Report
Demo-trials: Undersowing in celeriac and white cabbage 2025

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Research conducted within the framework of the EIP operational group "Groen-te-len: Green manures in organic vegetable cultivation", with financial support from the Agency for Agriculture and Sea Fisheries and the European Union.

Trial OO_BIO25SEK_TT01 and OO_BIO25WIK_TT01
Cluster Organic production

ondernemen in west-vlaanderen

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ONDERZOEK & ADVIES IN LAND- & TUINBOUW

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2. Objective

Plants nourish the soil (life) through their root exudates. Diverse vegetation (crops, green manure, etc.) is therefore important. This is one of the principles of *Regenerative Organic Agriculture*. With the EIP project "Groen-te-len" (Green cultivation), we want to develop practical tools for applying this concept in an intensive organic vegetable growing system. To this end, two innovative and participatory processes are being developed:

- Undersowing of (diverse) green manure crops in vegetables.
- Keeping the paths/tractor tracks green through the year.

Through a combination of on-farm trials by the participating practical farms (10 CSA growers) and a number of practical demonstrative trials at Inagro, we want to conduct participatory research into which cover crops can lead to a successful approach under which conditions in which vegetables, so that the soil is covered as much and as diversely as possible with a minimal impact on crop development and yield. In this report, we present the results of the supporting Inagro demo trials from 2025.

We investigated the timing of undersowing and the choice of cover crop (pure/mixture). How does the cover crop grow and what is its impact on the crop, which species are abundant in the mixtures, and how much competition does the cover crop provide for weeds?

3. Trial design and crop management

No fewer than 18 cover crops were selected for testing in undersowing (table 1)! Ten mixtures were tried alongside eight mainly leguminous species in pure cultivation. Two of the mixtures were specially composed by the seed company Neutkens for the project (nr. 1 and 2). The sowing rate was chosen on the advice of the supplier. No undersowing was the reference.

The sowing times (table 2 and 3) were chosen on the basis of some preliminary exploratory tests with growers, taking into account crop development and choices regarding mechanical weed control. All cover crops were sown at two different times in both the celeriac and white cabbage fields. No parallel plots were established. The trial plots have been organic for several years. Soil management is reduced till and cultivation is according to controlled traffic farming (3m wide plant beds). The soil texture is sandy loam.

2025 was an exceptionally dry year with a precipitation deficit. August in particular was very dry (figure 1), which generally hampered the undersowing technique. Irrigation is common practice in vegetables in our region, this helped the germination and growth of the cover crops.

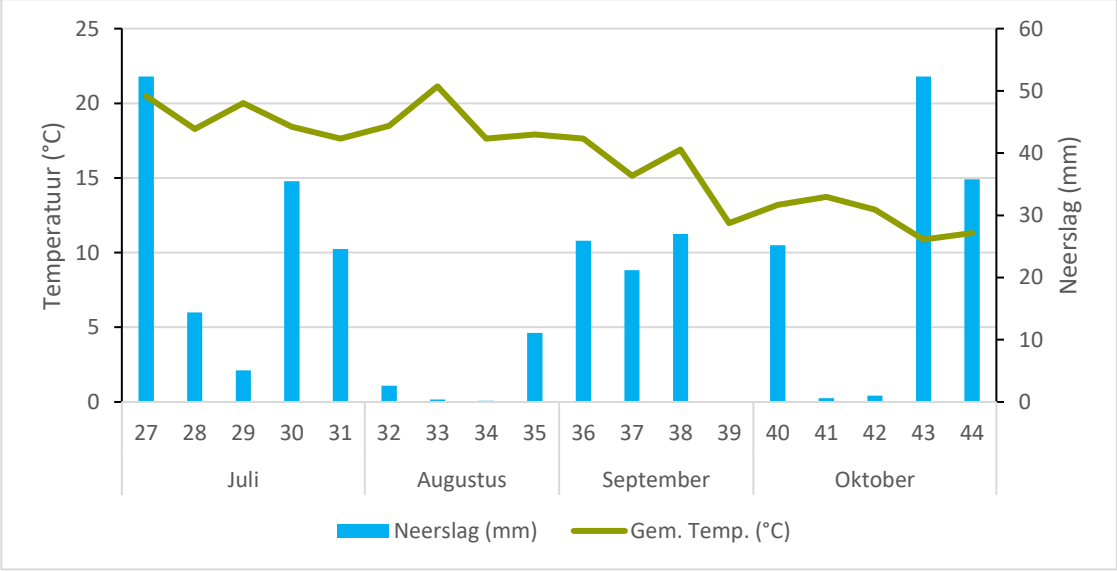


Figure 1: Average temperature and precipitation sum per week from the first undersowing until crop harvest

Table 1: Sowing dose, type of cover crop and composition of the cover crop mixes

Nr.		Sowing dose (kg/ha)	Cover crop
1	Mixtures from Neutkens (NL)	27,5	**Winter-hardy "Groen telen project":** *Fescue grass, Subterranean clover, Crimson clover, Purple vetch, Serradella, Flax*
2		16,5	**Frost-sensitive "Groen telen project":** *Spring oat, Buckwheat, Phacelia, Flax, Spring vetch, Serradella*
3		25	**Neutkens/Naturim winter-hardy mix:** *Fescue grass, Subterranean clover, Purple vetch, Hop clover, Strawberry clover, Narrowleaf plantain, Yarrow, Small burnet*
4		11	**White clover mix:** *Additionally- Flax, Winter vetch, Purple vetch, Camelina, Strawberry clover, Subterranean clover, Bird's-foot trefoil, Hop clover*
5		10	**Red clover mix:** *Additionally- White clover, Winter vetch, Purple vetch, Bird's-foot trefoil, Hop clover*
6		12	**Optima Food Forest:** *Chicory, Yarrow, Yellow chamomile, Micro-clover, Narrowleaf plantain, Hedge bedstraw, Wild carrot*
7	Mixtures from Camena (D)	12,5	**Green Carbon Fix:** *Perennial ryegrass, Timothy grass, White clover, Crimson clover, Camelina, Phacelia, Coriander*
8		25	**Glöz 8:** *White clover, Red fescue*
9		5	**Extensiver Getreideanbau:** *White clover, Hop clover, Bird's-foot trefoil, Marigold*
10		14	**Untersaat 10:** *White clover, Perennial ryegrass*
11	Pure cropping	15	**Micro-clover (type of white clover)**
12		15	**Hybrid clover**
13		20	**Subterranean clover**
14		12	**Crimson clover**
15		25	**Serradella**
16		40	**Flax**
17		25	**Red fescue**
18		6	**Phacelia**
19	-	-	**Reference (no undersowing)**

Tabel 2: Crop management of the Celeriac trial

Previous crop	
2024	Winter leek
Soil cultivation	
10, 18, 26/03/2025	Shallow cultivation with precision cultivator
28/03/2025	Incorporation of cattle manure using precision cultivator
4, 25/04 en 09/05/2025	Shallow cultivation with precision cultivator
14/05/2025	Subsoiling (Dent Michel) combined with rotary harrow
Fertilisation	
25/03/2025	400 kg/ha Calci-S – 39% Ca, 56% SO_3
28/03/2025	25 ton/ha organic cattle manure
29/03/2025	333 kg/ha Patentkali - 30% K_20, 10% MgO en 42% SO_3
15/05/2025	Greencircle: 30 kg N/ha at planting
Sowing/planting	
14/05/2025	Planting celeriac (cv. Markiz, density: 70 x 32 cm).
4/08/2025	First undersowing of the cover crop (Celeriac BBCH 43; estimation)
2/09/2025	Second undersowing of cover crop (Celeriac BBCH 47; estimation)
Weed management	
26/05 en 02/06/2025	Harrowing
12/06/2025	Harrowing (2x)
19/06/2025	Harrowing
24/06/2025	Hoeing with small blades, torsion weeders and harrow elements
2, 10, 14/07/2025	Harrowing
25 en 29/07/2025	Hoeing with small blades, torsion weeders and harrow elements
04/08/2025	Harrowing and incorporating the cover crop seeds
12/08/2025	Harrowing where no cover crop is present
02/09/2025	Hoeing with small blades and torsion weeders before sowing
Irrigation	
18 en 22/08	Each time: 30 l/m²

