TECHNICAL CLASSIFICATION OF MACHINES THAT TILL THE SOIL BETWEEN ROWS OF VINEYARDS

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Annotatsiya. The approach was to review, adapt and combine a range of subsoil improvement techniques previously developed in the broad acre farming context and combine them into a more efficient purpose-designed machine suited to the smaller low power vineyard tractor. The influence of ripper technology and capacity on the subsoil constraints of vineyards was considered for the quality of soil loosening, its influence on compaction and vine response. Consideration was then turned to the timing of sub soiling and vineyard interred management of subsoil compaction in vineyards. Factors such as the amount of soil loosening, soil disturbance, re-settling and compaction were investigated.

Keywords: vibration, maximize, comparison, technology, machinery ,development, soil, amplitude

Аннотация. Подход заключался в том, чтобы пересмотреть, адаптировать и объединить ряд методов улучшения подпочвы, ранее разработанных в контексте обширного земледелия, и объединить их в более эффективную специализированную машину, подходящую для меньшего маломощного трактора для виноградников. Рассмотрено влияние технологии рыхлителя и его мощности на почвенные ограничения виноградников на качество рыхления почвы, его влияние на уплотнение и реакцию лозы. Затем внимание было обращено на сроки под рыхления почвы и управления захоронением виноградников при уплотнении почвы на виноградниках. Были исследованы такие факторы, как степень рыхления почвы, нарушение почвы, повторное оседание и уплотнение.

Ключевые слова: вибрация, максимизация, сравнение, технология, техника, развитие, почва, амплитуда

INTRODUCTION

Using technology developed to enable deeper and more energy efficient loosening of subsoil in vineyards the project investigated the benefits of the new technology over currently available methods for reducing subsoil compaction between vine rows. This investigation encompassed many areas of comparison

-optimizing vibration settings
-maximize the capacity and efficiency
-comparison of different tine designs
-comparison of capacity and efficiency of different ripper designs
-using technology to increase output and capacity
-managing post ripping traffic and machinery usage
-development of an ameliorant applicator.

The influence of ripper technology and capacity on the subsoil constraints of vineyards was considered for the quality of soil loosening, its influence on re-compaction and vine response. Consideration was then turned to the timing of sub soiling and vineyard inter-row management of subsoil compaction in vineyards. Factors such as the amount of soil loosening, soil disturbance, re-settling and re-compaction

were investigated. This included the traffic management of vineyards to reduce and minimize the re-compaction of the vine mid-row.
As part of tackling subsoil constraints soil chemical modification was considered an important area, so a liquid amelioration system has been designed and built and is ready for testing which will be carried out in subsequent seasons.

Table 1 Soil Problems and recommended tillage action

Soil problem situations*	**Identified recommendations**
Soft rock/saprolite	Low disturbance deep ripping
Hard calcareous clays (fine lime to hard sheet boulders / hard fine sandy clay)	Deep ripping (high disturbance in fine texture soilsonly)
Compact subsoil clays (duplex soils)	Deep ripping / incorporate gypsum - organic matter
Bleached subsurface sandy layers	High disturbance deep rip/mix with top soil/incorporate organic matter. ripping by itself is often ineffective
Compact sands	Deep ripping / add organic matter
Compacted traffic lanes	Deep ripping to 600mm / limit and time traffickingoperations
Subsoil chemical toxicity (eg. acidity)	Incorporate/mix lime

RESEARCH MATERIALS AND METHODOLOGY

The approach was to review, adapt and combine a range of subsoil improvement techniques previously developed in the broad acre farming context and combine them into a more efficient purpose-designed machine suited to the smaller low power vineyard tractor. The new technology provides a versatile subsoil machine that encompasses the following technologies: 1) multi-depth tillage, to increase soil loosening at depth at no draft penalty, 2) multi-pass operations, successive strategic loosening passes by a lower power tractor and 3) vibratory tillage, where the tines are mechanically oscillated drastically reducing draft and increasing subsoil loosening efficiencies.
The results obtained with the penetrometer were compromised to some extent by the soil compaction variations influencing the moisture profile through the mid-row cross-section, where the measurement may have corresponded with soil moisture content rather than soil strength. It was difficult to find times when the whole profile was of a similar moisture content to facilitate cone index measurement.This was especially so in the wheel track zone where water tended to run off and enter the adjacent looser soil. The varied profile between the vines and the vegetation cover also tended to influence the moisture content profile. The drought conditions in spring of 2022 also resulted in minimal moisture content in the soil profile that was also influenced by the varying weed density between the vines.
Unfortunately the irrigation system of the vineyard failed at the main risers that couple to the dripper lines in about 40% of the vine rows contained within the experimental area. These failures occurred in the spring-summer irrigation period of late 2022. It is not known when and for how long these failures

occurred but indication of water movement down some of the mid-rows was clearly observed. These failures can thus be expected to have resulted in less pressure and flow in what dripper lines remained connected whilst also depriving some rows of any irrigation and tending to flood the mid- row of others. Thus the outcomes of the experiment following this irrigation period are expected to have been seriously effected. Therefore, any harvest and pruning yield results considered with great care

