Resource-conserving agriculture: under-sowing and mixed crops as stepping stones towards a solution

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Introduction and objectives

The ever-increasing stress imposed on our planet by mankind is a growing concern. The emergence of a free market economy in Europe at the end of the 17th century began an economic expansion culminating in today's global industrial economy. Science and technology has aided and abetted a doubling of the world's population in the last 50 years and scientists predict that the upheavals experienced the last three centuries will multiply in centuries to come. In 1999, the world's population reached 5 billion. It is growing at a rate of 80 million people per year and, if we are to feed the 8 to 12 billion people predicted for 2050, we will have to quadruple agricultural productivity and use 7-8 times the amount of energy that we are using today (Wallimann and Dobkowski 2003). Can the industrial economy support this growth without destroying itself or future generations' quality of life? It's hard to say whether the situation will evolve quite as predicted by Wallimann and Dobkowski but the world is heading in this direction.

The management of resources is an ongoing challenge. Conservation of water, soil and energy is of utmost importance and various approaches have been researched and tested in a practical environment. Under-sowing and mixed cropping might play an important role.

Under-sowing*:* Under-sowing is the practice of seeding one or more crops at the same time as the main crop, where only the main crop is harvested. Experiments were conducted in rape, winter and spring barley, winter and spring wheat, maize, linseed and soya. For example, rape is under-seeded with clover in order to:

- Supress weeds through natural competition and, possibly, through root exudations by the under-sown crop, to reduce or even eliminate the need for weed control;
- Fix nitrogen through the symbiotic rhizobium of legumes. Possibly a little nitrogen will be available for the main crop but more will be available for following crop;
- Increase ground cover and root penetration to combat soil erosion and increase trafficability;
- Produce humus to enhance soil fertility and soil structure.

Table 1: Under-sown crops tested in field studies

Common name	***Linnaen***
Legumes	
White clover (3 varieties)	*Trifolium repens*
Sub clover	*Trifolium subterraneum*
Lucerne (Alfalfa)	*Medicago sativa*
Sainfoin	*Onobrychis viciifolia*
Black medic	*Medicago lupulina*
Persian clover	*Trifolium resupinatum*
Berseem clover	*Trifolium alexandrinum*
Common vetch	*Vicia sativa*
Fenugreek	*Trigonella foenum-graecum*
Blue fenugreek	*Trigonella caerulea*
Non-legumes	

False flax Buckwheat Niger	*Camelina sativa* *Fagopyrum esculentum* *Guizotia abyssinica*
Mixtures White clover + Berseem clover + Phacelia White clover + Buckwheat White clover + Niger	 *Trifolium repens, Trifolium alexandrinum, Phacelia tanacetifolia* *Trifolium repens, Fagopyrum esculentum* *Trifolium repens, Guizotia abyssinica*

Mixed Crops: In this case, two species of crops are sown together and both are harvested. Well-matched crops achieve a more efficient utilisation of light, metabolizable energy, nutrients and soil water, expressed in the land-equivalent ratio (LER) where LER greater than 1 indicates that the resources are more efficiently used in the mixed crop compared with the principal crop grown as a monoculture.

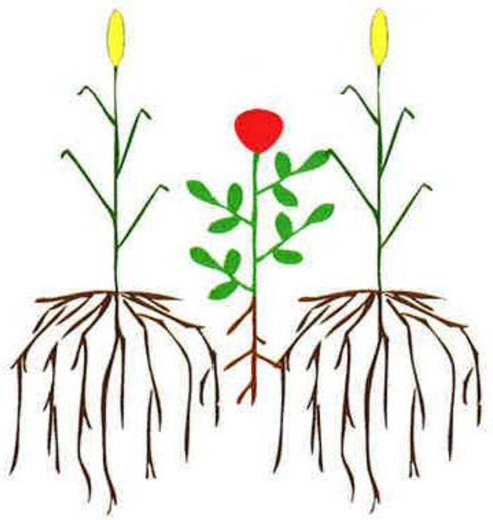

Figure 1: Complementary use of water, nutrients (roots) and metabolizable energy utilization (above ground) in mixed crops

Conducted studies

Under-sowing and mixed-crop studies have been conducted in Switzerland since 2006. Mixed-crop field studies were conducted mainly using a mixture of field peas and false flax, most have followed typical block designs; on-farm studies were conducted using strip plots. In order to answer specific questions, some pot trials were conducted in a climate chamber. Field studies have been conducted in Moldova since 2008.