Table 3: Crop management of the White cabbage trial

Previous crop	
2024	Spring wheat, followed by green manure: optima non brassica
Soil preparation	
14/03/2025	Clapping the cover crop remains
07/04/2025	Incorporating cattle manure using the precision cultivator
25/04 en 09/05/2025	Shallow cultivation with precision cultivator
22/05/2025	Subsoiling (*Dent Michel*) combined with the rotary harrow
Fertilisation	
24/03/2025	400 kg/ha Calci-S – 39% Ca, 56% SO_3
29/03/2025	333 kg/ha Patentkali - 30% K_20, 10% MgO en 42% SO_3
05/04/2025	30 ton/ha organic cattle manure
22/05/2025	Greencircle 50 kg N/ha at planting
09 en 16/07/2025	Spraying Molytrac (0,25 l/ha, Mo 153 g/l) en Epso microtop (5 kg/ha, MgO 15%, SO_3 31%)
30/09/2025	Epso microtop (5 kg/ha, MgO 15%, SO_3 31%)
Sowing/planting	
22/05/2025	Planting white cabbage (cv. Expect F1, density: 70x35cm)
4/07/2025	1st undersowing of the cover crop (cabbage BBCH 17; estimation)
14/07/2025	2nd undersowing of the cover crop (cabbage BBCH 19; estimation)
Weed control	
01/05, 12/06/2025	Harrowing (2x)
19/06/2025	Light ridging with the hoe, manual removal of large weeds
01/07/2025	Ridging with the hoe
Crop protection	
22/05/2025	Pre-planting module drench treatment with Tracer (Spinosad; 0,012 l/1000 plants)
16/07/2025	Xentari (*Bacillus thuringiensis*, 1 kg/ha) against caterpillars
30/09/2025	Treatment with Tracer (Spinosad; 0,2 l/ha)
Irrigation	
20/08/2025	25 l/m^2

4. General outcomes/results

Irrigation combined with early sowing ensured successful development of the various cover crops undersown in celeriac

The growth of the majority of the cover crops was successful when sown **at the beginning of august** in celeriac that was planted on the 14th of May (on average 5,4 and 0,7 ton fresh and dry aboveground biomass/ha at celeriac harvest: 28/10; figure 2). Various plant species grew well without substantially hindering celeriac tuber formation, which had already begun. In addition, ground cover was often good. Weed pressure on the plot was generally low due to effective weed control (on average 435 kg/ha).

There was no inverse correlation between cover crop biomass and celeriac yield (on average 78 ton/ha, figure 8 in annex). Celeriac productivity ranged from 68 to 90 ton/ha. In some cases, it was lower when the cover crop biomass was higher. But certainly not in all cases. The same conclusion could be drawn between cover crop biomass and weed biomass.

The pure sown phacelia grew strongest (2,1 ton DM/ha; figure 3 and figure 8) followed by the *Green Carbon Fix* mix (1,2 ton DM/ha) and the pure sown Flax (on average 1,9 ton DM/ha). Phacelia and Flax are fast-growing, non-leguminous species. These probably benefited from good nitrogen availability on the field. Also the leguminous species developed well. As pure crop Crimson clover produced the largest biomass (0,9 ton DM/ha), followed by Subterranean clover (0,9 ton DM/ha) and Micro clover (0,65 ton/ha). Hybrid clover produced the smallest amount of the clover(-related) species (0,42 ton DM/ha). Another legume covered the ground well visually but grew some less biomass; Serradella (0,49 ton DM/ha).

The biomass of the mixtures was good but more limited (except *Green Carbon Fix*): it ranged from 0,18 ton DM/ha (*Neutkens/Naturim mix and Red clover mix*) to 0,52 ton DM/ha (*Frost-sensitive 'Groen telen project'* , *Optima Food Forest* and *Untersaat 10*). The mixes did show a nice variety of plant species. Various types had emerged well and developed well. Increasing the seed dose and adjusting the composition may further improve biomass production.

The image of different mixtures was largely dominated by white clover or Micro clover (*White clover mix*, *Optima Food Forest, Glöz 8, Extensiver Getreideanbau* and *Untersaat 10*). Also Subterranean clover (*Winter-hardy 'Groen Telen project' mix*, *Neutkens/Naturim mix* and *White clover mix*), Red clover (*Red clover mix*) and Crimson clover (*Winter-hardy 'Groen Telen project' mix*) took a prominent place in some mixtures.

The grasses also grew nicely among the other species in various mixtures. However, they remained limited in volume. The fescue grasses (*Winter-hardy mix -'Groen Telen project'*, *Neutkens/Naturim mix, Glöz 8, pure sown Red Fescue*) stayed more compact than the ryegrass (*Green Carbon Fix and Untersaat 10*), which was a bit more vigorous. The spring oats (*Frost-sensitive mix 'Groen Telen project'*) was the most vigorous grass.

Although not dominant, flax, buckwheat and serradella were nice additions to various mixtures, providing a lot of diversity. Also including vetch species added to the diversity and nitrogen fixation. Despite being spread throughout the mixture, there is a possibility that vetch species may begin to "wind" around individual plants in the crop if sowing occurs too early. This was not observed in these trials. In addition, various (wild) herbs were also sometimes present, and they are not commonly used as green manure. The *Optima Food Forest mix* was the richest in this respect. The question is whether this mix is suitable for undersowing, as certain herbs such as yellow chamomile and yarrow can also remain as "weeds" in vegetable rotations.

Late sowing in celereac, without harrowing the seeds into the soil, meant on average 95% less biomass and large differences in development between cover crops

When sown between the celeriac **at the beginning of September**, after one extra time harrowing and one extra time hoeing, the growth was much less successful and varying strong between the cover crops (on average 0,22 and 0,04 ton fresh and dry biomass/ha at celeriac harvest (28/10) or 96 and 94% less than when sown a month earlier; figure 2). But at the same time weed pressure on the plot was also generally low due to the extra weed control (on average 90 kg/ha or 79% less than without the extra time for mechanical weeding).

Due to the very moderate development, there was no correlation between the cover crop biomass and the celeriac yield (figure 9 in annex). There was also no correlation with the weed biomass.

Also at this later sowing point the pure sown phacelia grew strongest (0,07 ton DM/ha, figure 4 and figure 9) but more scattered. In contrast; now the clovers grew proportionally better than the other cover crops species: Micro clover and Crimson clover (0,066 ton DM/ha) and also subterranean clover performed relatively well (0.046 ton DM/ha). Although they did not produce the largest biomass, a large number of small plants covered the ground relatively well. The clovers played an important and leading role in the ability of the best mixes to cover the soil at harvest (White clover mix (0,032 ton DM/ha), *Red clover mix* (0,031 ton DM/ha), *Optima Food Forest* (0,043 ton DM/ha), *Glöz mix* (0,068 ton DM/ha) and *Untersaat 10* (0,051 ton DM/ha)). And also the grasses were clearly present in these mixes.

