History and recent developments in under-vine weeding equipment

There is much current interest in techniques for non-chemical weed control. In this article, AWRI Principal Engineer **Simon Nordestgaard** summarises the history of under-vine weeding equipment.

Cultivation using hand tools and ploughs

Weeds in vineyards have traditionally been managed by cultivation – essentially digging them up or burying them. Initially this was performed with hand tools (Figure 1) then later using ploughs drawn by oxen or horses. Ploughs have been used since antiquity, but were not common in vineyards in many regions until much later. For example, in many winegrowing regions of France ploughs were only adopted in the 19th century. Even at the start of the 20th century, some authors stated that growers needed at least 4 ha to justify having a horse. Hand tools also remained the only option in steeply sloped plots. The vigneron's plough (Figure 2), however, was by this time quite well adapted to the specifics of vineyards. For example, it featured offset handles so it could be used close to vines, but it still left a 20 cm strip in the vine row that needed to be managed by hand. When vines were not trellised and square planted, cross-ploughing/hoeing was sometimes used to reduce the under-vine area needing to be tended by hand.

Spring-loaded under-vine hoes

Around 1910, several spring-loaded under-vine hoeing tools were developed

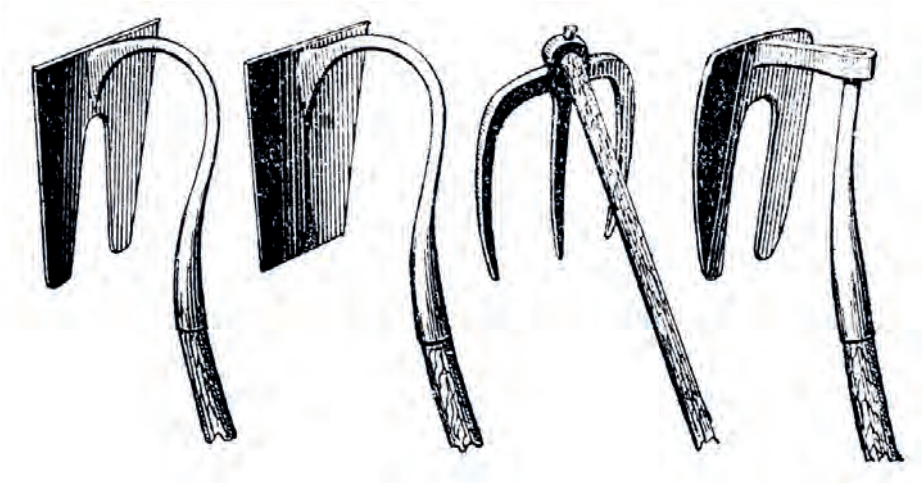


Figure 1. Early 20th century hand tools for vineyard cultivation (from Chancrin 1908)

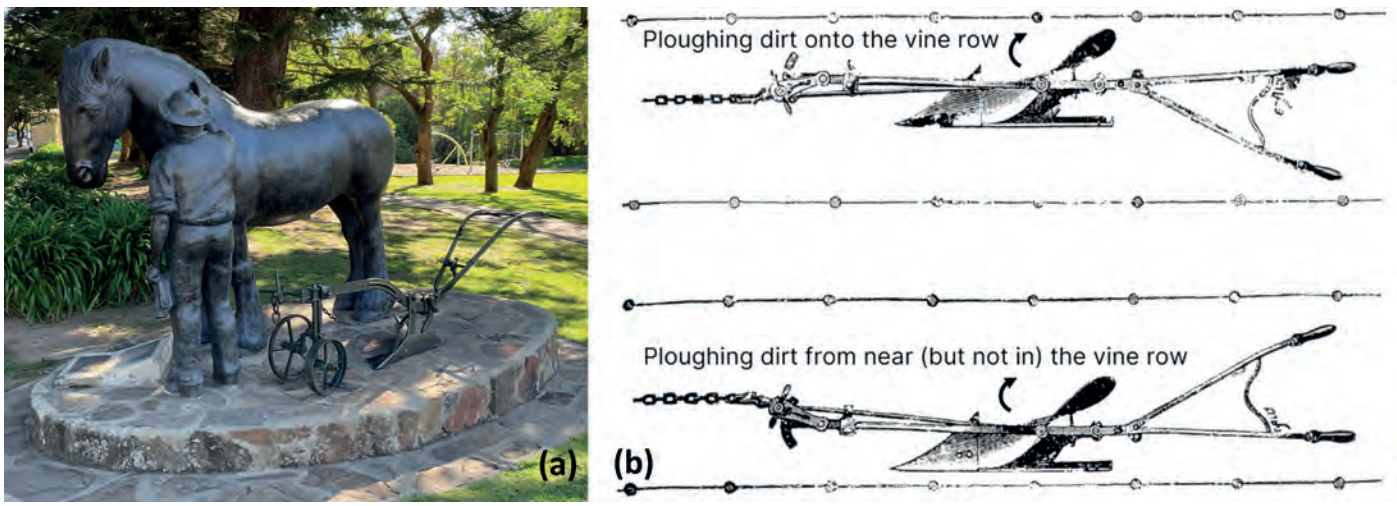


Figure 2. (a) 'Day off Peter' sculpture at Angaston in the Barossa Valley showing a vigneron's plough with a Clydesdale horse, (b) ploughing dirt onto the vine row, or from near the vine row (a single-furrow plough is shown adapted from Brunet 1910, but in wider rows a two- or three-furrow plough, drawn by two or three horses would often be used)

