Establishing perennial ground cover species, as a management practice to suppress weeds in a Pipfruit orchards "weed spray strip".

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Abstract

Can low growing, perennial plants be established as a ground cover in Pipfruit orchards, as a replacement for a traditional 'weed spray strip' management practice?

In this trial, seven low growing perennial species (Birds foot Trefoil - *Lotus corniculatus,* Narrow leaved Plantain - *Plantago lanceolata*, Common yarrow - *Achillea millefolium*, Chicory – *Cichorium intybus*, Alyssum – *Lobularia maritima*, Sheep's burnet – *Sanguisorba minor subsp. Muricata* and Strawberry clover – *Trifolium fragiferum*) were established in the 'weed spray strip' on a Nelson Pipfruit orchard. Two plantings were undertaken, one in Spring and one in Autumn.

We wanted to determine the ability of these species to establish and thrive in this area of low light, with poor structured, bare soil, that through testing showed signs of long-term herbicide use (low organic matter, low soil biology and low or unfavourable soil organisms and weeds present).

Results from this trial were that six of the seven species germinated and established well in Spring. Only one (Alyssum) had weak continued growth after good germination, resulting in slow establishment of yellowing growth, weed species within this plot were able to establish and cover more ground than this species could.

The species that 'established well' (covered the ground to varying degrees that helped to compete or shade out weed species, withstood foot traffic during harvest, continue thriving with little to no intervention and have not become a 'pest' plant) were Yarrow, Chicory, Sheep's Burnet, Trefoil, Clover, and Plantain.

Introduction

You will find many low growing perennial species are commonly found in orchard situations. Often observed species in the weed spray strips in our trial block included yarrow, clovers, and grasses. Alongside these persistent perennials were weeds such as thistle, mallow, dock, speedwell, and nightshade.
It's not uncommon for an orchard to have a mix of the above, what is uncommon is for any species to be kept for long in the 'weed spray strip', an area of ground under a Pipfruit canopy that is traditionally keep clear of any vegetation – with the use of herbicides.

In more recent times, 'cover crops' have been discussed as a solution for good soil health and are a big component of the regenerative agriculture movement. Keeping the ground covered with a living crop, year- round is said to encourage soil biology and biota (Dupont, 2018), provide erosion control, help retain soil moisture, increase organic matter, provide plant exudates to 'feed' soil biology, and sequester carbon into the soil.

- The *primary* focus of this trial was to establish perennial species in this 'weed strip' area and to determine the practicability and efficacy of this management practice. Are we able to replace the need for herbicide under tree?

- *Secondly*, was to begin understanding the effect these plants may have, if any, on tree health and crop quality. Do these 'extra' plant species have any effect on fruit quality and tree health in the long term?
- *Thirdly*, we wanted to understand the effect these perennial cover species may have on soil health and biology. Is the 'cover cropping' method of keeping ground covered year-round a solution to soil health issues?

Method and trial details

Location – The trial was established on a mature 2D Breeze (Royal Gala strain) orchard, in the Brightwater region of Nelson. The block is on M9 rootstock, at an intensive planting of 2.5m x 1.4m. This site was chosen for many reasons.

1) The block is mature, we did not want to interfere with any young trees.
2) The block is 'two dimensional' we wanted maximum sunlight to be able to reach the orchard floor, giving seeds the best possible chance for germination. Intensive 2D, V trellis or spindle planting is common for new orchard developments, with the industry tending to move away from traditional low-density plantings. We wanted to trial our species in a way that would work with future plantings.
3) The block soil type is Oronoko – f, a deep, well-draining loam over sand. Again, we wanted the species to have the best possible chance of germination, without any soil type extremes.
4) The grower involved was already interested in the concept being trial in Pipfruit and Kiwifruit, meaning we had good support from the beginning.