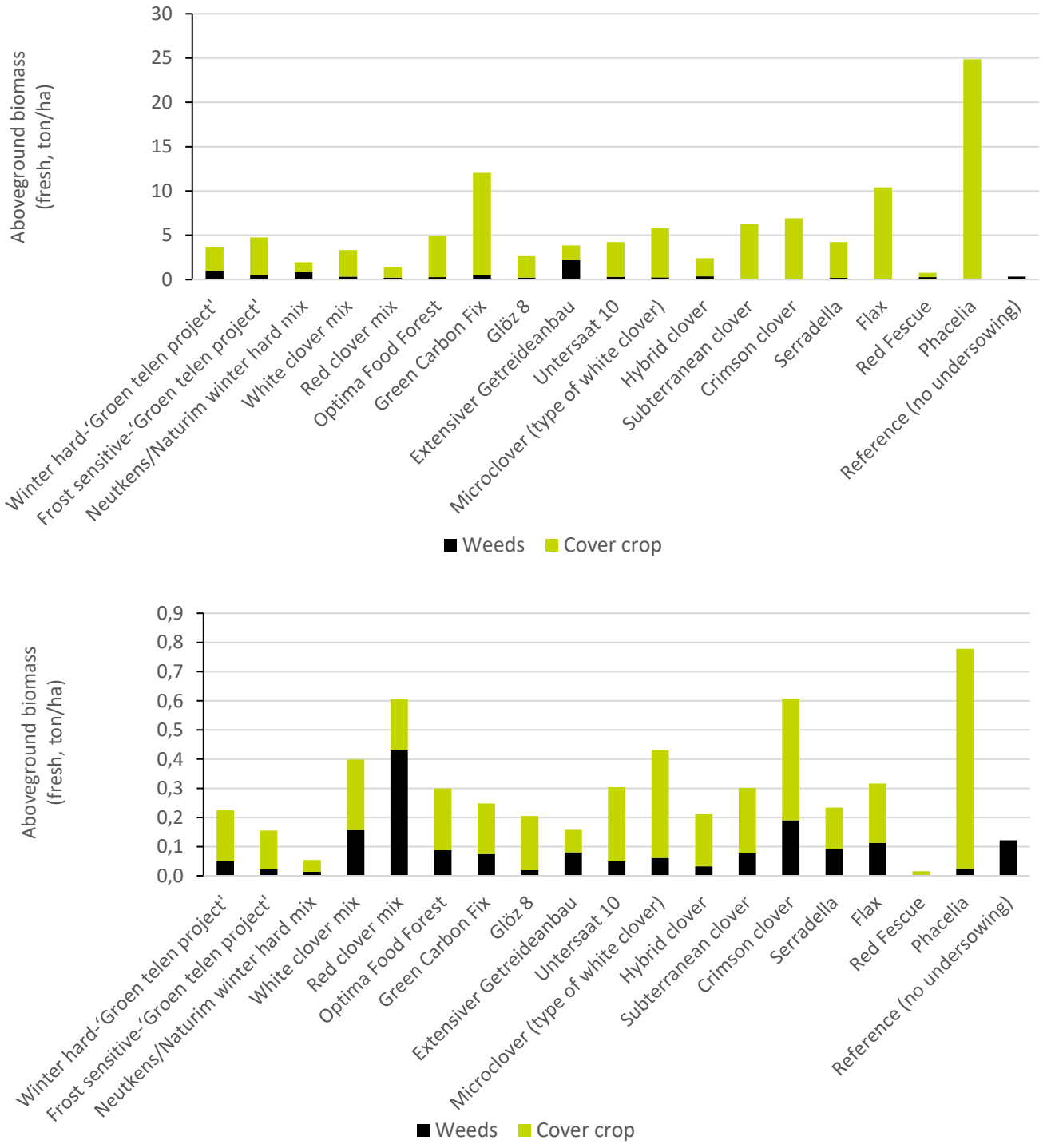


Figure 2: Aboveground fresh biomass (ton/ha) of the cover crops at Celeriac harvest in function of the sowing time. At the top: the first undersown cover crops (4th of August), below the last sown (2nd of September). Also the weed biomass is shown.

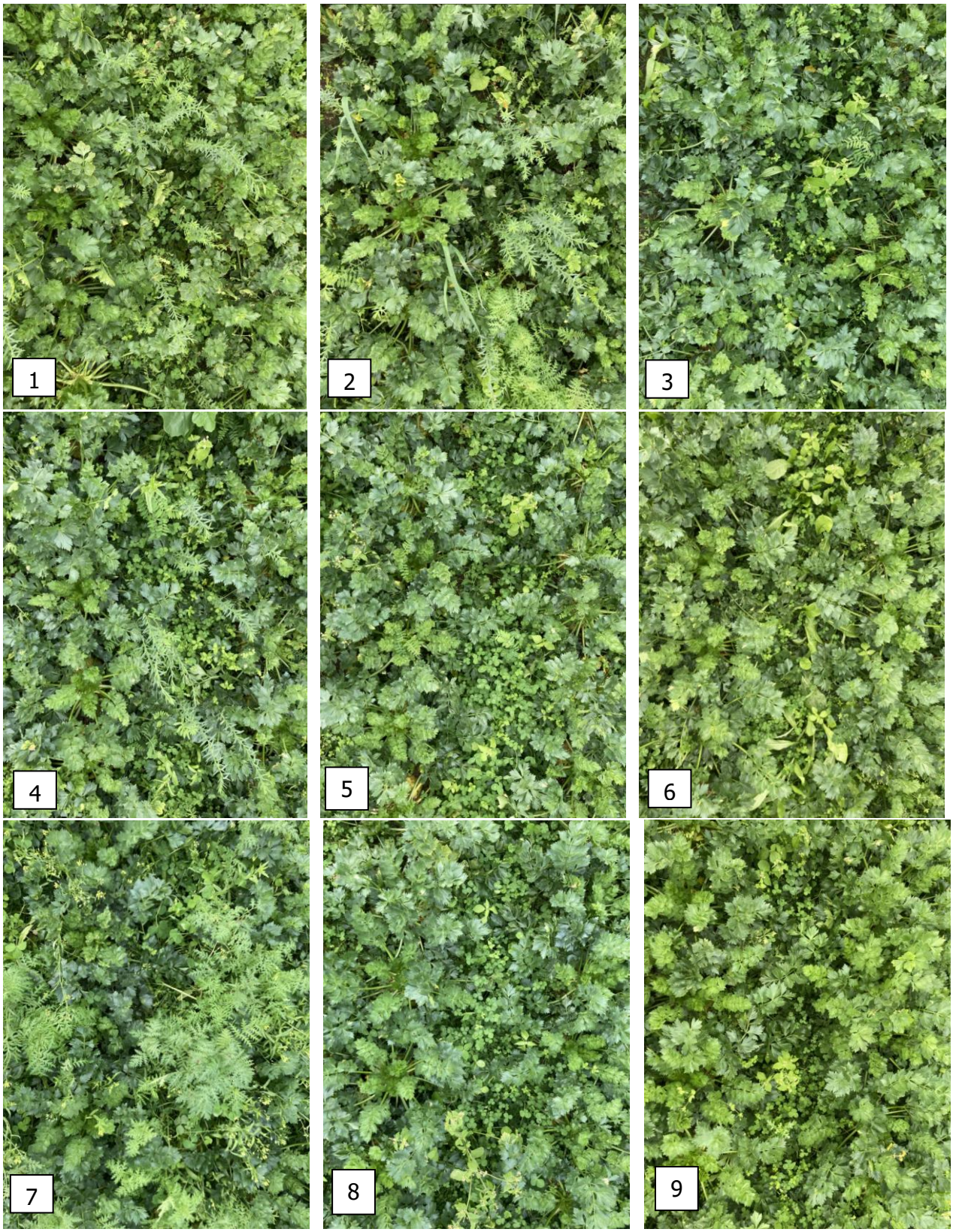
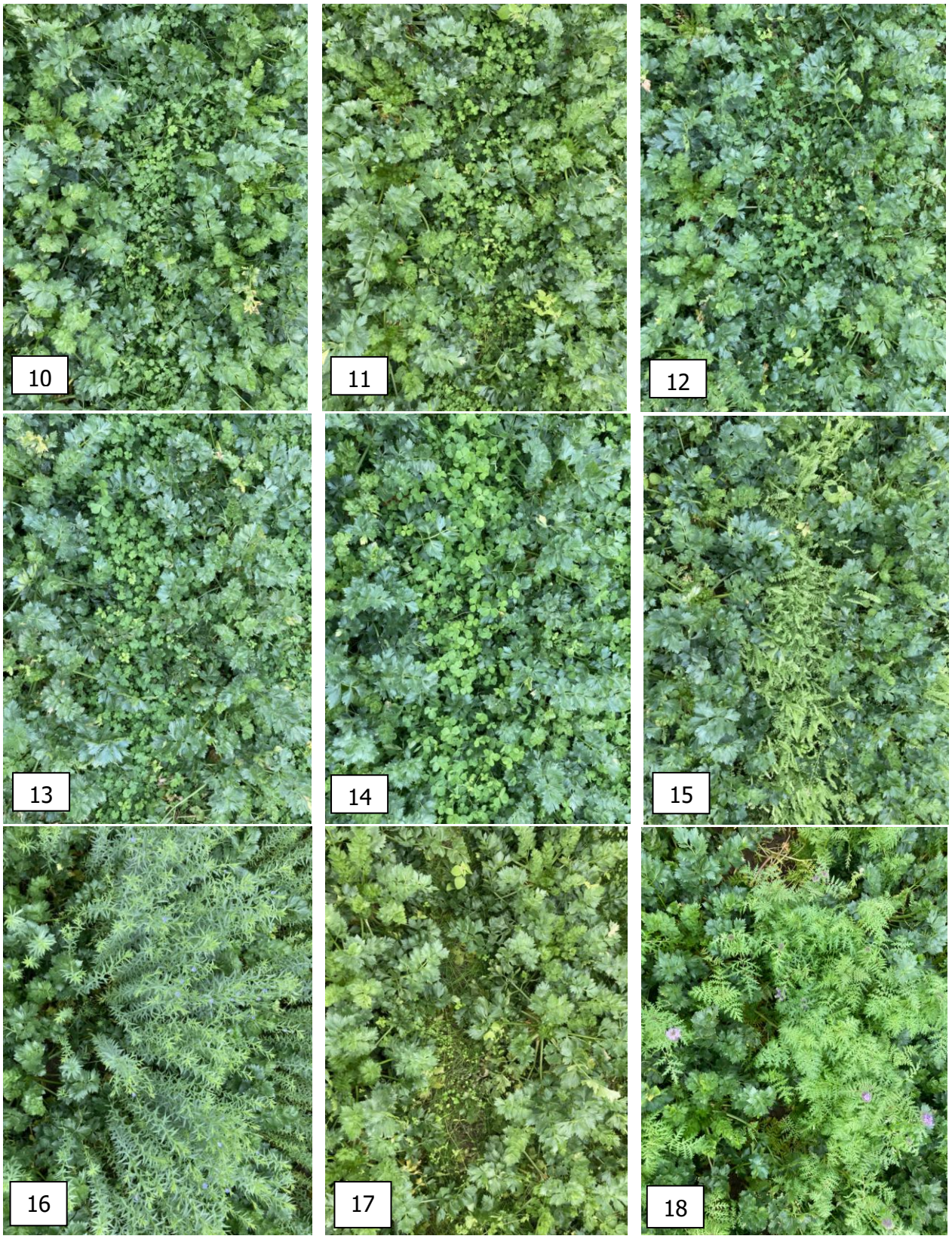


