.00-2.00	4.8	10.0
>2.00	6.6	36.6

c) Limesand

Sieve Range (mm)	% Weight	NV
0-0.125	2	90
0.125-0.250	37	88
0.250-500	40	94
0.500-1	21	71
>1	1	56

iLime was developed based on limesand research and, therefore, the interpretation of ENVs in iLime may not fully reflect the actual interaction seen in paddock due to an over-valuation of the large particle size. In iLime all particles >1mm are treated as 1mm in effectiveness even if they are much larger and less effective.

The trial had a criss-cross design with four randomised replicate blocks where the cultivation treatments were crossed with the ameliorant treatments at right-angles in each replicate (GenStat Statistics Guide 19th Edition). The randomisation was different for each replicate block.

Table 5. Trial lime source treatments showing rates applied of each source.

Lime Source	Lime Rate t/ha		
	Low	Medium	High
Limesand	2	4	8
Local depositional Morrel	4.3	8.6	17.2
Local dolerite	7.35	14.7	29.4
Nil Lime		0	

Results and Discussion

Yield response

In 2019, the main driver of yield improvement was cultivation across all sources, increasing yield on average by 0.8t/ha in the best performing treatment compared to the nil ($p<0.001$). There were significant ameliorant effects where the high rate of local dolerite and limesand significantly improved yield (0.55t/ha and 0.57t/ha respectively). When rates and cultivation were combined the local dolerite source also significantly improved yield (0.34t/ha, p=0.009). iLime predicted close to observed yields in the uncultivated treatments, but greatly under predicted cultivated treatments (Figure 1).

