### Review

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### Wheat (*Triticum aestivum* L.)-based intercropping systems for biological pest control

Thomas Lopes,<sup>a\*</sup> Séverin Hatt,<sup>a,b,c\*</sup> Qinxuan Xu,<sup>a,c</sup> Julian Chen,<sup>c</sup> Yong Liu<sup>d</sup> and Frédéric Francis<sup>a</sup>

### Abstract

Wheat (Triticum destivum L) is one of the most cultivated crops in temperate climates. As its pests are mainly controlled with insecticides that are harmful to the environment and human health, alternative practices such as intercropping have been studied for their potential to promote biological control. Based on the published literature, this study almod to review the effect of wheat-based intercropping systems on insect pests and their natural enemies. Fifty original research papers were obtained from a systematic search of the peer-reviewed literature. Results from a vote-counting analysis indicated that, in the majority of studies, pest abundance was significantly reduced in intercropping systems compared with pure stands. However, the occurrence of their natural enemies as well as predation and parasitism rates were not significantly increased. The country where the studies took place, the type of intercropping is a viable practice to reduce insecticide use in wheat production systems. Nevertheless, other practices could be combined with intercropping to favour natural enemies and enhance pest control. 0 2016 Society of Chemical Industry

Supporting information may be found in the online version of this article.

Keywords: sustainable agriculture; crop diversity; conservation biological control; predators; parasitoids; yield

### 1 INTRODUCTION

Wheat (Inticum aestivum L) is one of the most important crops worldwide (ranked fifth in terms of production according to FAOSTAT, http://faostat3.fao.org/browse/Q/QC/E). Therefore, findling alternative methods to improve its sustainable production is a major challenge for today's agriculture. Conventional farming practices contributed to increase yields during the twentieth century, but are today contested for their negative impact on the environment<sup>12</sup> and human health.<sup>3</sup> Industrialised monoculture systems, which are highly dependent on the use of external inputs such as agrochemicals (i.e. synthesised fortilisers, chemical posticides, growth regulators), favoured the simplification of agroecosystems.<sup>45</sup>

In contrast, promoting functional biodiversity, which supports ecological processes, may allow agricultural systems to benefit from various ecosystem services, including nutrient cycling, soil structuration and pest control.<sup>6,7</sup> One of the agrobiodiversity strategies' to improve the sustainability of wheat production (reviewed by Costanzo and Barber<sup>®</sup>) is to increase plant species diversity at the field scale through intercorpping designs.<sup>8–11</sup> Intercropping is defined as the cultivation of at least two plant species simultaneously in the same field,<sup>12–14</sup> without necessarily being sown and/or harvested at the same time.<sup>15</sup>

Andrews and Kassam<sup>13</sup> categorised intercropping into four principle types based on the spatial and temporal overlap of plant species: (1) mixed intercropping – two or more crops mixed with no distinct row arrangement; (2) row intercropping – two or more crops grown in separate alternate rows (when plant species are alternated within the same row, it is considered to be within-row intercropping); (3) strip intercropping – several rows of a crop (strip) alternated with several rows of one or more other crops; (4) rolay intercropping – two or more crops grown in relay, but with the growth cycles overlapping to some degree. Choosing a type of intercropping may depend on the associated crops and their valuation after harvest, in addition to the knowledge of the farmer and the level of mechanisation used.

intercropping systems tend to produce higher ytelds compared with monocultures and reduce the impact of agriculture on the environment. Specifically, intercropping may improve soil conservation, fertility and crop quality, while possibly reducing the

- Correspondence to: T Lopen or S Hatt, Passage des Déportés 2, B-5030 Gembloux, Belgium. E-mail: tlopen@doct.ulg.ac.be (Lopes); severin.hatt@ulg.ac.be (Hatt)
- Functional and Evolutionary Entomology, Gembloux Agro-8io Tech, University of Linge, Gembloux, Belgium
- b TERRA AgricultureluLife, Gembloux Agro-Bio Tech, University of Linge, Gembloux, Belgium
- State Key Laboratory for Biology of Plant Diseases and Insect Pents, Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China
- d College of Plant Protection, Shandong Agricultural University, Taian, Shandong, China