Figure 3: The various cover crops at the 28th of October. Sowing date= 4/08



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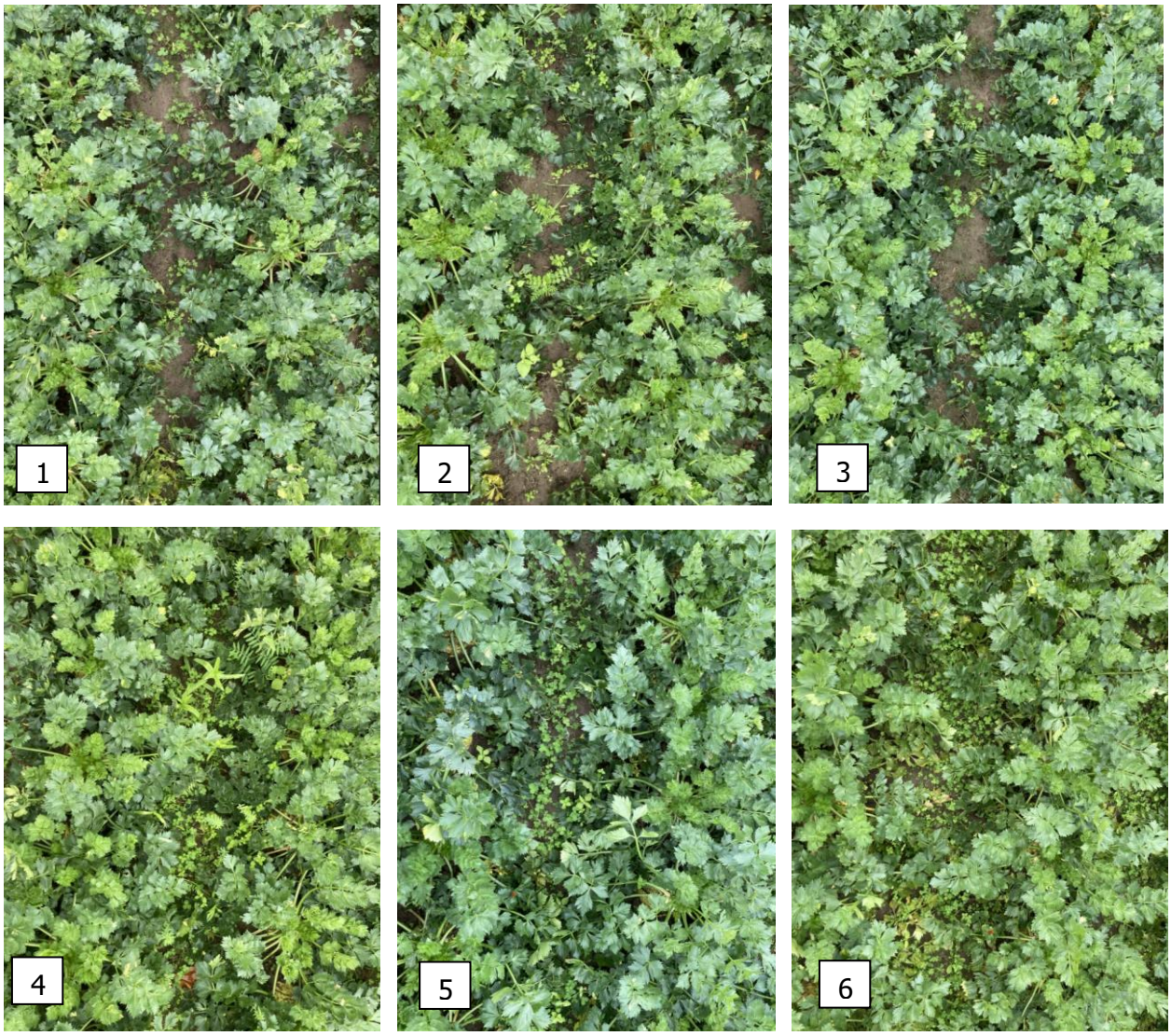