Ground preparation – To ensure good seed to soil contact, we needed first to till the soil. This narrow area (0.5m at its widest) is a difficult area to fit machinery into. We want to cultivate right up next to the tree trunks without damage, and far out enough into the interrow space that we could cover the entire 'weed spray strip' – without disturbing the permanent grass sward. We had a local viticulturist provide a piece of machinery that did just this, a row hucker. This tractor attachment was rear mounted, with hydraulic movement to get close to the trees as needed. Three tined discs on an 80-degree angle, tilled 8cm into the ground. This depth was enough to establish a seed bed, without damaging any tree roots that were close to the surface.

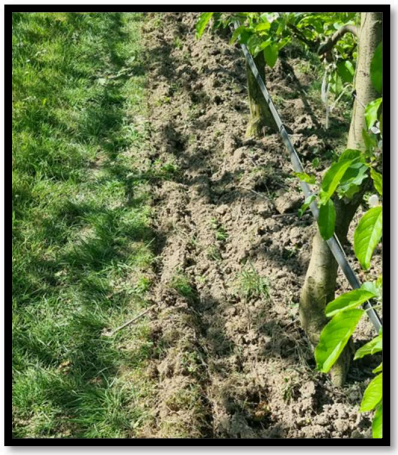
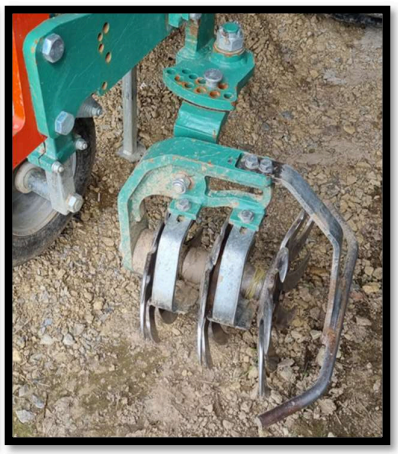


Figure 1 Spring seed bed, soil dry and compacted.

Figure 2 Autumn seed bed, soil moist making it more friable.



The Spring tillage of this area was undertaken during flowering, there was no obvious impact on flowering or tree stress.

Three passes were needed in Spring to break up the dry soil into workable clods. In Autumn only two passes were needed (soil moisture was ideal).

Spring sowing – The first sowing was undertaken at the end of October, with the soil warming up and rain still in the forecast.

Species	Sow rate	Seed weight
Plantain	10g/m2	4,000 seeds/ g
Sheep's Burnet	16g/m2	140 seeds/ g
Birds foot trefoil	14g/m2	2000 seeds/ g
Common yarrow	14g/m2	1,700 seeds/ g
Chicory	10g/m2	700 seeds/ g
Strawberry clover	10g/m2	330 seeds/ g
Alyssum	14g/m2	1,000 seeds/ g

Figure 1 Source: (Harvest, 2023)

Each species was sown individually, at a heavy rate. This was to ensure good coverage as they were sown by hand. These are not 'usual' sowing rates for normal practice.

We wanted to trial each species as an individual before moving on to any mixtures, so we could compare any species characteristics individually, as well as any impacts on soil and tree health that may have arisen from each species.

Once sown the workable clods left after tilling with the row hucker were broken up and raked by hand to ensure seed was lightly covered. In an ideal situation we would use a piece of machinery that could till then broadcast or air drill seed, then lightly rake and/ or roll soil – again the area is narrow, and this piece of machinery does not yet exist.

Irrigation (in the form of sprinklers) was set up for the Spring sowing to ensure we had access to water in the event of a dry season, it was used only twice during germination. Once all species were established, no more water was used specifically for the trial. Irrigation was still provided through the usual plan for the trees, and of course some of this water was used by our trial species to establish.

Autumn Sowing – This second sowing was undertaken much in the same way as the first. Species were sown at the same rates on the 26th of April. At the end of this trial (June) observation of these plots determine that germination has been poor. These trial plots were not 'raked' over as the Spring plots were, and perhaps this has resulted in less seed to soil contact, and therefore poor germination. This only re-enforces the fact that sowing seed in these areas means we must have a decent seed bed to begin with, and the ability to cover the seed if needed.