Cultivation cycle

Multiple French viticultural textbooks were published in the late 19th and early 20th centuries and these provide some of the best records of viticultural practices at that time. They outline the cycle of vineyard cultivation and the functions it performed. In cooler areas the first cultivation was in autumn, 'hilling' the vines to help protect them from the cold. In late winter or spring, the soil would be stripped from the feet of the vines. In warmer areas this was the first cultivation. This stripping cultivation would destroy emerging weeds, aerate the soil and vines and help kill insect larvae under the bark. It would also cut surface rootlets, with the goal of encouraging the formation of deeper roots. Later the soil would be ploughed back on. Shallower hoeing (by hand or harnessed tools) would then be performed several times in the growing season to level the ground, prevent water-consuming weed growth and cut capillary channels that could bring water to the surface. There is an old French saying that summarises how importantly hoeing was viewed for its role in managing soil moisture in these unirrigated vineyards: "Two hoeings are worth one watering".

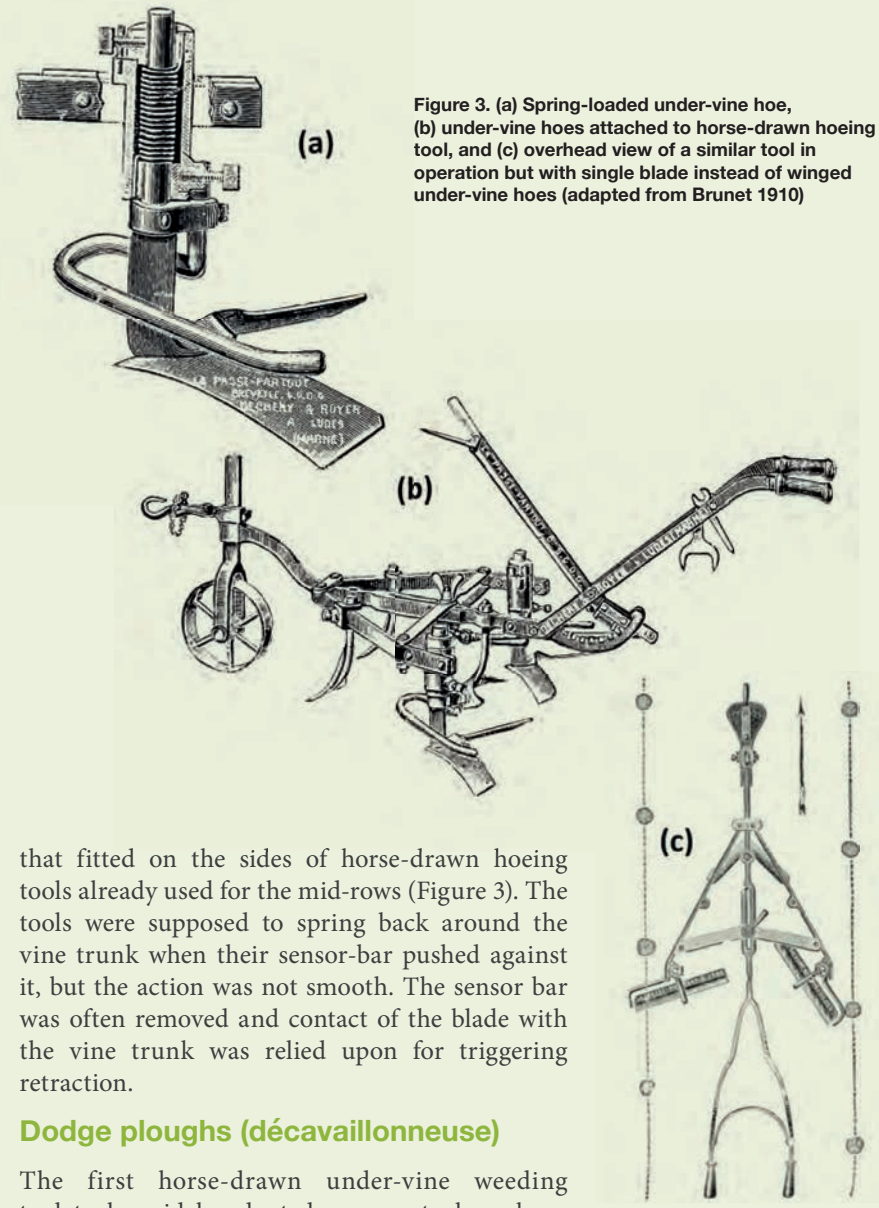
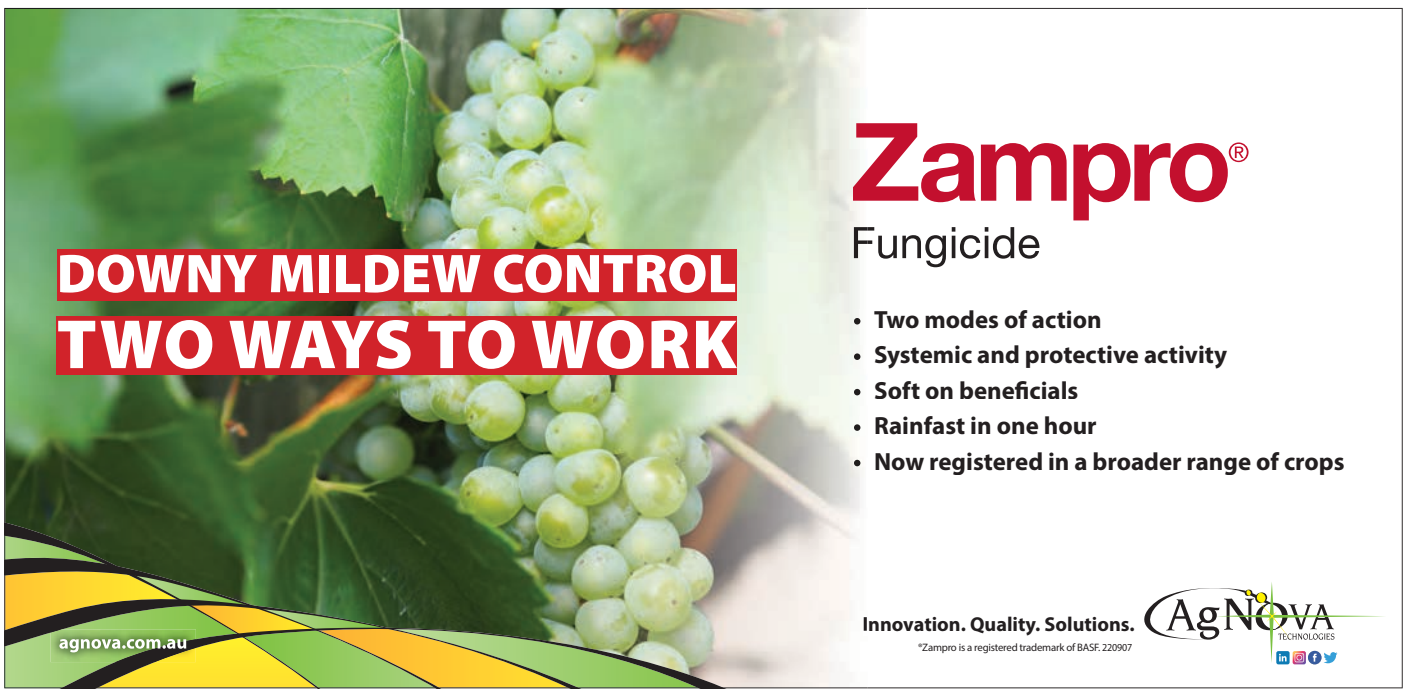