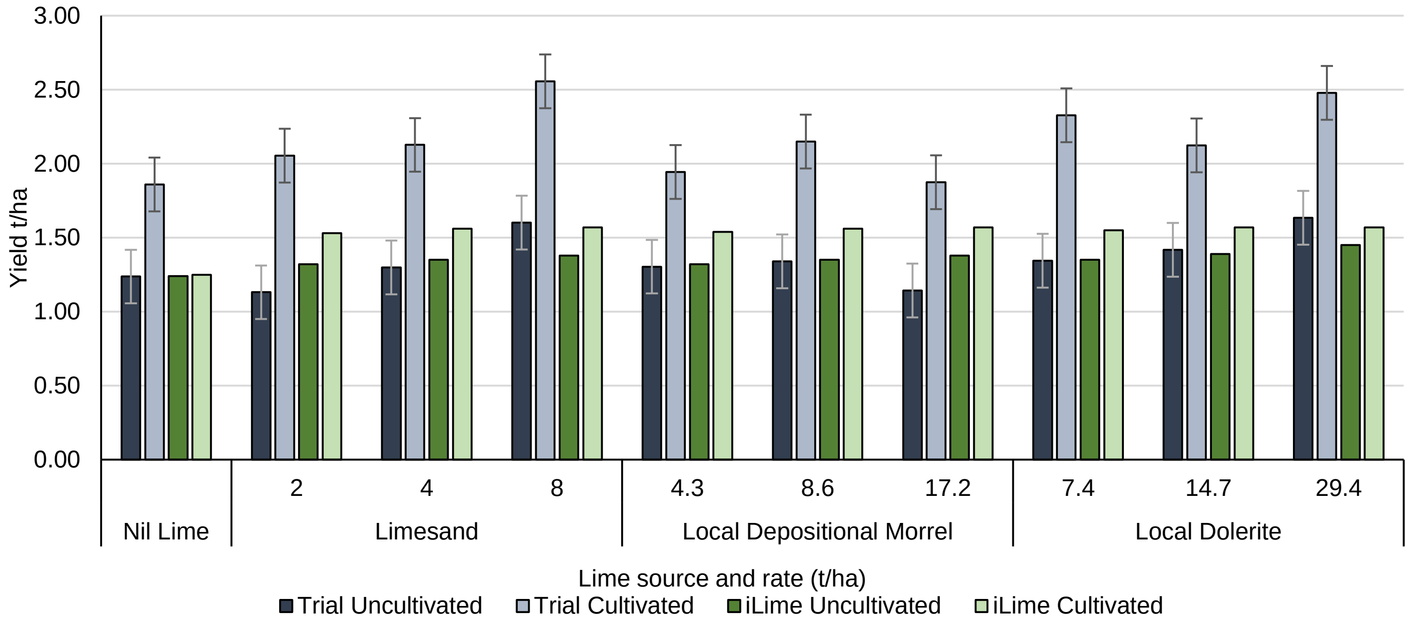

Figure 1. 2019 Trial crop yield response to ameliorants compared to iLime predicted first year yield response in cultivated and uncultivated treatments. Lsd p=0.05

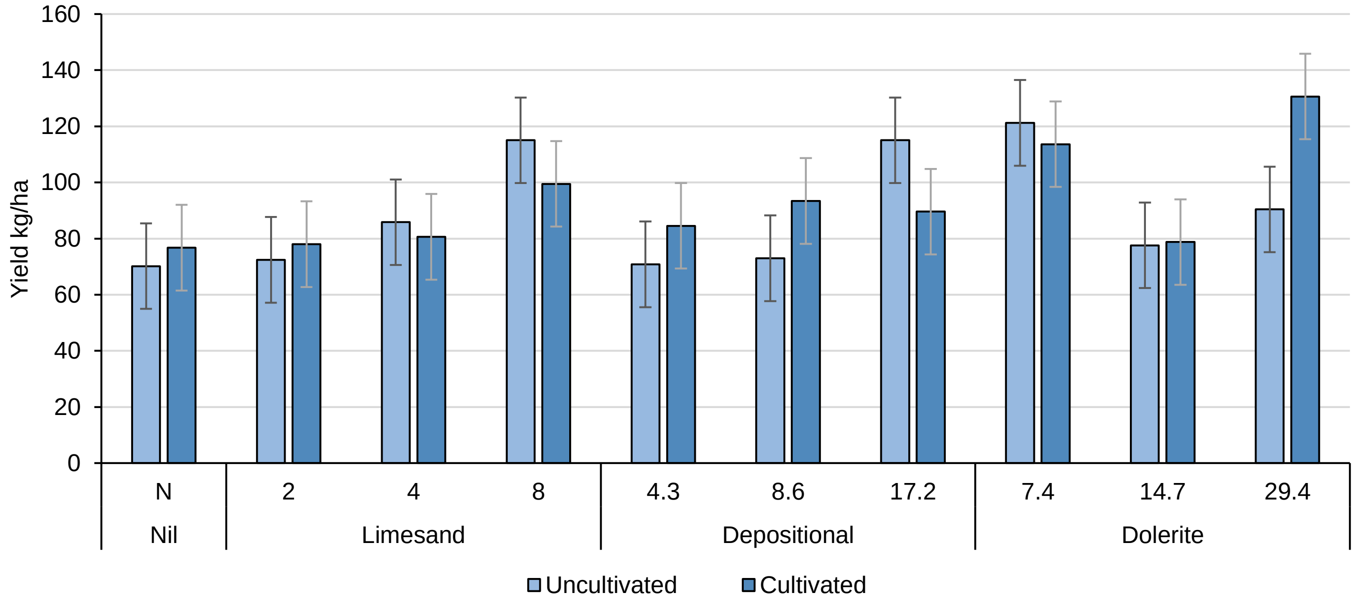

Figure 2. 2020 Trial crop yield response to ameliorants second year yield response in cultivated and uncultivated treatments. Lsd p=0.05.

Unlike in 2019, there was no obvious benefit of cultivation in the 2020 season. However, the false break, low rainfall, poor yields and in season challenges may have had an effect on the reliability of the 2020 data.

In 2020 there were no overall significant differences between cultivated and uncultivated plots, with cultivated treatments yielding on average 90kg/ha, and uncultivated treatments yielding 86kg/ha (p=0.449). There were no differences between ameliorants (p=0.133), or any significant interaction between cultivation treatments and lime treatments (p=0.887).

