Multi-species green manure crops as pre-crop for organic vegetables

On-farm field trials in Estonia

One of the activities of the Maheklaster NGO (Organic Cluster, Estonia) project "Innovation in organic plant production" was to study the use of multi-species green manure crops as pre-crops for organic vegetables. The effects of four different multi-species green manure crop mixtures on weed infestation, soil microbiology and the yield of carrots grown as a next crop to the green manure crop were investigated in on-farm trials. The results were compared to a green manure crop grown as a monoculture (crimson clover).

In organic vegetable production, the main factors limiting yields (according to producers) are weeds and soil fertility. The growing of green manure crops is one of the main methods of maintaining soil fertility in organic vegetable rotation, and producers traditionally grow green manure crops as a monoculture or mixtures of 2-3 species. The cultivation of mixtures of many species (10+ species/varieties) as a one-year pre-crop was not used in Estonian organic vegetable production at the time of planning the trials and is not a widespread practice in other countries.

It was expected that a more diverse use of green manure crop species would give better results than growing green manure crops in monoculture. Growing a mixture of species with different growth rate, root shapes and depths, nitrogen fixation capacity, weed suppression capacity and biomass productivity can significantly reduce weed pressure, increase soil humus content and improve soil structure and water holding capacity. Multi-species mixtures also promote beneficial insect species richness and increase soil microbial activity, which can help to reduce the incidence of pests and promote the development of mycorrhizal fungi. As plants decompose in the soil, nutrients slowly and evenly become available to succeeding crops, improving the stability of nutrient supply. Diverse mixtures also have more diverse impact on the soil than leguminous plants grown as single species or mixtures of just a few species. Growing green manure crops in mixtures also helps to reduce growing risks, as during some growing seasons the weather conditions are not suitable for some species but might be for others.

A trial of diverse green manure mixtures was carried out over three years (2018-2020) at Kiltsimäe organic farm in Harju County, Estonia. Green manure crops were grown in 2018 and 2019, followed by carrot in 2019 and 2020, respectively. Four different mixtures were used, with the addition of an Alexandrian clover sown as a pure crop control variant). The mixtures of green manure had different numbers of species (10, 14, 16, 19) as well as different proportions of annual and perennial species (Table 1). The carrot 'Bolero' was grown in the year following the green manure crop.

Table 1. Species used in multi-species mixtures

Species	Species (in Latin)	Mix I kg/ha	Mix II kg/ha	Mix III kg/ha	Mix IV kg/ha
Phacelia	*Phacelia tanifolia*	1	1	1	0,5
Buckwheat	*Fagopyrum esculentum*		6	6	3
Common vetch	*Vicia sativa*	4	2	6	
Hairy vetch	*Vicia villosa*		3		
Field bean	*Vicia faba*		12		
Forage pea	*Pisum sativum*	12			
Crimson clover	*Trifolium incarnatum*	1,4	0,85	3	1
Alexandrian clover	*Trifolium alexandrium*	1,4		1,6	
Persian clover	*Trifolium resupinatum*		0,6		0,6
White clover	*Trifolium repens*	0,7			0,55
Red clover	*Trifolium pratense*	1			0,8
Alsike clover	*Trifolium hybridum*		0,6		0,6
White sweet clover	*Melilotus albus*	0,5	0,5		0,5
Bigleaf lupin	*Lupinus polyphyllus*	0,9			1,5
Lucerne	*Medicago sativa*		0,9		0,9
Sainfoin	*Onobrychis viciifolia*	1,5	1,5		1,5
Sunflower	*Helianthus annus*		0,4	0,4	0,4
White Mustard	*Sinapis alba*	0,8		1	0,8
Westerwold ryegrass	*Lolium multiflorum westerwoldicum*		2,5	2,5	
Italian ryegrass	*Lolium multiflorum*	3			1,5
Timothy	*Phleum pratense*		0,5	1	0,5
Meadow fescue	*Festuca pratense*	0,7			0,7
Oats	*Avena sativa*		12		8
Rye	*Secale cereale*	15	12	15	8
Linseed	*Linum usitatissimum*				1,75
	Number of species	*14*	*16*	*10*	*19*
	Quantity (kg/ha)	*43,9*	*56,35*	*37,5*	*33,1*

Results

The year 2018 was an extremely warm and dry year, which had a negative impact on seed germination and early plant development of various species. There was very little precipitation at the site, with no rain in May, only two times in June and no rain in July. Several species of green manure crops didn`t emerge at all, but weeds, especially goosefoot, which had not been a problem in the field in previous years, started to grow rapidly in the second half of the summer. To prevent the spread of weed seeds, the experimental field was mowed (high cut) in August.