Figure 3. (a) Spring-loaded under-vine hoe, (b) under-vine hoes attached to horse-drawn hoeing tool, and (c) overhead view of a similar tool in operation but with single blade instead of winged under-vine hoes (adapted from Brunet 1910)

that fitted on the sides of horse-drawn hoeing tools already used for the mid-rows (Figure 3). The tools were supposed to spring back around the vine trunk when their sensor-bar pushed against it, but the action was not smooth. The sensor bar was often removed and contact of the blade with the vine trunk was relied upon for triggering retraction.

Dodge ploughs (décavaillonneuse)

The first horse-drawn under-vine weeding tool to be widely adopted appears to have been



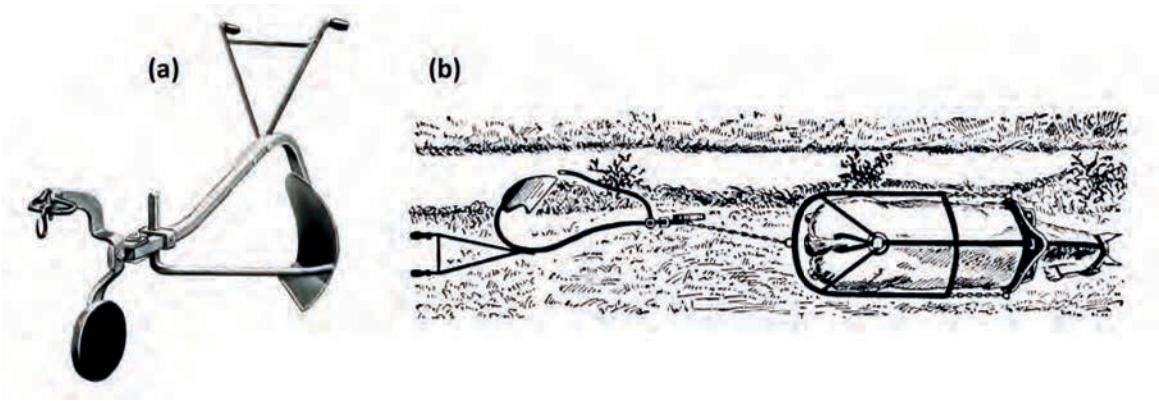


Figure 4. (a) Dodge plough, and (b) mode of dodge plough operation (Kirpy)

the dodge plough (Figure 4). This is a relatively simple and manoeuvrable tool that the user can dodge around the vines. In French, it is known as a 'décavaillonneuse' because it removes the cavaillon (the French name for the under-vine strip).