Selected results and discussion

Republic of Moldova

Field trials were conducted using spring barley by Dr Valentin Crismaru at the Institute of Plant Protection and Ecological Agriculture in Chisinau.

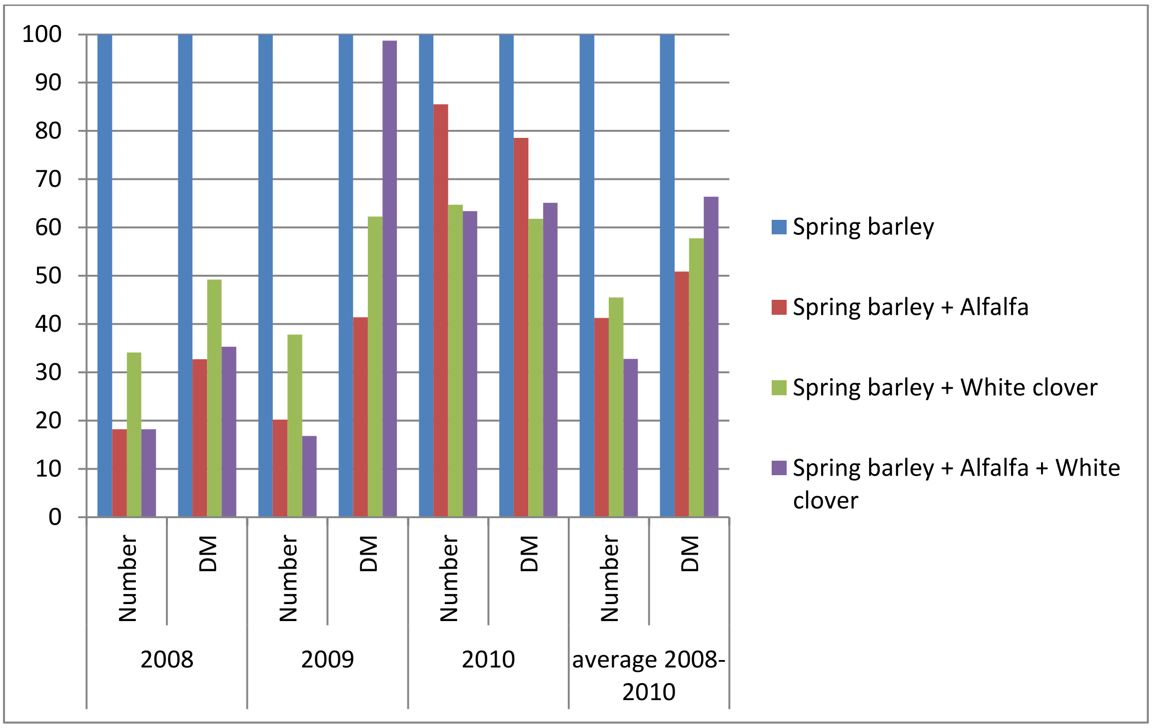

Figure 2: Number and dry matter (DM) of weeds in spring barley with and without under-sowing, 2008-10 (% compared with scores without under-sowing)

Under-sowing significantly reduces the number of weeds and their dry matter is, on average, 34-49% less in the under-sown crop (Fig.2). Yields were significantly higher with under-sown crops throughout all three trial years (Table 2). This may be attributed to the drastic decrease in weed competition; the subsequent crop also profited from the nitrogen fixed by the legume.

Figure 3: Spring barley under-sown with white clover, Chisinau 2008. Competition from the quick-emerging clover is quite evident.

Table 2: Spring barley yields 2008-2010, Chisinau

Procedure	Yield (kg/ha)				Increase of yield 2008-10	
	2008	2009	2010	2008-10	kg/ha	%
Spring barley alone	1 970[a]	1 368[a]	2 265[a]	1 868		
Spring barley + alfalfa	2 268[b]	1 713[b]	2 560[b]	2 180	+312	+17
Spring barley + white clover	2 145[b]	1 640[b]	2 445[b]	2 077	+209	+11
Spring barley + white clover + alfalfa	2 295[b]	1 628[b]	2 600[b]	2 174	+306	+16

Superscripts mark statistically significant differences (ANOVA, $p < 0.05$)

Switzerland

Under-sown rape

As a specific example of under-sown rape, we take the trials on the Schaedeli farm at Uettligen, 2008/09. Trial 1 was a randomized block design with 6 treatments: control (hoeing), under-sown white clover (10kg/ha), under-sown alfalfa (20kg/ha), under-sown sainfoin (100kg/ha), under-sown buckwheat (40kg/ha) and white clover (5kg/ha), and without under-sowing or weed control. Trial 2 was a strip plot with 2 treatments: hoeing, and under-sown white clover (10kg/ha) also hoed.