Gembloux Agro-Bio Tech Université de Liège





Institute of Plant Protection, Chinese Academy of Agricultural Sciences



## Writing a review like a research paper

# The methodology used to collect the data and write this paper

### By Séverin Hatt

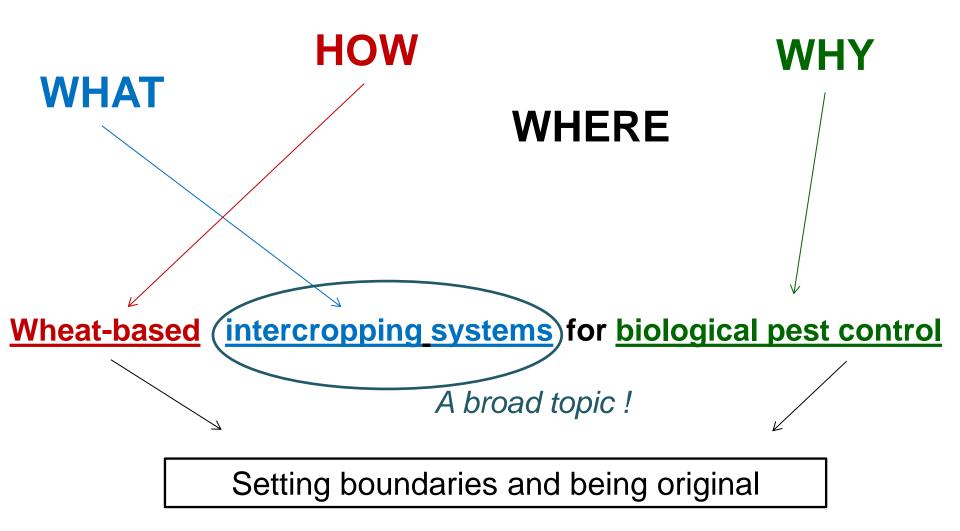
"A review of prior relevant literature is an essential feature of any academic project. An effective review creates a firm foundation for advancing knowledge. It facilitates theory development, closes areas where a plethora of research exists, and <u>uncovers areas where research is needed</u>."

Webster J. & Watson R.T., 2002. Analyzing the past to prepare the future - Writing a literature review. MIS Quarterly (26)2, pp. xiii-xxiii

## PART I

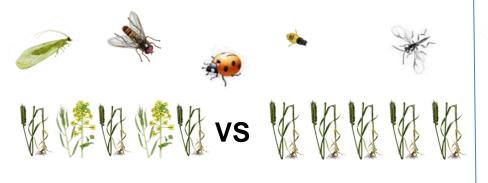
## DEFINING AND DISSECTING YOUR TOPIC

# **Step 1: Define your topic and set the boundaries of your research**



### **Step 2: Define your research questions**

1. Effect of intercropping on pests and natural enemies?



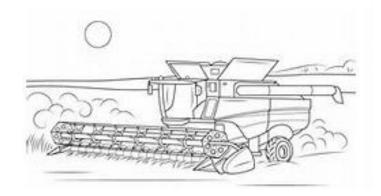
2. Correlation between pest control and yield?