Tractors

While some tractors were used in vineyards in the early 20th century, this was mainly for preparing land for planting, rather than for everyday operations. Tractors only started to become common in the late 1940s. Just like during the shift to horse-power, under-vine weeding was slower to be adapted to tractor power than basic ploughing and hoeing. Early implements also still often needed extra people walking behind or sitting on them to dodge the plough in and out around the vines.

In the 1950s, automated dodge ploughs actuated by a sensor rod were developed (e.g. Figure 5). In this classic design, the plough is on a parallelogram. When the sensor rod hits the vine, the plough is moved out and around the vine but keeps the same angle of attack, so when the vine is clear, the resistance of the soil on the plough brings it back into the working vine line. These tools could be attached to the side of vineyard ploughs that already worked the mid-row. This tool works without hydraulics and the springs only perform secondary functions – priming and safety opening for if the tool gets entangled. Modern variations of this sensor-actuated dodge plough appear to still be quite common in France but are rare in Australia.

In the 1970s, hydraulically powered tools were developed (e.g. Figure 6). With hydraulic assistance, the sensor rod doesn't need to push as hard against the vine for the tool to retract. Hydraulic power can also be used to return the tool to the working line independent of the plough shape and soil resistance.

In Australia, hydraulically powered dodge ploughs appear to have also been widely used, but generally they were actuated by a foot pedal or handle rather than by a sensor rod (Figure 7). These tools are still used to a limited extent today.

Herbicides

Synthetic herbicides began to be used in some French vineyards around 1960.

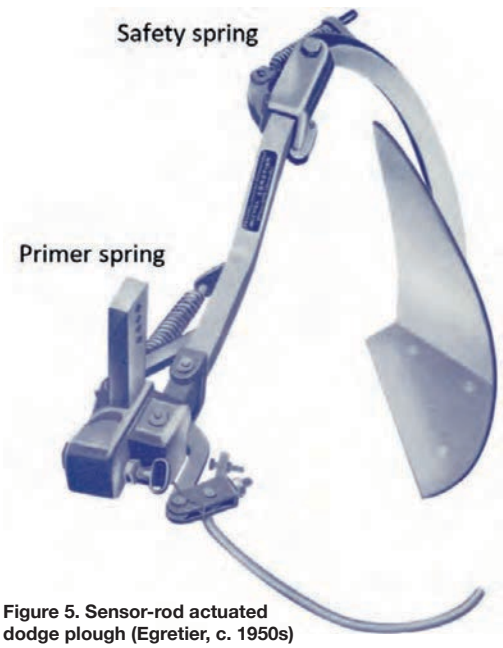


Figure 5. Sensor-rod actuated dodge plough (Egretier, c. 1950s)

Figure 6. Hydraulically assisted sensor-rod actuated under-vine weeding tool (Boisselet, c. 1970s)