Site Assessment of soil profiles prior to deep ripping (Jeanette Chapman):Root development was most prolific under vine, as would be expected. Abundant root development, >200 roots/10 cm^2, was due to branching up to 4 main orders which resulted in 4th order roots being spaced within 10 mm, with visible prolific root hairs. Two-three sets of these roots were found per 10 cm^2. Many roots, 20-200 roots/ 10 cm^2, were associated with reduced branching and/or fewer primary roots. Root exploration within the soil would be good.

Compaction under, the wheel track, and natural compaction within massive subsoil layers quickly reduced root density to a few larger diameter roots. Occasionally roots found natural planes of Soil A - Top 100-200mm is a loamy clay to clay loam over a light to medium clay to salty clay in the top 600mm (northern end of field) Soil B - Top 100-150mm: light sandy clay loam to light clay.

From 100-150 down to 300-350mm a light medium clay to a medium clay. Below 300-350mm from north to south of this plot was a transition from medium clay to a sand. Soil density was determined by using sampling cylinders while moisture content was gained from augured soil samples. An indication of soil strength was also found by conducting cone index probes across each block of each experiment. The cone index measure of soil strength is shown in Figure 1 along with the corresponding soil density, and moisture contents. The cone index values for soil B were largely underestimated below 150mm as a large portion of sites could not be penetrated below this depth. This greater soil strength limited the rigid tillage to 390mm depth in soil B compared to 410mm in soil A.

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RESEARCH RESULTS

Draft reduction is the reduction in draft achieved by vibratory tillage compared to rigid tillage of a similar tine at the same depth. The total power ratio is the ratio of (PTO and drawbar) power of the vibrating tine over the drawbar power of an equivalent rigid tine operating at the same depth.

Vibratory tine settings that maximize draft reduction and hence potentially the sub soiling capacity of the tractor, also increase the total power ratio, which needs to be minimized to make the best use of the tractor engine power.

A multiple linear regression analysis of both % draft reduction and total power ratio found that both increased significantly with an increase in tine oscillation frequency and amplitude. The 30° angle of vibration also increased draft reduction and total power ratio, as did a reduction in tractor forward speed. These parameters can be combined by considering the velocity ratio which is the ratio of the maximum tip speed of the tine (i.e. amplitude x frequency) over forward travel speed. Figure 9 shows that increasing the velocity ratio maximizes both the draft reduction and total power ratio. This is thought to occur as increasing the velocity ratio increases the portion of subsoil loosening done by the oscillation motion of the tines compared to that achieved by the overall forward movement of the tine through the soil, thus increasing draft reduction. In addition less soil contact when the tine is oscillating may also reduce soil-tine frictional forces thus reducing draft requirements. However the additional energy required to oscillate the tines faster and over a greater stroke increases the demand on PTO power from the tractor. Results in show that only a few vibratory treatments could be operated with total power ratios less than or equal to one. Performance gains in tractor engine power however can still be made using vibratory tines due to the very efficient transfer of engine power to the PTO compared to the transfer of engine power to the drawbar which typically is no greater than 70%. Performance gains can also be made in sub soiling capacity by travelling slower and leaving more engine power for oscillating the tines.

Choosing the most desirable settings should be a balance of low seat acceleration and high ERD. The vibratory ripper settings that best fit this criteria across both soils were a 2.5km/h speed, 0 tine vibration angle, 70mm amplitude and the higher velocity ratio. This setting had the equal highest ERD in both soils potentially giving a 57-61% increase (beyond measured rigid tillage) in sub soiling capacity. This setting also minimized the 3D weighted seat vibration that was the equal lowest of any of the vibratory settings at 0.56 m/s^2 fitting within the acceptable levels of the standard.