The high rates of the two local limes, and the low rate of the local dolerite lime significantly improved yield compared to the nil, however they were not significantly better compared to the other treatments. Overall the local dolerite source did significantly increase yield at the 10% level (p=0.071) (Figure 2).

Due to the seasonal effects in 2020, and very low yields, the predicted iLime yields were much higher than the in-field yields. iLime predicted yields of 0.5−1.4t/ha, where the trial averaged 87kg/ha. This highlights that though iLime is a decision support tool, there are in season effects on yield which also need to be accounted for when considering the economic return of different liming activities. Using the app within this trial, outside influences are likely the cause of the field yield and predicted yield inconsistencies.

In season response

In season Canopeo measurements were taken at GS65 to compare % green canopy cover (GCC) in 2020 (Figure 3). There were significant differences between ameliorants when cultivation treatments were combined (p=0.046), with the medium rate of the local dolerite having the highest GCC of 45.19%. Though there were amelioration effects, there were no significant differences between cultivation treatments (p=0.745) or interaction effects between cultivation and ameliorants (p=0.154). There was a significant lime source effect (p=0.003), with the local dolerite having the highest average GCC of 41.96%.

Some of the treatments had improved from the nil, these include the cultivated medium rate of local dolerite (42.8%), the uncultivated high rate of local depositional (43.05%) and the low and medium rates of uncultivated local dolerite (49.49% and 47.58% respectively) (Figure 3).

These results would have been affected by the false break. Additionally there was also a large proportion of wild radish (*Raphanus raphanistrum*) in some areas of the trial, which may have had an influence on the Canopeo results. Canopeo does not differentiate between species for canopy cover, so some of the weeds present may have caused an overestimation of the GCC.

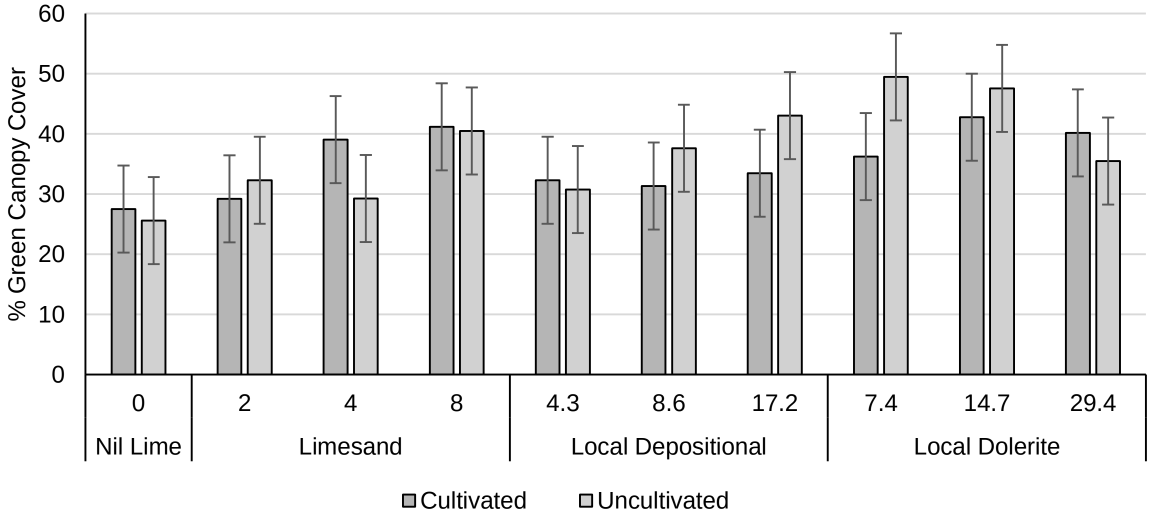

Figure 3. 2020 In season trial crop Canopeo % green canopy cover response to ameliorants in cultivated and uncultivated treatments at GS65. Lsd p=0.05.