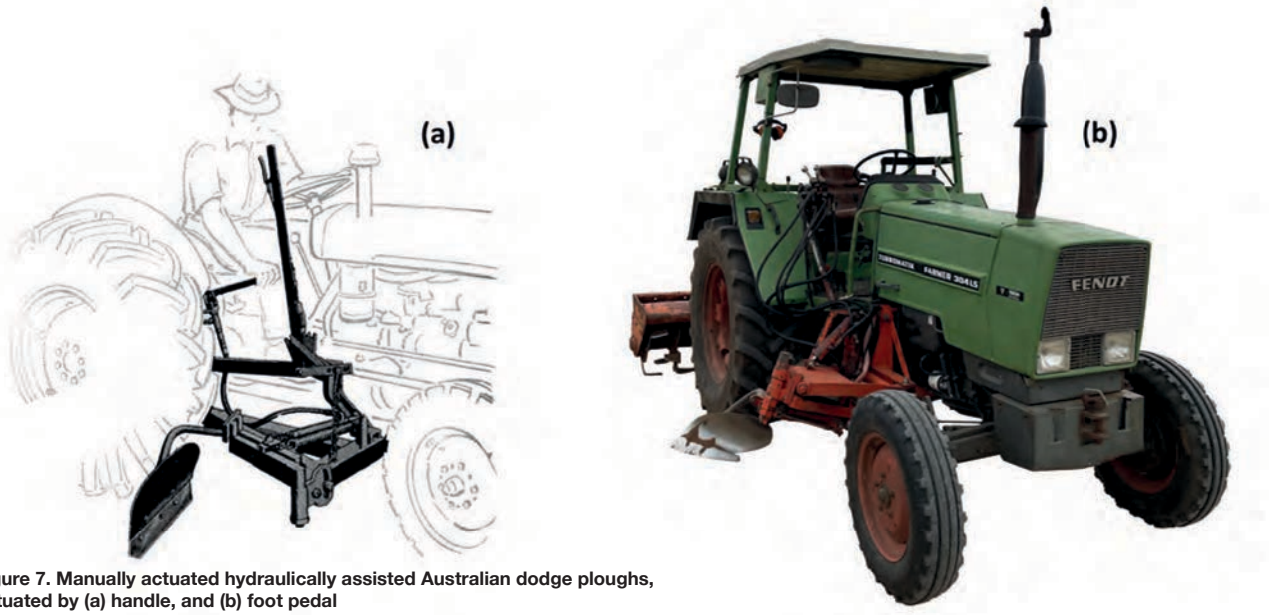


Figure 7. Manually actuated hydraulically assisted Australian dodge ploughs, actuated by (a) handle, and (b) foot pedal

However, early synthetic herbicides were not easy to use as they left residues in the soil and there was some risk of damaging vines. They were also ineffective at managing perennial weeds. It wasn't until safer perennial grass herbicides such as glyphosate were developed that herbicides really became a viable alternative to cultivation for weed management. Glyphosate was released in the USA in 1974 and registered for use in Australia in 1976. Some of its advantages over cultivation are neatly summarised in an advertisement from the April 1985 edition of *Australian Grapegrower and Winemaker* magazine (Figure 8). Herbicides became the most common technique for under-vine weed management and this is still likely the case for most of the world. Herbicides also started to be used for managing weeds in the mid-row, but this practice declined, and in Australia mowing is now the most common technique for managing mid-row growth.

In Australia, when herbicides were first being considered as an alternative to under-vine cultivation, there was some debate about whether vines would continue to grow without the rootlet pruning that under-vine cultivation achieves. It took successful no-till trials in

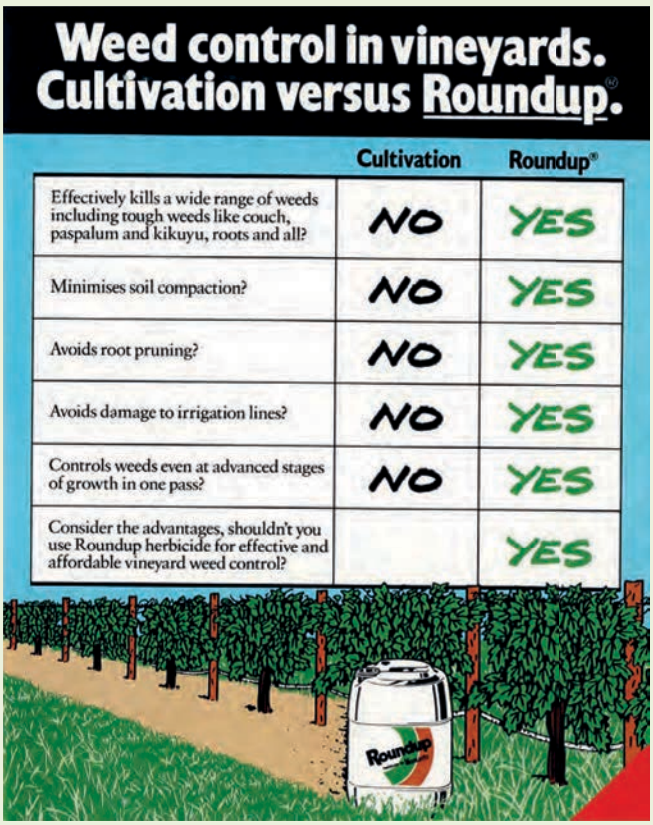


Figure 8. Advertisement for glyphosate in the April 1985 edition of Australian Grapegrower and Winemaker magazine

Irrigation

It is likely that changes in irrigation practices have facilitated changes in weed management, in particular the shift away from total cultivation. Irrigation can compensate vines for some water consumption by weeds. It also reduces the need for surface rootlet pruning since roots do not need to be encouraged to go as deep to access water.

When many vineyards used to be furrow-irrigated, cultivation was also a necessary part of the management system, because the furrows needed to be formed. With the shift to drip irrigation in the 1970s to 1990s, this need for cultivation was removed, opening the way for alternatives. Furthermore, the more focused under-vine drip irrigation likely reduced the radial spread of roots, and therefore the importance of weed management in the mid-rows, possibly making mowing a suitable alternative to cultivation in the mid-rows.

the Barossa Valley, in which the vineyard floor was completely covered with straw mulch, to prove that cultivation was not a necessity, provided there was another means of controlling weeds.

This followed many historical debates on what depths should be used for cultivation and the need for cultivation at all. In one interesting series of experiments in Montpellier from 1908 to 1927, vines were surrounded by concrete to see if they could survive without cultivation, and yields were slightly better than with a cultivated control treatment.