For this sowing, the same seven species were sown individually, and we also trialled some smaller areas of species mixed together so when they are established, we can determine what grows together well and what potentially provides better ground cover and weed suppression.

Measurements and results

Establishment of species

The images below show the germination, establishment, and continued growth of the trial species. Table 2 gives a brief description of all species and observation comments on their progress over the 9 months.

Figure 4 Early November 2022, multiple trial species germinated.

Figure 5 Rabbit damage seen in Alyssum and Clover

December, Left Burnett, middle

mid harvest. Species reaction to harvest foot traffic.


Yarrow
Trefoil
Clover


Plantain
Trefoil
Burnet
Alyssum
Clover
Chicory
Yarrow

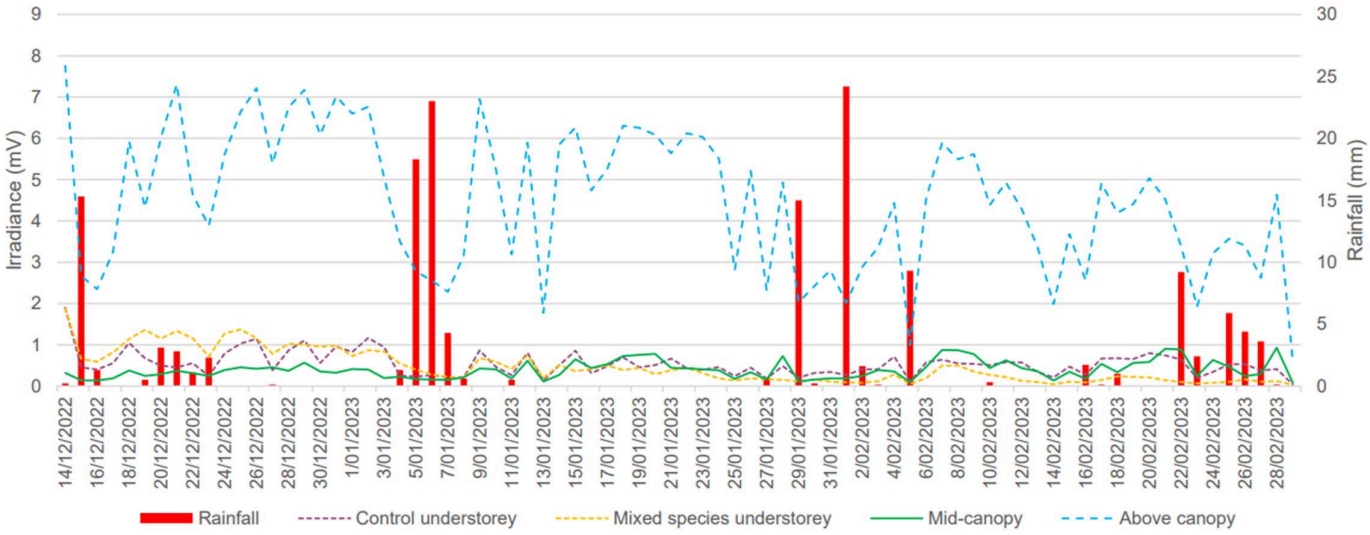
		Species observations (Spring/ Summer)		Species observations (Autumn/ Winter)
Trial species	**Germination (November 2022)**	**Initial establishment (Dec 2022 – Feb 2023)**	**Establishment (Feb 2023 – April 2023)**	**Continued growth (April 2023 – June 2023**
Plantain	Good, heavy sowing rate meant very good cover.	Clumpy, heavy rate means many plants growing.	Still very dense, haven't 'self-thinned' but maybe some competition as plants have not yet got to 'mature size'. **Great weed suppression ~70%**	Still very small plants, very good weed suppression. Plants have not matured/ competing with each other due to high sowing rate (?) **Weed suppression around ~95%**
Sheep's Burnett	Good, quick germination. True leaves in 1 week.	'Fine' leaf, light plant with small foliage, quick to establish. OK coverage.	Plants still giving good weed suppression, low growing. **Weed suppression ~65%**	Very good coverage, continued growth into frosty winter days. Good weed suppression, good coverage, OK height – some aerial roots here as ground cover is close to trunks, and scion is close to ground. **Weed suppression ~95%**
Trefoil	Good, easy establishment.	Good, also a bit patchy from hand sowing, OK coverage. Plants tend to grow upright to begin with, then fall to create mat.	Plants still giving good weed suppression, low growing once they grow up then have fallen. **Weed suppression ~60%**	Ok coverage, very small leaved plant so where not as dense, weeds have come through, potentially better coverage would mean better ground cover as the mat it creates is dense. **Weed suppression ~75%**
Strawberry clover	Good, easy establishment.	Good quick growth, great coverage when young, long stems create 'matted' carpet.	OK coverage. Tended to grow up, tall and lanky. When foliage fell it then created a mat with OK coverage. **Weed suppression ~50%**	Ok cover, however, it has been eaten partially by rabbits (the only species with this issue) cover is good and dense in well sown areas. **Weed suppression ~60%**
Common Yarrow	Good. Tiny, very light seed, difficult to sow well.	Slower to grow, clumpy from hand sowing the light seed.	Great coverage, feathery foliage creates dense low growing mat in areas were evenly sown. **Weed suppression ~65%**	Cover is good and dense in well sown patches; weeds have come through where there are gaps. **Weed suppression ~55%**
Chicory	Good, very easy germination in Spring.	Great, quick establishment. Well suited to this area.	Great coverage, big leaves physically cover ground, and potentially strong competition with other species/ weeds around it. **Weed suppression ~70%**	Very good cover, very little weeds coming through/ Ground cover is close to trunks and has the highest foliage so far – aerial roots here also. Height to be an issue? **Weed suppression ~95%**
Alyssum	Good, first to show/ germinate, heavy cover.	Quick growing in this early stage.	Started to yellow off in summer, potentially too hot? This made the plants die back a bit, and weeds were able to re-establish. **Weed suppression ~20%**	Poor growth. **Weed suppression ~10%**