Figure 4: The various cover crops at the 28th of October. Sowing date= 2/09

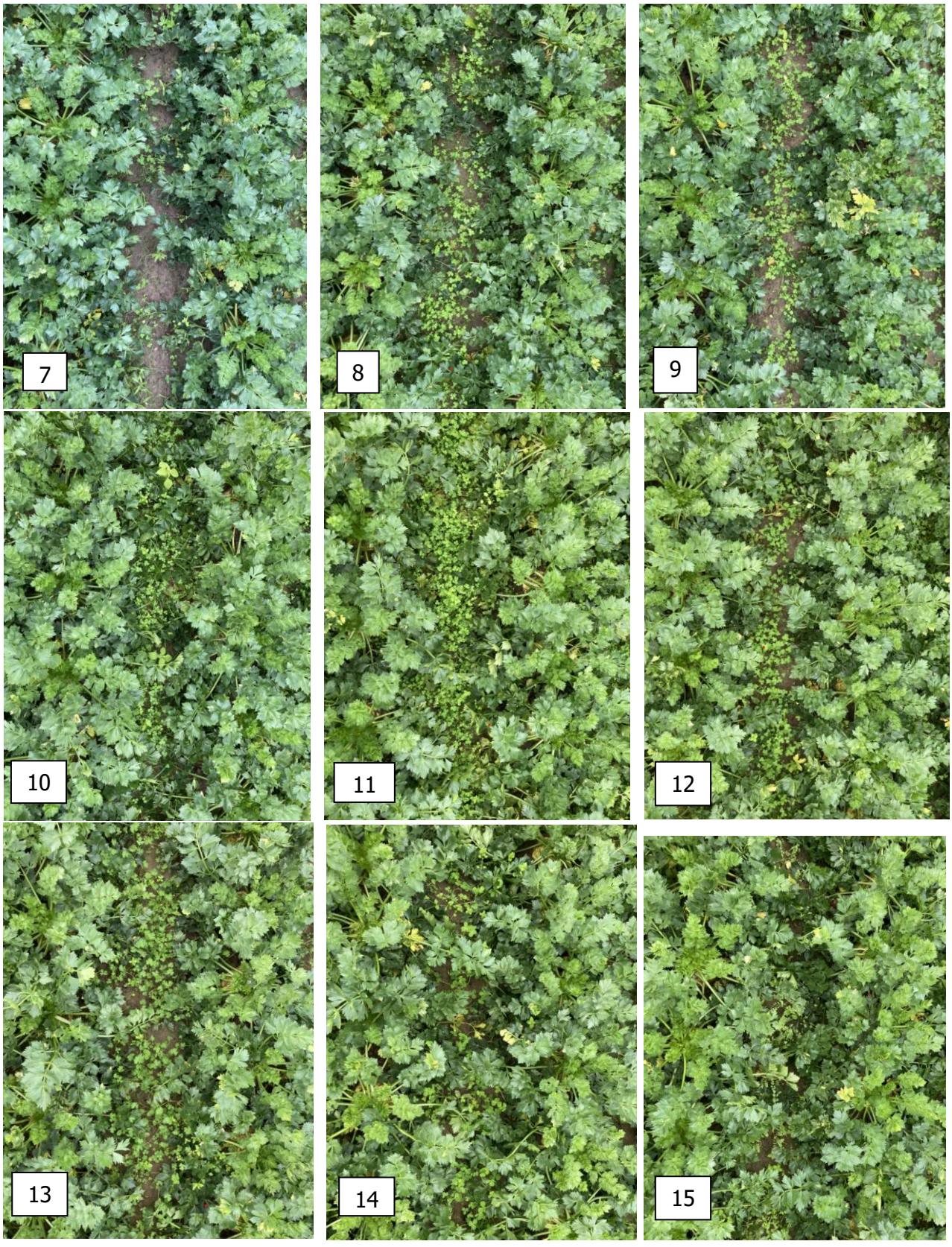

Figure 4: The various cover crops at the 28th of October. Sowing date= 2/09

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Possibly weed pressure and competition from the white cabbage crop negatively affected the growth of the first sowing and highlighted the advantage of using clover

The growth of the cover cops varied greatly and was not always successful when sown **at the beginning of July** in white cabbage planted on the 22th of May (on average 0,8 and 0,13 ton fresh and dry biomass/ha at white cabbage harvest: 27/10, figure 5). Due to the experimental design (demonstrative), we were unable to determine with certainty that the growth of the cover crop hindered the growth of the cabbages and vice versa (no correlation, figure 10 in annex). Nevertheless, there may have been some competition for nutrients, water and light in the field. White cabbage productivity was on average 93 ton/ha and ranged from 82 to 116 ton/ha.

White cabbage is a more dense crop than celeriac. Although the green manures had to cover just a small area of uncultivated soil, weed pressure was relatively high (on average 910 kg/ha, often *Galinsoga,* figure 6). A few extra hoeing sessions before sowing would probably have given a better result. However, because the plants can be too large at a later time point, sowing may be less efficient (a larger portion of seeds will remain on the plants and not fall to the ground). In addition, the growth and suppressiveness of the cover crops was often just not good enough.

The *Red clover mix* grew strongest (0,43 ton DM/ha, figure 10) followed by the pure sown Crimson clover (0,38 ton DM/ha) and the *Optima Food Forest mix* (0,33 ton DM/ha). To some extent, this was due to the presence of well-developing winter-hardy clovers: red clover, white clover (Micro clover) and crimson clover, which were further enhanced in the mixtures by the other plant species present. The pure sown Micro clover and the hybrid clover grew visually well, but produced less biomass. But thanks to good ground cover, as well in this cases the weeds did not have much room to grow.

Also the *Green Carbon Fix mix* (0,17 ton DM/ha), the *Glöz 8 mix* (0,14 ton DM/ha) and the pure sown Serradella (0,18 ton DM/ha) and Flax (0,15 ton DM/ha) developed reasonably. In these mixes the clovers (white and/or crimson) seemed again to be important factors (and also the grasses next to some other species). We also noticed that the pure sown non-leguminous flax possibly showed some signs of limited nutrient availability and maybe light during its growth.

The *winter-hardy 'Groen Telen-project' mix*, the *frost-sensitive 'Groen Telen-project' mix*, the *Neutkens/Naturim mix* and the *White clover mix* grew at a weedy spot in the field but couldn't compete with it (1,7 ton fresh weed biomass/ha !). Maybe the sowing dose could be higher. Also the subterranean clover, elsewhere in the field, didn't grow as well and left place for weeds to grow (1,9 ton/ha). Finally the phacelia seeds didn't germinate, so there were no plants present. The seed was of sufficient quality, so something may have gone wrong during or just after manual sowing (for instance: the seeds had not been incorporated in the soil with the harrow).

An additional hoeing shortly after undersowing resulted in fewer weeds between the white cabbage rows, but also in much less soil cover…

The second sowing **around Mid-July** was a failure. An attempt was made to hoe once more after sowing, when the cover crops had not yet emerged, due to the high weed pressure on the plot. This greatly reduced the chances of the under sown cover crop establishing itself properly. Only the *Winter-hardy 'Groen telen-project' mix* (0,47 ton DM/ha, probably an over estimation), where serradella was abundant, and the pure sown serradella (0,29 ton DM/ha) grew relatively good still (figure 7 and figure 11 in annex). But also *Optima Food Forest*, *Glöz 8* and *Untersaat 10*, which contain white (/micro) clover were somewhat more present (0,11 ton DM/ha). On the other hand, we observed that weed pressure was generally lower due to the additional weed control measures (on average 380 kg/ha).