Organics and sustainability

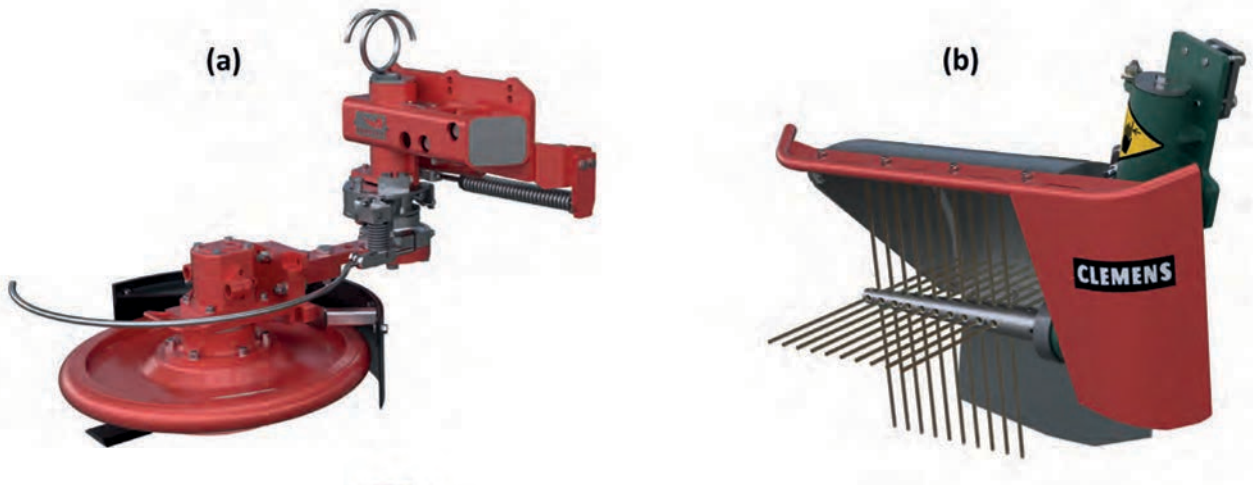
In recent years there has been growing pressure to reduce the use of herbicides in agriculture. Glyphosate is becoming increasingly restricted in Europe. It was almost not relicensed there in 2017. Furthermore, glyphosate and other important herbicides are not permitted in organic production systems. There is much debate about the sustainability of organics and moves to restrict the use of herbicides and some fungicides. For example, some argue that cultivation is more natural than using herbicides for managing weeds, but others argue that cultivation, the most common organic alternative, negatively impacts soil structure, increases production costs, and uses more diesel and is therefore less sustainable than using herbicides.

Modern under-vine weeding tools

For growers that do not want to cultivate, under-vine mowing is an alternative. There are various systems available (e.g. Figure 9). However, mowing does not remove as much plant matter as cultivation, so it often requires more passes. Generally, mowing tools also have parts that wear more quickly than cultivation tools.

Blade/knife weeders are a common modern under-vine cultivation tool that does not dig as deep as a dodge plough (Figure 10). They retract on a vertical axis following contact of a sensor rod with the vine and open out again once the vine passes. They are sometimes used in conjunction with a rotary tiller that breaks apart the weeds from the soil that has been cut out, and a serrated disc to cut a line ahead of the blade.

Figure 9. Under-vine mowing tools: (a) mower head with blades rotating on vertical axis – retracted around vines based on sensor rods, and (b) mower head with cords rotating on a horizontal axis mounted on spring-loaded bumpers to get around vines (Clemens)



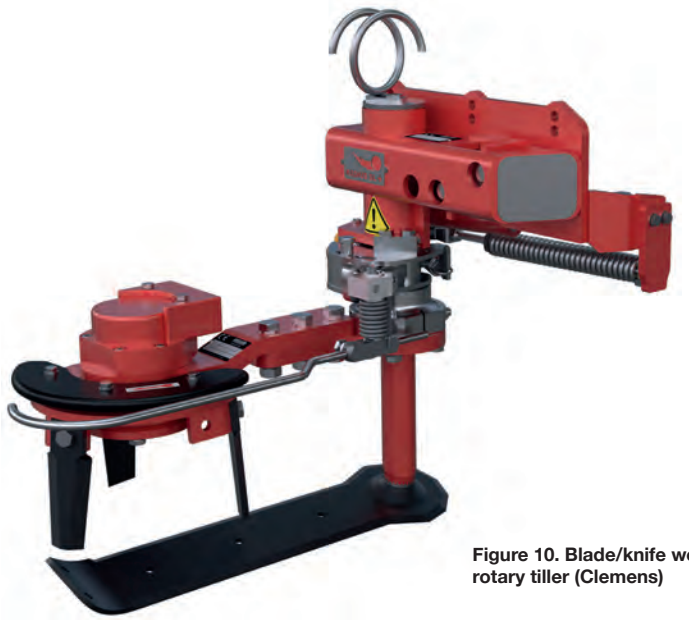


Figure 10. Blade/knife weeder with rotary tiller (Clemens)

Roller hoes (Figure 11a) also known as Rollhacke (hacke means hoe in German) are another tool that has become common. They can run at much higher speeds than dodge ploughs or blades. However, they do not extend into the vine row and therefore can result in some mounding. Roller hoes appear to have originally been developed to run uphill in steep-sloped vineyards as the star design does not create an edge that water can run down.