Soil pH response

2019 soil results showed that for the uncultivated treatments, all except the low rate of local depositional improved pH in the 0-5cm. In the depths between 10-15cm and 20-30cm, the medium rate of dolerite improved pH compared to the nil. The high rate of dolerite was the only source to bring the pH up significantly in the 15-20cm depth (Figure 4).

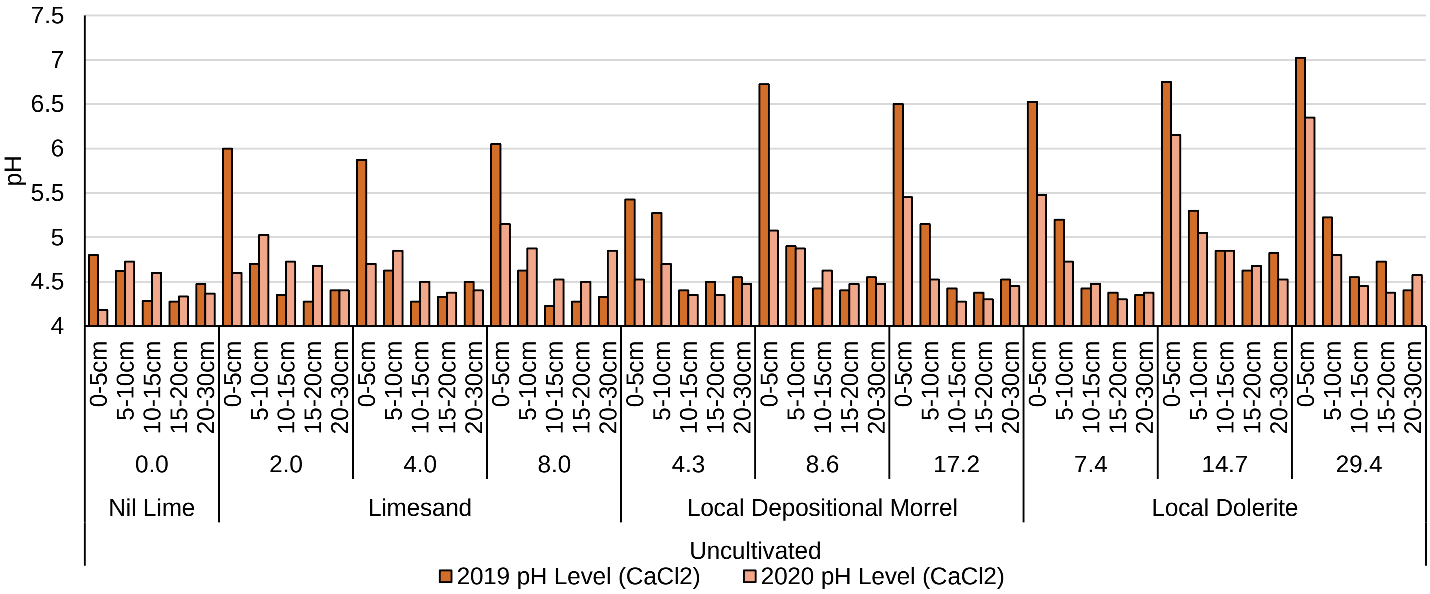

Figure 4. 2019 and 2020 Trial pH response to ameliorants under no cultivation. Note: the vertical axis does not start at the origin

For the 2019 cultivated treatments, the high rates of all sources and all the rates of the local dolerite source improved pH in the top 5cm. For the subsoil, only the high rate of dolerite improved pH at all depths, and the high local depositional and limesand rates improved pH at the 10-15cm depth (Figure 5). Across all ameliorants, cultivation significantly improved pH compared to the nil between 0-15cm, and this response was more pronounced in the higher rates of all products. In 2019, compared to the uncultivated treatments, cultivation improved pH deeper to 15cm and brought the pH up to or closer to the recommended pH levels of 5.5 and 4.8 more consistently across treatments.