Whilst the sub soiling capacity maybe increased by wings, vibration, dual depth or dual pass configurations, the cost in efficiency of transferring tractor engine power to the subsoil loosening needs to be considered. Traditionally, sub soiling efficiency may be compared in terms of draft force required to loosen the cross-sectional area, this would be appropriate if the soil was homogenous and draft (or drawbar power) was the only transfer of tractor output to the soil loosening operation. However where tines are oscillated and power is also taken from the PTO, it is more representative to consider overall power input to the ripper. However, as transfer of power through the PTO and tire/soil interaction have varying efficiencies, the power to conduct the operation at the engine flywheel was the basis considered, which is the maximum power, the operator has as a resource. In Figure 10 a comparison of this power to both area loosened and the SLE parameter have been made. In soil A, engine power to area loosened was similar for all four configurations whilst in soil B gains of 20-30% were made when the wings were added. In both soils gains of about 10% in efficiency (power/SLE) were made with vibrating wingless tines, when wings were added this efficiency improved by a further 10-20%. If fuel use was compared to SLE efficiencies increased further, due to fuel use becoming more economical as more of the tractor available power is used. As vibrating the tines at the 2.5km/h speed used more of the available engine power, fuel use efficiency looked more favorable. In reality, operating the rigid configurations at higher speed (also using more of the available engine power) could effectively improve the engine's fuels use economy to a similar level.

Implementing the one pass dual depth configuration achieved gains of 20-40% in tractor output use compared to two single tines used in one pass. The reason is that the strategically placed shallow tines improve the loosening capacity (cross-sectional area) and efficiency (draft) at depth of the deep tines. Without shallow leading tines, soil failure at depth can be constrained by critical depth where the soil tends to be compacted to either side of the tine rather than failed upwards. Similar gains should be expected using the dual pass approach, however the strategic placement of the tines is more difficult to achieve successfully.