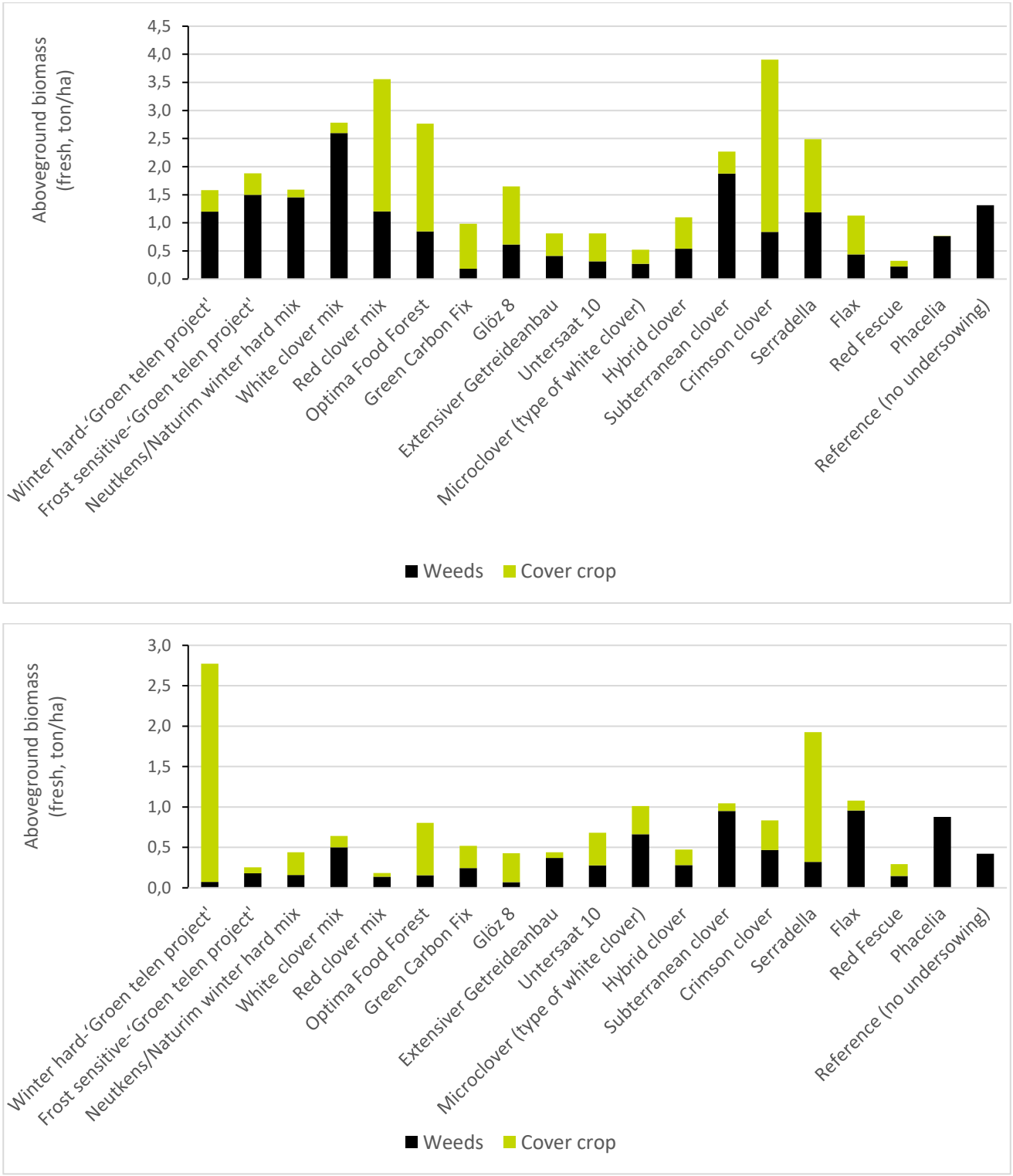

Figure 5: Aboveground fresh biomass (ton/ha) of the cover crops at White cabbage harvest in function of the sowing time. At the top: the first undersown cover crops (4th of July), below the last sown (14th of July). Also the weed biomass is shown.

Figure 6: The most important cover crops at the 25th of October. Sowing date= 4/07

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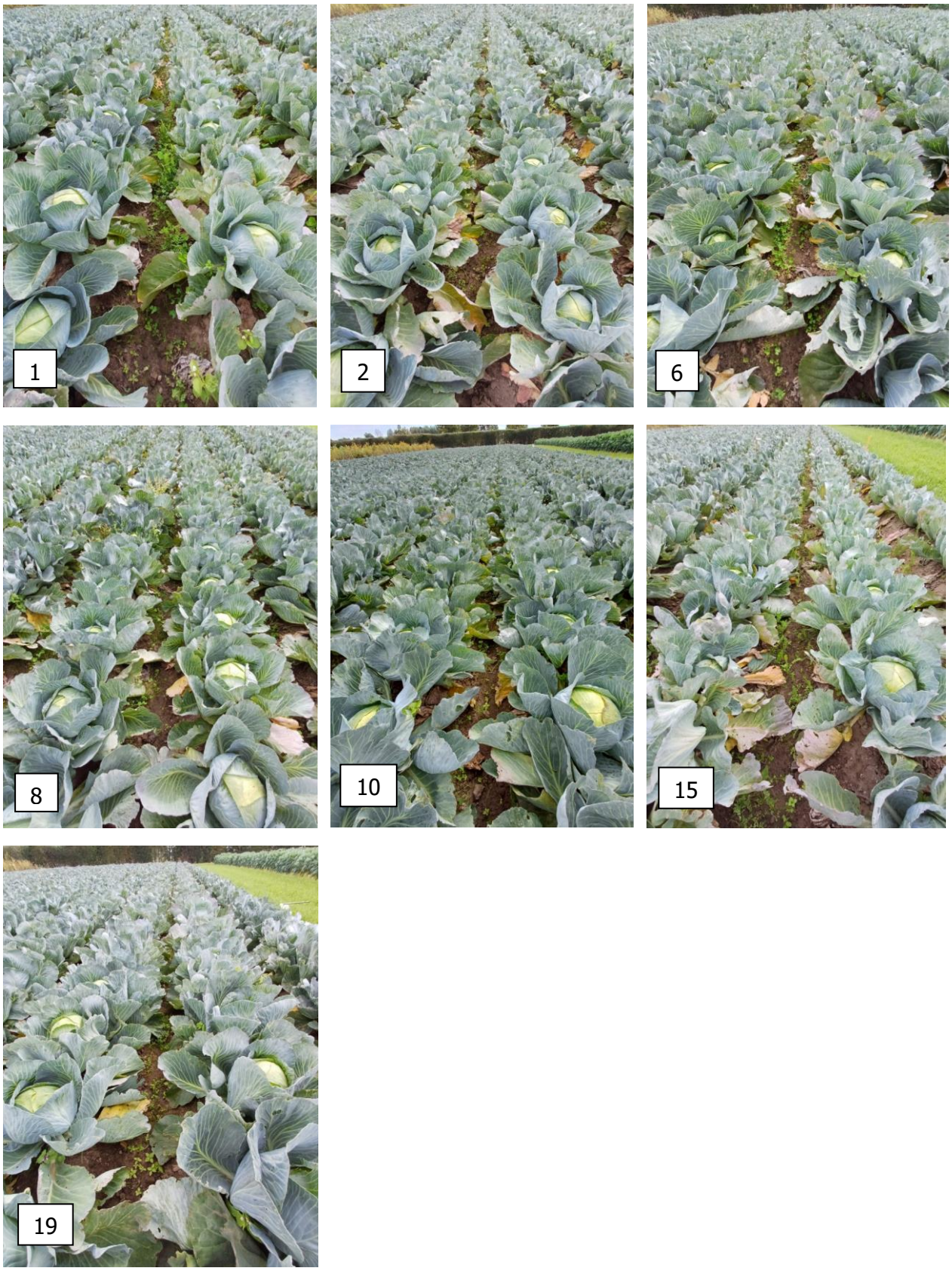

Figure 7: The most important cover crops at the 25th of October. Sowing date= 14/07

5. Conclusion

The year 2025 was exceptionally dry with a precipitation deficit. August in particular was very dry, which generally hampered the performance of the undersowing technique. However, irrigation is common practice in vegetable production in Flanders, and this helped the germination and growth of the undersown cover crops. This (and other factors such as the sowing date) may have contributed to the fact that no (negative) correlation was found between main crop and cover crop development.

Irrigation combined with early sowing (**beginning of august**) ensured successful establishment and development of most cover crops undersown in celeriac. Among the treatments, the pure-sown phacelia produced the highest biomass (2,1 ton DM/ha) followed by the pure-sown Flax (on average 1,9 ton DM/ha) and the *Green Carbon Fix mix* (1,2 ton DM/ha). Phacelia and Flax are fast-growing, non-leguminous species and likely benefited from the relatively high nitrogen availability in the field.

Several mixtures displayed a high diversity of plant species, but their overall biomass production was generally lower than that of some pure-sown treatments. In many mixtures, clovers (e.g. white clover) were dominant. Grasses also established well among the other species without becoming predominant. Although not dominant, species such as vetch, flax, buckwheat, and serradella contributed positively to species diversity and added functional value to the mixtures.

Late undersowing in celeriac **(beginning of September**), without harrowing the seeds into the soil, resulted in on average 95% less biomass compared to early sowing. Moreover, large differences in establishment and growth were observed between cover crop species. Even under these conditions, pure-sown phacelia produced the highest biomass (0.07 ton DM/ha), although plant distribution was more scattered. While clovers did not produce the highest biomass, they established as numerous small plants that covered the soil relatively well. As a result, clovers played a key role in soil cover at harvest and largely determined the soil-covering capacity of the best-performing mixtures.

Undersowing in white cabbage proved more challenging than in celeriac. Possibly high weed pressure and strong competition from the cabbage crop negatively affected the development of the first sowing **(beginning of July**) and highlighted the advantage of clover-based cover crops. White cabbage forms a more dense canopy than celeriac, further limiting light availability for undersown plants. The *Red clover mix* performed best (0,43 ton DM/ha), followed by the pure-sown Crimson clover (0,38 ton DM/ha) and the *Optima Food Forest mix* (0,33 ton DM/ha). These results were partly explained by the presence of well-developing, winter-hardy clovers such as red clover, white clover (Micro clover), and crimson clover. For unknown reasons, establishment of pure-sown phacelia failed in white cabbage.

An additional hoeing shortly after undersowing reduced weed pressure between the cabbage rows, but also reduced soil cover. Consequently, the second sowing (**mid-July**) largely failed. Only the *Winter- hardy 'Groen telen-project' mix*, in which the leguminous serradella was abundant, and the pure-sown serradella showed relatively good development under these conditions.