Weed suppression

Fewer weeds appeared on the under-sown plots compared with the control; alfalfa proved to be most effective in suppressing weeds. The effect of under-sowing on specific weed varieties varied greatly: white clover suppressed shallow-rooted weeds such as annual meadow grass *(Poa annua)* and chickweed *(Stellaria media)* but not forget-me-not *(Myosotis arvensis)*, which thrived in this trial.

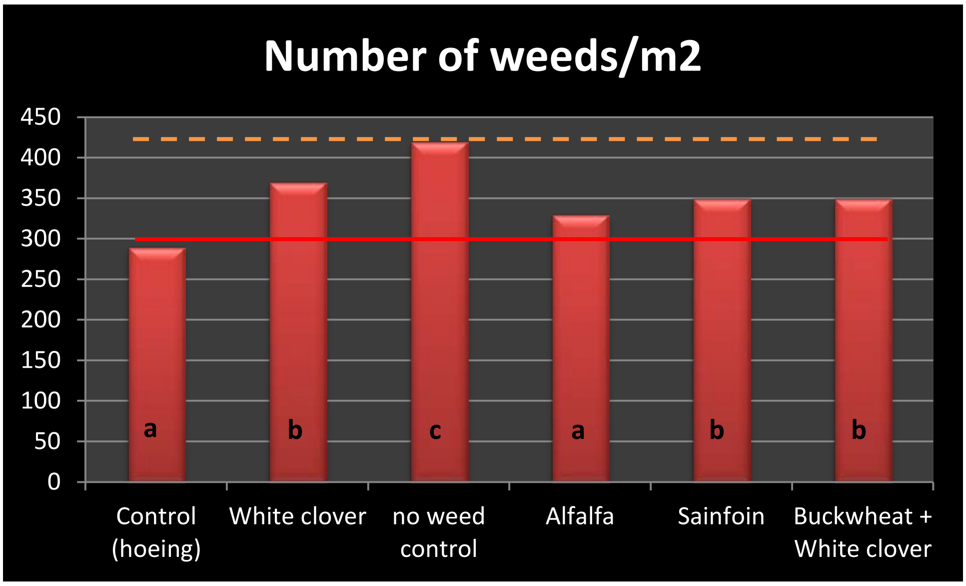

Figure 4: Uettligen block trial, total weeds/m^2 in autumn 2008. Different letters indicate significant differences (ANOVA $p \leq 0.05$)

In spring 2009, the biomass of the rape and the under-sown plants in the strip plot was measured (Fig. 5). The biomass of rape showed a small benefit from the white clover. The biomass of accompanying plants (white clover and weeds) showed no difference.

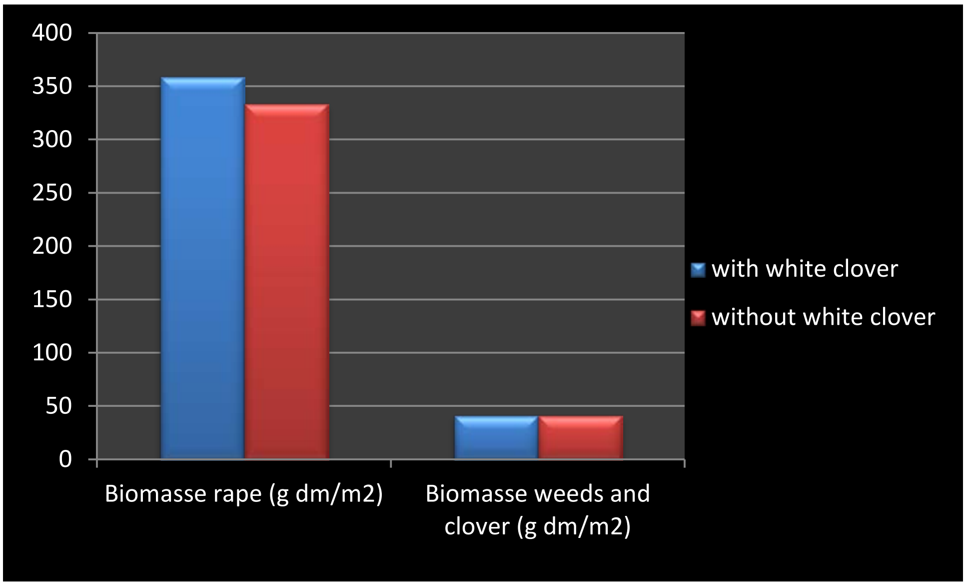

Figure 5: Uettligen strip trial, biomass of rape and accompanying plants (weeds and white clover) in spring 2009