The biomass of green manure mixtures varied between 1187 and 2481 kg/ha in 2018, with Alexandrian clover sown as single-species green manure (as a control variant) having a significantly lower biomass by autumn compared to the multi-species green manure mixtures (Figure 1). In this experimental year, the proportion of weeds was very high due to weather conditions, accounting for 25 - 51% of the total aboveground biomass (Figure 2). In all variants, phacelia survived as well as buckwheat (used in mixtures 2-4). Sunflower was included in mixtures 2-4, but by autumn it was

only found in mixtures 2 and 4. Grass and leguminous species were present in all mixtures but not all species were present.

The year 2019 was similar to the previous year, also warm and dry, but there was slightly more rainfall at the beginning of the growing season. Compared to the previous year, green manure crops had a marginally better emergence and the proportion of weeds in the biomass in autumn was significantly lower. However, similar to the previous year, weed biomass accounted for more than half (52% of total biomass; Figure 2) in the control variant. In different green manure crop mixtures, the proportion of weeds in the total biomass varied between 13 and 24%. Biomass of green manure crops varied between 1302 and 2729 kg/ha (Figure 1). From the multi-species mixtures sown, the highest number of species in the autumn biomass was found in Mixture 4. White mustard (31%) proved to be the most dominant crop in this mixture, followed by phacelia + buckwheat (20%). Similarly to previous year, phacelia persisted in all variants as well as buckwheat (used in mixtures 2-4). In contrast, no sunflower plants were found in 2019. Grasses were present in all mixtures and in a significantly higher proportion than in the previous year. Leguminous species were also present in the autumn (when biomass was weighed) in all experimental variants, but with a low proportion of the total biomass due to poor germination of the clovers.

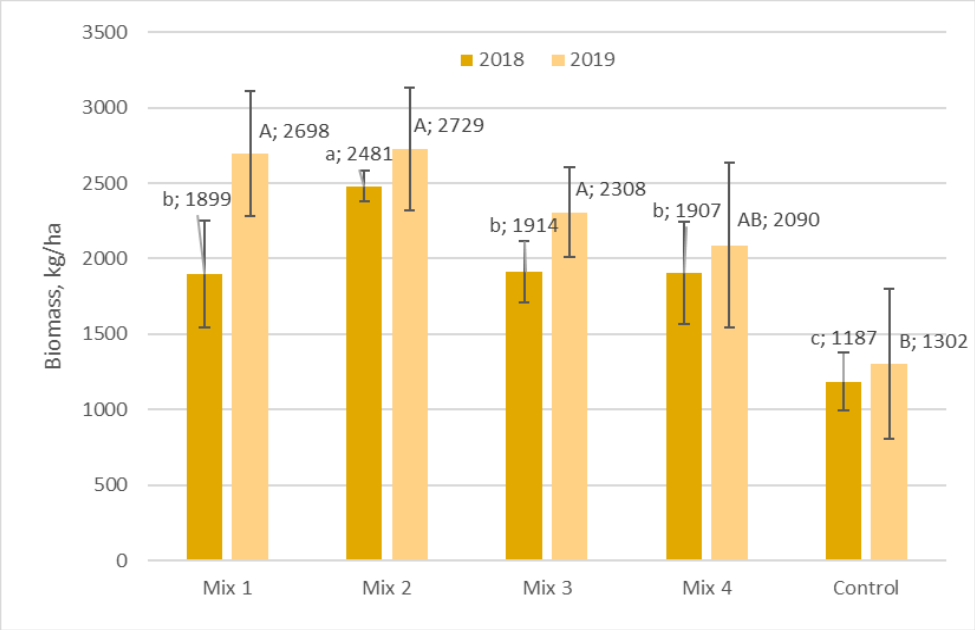

Figure 1: Biomass of different green manure crops (kg/ha) in Kiltsimäe farm trials in 2018 and 2019. Different letters within the same test year refer to plausible differences at PD95% and the "whiskers" in the figure denote the standard deviation.