Flexible rubber finger hoes (Figure 11b) are a tool that extends into the vine row with the fingers bending around the vines

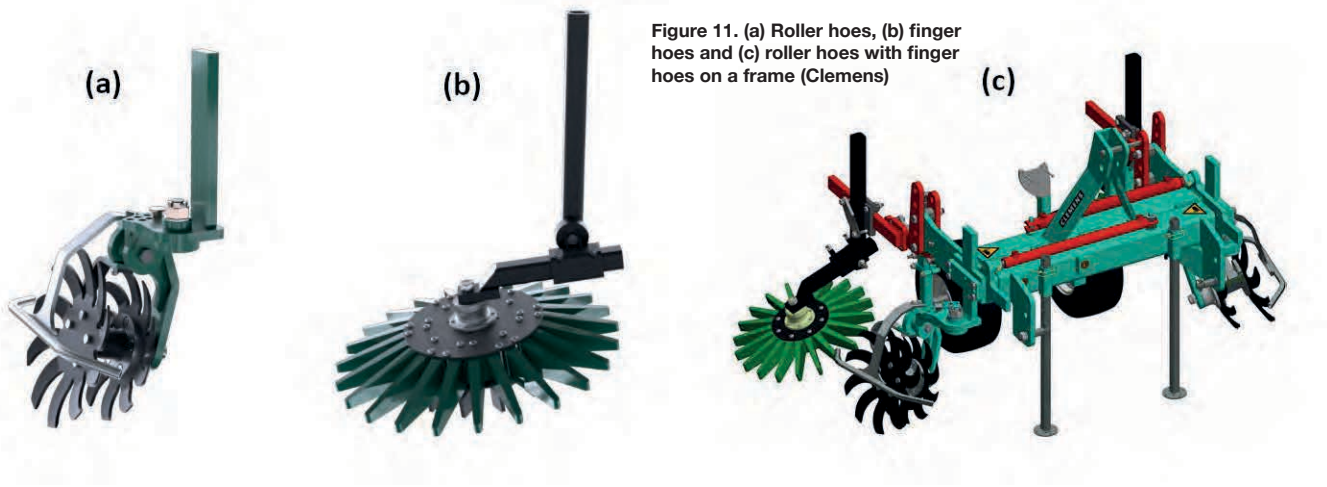


Figure 11. (a) Roller hoes, (b) finger hoes and (c) roller hoes with finger hoes on a frame (Clemens)

and posts. They do not need sensor rods or a retraction mechanism, and therefore do not create 'weed shadows' like many of the other tools. The patented Kress design used by several suppliers features metal driving fingers underneath to keep the finger wheel turning and limit bulldozing. They are often now used in conjunction with roller hoes (Figure 11c) to try and limit the mounding that can occur with that tool, but it will likely still occur eventually, requiring a pass with a different tool to level the ground.

Other novel weeding techniques

There is also interest in other non-chemical weeding techniques. Steam and flame weeding have been used to some extent, and microwave weeding is also being trialled, but the technique that is attracting the most recent attention is electric weeding (Figure 12). Positive and negative electrodes drag along the ground and high voltage electricity flows between them, damaging the weeds. The technique is already being used commercially in some European vineyards and is being trialled this year in an Australian vineyard.

Autonomous under-vine weeding

One approach to managing the slower speeds, extra tractor passes and therefore higher labour costs when weeding by cultivation or mowing is to perform these operations autonomously. This may be achieved using tractors fitted with an autonomy-kit or using dedicated