ANNEX

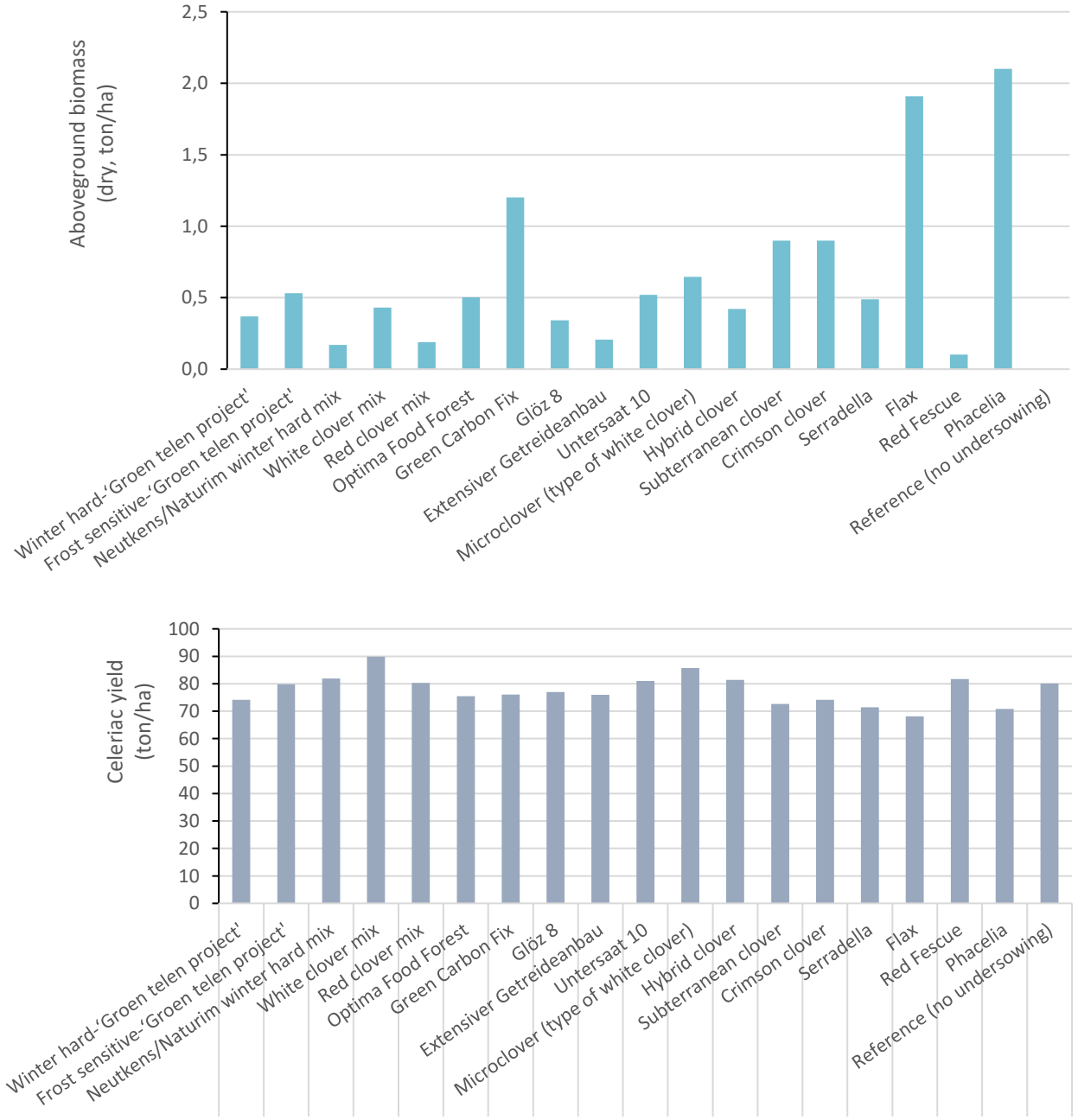

Figure 8: Aboveground dry biomass (ton/ha, above) of the cover crops at Celeriac harvest (sowing time= 4/08). Marketabele Celeriac yield (ton/ha, below) in function of cover crop choice.

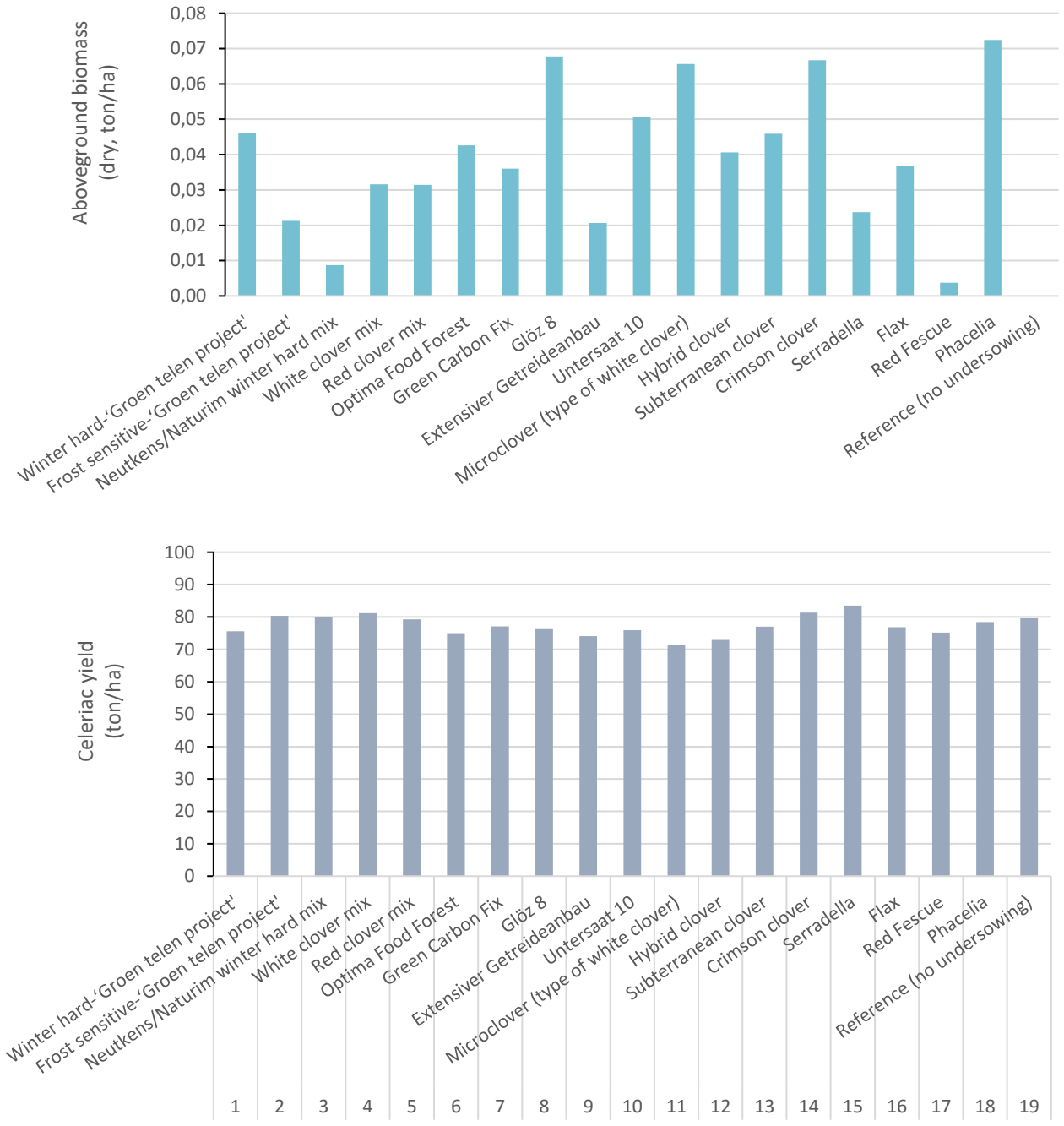

Figure 9: Aboveground dry biomass (ton/ha, above) of the cover crops at Celeriac harvest (sowing time= 2/09). Marketable Celeriac yield (ton/ha, below) in function of cover crop choice.