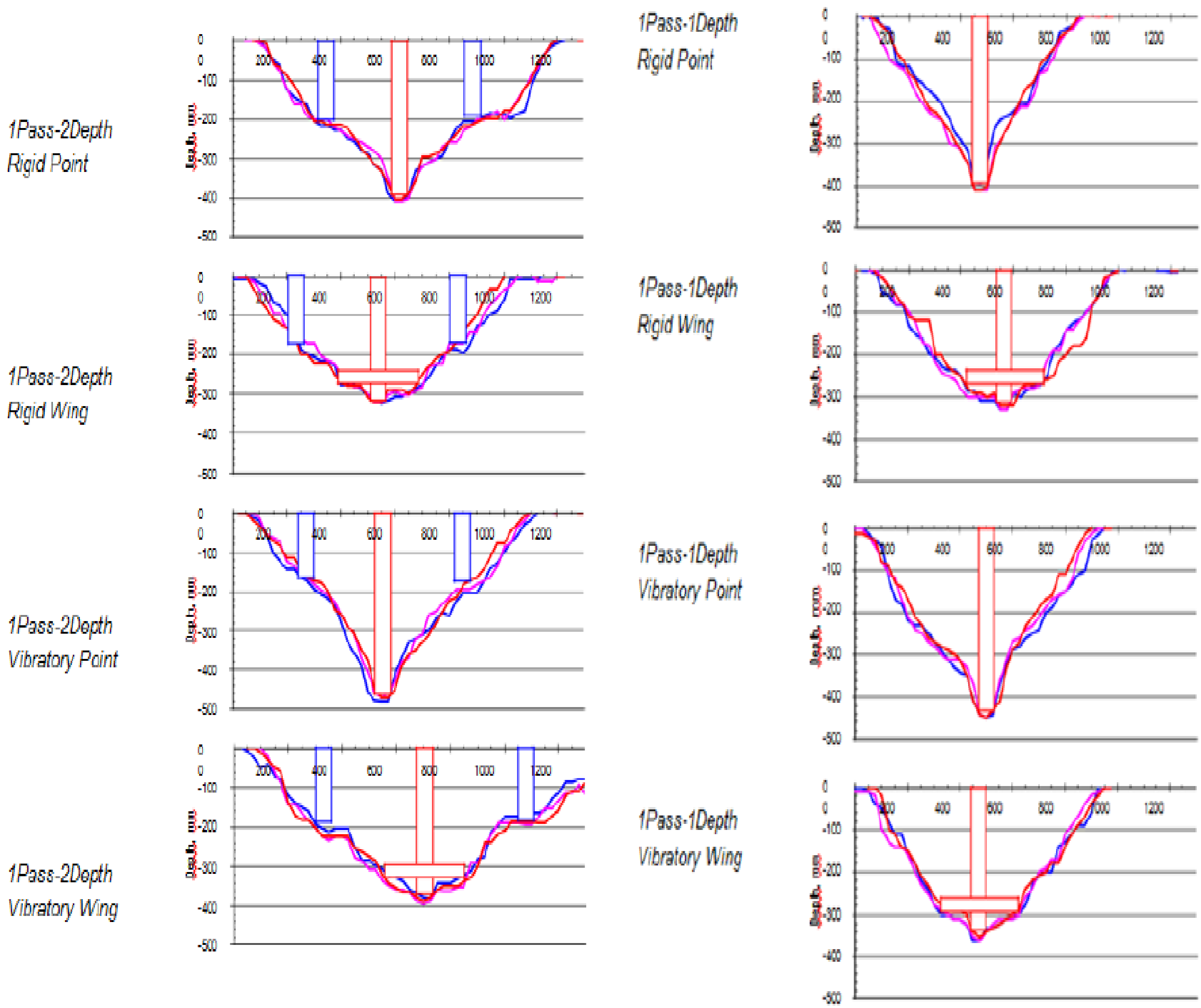

Figure 1 Experiment Loosened soil profile shapes for Soil

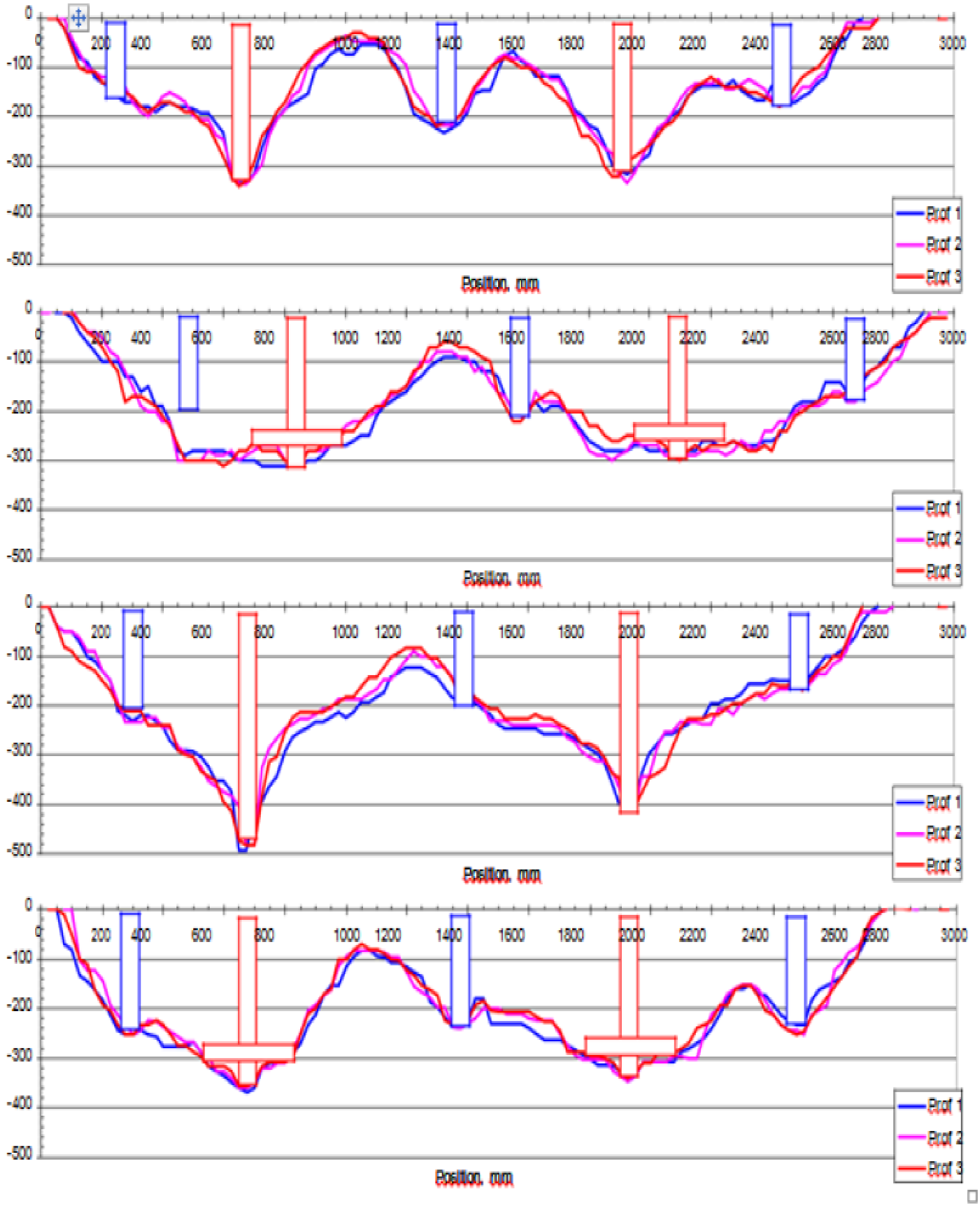

Figure 2 Experiment Loosened soil profile shapes for Soil B acceleration of three loosening strategies.

It should be noted that all the 3PL rippers were operated with a floating hitch arrangement with depth controlled by depth wheels or roller. In practice the draft control of the 3PL system could be used to transfer some of the ripper down force (generated by the tine tips pulling into the soil) to the tractor thus effectively increasing the tractor's dynamic weight. This additional weight would increase the tractor's traction and thus generate higher draft that could then potentially increase the subsoil loosening capacity of these 3PL-mounted rippers. Use of the 3PL system to increase the draft was avoided due to the difficulty in keeping this constant throughout the tests and between rippers.

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Figure3. Relative comparison of sub soiling capacity, efficiency and weighted 3D seat

The **%** reduction in soil bulk density determined from the change in the loosened area to the sum of the loosened and upheaved area was not found to vary significantly between ripping treatments. Within and across all the treatments there was great variation is from about 7.5% to about 34.5% that accounts for the lack of measurable differences. Blocking across the three treatments did however show that some of these variations maybe attributed to position and soil type. On average the % reduction in bulk density was 18.9%.

The area of upheaval was also highly varied and would have contributed to the high variation in % of bulk density reduction. The variation was high within and across treatments with no significant differences being associated with ripper types, however on average the area upheaved was about $0.034m^2$. Blocking across the experiment for this variable also showed that position and soil type may have had an influence.