Table 1 Comments/ observations on trial species over 9-month trial period.

Trial species results

Ground cover's ability to 'cover the ground' – (how much light is able to reach the orchard floor)

We worked with PFR (Plant and Food Research) to understand if there would be a difference between each species ability to cover the ground, and potentially reduce the level of light to the soil. To measure this, we used a light meter and placed it on the orchard floor, under the ground cover species "canopy" and a control of a bay. The control bay was left as weeds only – this bay should



have been weed sprayed, but unfortunately this did not happen – however, this bay was devoid of weeds until mid-summer.

The yellow dotted line shows the trial species, at the beginning when the seedlings are still small, and the Pipfruit canopy has less leaf, there is more light reaching the orchard floor. As the plants grow, less light reaches the orchard floor. In February 2023, the trial species understory is showing less light at orchard floor level, than is being found in the 'control' bay, the trial species 'canopy' is older with more dense foliage cover, blocking out more light. (Ibell & Campbell, 2023)

Trial species results

Trial species ranked, based on their ability to suppress weeds, and their growth when densely sown (images/ observations).

1st Equal– Sheep's Burnett and Plantain.

These species had the least amount of weed species present at the end of the trial. They also covered ground the best, creating a low growing ground floor 'canopy'. Both species are still low to the ground and have not yet encroached into the pip fruit canopy. However, Sheep's Burnett has a better habit, it is lower to the ground and branches rather than growing straight up, where Plantain will continue to grow higher, and its flowers will likely be in the Pipfruit canopy.

