Cover Crops for Mulch Direct Planting

in New Zealand Vegetable Production

On-Farm Experiment

In Palmerston North

(Manawatu)

2023

This resource is provided by live2give Organic Farm (previously trading as ‘Wholegrain Organics’) in Palmerston North. It is the result of a project under MPI’s Sustainable Food and Fibre Futures programme (SFFF) which was jointly funded by the Ministry of Primary Industries and live2give Organic Farm.

Sustainable Food and Fibre Futures (SFF Futures)

Proof of Concept: Mulch-direct planting for commercial vegetable production and its technical implementation in NZ conditions (SFFF 21070)

Preliminary Remarks

The mulch direct planting trial under this programme is investigating the economic and environmental performance of a vegetable production system where seedlings are planted directly into soil covered by a protective layer of organic material without further tillage. Cover crops play a key role in these production systems as they provide the organic material required to cover the soil, and also the root penetration to aid tilth and soil structure (MOYER, 2021). Reaching maximum dry matter yields at as many different times of the growing season as possible, will greatly aid the feasibility and profitability of mulch direct planting in vegetable production systems as the costs for transferring mulch can be reduced or avoided. Practical experiences in Germany have shown that dry matter yields between 15 and 18 t/ha are suitable to obtain the desired effects without the addition of transferred mulch from other plots (LIVE2GIVE, 2022).

Since the climatic and seasonal conditions in New Zealand differ substantially from those in Central Europe and the United States where much of the existing experience with cover crops for vegetable direct planting has been gained, the aim is to complement this trial with an experiment investigating how different sowing dates will influence the flowering time and dry matter yield of cereal-based cover crops with the addition of leguminous plants. The aim is also to discover the climatic potential at our trial site in Palmerston North (Manawatu) for achieving maximum biomass yields for a range of termination dates between the beginning of November and the end of April to maximise the number of possible vegetable transplanting dates with less mulch transfer involved. This booklet summarises the activities and results of the first year of this experiment.

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List of Abbreviations

C/N ratio	Carbon to nitrogen ratio
DM	Dry matter
GCCS	Green Chop Cereal Silage
ha	Hectare
Jap:	Japanese
kg	Kilogram
m^2	Square meter
N	Nitrogen
t	Metric ton
WCCS	Whole Crop Cereal Silage

Table of Figures

1 Introduction

This cover crop experiment was designed to be a precursor to generate knowledge and experience relating to mulch direct planting of vegetable crops in New Zealand conditions and is therefore a simple head-to-head comparison of different mixtures, seeding dates, and termination dates without a randomised and replicated trial design. The outcomes will be shared with other growers or consultants and can serve as a preparation for other on-farm trials or for scientific research.

The cereal-based cover crops in this experiment were grown within our vegetable rotation. For this reason, crop and mulch residues with their associated nutrient content that were left behind by preceding crops, provided adequate levels of fertility. Like catch crops, the cover crops in this experiment were therefore grown without any additional fertiliser inputs. If grown under different circumstances, best practice for forage crops must be applied to reach optimum yields.

2 Overview of Cover Crop Mixes and Timing

The following table shows the forage cereal types and cultivars that were used for the cover crop mixes. In brackets behind the cultivar name is the approximate stage in which the cover crop was terminated and analysed. On the right side are the actual sowing dates and termination dates.

The forage cereals were combined with faba beans and crimson clover (see percentages below). The April-sown cover crop was an extremely dense, pure faba bean stand which was not originally intended to be part of this experiment but was later included because of the interesting results.