In 2020 in all depths and treatments, there were only significant differences in pH at the 0-5cm depth. At this depth all treatments significantly improved pH compared to the nil except the low rates of local dolerite and limesand ($p=<0.001$). A significant rate effect was also observed when comparing the lowest rate to the highest of the same lime source. There was also a significant cultivation effect ($p=0.009$) observed, where the cultivated treatments had higher pH. While all sources significantly improved pH in the 0-5cm, the local dolerite was significantly more effective at improving pH compared to the other sources ($p=<0.001$). Unlike in 2019, there were no observed differences in pH in the depths below 5cm.

Where treatments in the trial were uncultivated there were few differences compared to 2019, however across all treatments there was a decrease in pH in the 0−5cm. Generally this decrease was largest in the lower lime rates. The depths greater than

5cm generally increased or remained comparable in pH (Figure 4). There were also few differences observed in soil pH between 2019 and 2020 in cultivated treatments, however the high rates of the local sources decreased in pH at all depths. The lower rates of local sources and limesand had either similar pH or a slight increase in pH (Figure 5).

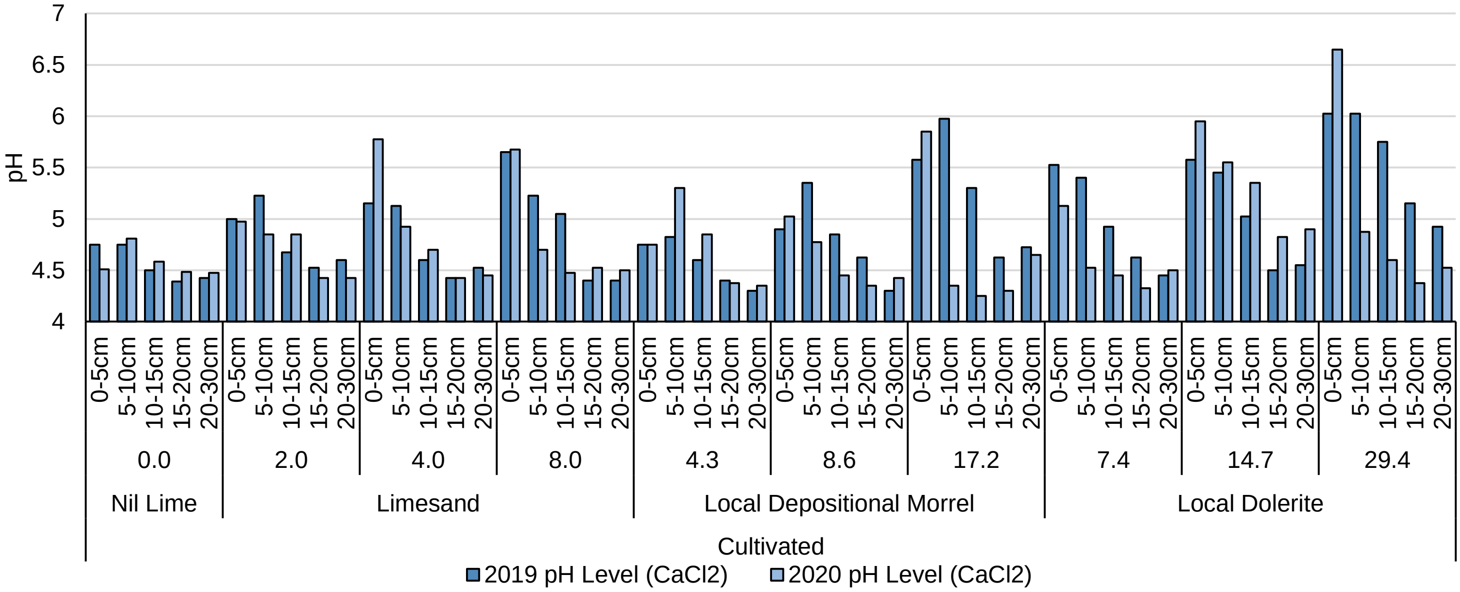

Figure 5. 2019 and 2020 Trial pH response to ameliorants under cultivation. Note: the vertical axis does not start at the origin.

