Relay intercropping can efficiently support weed management in cereal-based cropping system when appropriate legume species are chosen

Federico Leoni[1], Mariateresa Lazzaro[2], Matteo Ruggeri[3], Stefano Carlesi[1], Pierluigi Meriggi[3], and Anna Camilla Moonen[1]

[1]Scuola Superiore Sant'Anna, Center of Plant Sciences, Group of Agroecology, Piazza Martiri della Libertà, 33, 56127, Pisa, Italy

[2]Research Institute of Organic Agriculture, FiBL, Ackerstrasse 113, Box 219, 5070, Frick, Switzerland

[3]Horta s.r.l., Az. sperimentale Ca Bosco, Via S. Alberto, 327, 48100, Ravenna, Italy

[*]Correspondence to: camilla.moonen@santannapisa.it

1 Supplementary material

	S Strengths	W Weaknesses	O Opportunities	T Threats
Sowing techniques of legumes				
Drill	• Better establishment of legumes • Less susceptibility of seeds to unfavorable environmental condition	• Slower sowing method	• No need to increase the legume seeding rate • Optimize the spatial configuration of legumes with respect to the crop and therefore reduce competition and optimize resource use efficiency, leaving less resources available for weeds	• Drill sowing require optimal weather and soil condition which are often a limiting factor in the winter • Necessary to apply wider row spacing of wheat crop and therefore not all farmers have suitable machinery
Broadcast	• More rapid and less costly sowing method	• Lower establishment of legume	• Combine sowing with mechanical weed control • Widely applicable because all farmers posses necessary equipment	• Higher variability in seed distribution and seeding depth • Less soil-seed contact • Higher exposition of seeds to unfavorable environmental condition • Increase the seeding rate by 20 to 50% when broadcasting is performed
Legume performance during the intercropping period				
Pisa	• No negative effects on wheat production: MEDSA, TRFRE, HESCO, MEDLU, TRFIN, MEDPO, TRFSU, MEDSC, MEDTR, TRFMI • Improve the weed control: MEDSA, HESCO, MEDLU, TRFIN, MEDPO, MEDTR, TRFRS, VICVI	• Late competition of legumes with wheat: TRFRS, VICVI • Presence of tall-growing legumes can hinder the wheat harvest operation: TRFRS, VICVI	• Establishment of the forage crop nine months in advance in comparison with the common timing of the crop rotation • Resources use optimization • Limit the soil erosion • Reduce herbicides application	• Knowledge-intense practices. Relay intercropping can be difficult to be implemented by farmers because of the low level of knowledge exchange/access
Ravenna	• No negative effects on wheat production: MEDSA, TRFRE, HESCO, MEDLU, TRFIN, MEDPO, TRFSU, MEDSC, MEDTR, TRFMI, TRFRS, VICVI	• In a competitive wheat stand the legumes do not grow well and have a low control capacity of weeds, in case this would be required		
Legume performance after the wheat harvest				
Pisa	• Persistence of legumes: MEDSA, TRFRE, HESCO, MEDPO, TRFSU, TRFMI, VICVI • Improve the weed control: MEDSA, TRFRE, HESCO, TRFSU	• Low or no persistence of legumes: MEDLU, TRFRS, MEDTR, MEDSC • Legume with low biomass or re-growth capacity favor weed growth and dissemination: TRFRS, MEDTR, MEDSC	• Limit the soil erosion • Improve the soil fertility • Reduce herbicides and nitrogen fertilizers applications in the following cash crop	• Lack of efficient alternatives to the use of herbicides for the termination of annual self-seeding and perennial legumes
Ravenna	• Persistence of legumes: MEDSA, TRFRE, HESCO, MEDLU, TRFIN, MEDPO, TRFSU • Improve the weed control: MEDSA, TRFRE	• Low or no persistence of legumes: TRFRS		

SM 1: SWOT analysis carried out for the sowing method in the already established wheat and for the suitability of legumes during the intercropping period and in the subsequent spring. MEDSA: *Medicago sativa*; TRFRE: *Trifolium repens*; HESCO: *Hedysarum coronarium*; MEDLU: *Medicago lupulina*; MEDPO: *Medicago polymorpha*; TRFSU: *Trifolium subterraneum*; TRFIN: *Trifolium incarnatum*; TRFRS: *Trifolium resupinatum*; MEDSC: *Medicago scutellata*; MEDTR: *Medicago truncatula*, TRFMI: *Trifolium michelianum*; VICVI: *Vicia villosa*.

SM 2: Mean density (plant·m^{-2}) of weed species in the two experimental location in 2017/18 and 2018/19 at wheat harvest time

Weed species	Code[(1)]	Pisa		Ravenna	
		2017/18	2018/19	2017/18	2018/19
Alopecurus myosuroides Huds.	ALOMY	0.4	-	-	-
Amaranthus retroflexus L.	AMARE	-	-	0.1	-
Ammi majus L.	AMIMA	9.4	-	-	-
Anagallis arvensis (L.) U. Manns and Anderb.	ANGAR	116.3	3.9	0.1	-
Anthemis arvensis L.	ANTAR	0.4	-	-	1.4
Beta vulgaris L.	BEAVX	-	-	-	-
Borago officinalis L.	BOROF	0.1	-	-	-
Cardamine hirsuta L.	CARHI	-	3.4	-	0.2
Cerastium glomeratum Thuill.	CERGL	-	2.1	-	-
Chenopodium album L.	CHEAL	-	109.1	-	-
Cirsium arvense (L.) Scop.	CIRAR	14.0	-	0.1	-
Convolvulus arvensis L.	CONAR	0.5	-	0.1	0.5
Cynodon dactylon (L.) Pers.	CYNDA	1.7	-	-	-
Datura stramonium L.	DATST	-	0.1	-	-
Equisetum sylvaticum L.	EQUSY	0.9	0.1	-	-
Fumaria capreolata L.	FUMCA	-	-	-	0.1
Lolium spp.	1LOLG	0.2	0.8	-	-
Myosotis arvensis (L.) Hill	MYOAR	13.0	-	-	-
Oxalis acetosella L.	OXAAC	-	0.2	-	-
Papaver rhoeas L.	PAPRH	9.2	1.5	0.1	0.6
Helminthotheca echioides (L.) Holub	PICEC	14.9	-	-	0.1
Poa annua L.	POAAN	0.2	3.5	0.1	0.2
Polygonum aviculare L.	POLAV	2.3	0.9	0.1	-
Ranunculus arvensis L.	RANAR	0.1	-	-	-
Rapistrum rugosum (L.) All.	RASRU	28.0	-	-	-
Rumex crispus L. spp.	RUMCR	3.8	-	-	-
Senecio vulgaris L.	SENVU	-	0.1	0.1	-
Sonchus oleraceum (L.) Scop.	SONOL	-	-	0.1	-
Veronica hederifolia L.	VERHE	12.24	4.3	0.1	5.2
Vicia villosa Roth	VICVI	-	0.1	-	-