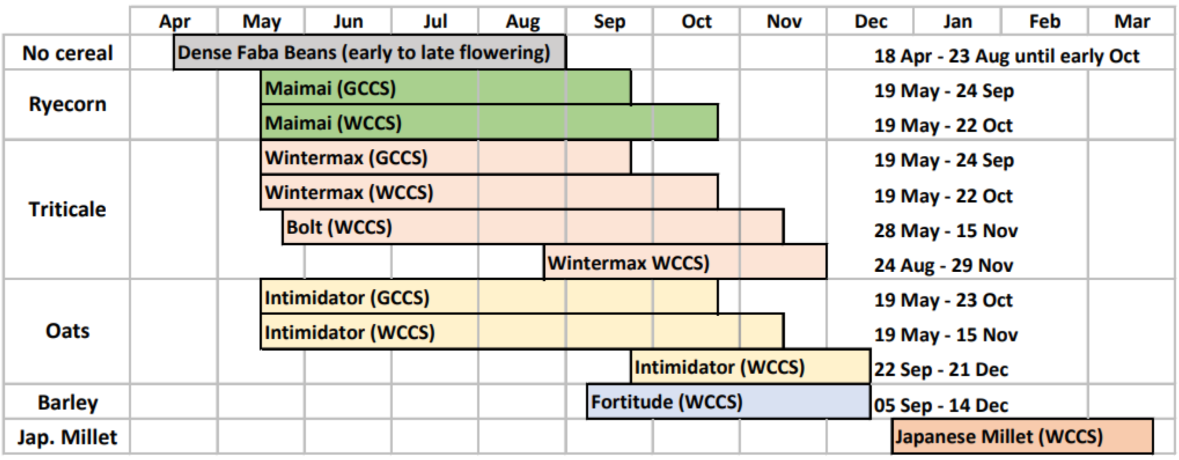

Figure 1 Forage cereals and cultivar names used for this experiment with sowing dates, termination dates and cereal stage at the time of termination. Illustration: Tobias Euerl (2024)

The composition of the seed mixes and the sowing rates are shown in the table below:

Cereal	Composition of the seed mix incl. percentage (based on seed weight)	Seed rate
	Faba bean (100 %)	1,000 kg/ha
Triticale	Triticale (45 %), Faba bean (53 %), Crimson clover (2 %)	180 kg/ha
Ryecorn	Ryecorn (45 %), Faba bean (53 %), Crimson clover (2 %)	180 kg/ha
Oats	Oats (45 %), Faba bean (53 %), Crimson clover (2 %)	220 kg/ha
Barley	Barley (45 %), Faba bean (53 %), Crimson clover (2 %)	220 kg/ha
Millet	Jap. millet (60 %), Common vetch (24 %), Flaxseed (12 %), sunflower (4 %)	41.5 kg/ha

3 Experiment Report for 2023

3.1 Autumn Sowing (April 2023)

We’re starting out with an exception to the rule because the April-sown cover crop did not contain a forage cereal component. It was only faba beans, sown at the extremely high rate of 1,000 kg/ha. The idea was born because by August, when early spring planting of vegetable crops begins, forage cereals have a strong tendency to re-grow when terminated mechanically and do not yield ideal levels of biomass at this time. This is where faba beans have a great potential as the grow vigorously during the winter and are easy to terminate at the same time.

Figure 2 Pure faba beans drilled on 18 April 2023 at the rate of 1,000 kg/ha. Images: Tobias Euerl (2023)

For larger scale applications we would consider different equipment as the seed drill hired for this experiment required five passes to drill the high seed rate.

Figure 3 Young faba bean stand, 18 days after seeding on 06 May (left) and spade sample with the same crop on 01 June 2023 (right). Images: Tobias Euerl (2023)

Figure 4 Faba bean stand, 80 days after seeding on 07 July (left) and on 04 August, after 108 days (right). Images: Tobias Euerl (2023) and Gosia Euerl (2023)

Figure 5 Termination of the cover crop on 17 September using a flail mower (switched off) as a roller (left) and the result (right). Images: Tobias Euerl (2023)

On 04 August, 108 days after seeding, the first flowers were visible on individual plants. We began terminating the stand for vegetable transplanting on 23 August (after 127 days) and continued rolling the beans successively as needed until early October. At that point the plants were in the late stage of flowering with several pods developed on the lower stems. There were no issues with volunteer beans in the following broccoli crop.

Since this cover crop was not originally intended to be part of the experiment, we do not have any test results for carbon and nitrogen content, C/N ratio or dry matter yield.

3.1.1 Conclusions

Here is a summary of pros and cons derived from our experiences so far:

Positives

+ Vigorous growth of biomass during winter under our climatic conditions.

+ Easy to terminate mechanically even without crimp roller if topped up with an additional thin layer of mulch.

+ Flexible termination dates from early to late flowering (approx. 6 weeks).

+ Possibility of early no-till planting which other cover crops cannot provide at this time of year.

+ Provides ground cover and weed suppression for a long time.

+ Considerable nitrogen fixation in a short time. Too early termination must be avoided to prevent nutrient losses and it should be followed by vegetable crops with high nitrogen demand.