Grape vine yield was compared in terms of bunch number/vine, yield weight/vine, bunch weight, and weight/cordon length. All these yield variables were found to be statistically similar for all treatments with averages of 133 bunches/vine, 6.7kg grapes/vine, 50.7g/bunch and 2.98kg/m of vine. In terms of yield a slight difference was measured with the non-ripped control treatment having a Brix value of that was significantly lower than all the ripped treatments. Typically lower Brix values are found to correspond to higher yields and vice versa. The similar measured yield response of all the treatments is likely to be due to;

- the drought conditions and uneven weed growth in the mid-row that would not have encourage root growth into the dry mid-row zone;

-the result of the irrigation system failures contributing to very uneven water application during the spring/summer period of vine growth and grape development;

- the large variation in vine size and structure of the 39 year old vineyard. In addition it is possible the benefits of root growth into a loosened vine mid-row may not be fully realized until the second season;.

Vine and vine root growth can be related to pruning cane weight and number. While number of pruned canes and their weight were related to both each vine and cordon length no statistical differences were established between the treatments. The average pruning results were 570g/vine, 44.3 canes/vine, 266g of canes/m and 20.3 canes/m. The points listed above for the grape yield would also have significantly influenced the outcome of these growth results.

The average maximum depth of sub soiling was 375mm in June and 365mm in September. The slightly greater depth achieved in June resulted in a greater area of soil loosened of 0.281m^2 compared to the 0.253m^2 achieved in September. The greater tillage achieved in June is thought to be due to the wetter soil and thus lower soil strength that is thus required to be overcome by the sub soiling machinery. Interestingly a slightly greater average area of soil was upheaved with the September ripping of 0.111m^2 compared to the 0.090m^2 achieved in June, this resulting in a larger calculated percentage reduction in bulk density of 30.5% compared to 24.3%. Figures 3 and 4 below show an example of the subsoil loosening and surface upheaval profiles that were measured following the ripping in September. These figures show the different surface profile left when the roller is used or not.