Sheep's Burnett- *Sanguisorba minor subsp. Muricata*

Plantain- *Plantago* lanceolata

2nd Chicory- *Cichorium intybus*

Chicory covered the ground very well, with little weed incursion at the end of the trial period and well covered orchard floor in its trial plot. The issue we may have with Chicory over time, is that it will grow taller, and grow up into the pip fruit canopy.

3rd Trefoil- *Lotus corniculatus*

Trefoil had a decent ground covering ability, but its small leaves and wiry stems meant that more light could come through its 'canopy' even though it was well sown and was well spread over the trial plot. This species may 'come away' again next Spring, if it can persist it could cover the ground better next season.

5th Yarrow- *Achillea millefolium*

Yarrow was difficult to sow, it was very light seed. In more heavily sown areas where the seed germinated well the yarrow has covered the ground exceptionally. Its prostrate habit means it can cover the ground, excluding most weeds; the small leaflets create an entwined 'matt' which blocks out a lot of light from the orchard floor. Where the seed was not as well spread, weeds have persisted and have grown up through the trial species.

4th Clover- *Trifolium fragiferum*

Clover was the only species to have rabbit damage, first as the seedlings were young, and now, in June many of the tops (and perhaps the flowers) have been chewed off. The species is still persisting well, and where it is a dense matt, it covers the ground well and can suppress some weeds. As the foliage is eaten more light is able to reach the ground.

6th Alyssum- *Lobularia maritima*

Although it had a quick germination and established fine, once the days got hotter and drier, the Alyssum seedlings yellowed, and at the end of the trial period the species is insignificant in its plot. As a species it could have merit in a mix, with its quick flowering useful for pollen/ beneficial insects, but as a stand- alone trial species it was poor.

Figure 4 Image taken in April 2023, Spring sown row on the right, Autumn sown row on the left (pre sowing)

Hills Laboratory – soil mineral analysis data

We wanted to understand if there would be any nutrient differences between the row that contained the trial plot species, and the control row. We didn't expect any major differences so early (second samples taken 6 months post sowing) but we intend to keep mineral sampling to create a baseline of each species. Keeping in mind that a whole season of growing has occurred here also, with harvested apples being part of the equation also.

Sample	pH (pH units)	K (me/100g)	Ca me/100g)	Mg me/100g)	CEC (me/100g)	Potentially available Nitrogen (kg/Ha)	Anaerobically mineralizable Nitrogen (µg/g)	Organic matter (%)
Range	**5.8-6.8**	**0.50 - 1.00**	**6.0-12**	**1.00-3.00**	**12 to 15**	**100-150**		**7.0-17**
Pre-sowing - Spring sample	6.4	0.36	8.3	1.18	12	65	39	3.1
6 months post Spring sowing								
'Control' row - Autumn sample	5.9	0.44	6.3	1	12	85	54	3.4
'Trial' row - Autumn sample	6.2	0.41	7	1.17	12	92	61	3.4

Figure 5 Hills soil certificate of analysis.

Soil Food Web results – soil organism biomass data and ratios

The 'Pre sowing' samples were taken in November 2022, and "6 months post Spring sowing" taken in May 2023. We wanted to determine changes (if any) to the fungi and bacterial biomass found in each trial plot. Again, we were not expecting any significant differences, but it was imperative for us to get a baseline at the start of the project.

'Total' fungi and bacteria, refers to the entire fungal or bacterial biomass found within the sample, 'Active' refers to the living fungi or bacteria found. The control sample (pre sowing) shows a baseline of biology found in the soil. We can see both fungi and bacterial levels are low, likely meaning low food resources available. We can definitely see some changes in fungi and bacterial amounts after 6 months, some that stand out are Trefoil, with a huge decrease in Active fungi after 6 months. Another is Burnett, which has doubled Active fungi levels in 6 months.