+ Minimal or no need of commercial nitrogen fertilisers for the following vegetable crop

+ Tolerant of a wide range of soil types and even some compaction.

Negatives

- Seed very expensive, especially at the high seeding rate of 1,000 kg/ha.

- Requires seed drills that can handle high seed rates or else multiple passes.

- Low biodiversity below and above ground, probably more prone to plant diseases.

- The positive effect on the soil structure is noticeably inferior to other winter cover crops with a cereal component.

We topped up the faba bean cover with a thin layer of millet silage and produced a great broccoli crop. The stalks of the faba beans were still noticeable at the time of harvest. Despite a high pressure of spurrey on this plot, there was nearly complete suppression of weeds from seed. Some dock which was present before establishing the cover crop grew back through the mulch and was removed by hand around two weeks before the broccoli harvest.

Figure 6 Topping up with millet silage (left), area ready for transplanting (centre) and broccoli crop at harvest from this plot (right). Images: Tobias Euerl (2023)

3.2 Autumn Sowing (May 2023)

In May we sowed seven variants for this experiment. The month was wet in Palmerston North (121 mm rainfall). This meant there were only a few short time windows for soil preparation and sowing. We managed to seed six of the seven variants on 19 May but decided to broadcast the seed by hand since the conditions were not dry enough to operate a seed drill. All these plots developed very well. Triticale Bolt had to be delayed until 28 May and struggled at the beginning but outperformed the other triticale variants at its later time of harvest.

Plot sizes were approximately 300 m^2.

Figure 7 Broadcasting cover crop seed by hand, incorporating with a rototiller and finished plots. Image left: Gosia Euerl (2023), Images centre and right: Tobias Euerl (2023)

Triticale Wintermax T100 and Oats Intimidator showed a rapid early development and increase in height with minimal tillering whereas Triticale Bolt and Ryecorn Maimai were lower in height but grew more tillers. A later assessment on 17 August 2023, 90 days after seeding, showed an average of three tillers per plant for Wintermax T100 and Intimidator and an average of 12 tillers per plant for Maimai.

Figure 8 Cover crop mixes side by side on 25 June 2023, 37 days after seeding: Triticale Wintermax T100 (left) and ryecorn Maimai (right). Image: Tobias Euerl (2023)

Figure 9 (left) The same perspective as Figure 8 showing Triticale Wintermax T100 (left) and ryecorn Maimai (right) 70 days after seeding on 28 July 2023. Images: Tobias Euerl (2023)

Figure 10 (right): Oats Intimidator, identical seeding date, also on 28 July 2023. Image: Tobias Euerl (2023)

Figure 11 Poor stand of Triticale Bolt mix (sown 28 May) on 7 July (left) and 13 August (right) with significant weed competition, predominantly spurrey. This crop outperformed the other triticale variants at the time of its termination mid-November. Images: Tobias Euerl (2023)

On 24 September, 128 days after seeding, the timing of both Triticale Wintermax T100 and Ryecorn Maimai was almost identical with their ears having just emerged. Ryecorn had now overtaken triticale in height, but dry matter yield was higher for Wintermax T100 (see table with yield summaries below).

Intimidator Oats took longer and were still in the booting stage (approx. GS45).