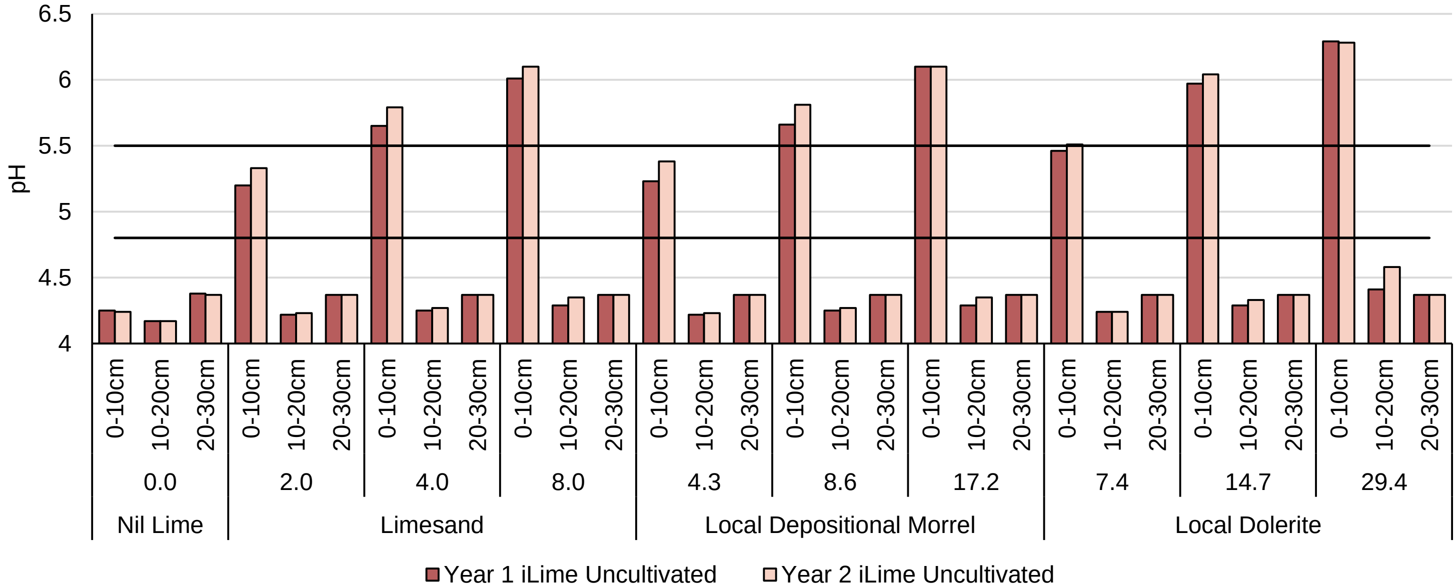

Figure 6. Year 1 and 2 iLime pH prediction to ameliorants under no cultivation. Note: the vertical axis does not start at the origin

iLime

In 2019 iLime predictions were similar to what was observed in the paddock. However, in 2020, the uncultivated trial treatments decreased in pH in the 0−10cm, whereas iLime predicted that these shallow depths would remain at a similar pH or increase slightly. At depths greater than 10cm, uncultivated predictions from iLime were similar to those observed in the trial (Figure 4 and 6). The high rates of the local lime sources when cultivated had a similar outcome. Many of the cultivated trial treatments followed a similar trend to what was predicted by iLime, however the high rates of all sources and the low rate of local dolerite below 5cm had a large decrease in pH at the end of the 2020 season despite iLime predicting that these would increase slightly (Figure 5 and 7).

While the pH changes and trends simulated in the app may not necessarily reflect exactly what happens in the paddock, it is a useful decision support tool to simulate potential outcomes when liming decisions are being made.