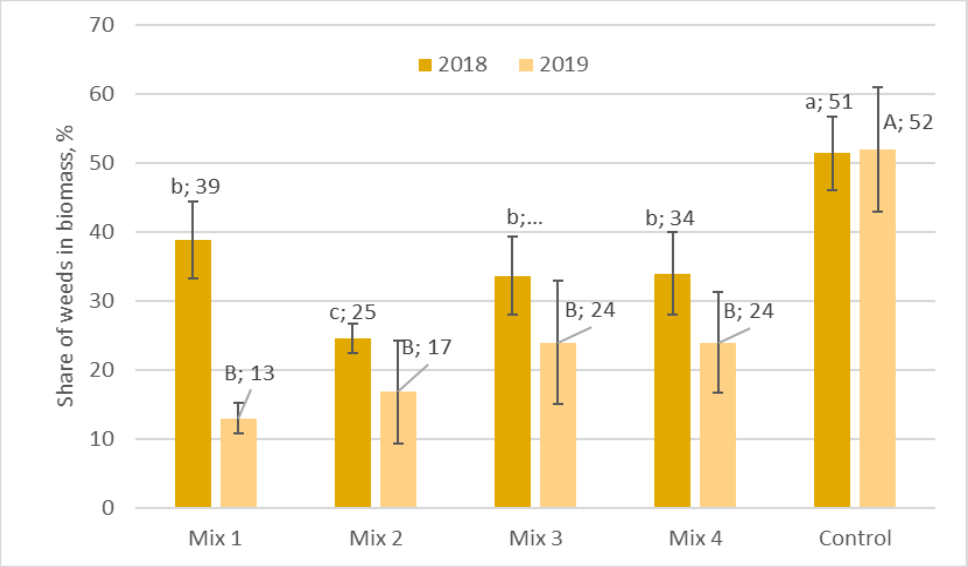

Figure 2: Share of weeds in biomass (%) depending on the green manure crop variants grown in Kiltsimäe farm trials in 2018 and 2019. Different letters within the same test year refer to plausible differences at PD95% and the "whiskers" in the figure denote the standard deviation.

Yield of carrots grown after green manure crops

To evaluate the effect of the green manure crops grown on the next crop in rotation, carrots (variety 'Bolero') were grown in the test fields during the following year (2019 and 2020). Considering the conditions of organic production, the commercial yield of carrot was average in 2019, varying between 27.8 and 33.9 t/ha (Figure 3). The carrot following the mixture with high proportion of leguminous species (variant 4) and the control variant had the lowest yields. Experimental variants of Mixtures 1 to 3 had statistically significantly higher yields than the control variant.

2020 was a slightly more favourable year for carrot growth and therefore the average commercial yield was a bit higher, ranging from 28.6 to 41.5 t/ha. Mixture 1 gave a significantly higher yield than the control. Mixture 2 had 7 t/ha higher carrot yield, but there was not a statistically reliable difference from the control. Both variants also had the highest green manure biomass in the previous year.

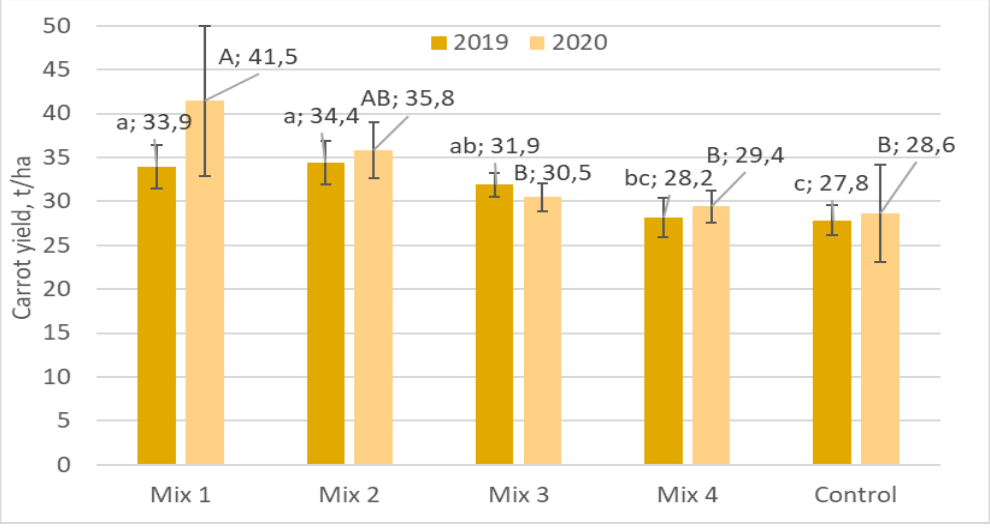

Figure 3: Commercial carrot yield (t/ha) in 2019 and 2020 after green manure crops in Kiltsimäe farm trials. Different letters within the same test year refer to plausible differences at PD95% and the "whiskers" in the figure denote the standard deviation.

Summary and recommendations for producers

Trials of multi-species green manure crop mixtures were conducted in 2018 and 2019, both unusually warm and dry years. The weather conditions resulted in uneven emergence and lower biomass. However, in both years, the positive effects of different multi-species mixtures on both green manure crops biomass and weed reduction were observed. Mixture 4, which was the mixture with the highest proportion of leguminous species at sowing, probably suffered the most from the post-sowing droughts and as a result the proportion of leguminous species in the biomass was quite low and the biomass was also the lowest.
Overall, multi-species green manure mixtures had an effect on increasing the commercial yield of carrots, but the preference for particular mixtures cannot be identified here because of the rather extreme weather conditions in the experimental years. The same applies to the recommendations to producers. Based on the results of the trials, a wide range of green manure plants can be recommended for use in organic vegetable rotations, but it is not possible to highlight a preference for specific mixtures. The results show that growing green manure crops in mixtures contributes to the reduction of growing risks, as during different growing seasons weather conditions are different and during different years different species have preferable conditions. This is illustrated by the lower biomass and higher weed infestation of the monoculture green manure crop used as a control in both experimental years.

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