3. Where such studies took place?



4. Technical characteristics of such studied systems?



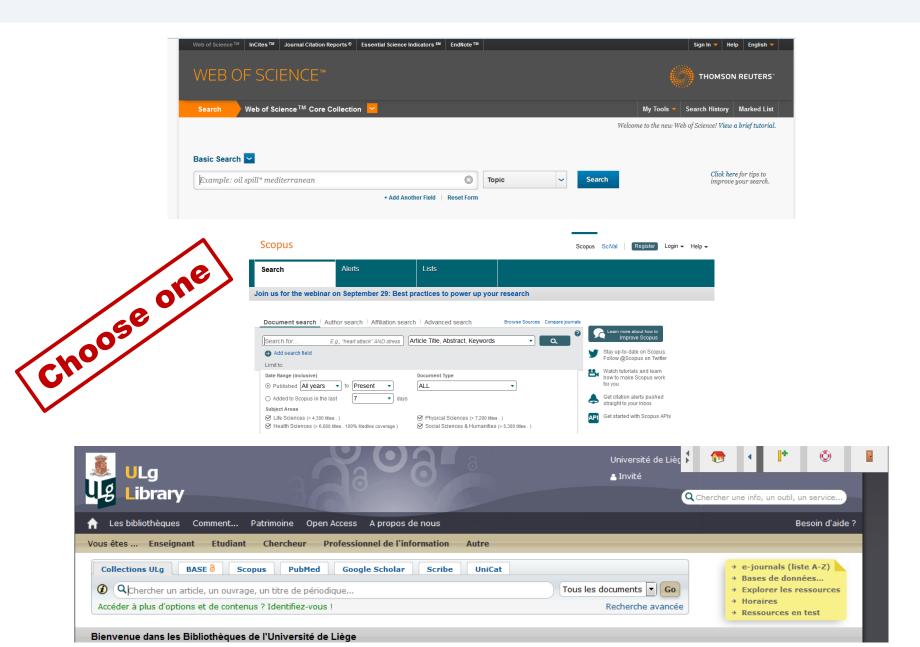
### Wheat-based intercropping systems for biological pest control

Wheat *Triticum aestivum*  Intercrop\* Crop association Crop combination Combined crop Associated crop Crop mix Mixed crop Mixed cropping

Row cropping Relay cropping Strip cropping Pest\* Herbivor Natural enemy Predator\* Parasit\*

**Dictionary** of synonyms & related topics

### **Step 4: Search for literature...**



### **Step 4: ...by setting a request**

using the boolean operators

### Wheat-based intercropping systems for biological pest control

(intercrop\* OR 'crop association' OR 'crop combination' OR 'combined crop' OR 'associated crop' OR 'crop mix' OR 'mixed crop' OR 'mixed cropping' OR 'row cropping' OR 'relay cropping' OR 'strip cropping') AND (wheat OR 'triticum aestivum') AND (pest\* OR herbivor\* OR 'natural enemy' OR predator\* OR parasit\*)

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In Part Of: Field Crops Research, 2009, Vol.110(1), pp.1-20

Evaluation of the efficiency of spring wheat and vetch mixed crops Author: Pa kove, E : Zeveln, A

Language: English Is Part Of: Russian Agricultural Sciences, Feb 2010 Description: It is shown that a comparative evalue ces, Feb 2010, Vol.36(1), pp.5-8

**SELECT THE PAPERS &** 

**CREATE YOUR** 

DATABASE

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# **PART II**

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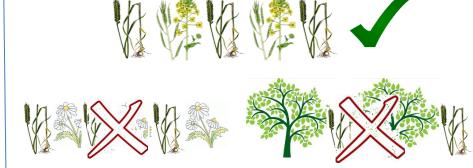
Conservation of the second sec

Studies on ecological niche of primary insect peats and enemies in the fields of spring cotton interpi

# Step 5: Read abstracts and select the relevant papers according to criterias

1. Research papers from peerreviewed journals

REVIEW Do polyculture cected ns or trade-offs in agricultura Rejection A meta-analysis 2. Intercropping: wheat + harvestable and consumable other crop(s)