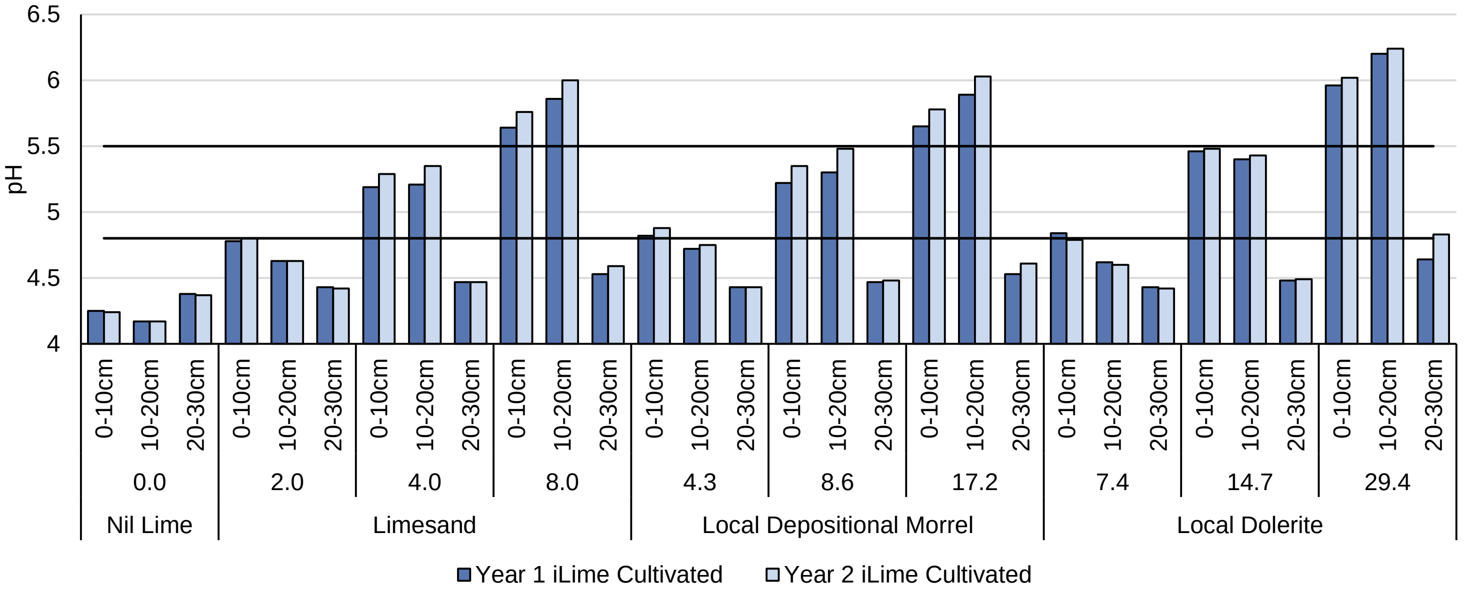

Figure 7. Year 1 and 2 iLime pH prediction to ameliorants under no cultivation. Note: the vertical axis does not start at the origin

iLime economic response

Economic results were based on the allocated rotation (W-C-W-L-C) using iLime.

Table 6. iLime predicted return on investment at 5 and 10 years, net present value after 20 years and average $/ha/year benefit for all different rates and sources.