Soil Cover

White clover provided a thick ground soil cover. Even in the strip plots, where both the control and under-sown strips were hoed, clover quickly refilled gaps in the rows. After harvest, there was a visible difference between the treatments with and without under-sowing; the stubble was mown after harvest and transported along with the white clover to a dryer and made into pellets. Afterwards, the white clover was allowed to re-grow and harvested and pelleted once more before sowing winter wheat.

Forage value of under-sown crops

Table 3: Harvested fodder after the rape harvest, Uettligen 2009

	Total pellets (tonnes)	Pellet yield (t/ha)	Dry matter (t/ha)
First cut	2.40	1.71	1.57
Second cut	2.50	1.79	1.60

Table 4: Values of dry white clover pellets, Uettligen, 2009

Investigated value	**First cut after rape harvesting**	**Second cut after rape harvesting**
Dry matter (DM, %)	91.6	89.8
Neutral detergent fibre (g/kg DM)	651	335
Hemicellulose (g/kg DM)	207	91
Lignin	90	38
Crude protein (g/kg DM)	131	212
Soluble protein as % of crude protein	26	21
Net energy (MJ/kg DM)	3.8	6.8
Calcium (g/kg TS)	129	114

The under-sown white clover has a high economic value and the profit greatly exceeds the additional costs for seed and extra work involved. The first cut of forage had a low energy level and high amounts of cellulose, hemicellulose and lignin a result of the presence of rape stems in the forage. However, it contained a high amount of protein, even more than hay from an extensive meadow, and lots of calcium from the white clover. The second cut contained a higher amount of net energy as well as a high concentration of protein (typical for white clover) - ideal as a concentrate for dairy cattle in early lactation. However, high-producing cows need a quicker metabolizable source of energy; this is not important for organic farms where high-producing cows are not a priority. Once again, the high calcium content makes this a useful feed for mineral absorption.

Nitrogen production from under-sown white clover

Symbiotic *Rhizobium* in the clover roots fixes atmospheric nitrogen. This nitrogen is used for the above-ground parts of the plant parts but much remains in the soil and becomes available for future crops. Yield studies of subsequent crops have shown an increased level of nitrogen. After rape, the field was planted with winter wheat and measurements were made at harvest (Table 5).

Table 5: Effect of white clover on following wheat yield, Uettligen, 2010

Practice	**Yield (t/ha)**	**Ears/m2**	**Grains/ spike**	**WTG (g)**	**Weight (kg/hl)**
Without white clover	5.19	419	31.2	39.8	81.1
With white clover	5.78	461	32.7	38.3	81.1

Because of the nitrogen inherited from the white clover, more nitrogen was available to the wheat, which produced more tillers and thus more spikes per m^2. The crop following white clover yielded 11% more yield than the crop without this benefit.

Field peas and false flax (Camelina sativa) as a mixed crop

Effective suppression of weeds was observed in all trials of field pea and false flax as a mixed crop. As an example, in trials at Zollikofen in 2009, 4kg/ha *Camelina* was seeded. The field without weed control produced an exceptionally high yield of 4.7t/ha (Table 6); that which was had been assumed from the suppression of weeds was proven by the high yields. The planting of *Camelina* resulted in some decreased yield of field peas (not statistically significant) but the protein yield per hectare remained the same. In addition, a bonus was achieved with the yield of 88 – 162 litres/ha of *Camelina* oil.