	Active fungi (µg/g)	Total fungi (µg/g)	Active bacteria (µg/g)	Total bacteria (µg/g)
Ideal range	**>375**	**>1,500**	**>75**	**>300**
Pre sowing	15.6	280.17	10.72	230.6
6 Months post Spring sowing				
Plantain	10.47	285.79	8.33	229.87
Trefoil	1.33	195.59	1.9	307.86
Alyssum	10.75	382.65	12.9	251.42
Yarrow	11.14	191.75	2.11	281.11
Sheep's Burnet	30.06	154.08	6.74	353.91
Chicory	24.22	241.51	7.28	316.08
Clover	21.6	305.92	18.32	249.03

Figure 6 Soil Food Web NZ - Soil detail report

Fruit size at Harvest

We wanted to establish some baseline measures around fruit quality, to determine if there were any differences between fruit size from each trial plot, at harvest. Crop load/ tree, however, was not determined this season, which would have a major impact on these fruit size/ trial species. In the coming season we will need to determine fruit/ TCA in each trial plot, so we can ensure any fruit size differences between species plots is measured against the crop load.

Terminated shoot length – mid January.

We wanted to determine if there would be any difference in tree vigour, as the trial species were establishing. Below table shows the average length (mm) of x20 terminated annual shoots in each trial plot. There were no major differences between the average length of shoots in each plot, and the deviation of each plots measurements also doesn't show any particular trend for the trial species.

Trial species	Average terminated shoot length (cm)
Plantain	17
Trefoil	19
Alyssum	20
Yarrow	19
Sheep's Burnet	19
Chicory	17
Clover	20
Mixed Bay	17
Control	19

Fruit quality at harvest –

Establishing a baseline for fruit quality from these trial areas was important going forwards, so we can compare quality in subsequent years. Dry matter is a big driver of fruit quality, but like fruit size it can be determined by the crop load on the trees that samples are taken from. As stated in "Fruit size at Harvest" the crop load in each trial area was not determined, and therefore any subsequent findings around fruit quality this year cannot be directly linked as an 'effect' of the trial species.

Trial species	Dry Matter (%)
Plantain	13.4%
Trefoil	12.2%
Alyssum	13%
Yarrow	12.3%
Sheep's Burnet	12.7%
Chicory	12%
Clover	12.4%
Mixed Bay	12.6%
Control	13.2%

Conclusion

This trial has shown that we can establish Spring sown, perennial ground cover species in a 2D apple orchards 'weed spray strip'. The ability of the species to 'cover ground' depended strongly on how well the species was sown and its individual growth habit.

The species ability to establish quickly and cover the ground before weeds were able to overtake depended on.

- How well it was sown, this trial was sown by hand, (which resulted in inconsistent germination). The creation of a 'seed bed', and lightly covering the seed was imperative, for good seed to soil contact.
- The species growth habit – prostrate or 'leggy' species that collapse over, and entwine to create a mat, or/and have a prostrate habit, with dense foliage gives better results with less light reaching the orchard floor.

This tells us that the best way to ensure success of ground cover species in this area of the orchard, is to have the machinery to create a seed bed, and to sow seed efficiently. Careful species selection to ensure chosen species have a growth habit that can create a 'mat' of dead and living foliage and/ or a prostrate habit that can cover ground well and also has dense foliage.

The trial species impact on the main crop (Pipfruit) was minimal to none this year. We predict that 2 – 3 years plus will be needed to determine any direct issues that may arise between with tree health or fruit quality, and the established ground cover species. This trial needs to be kept as a permanent site to we can determine year – on – year any changes as a direct result of the trial species.

The biggest hurdles found in this trial has been the ability to source specialised machinery for cultivating and sowing under/ next to a canopy. In a 2d block, we can look into viticultural solutions, that are made to work directly next to canopies. In orchards with wider, 3d canopies it would be much harder to find a cultivating solution. We think that once the demand is here for this resource, we may see more machinery being created/ becoming available, but for now it can prove difficult.

Further work is necessary in this area, so we can understand the full picture of what this 'new management practice' will entail for Pipfruit orchards. We need to understand any fruit quality and tree health issues that may arise, which means further trial replicates need to be created, and consistent, accurate sampling undertaken.

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