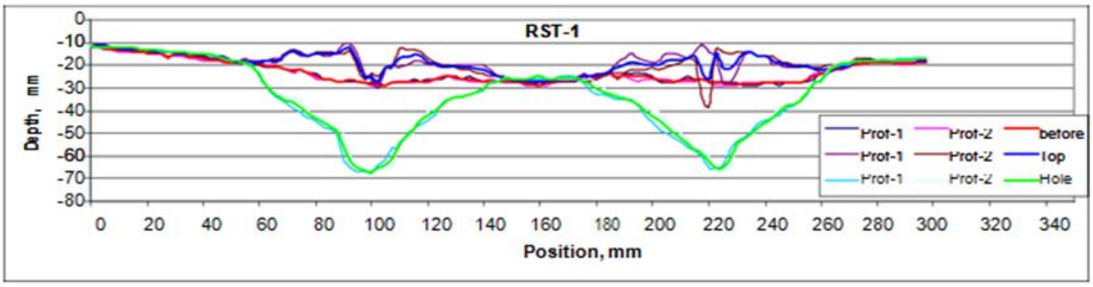

Figure 32 Example of subsoil and surface soil profile after ripping with out a crumbling roller.

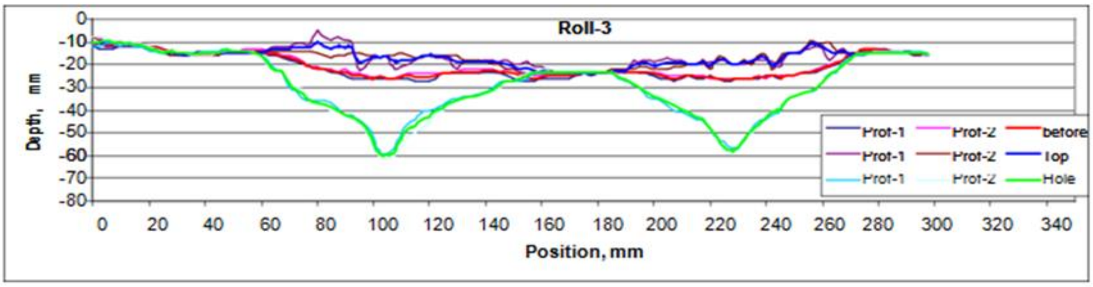

Figure 4 An example of surface subsoil profiles after ripping with a trailing crumbling roller

The area of soil upheaval one week after ripping was determined, as the vertical cross-sectional area between the original soil surface profile and that measured after ripping. The settling of this upheaved loosened soil from the time of ripping until September 2022 was then found by again measuring the surface profile and determining the area that had not yet settled back to the pre-rip soil level. These settling results were thus determined for the treatments that were ripped in June. It was found that the soil had settled such that the area remaining up heaved in September was 69.4% where traffic was minimized but significantly reduced to 14.1% where typical vineyard traffic was allowed to continue. If we relate this to the average bulk density measured in the ripped area of 1.52t/m^3, the subsoil area loosened and the original area up heaved we can predict the resulting effect on the bulk density in the ripped zone. It is expected that thus minimizing traffic will provide a greater opportunity for root growth to take advantage of this loosened soil whereas where typical traffic is continued it can be observed that the soil bulk density is quickly returned to close to that found prior to ripping. Much of the settling or re-compaction of the typical traffic treatment is expected to have occurred when soon after ripping a tractor mounted pruner was used requiring two passes in each mid-row one in each direction. The result of this is that as the tractor is offset from the center of the mid-row a large portion of the mid -row is wheeled by the tractor with this operation. An example of better mid-row water penetration and reduced runoff is shown in Figure 3 with water clearly running to a low point and gathering in the mid-row that was not ripped compared to the adjacent autumn ripped minimum traffic treatment.

Figure 5 Left mid-row was ripped in autumn with traffic minimized while the adjacent mid-row to the right has not been ripped.

CONCLUSION.

Vineyard and open field trials conducted by the University of South Australia have shown that a prototype dual-depth vibratory ripper can be used to maximize the subsoil loosening capacity of a 63kW narrow vineyard tractor. Vibrating the ripper tines has been found to reduce the draft or pulling effort required by these lightweight tractors by up to 38% compared to a similar rigid tine machine. The vibratory technology was found to increase the subsoil loosening capacity by up to 59% over equivalent rigid ripper configurations. Sub soiling capacity of a dual-depth ripper configuration was found to exceed that of a single depth arrangement by 30 to 50% whilst an additional pass preceding the dual-depth operation yielded a further 15 to 20% increase in capacity. The capacity and performance of a range of rippers with the small vineyard tractor were also evaluated. The greatest soil loosening capacity was achieved with the dual-depth vibratory ripper that was up to 3 times that of some commercial 3 -point linkage rippers. A three-point linkage 2-tine Para plow with long trash clearance tines also performed well with a subsoil loosening capacity of 80 to 85% of that achieved with the dual depth vibratory ripper.

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