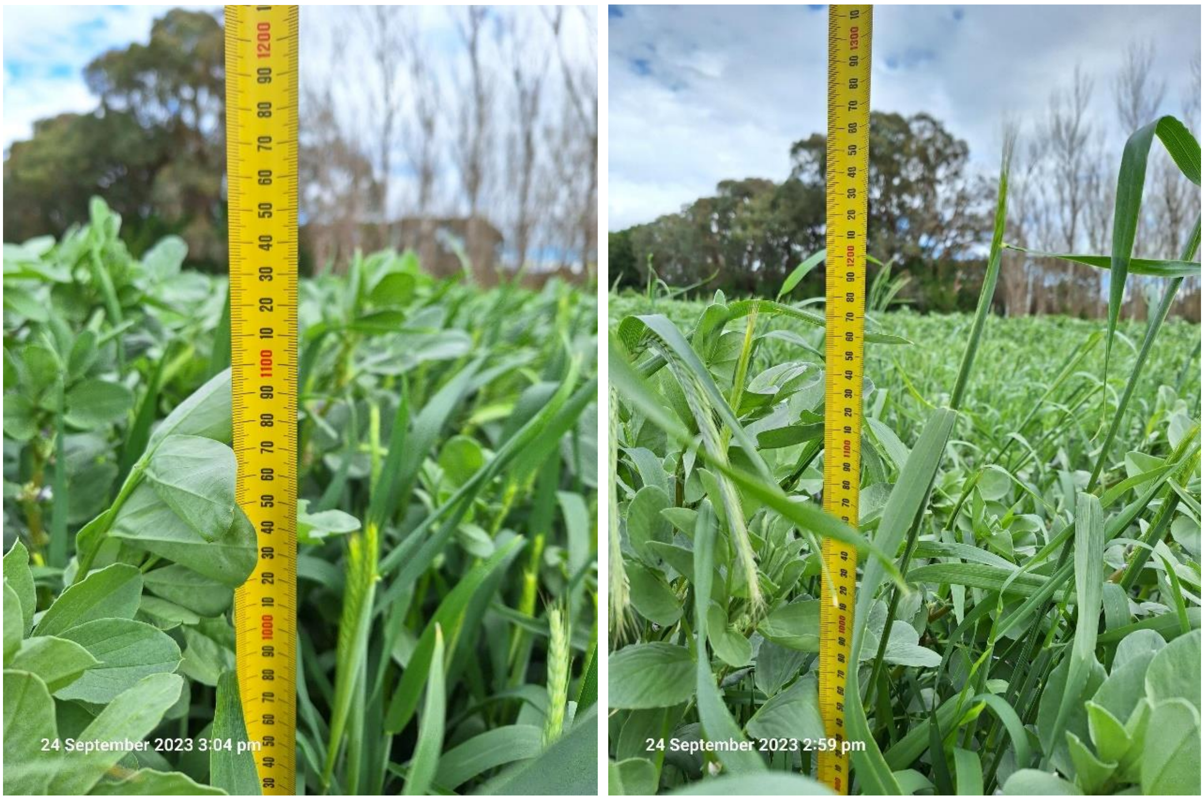

Figure 12 Triticale Wintermax T100 (left) and Ryecorn Maimai (right) after ear emergence on 24 September 2023. Images: Tobias Euerl (2023)

Figure 13 Oats Intimidator stand still in booting stage on 24 September 2023 and sliced flag leaf sheath (right). Images: Tobias Euerl (2023)

Figure 14 Triticale Wintermax T100 (left) and Ryecorn Maimai (right) side by side on 14 October (after 148 days) shortly before anthesis. Ryecorn grew noticeably higher but with a slightly lower DM yield. Image: Tobias Euerl (2023)

The late boot stage or early ear emergence of the forage cereal is when terminating these cover crops for the purpose of in-situ mulch first makes sense. At this early point (approx. the timing for green chop cereal silage GCCS), the mulch material will release nitrogen to the vegetable crop more quickly, but the stand will have a stronger tendency to grow back. For this reason, top-up mulch (to reach a total of 15-18 t DM/ha) is required to suppress cereal re-growth in herbicide-free systems.

Maximum dry matter yields and a wider C/N ratio will be obtained when the cover crops are terminated during complete anthesis of the cereal component. The crop will then not re-grow after mowing.

With the may-sown mixes, the cereals reached full anthesis in the following sequence:

1) Triticale Wintermax T100 and Ryecorn Maimai simultaneously around 22 October 2023
2) Triticale Bolt and Oats Intimidator simultaneously around 15 November 2023

The oats were moderately affected by crown rust, but had the highest yield of almost 14 t DM/ha nevertheless.