Lime Source	ROI (5 years)	ROI (10 years)	NPV (20 yrs) $/ha	Average $/ha/year
Depositional Morrel 8.6t/ha Cultivated	350%	630%	1910	95.5
Limesand 4t/ha Cultivated	250%	470%	1835	91.8
Depositional Morrel 4.3t/ha Cultivated	610%	1050%	1795	89.8
Dolerite 14.7t/ha Cultivated	180%	360%	1770	88.5
Depositional Morrel 17.2t/ha Cultivated	150%	310%	1760	88.0
Limesand 8t/ha Cultivated	90%	210%	1645	82.3
Limesand 2t/ha Cultivated	450%	780%	1610	80.5
Dolerite 29.4t/ha Cultivated	50%	150%	1520	76.0
Dolerite 7.35t/ha Cultivated	350%	610%	1515	75.8
Depositional Morrel 17.2t/ha Uncultivated	40%	170%	1305	65.3
Dolerite 14.7t/ha Uncultivated	50%	200%	1290	64.5
Dolerite 29.4t/ha Uncultivated	10%	90%	1245	62.3
Limesand 8t/ha Uncultivated	20%	130%	1235	61.8
Depositional Morrel 8.6t/ha Uncultivated	90%	280%	1125	56.3
Limesand 4t/ha Uncultivated	60%	22%	1035	51.8
Depositional Morrel 4.3t/ha Uncultivated	170%	380%	650	32.5

Limesand 2t/ha Uncultivated	120%	290%	565	28.3
Dolerite 7.35t/ha Uncultivated	70%	190%	560	28.0

Cultivated treatments consistently have higher net present values (NPV) over the 20 year simulation compared to when uncultivated. The cultivated medium rate of Depositional Morrel (8.6t/ha) and Limesand (4t/ha) had the best NPV, followed by the low rate of Depositional Morrell (4.3t/ha) and medium rate of Dolerite (14.7t/ha) (Table 6).

When uncultivated, the high rates of the on-farm limes performed best in terms of NPV and the low rates of all sources were the poorest performing. For the Depositional morrel source at 17.2t/ha (best performing uncultivated treatment), there was a 22.8$/ha/year benefit to cultivating the lime source. Similarly, the 8.6t/ha Depositional Source cultivated (best performing cultivated treatment), there was a 39.3$/ha/year benefit to cultivation. All sources had improved NPV when cultivated to 20cm, and higher ROI at 5 and 10 years. These findings indicate a higher potential economic return and more immediate returns on investment when cultivation and a lime source are used together to ameliorate soil acidity.

Conclusion

On-farm lime sources can be effective ameliorants for soil acidity; they would preferably be of a high quality to produce an economic benefit compared to limesand. Particle size distributions and NVs associated with the different particle fractions are important when considering using an on-farm lime source. This needs to be assessed for each situation and source.

In 2019, iLime did a reasonable job in predicting the uncultivated yields; however, when cultivated the yields were underestimated. The high rate of local dolerite and limesand, when cultivated, improved the yield significantly.

Due to the 2020 seasonal conditions, yield was poor and not comparable to predictions produced in iLime. This also impacts the ability to compare the actual and predicted ROI and NPV.

The 2020 % green canopy cover showed differences between treatments and ameliorants at GS65 (flowering). These measurements may indicate that there was potential for differences in yield that were not observed at the end of the season due to bird, wind and poor end of season rainfall.

In 2019 pH change in the top 15cm was significantly improved across all ameliorants when the soil was cultivated. When no cultivation was applied all lime sources brought the pH up significantly in the top 5cm other than the low depositional Morrel rate. Generally the higher rates of the local products were the most effective in bringing the pH up below 15cm when cultivated. When uncultivated the medium and high rates of local dolerite did improve some of the subsoil; however, there were no observed differences for the other products.

In 2020, the pH change was only significant compared to the nil at the 0−5cm depth where all sources significantly improved the pH. The local dolerite source significantly improved pH compared to the nil and the other lime sources. The local dolerite source had a higher proportion of fine (<75µm) particles that had a reasonable neutralising value. This may be reflected in the larger increase in pH in the 0−5cm depth in 2019. However, depths greater than this had no significant differences. Compared to 2019 there was a general decrease in pH, in particular in the 0-5cm depth.

In 2019, utilising iLime produced similar results to the trial and it was a good support tool. Though there are some seasonal differences which are to be expected, considering both the 2019 and 2020 seasons, iLime does have potential to be a reasonable liming decision support tool. However further investigation in adjustments for eastern wheatbelt conditions and on-farm limes may be required to improve the reliability of the app.

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