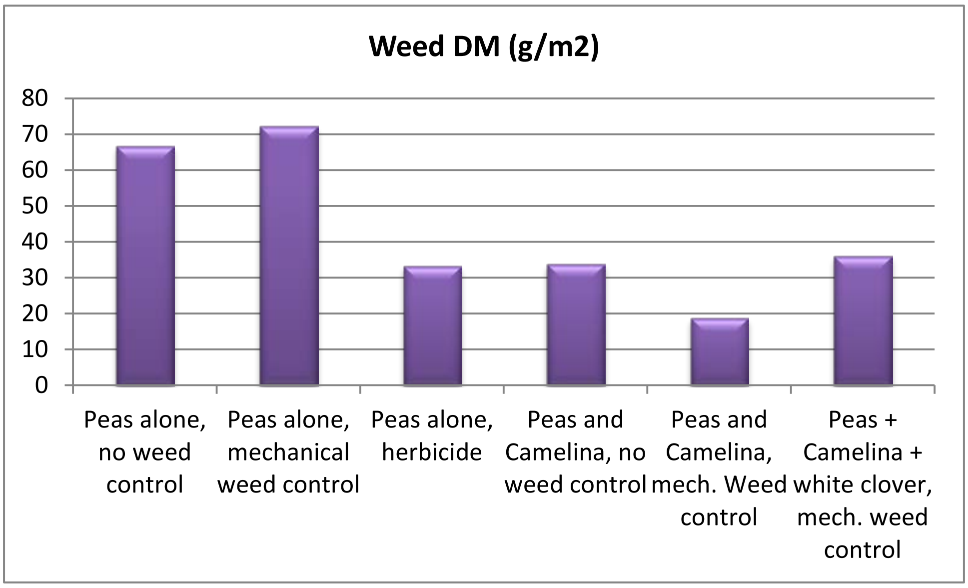

Figure 6: Weed dry matter/m2, block trial Zollikofen, 2009

Table 6: Grain yield, crude protein and calculated oil yield of Camelina in the Zollikofen block trial, 2009

Yield component	Peas alone no weed control	Peas alone mech-anical weeding	Peas alone, herbicide	Peas + Camelina no weed control	Peas + Camelina mechanical weeding	Peas + Camelina + white clover, mechanical weeding
Yield, peas (dt/ha)	47.5[a]	41.6[ab]	52.5[a]	42.0[a]	30.0[b]	34.2[ab]
Yield, Camelina (dt/ha)	0	0	0	4.4	8.1	7.1
Crude protein (dt/ha)	11.8[a]	10.4[a]	13.1[a]	12.1[a]	10.5[a]	11.1[a]
Approximate yield of Camelina oil (l/ha)	0	0	0	88	162	142

Different letters indicate significant differences (ANOVA $p \leq 0.05$)

Figure 7: Camelina-pea mixture, Zollikofen June 15, 2009

In 2010 a field trial was conducted to ascertain the optimal amount of *Camelina* to be seeded with peas; previous results had suggested an ideal amount between 2 and 2.5kg/ha. In 2011 another block trial was undertaken with 1.8kg/ha *Camelina* (Table 7).

Table 7: Yield components in block trial of field pea – false flax, Zollikofen 2011

Factor	Peas alone, herbicide	Peas alone, no weed control	Peas + *Camelina*
Dry matter weeds/m^2 (g)	59.5	93.8	31.9
Yield, peas (dt/ha)	47.2	44.6	18.8
WTG (g)	116.0	119.7	100.3
Yield, *Camelina* (dt/ha)	-	-	16.34
Approximate oil yield of *Camelina* (l/ha)	-	-	327

The trial confirmed the weed-suppression capabilities of *Camelina sativa*. It also demonstrated that the ideal seed amount is hard to determine. In the above, peas were seeded at the end of February and, because of the early seeding, the amount of Camelina was reduced to 1.8kg/ha. Even so, the Camelina competed with the peas. The oil yield of 320l/ha can be categorized as very high and, if there is a market for Camelina oil, no further precautions need be taken; if this isn't the case, the competition cannot be tolerated.

Conclusions

Soil is the vital basis of our agricultural practice: maintaining good soil structure, high humus levels and biological activity are as important as erosion minimization. A key factor is care in the handling of the soil. Resource-conserving farming systems are vital for the future. Practices such as good varied crop rotation, selection of resistant crop varieties and seed quality are indispensable, and the above results show that under-sowing and mixed crops can be a valuable component of conservation farming.

Our objectives can only be achieved through international cooperation. Research partnerships, international knowledge exchanges – as in the Sustainable Agriculture (SAI 2010) are of vital importance. Sustainable agriculture is productive and competitive and efficient way to produce safe agricultural products, while at the same time protecting and improving the natural environment and social/economic conditions for local communities.

References

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