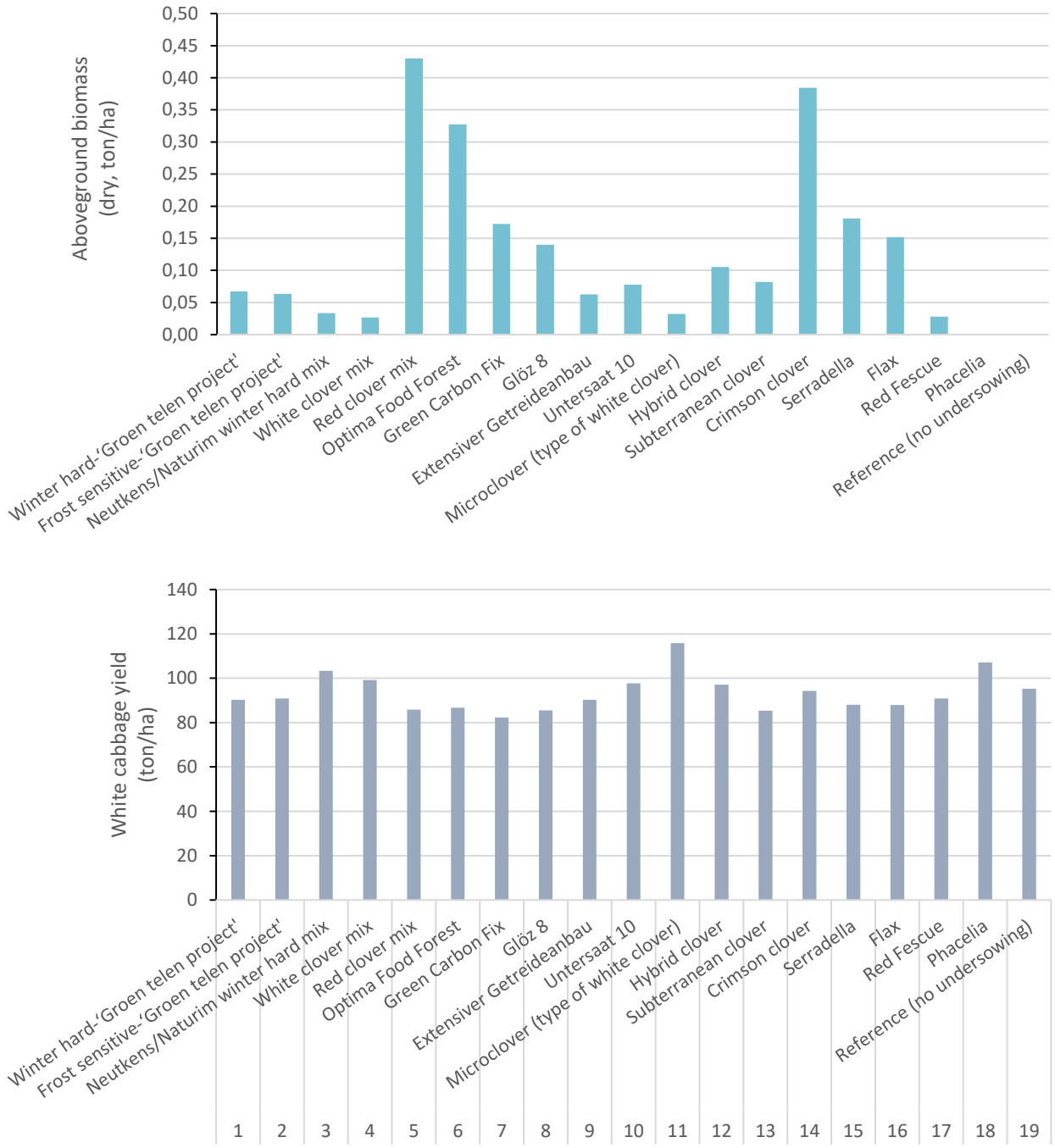

Figure 10: Aboveground dry biomass (ton/ha, above) of the cover crops at White cabbage harvest (sowing time= 4/07). Marketable White cabbage yield (ton/ha, below) in function of cover crop choice.

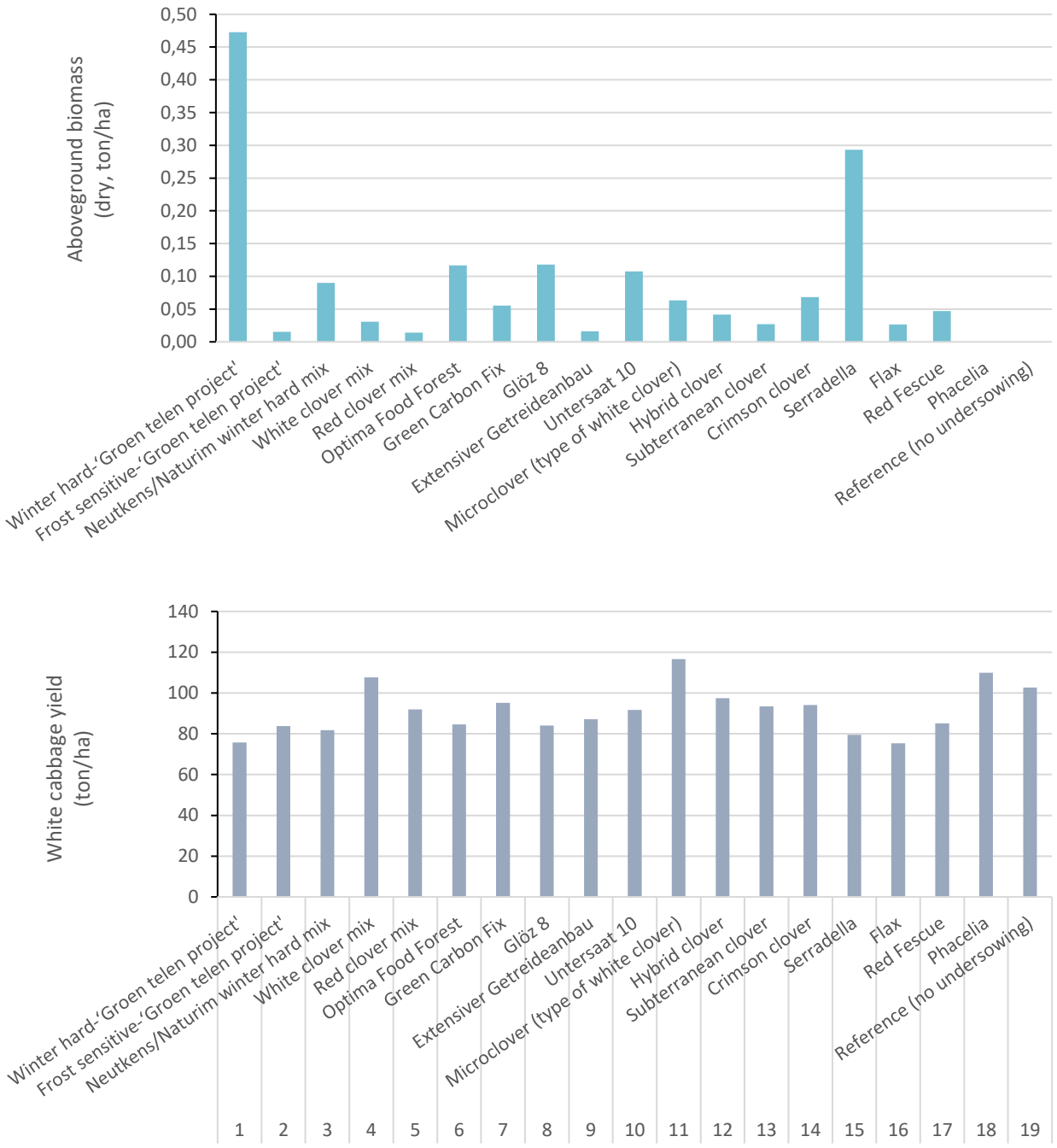

Figure 11: Aboveground dry biomass (ton/ha, above) of the cover crops at White cabbage harvest (sowing time= 14/07). Marketable White cabbage yield (ton/ha, below) in function of cover crop choice.