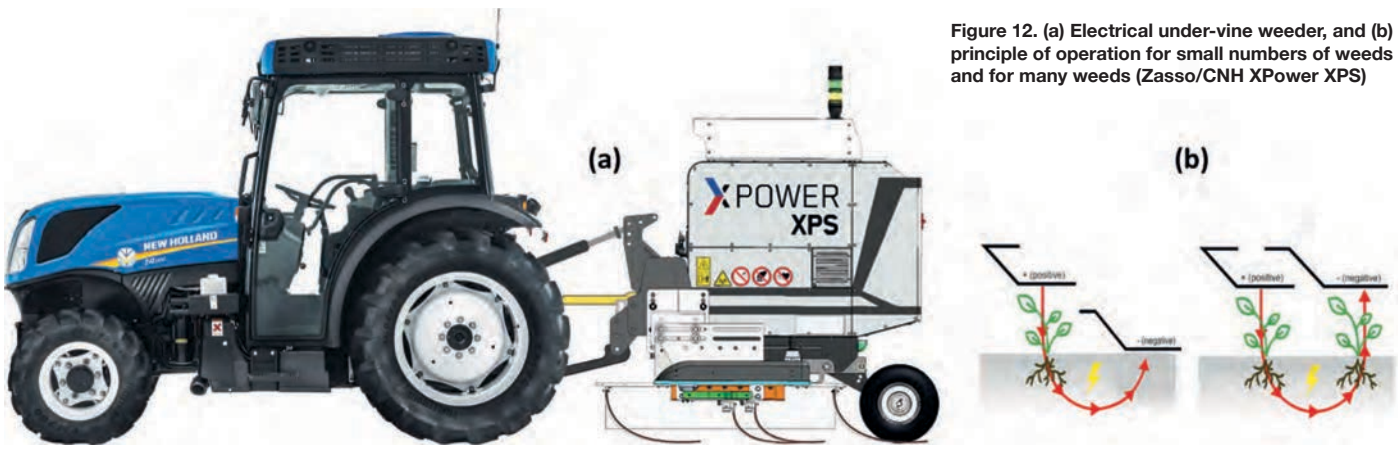


Figure 12. (a) Electrical under-vine weeder, and (b) principle of operation for small numbers of weeds and for many weeds (Zasso/CNH XPower XPS)

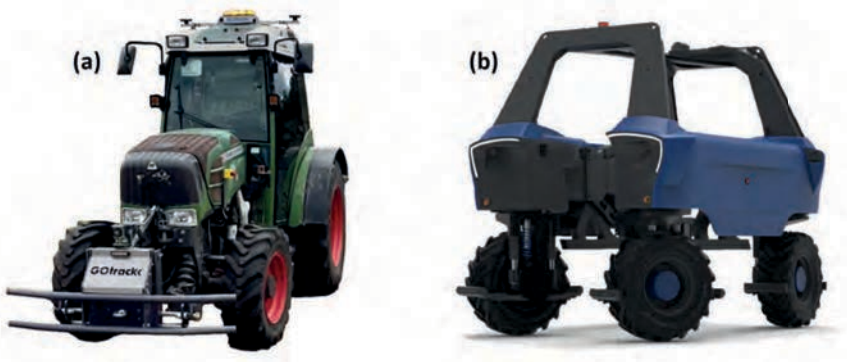


Figure 13. (a) Autonomy-kit fitted to a tractor (GOtrack), and (b) autonomous vineyard robot (Vitibot)

Figure 14. Autonomous electric lawnmower (Husqvarna)

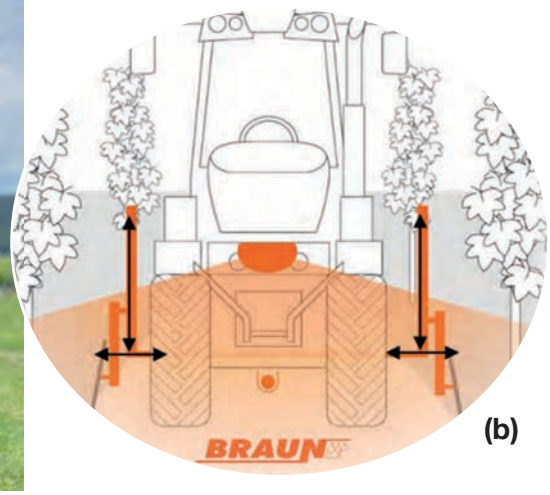


Figure 15. (a) Auto-steer tractor kit with automatic tool positioning, and (b) principle of operation (Braun)

vineyard robots (Figure 13). Standard weeding tools seem to be used in most cases, but some machines employ tools that have been adapted to provide feedback during autonomous operation, for example to detect blockages and stop the machine. Some robots have the advantage of being battery-powered and therefore can avoid some of the carbon dioxide emissions associated with diesel tractors. Tractors have the advantage of being a proven robust machine that can still be driven manually when desired.

In recent years small autonomous electric lawnmowers (Figure 14) have become more prevalent. Unlike a traditional mower that cuts a large amount of grass off each pass, they mow much more frequently, only trimming a few mm of grass each pass and therefore keeping the lawn at an almost constant height. They automatically return to their charging station when their battery is getting flat and head out again when their battery has been recharged. These lawnmowers could potentially be used for mowing vineyard floors, perhaps in conjunction with off-grid solar charging and suitable grass groundcover that does not compete deleteriously with the vines. The number of machines needed for coverage of large areas may be a limitation.

Systems that still need a driver but that auto-steer and precisely control tool positioning in the row and facilitate faster operation are another alternative (Figure 15).

Conclusions

Under-vine weeding techniques have evolved significantly over time, from cultivation to herbicide and now some shift back to cultivation, mowing and other alternatives. There is also much work being performed on under-vine cover-cropping. It will be fascinating to see how all these techniques evolve and interact in coming years. The AWRI has a webpage with resources on weed management, including a non-chemical weed control decision tool developed by Robyn Dixon and Chris Penfold. For those interested in autonomous approaches and electric weeding, the AWRI will also be running a demo day in the Barossa Valley this November to share some of our experiences.

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