Figure 15 Triticale Wintermax T100 (left) and Ryecorn Maimai (right) on 20 October (after 154 days) during anthesis. Images: Tobias Euerl (2023)

Figure 16 Oats Intimidator (left) with moderate signs of crown rust and Triticale Bolt (right) on 15 November (after 180 days) during anthesis. Images: Tobias Euerl (2023)

3.2.1 Results and Conclusions

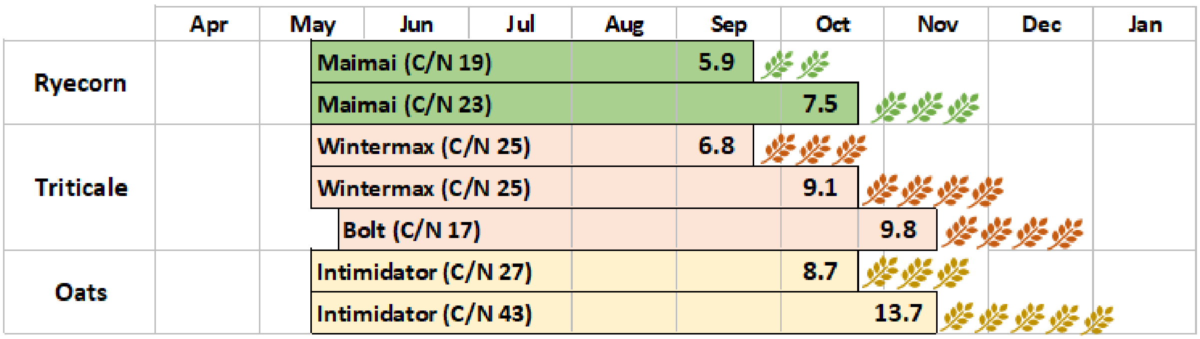

Figure 17 Timing of May-sown mixes with dry matter yields in t/ha, C/N ratio at the time of termination and visual illustration of yield range. Illustration: Tobias Euerl (2024)

From the measurements and observations during the first year of this experiment we can draw the following conclusions:

- Triticale Wintermax and Oats intimidator scored highly with their rapid early development during winter. For several weeks, their growth was ahead of other cultivars.
- Triticale Bolt initially had a slower development but grew more tillers and had a slightly higher yield at anthesis despite imperfect seeding and high weed pressure.
- Triticale Wintermax and Ryecorn Maimai kept to an almost identical timeline. Even though shorter, Wintermax yielded higher, and we imagine it to be less prone to lodging under rougher weather conditions.
- Oats Intimidator ...
    - Reached the highest dry matter yield.
    - Are ideal for later transplanting dates when drilled at the same time in autumn.
    - Were moderately affected by crown rust but without concern in terms of yield.

For the 2024 experiment we seeded Triticale Wintermax T100, Ryecorn Maimai and Oats Intimidator in April and are looking forward to the new results.

3.3 Spring Sowing (August 2023)

Triticale Wintermax T100 is also recommended for early spring sowing (until the end of August). The identical mix as in autumn was sown on 24 August 2023 at a rate of 180 kg/ha.

Figure 18 Spring-sown triticale mix, after 36 days on 29 September 2023. Images: Tobias Euerl (2023)

Figure 19 The same triticale stand, after 57 days on 20 October 2023. Images: Tobias Euerl (2023)

The triticale reached anthesis after 97 days, on 29 November 2023 when samples were taken and sent off for analysis. The C/N ratio of the spring-sown crop was 22:1 and was narrower than the autumn-sown crop with 25:1 at the same stage of development.

Figure 20 Spring-sown Triticale Wintermax, 84 days after sowing with emerged heads on 16 November 2023. Images: Tobias Euerl (2023)

Figure 21 The same stand after 97 days during anthesis on 29 November 2023. Images: Tobias Euerl (2023)

3.3.1 Results and Conclusions

The spring-sown triticale variant yielded 8.7 t DM/ha at anthesis which is below the level of the autumn-sown crop (9.1 t/ha). Considering that the crop development was 57 days shorter with spring sowing, this option is still of great interest, especially after vegetables that are harvested during winter. A following triticale mix (which can be sown all throughout July and August) has a convincing potential to make use of excess nitrogen and water and converted them into biomass, providing ground cover and nutrient release once it is needed for another vegetable crop (transplanting dates around late November).

3.4 Spring Sowing (September 2023)

Oats and Barley can be sown later into spring than is recommended for triticale and ryecorn.

We sowed barley (cv Fortitude) on 05 September 2023 and oats (cv Intimidator) on 22 September 2023, both at a rate of 220 kg/ha (complete mix with legumes; see details under item 2).

Figure 22 Spring-sown barley mix 19 days after seeding (left) and spring-sown oats 22 days after seeding (right). Images: Tobias Euerl (2023)

Figure 23 Barley mix after 100 days (left) and Oats mix after 90 days (right) at the time of termination. Images: Tobias Euerl (2023)

3.4.1 Results and conclusions

When assessing the growth stage and ideal termination date for forage barley, it important to consider that in barley, unlike other cereals, pollination usually occurs just before or during head emergence (The State of Victoria, 2009). In this experiment the barley crop was terminated too late and would have resulted in a barley weed problem if used for mulch direct planting. The ideal termination date would have been around 87 days after seeding on 1 December.

This makes spring-sown barley mixes an interesting option to generate a reasonable amount of biomass within the shortest period possible. The yield of 7.1 t DM/ha seems acceptable for this setting.

With the spring-sown oats, the yield of 4.8 t/ha was rather disappointing, especially when compared to the autumn-sown variant (almost 14 t/ha). Here, the location may have played a role with lower fertility levels and an oat cover crop growing there only 1 year before, resulting in the spring-sown stand being more rust-affected.

We will certainly continue to use spring-sown oat mixes, given the much greater yield potential and rapid growth at this time of year.

3.5 Summer Sowing (December 2023)

For cover crops during the hottest part of summer, C4 plants are favourable as the basis of the mix, especially when irrigation is restricted or not possible. We know of excellent results with sorghum x sudan grass hybrids but are currently unable to source untreated seed which excludes this option for organic operations.

We used Japanese millet as an alternative option sown on 22 December 2023 for the purpose of this experiment.

Figure 24 Millet mix after 7 days (left) and after 28 days (right). Images: Tobias Euerl (2023/2024)

Figure 25 Millet mix after 74 days on 5 March 2024. Images: Tobias Euerl (2023/2024)

3.5.1 Results and conclusion

Unfortunately, the Japanese millet in this experiment was not suited for organic no-till planting as maturity was not reached homogenously across the crop. While some plants with a slower development would have had a strong tendency to re-grow after mowing, the more advanced plants would have been likely to produced viable seed after termination, leading to a volunteer millet ‘weed problem’ among the subsequent vegetables. However, the fresh matter yield of 59.9 t/ha after 74 days is promising and suggests approx. 15 t DM/ha with an estimated dry matter percentage of 25 %.

Other than for in-situ planting, the material is great for making silage as a welcome resource for top-up mulch in spring.

We will continue to experiment with summer mixes for direct planting next summer.

4 Summary and Useful Hints

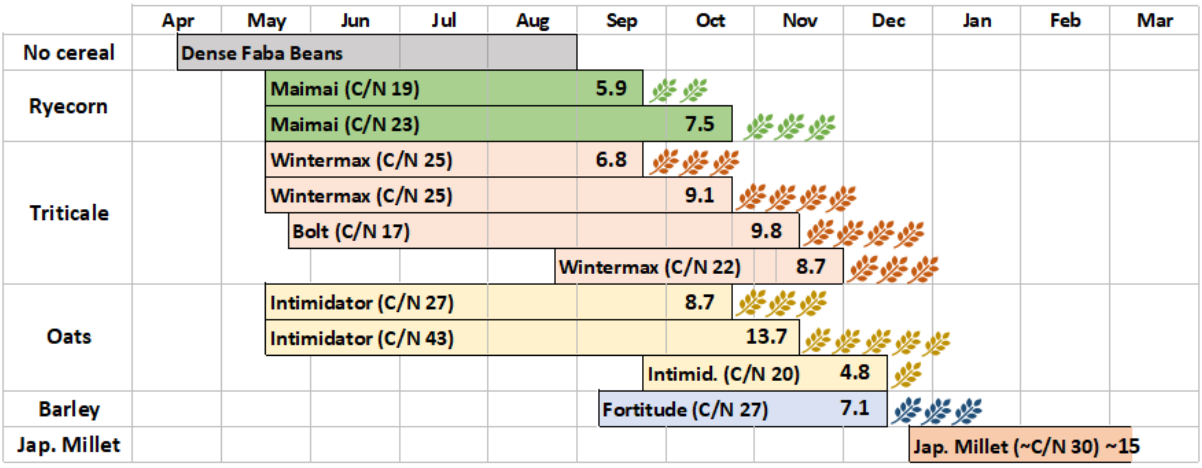

Figure 26 Overview of the cover crop mixes for the 2023 experiment with C/N ratio behind the cultivar name and dry matter yield in t/ha on the right end of the bars. Illustration: Tobias Euerl (2024)

Autumn-sown mixes yielded more biomass than spring-sown mixes at the same stage of development. However, the drastically shorter growing period makes spring sowing a very interesting option, enabling growers to use the land for vegetables over winter.

Besides the summer mix, Intimidator oats reached the highest dry matter yield. Seed mixes based on this cultivar, if grown under favourable conditions, could enable vegetable transplanting at the beginning of November without handling transfer mulch. The susceptibility to crown rust (puccinia coronata f. sp. avenae) should be kept in mind with breaks of 3-4 years suggested between oats in organic farming.

4.1 Management example

Here is an exemplary cover crop plan for continuous vegetable direct planting in spring:

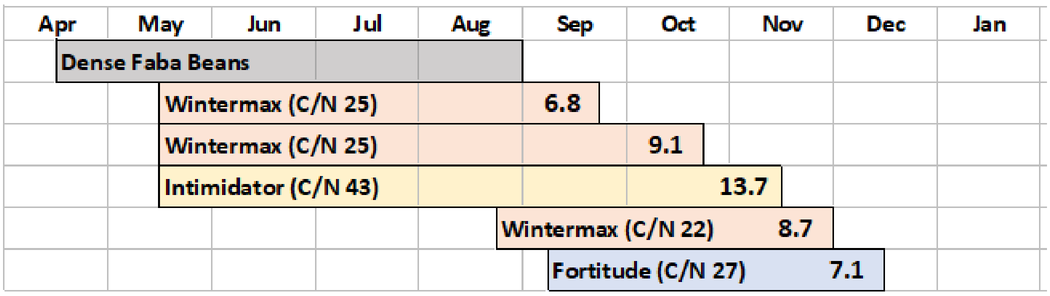

Figure 27 Four sowing dates can potentially enable continuous mulch direct planting from late August to mid-December. Illustration: Tobias Euerl (2024)

Seasonal and climatic variations can cause changes in this schedule, but the experiences gained during this experiment show how the different cultivars relate to each other regarding their timing.

4.2 Getting the timing for termination right

Knowing when to terminate a cover crop is crucial for herbicide-free mulch direct planting. Cutting the cereal component very early (before anthesis) means lower biomass yields and an increased risk of re-growth, implying the need of thick mulch layers for suppression, while cutting too late (some kernels in milk or dough stage) can lead to the emergence of volunteer cereal plants as a weed in the following vegetable crop.

Considering the different factors, earlier mowing (e.g. in boot stage) can be deliberately chosen in combination with an evenly spread mulch layer of 15+ t DM/ha which will generally suppress cereal re-growth but would not keep viable cereal seed from emerging.

Anthesis is easy to determine for ryecorn and triticale due to their clearly visible anthers (see figure 48) but requires more attention for oats (anthers are generally covered) and barley (anthesis taking place just before or during ear emergence).

Figure 28 Ryecorn ears with visible anthers. This stage enables mechanical termination. Image: Johannes Storch (2023)

Figure 29 Forage triticale germinating from a seedhead that was mown too late and produced viable seeds in a mulch layer. This crop was mown approx. two weeks after anthesis. Image: Tobias Euerl (2023)

4.3 Sowing Equipment for mulch systems

Sowing cover crops with minimal soil disturbance in a vegetable crop rotation can be challenging because of crop and mulch residues that are left behind after harvest. At this point cover crops are needed to take up excessive nutrients, protect soil structure with their roots and create cover above ground.

Our farm in Palmerston North has ordered a MulchTec-RotoSeeder which is scheduled to arrive in September 2024 to be available for the next year of this cover crop experiment. This mulch-till seeder places cover crop seed below mulch layers and harvest residues. It cuts into the soil at a shallow depth using precise height guidance. Any existing residues are lifted by the cutter head, exposing a seed layer with contact to capillary groundwater where the seeds are place before the material from the tillage stream (mixture of soil and mulch) covers them again (see figure 50 and 51 below).

Figure 30 Functionality of MulchTec-RotoSeeder (left) and seeder bar with cover crop seed (right). Illustration: MulchTec, Germany (2023) and Johannes Storch (2023)

Figure 31 MulchTec-RotoSeeder used to sow a winter cover crop with minimal soil disturbance after mowing cabbage residues. Image: Johannes Storch (2023)

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