3. Studying insect pests and/or natural enemies + the effect of biological control



4. Comparison of intercropping with a pure stand control

# Step 5: Read abstracts and select the relevant papers according to criterias

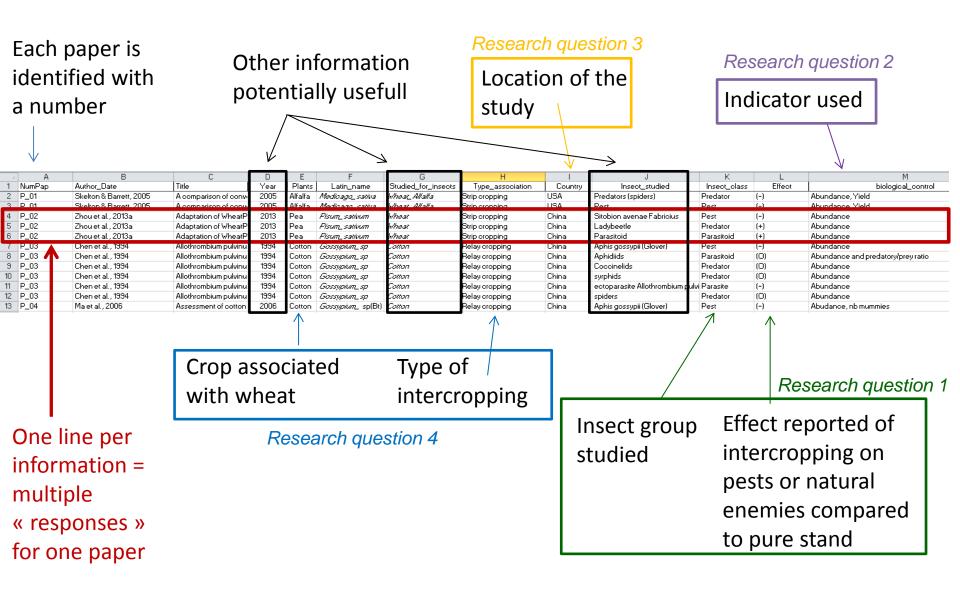
	А	В	С	D	E	F	G	Н
1	Title	Authors	Year	Abstract	Research paper?	Association?	Including wheat?	Analyzing pests and/or natural enemies?
2	Maize rev	Smale, Melin	2011	There have b	no	no	no	no
3	Should Af	Larson , Donal	2012	In Africa, mo	no	no	no	no
4	Editorial	Naylor, R. E. L.	2006	In our Editori	no	no	no	no
5	Annual M	NONE	2005	NONE	no	no	no	no
6	Breeding	Njoku, D. N. ; '	2011	This review p	no	no	no	no
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83	Response	Hummel,	2010	Graphical	yes	yes	yes	yes
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85	How to re	Hansen, Li	2008	There is a	yes	yes	yes	yes
86	IMPACT O	Singh, H.P	1999	To compar	yes	no	yes	no
87	Intercrop	Reynolds,	1994	Two cerea	yes	yes	yes	no
88	Reduced a	Hobbe D	1997	Changes is	VAC	no	VAC	no



50 papers answered our creterias and were selected for further analyses

# Step 6: Fill your data table by reading the 50 abstracts (and the full papers if possible and needed)



### **Step 6: Fill your data table by reading the abstracts** (and the full paper if possible and needed)

### A data table to be analysed...

Skelton & Barrett, 2005           Zhou et al., 2013a           Zhou et al., 2013a           Zhou et al., 2013a           Chen et al., 1994           Ma et al., 2006           Ma et al., 2006           Ma et al., 2006	Title A comparison of cor A comparison of cor Adaptation of Wheat Adaptation of Wheat Allothrombium pulvir Allothrombium pulvir Allothrombium pulvir Allothrombium pulvir Allothrombium pulvir Allothrombium pulvir Allothrombium pulvir	Year 2005 2005 2013 2013 2013 2013 1994 1994 1994 1994 1994	Alfalfa Pea Pea Cotton Cotton Cotton	Latin_name Medicago_sativa Medicago_sativa Pisum_sativum Pisum_sativum Risum_sativum Gossypium_sp Gossypium_sp	Studied_for_insects whear_Alialia whear_Alialia whear whear whear cotton 	Strip cropping Strip cropping Strip cropping Strip cropping	Country USA USA China China		Pest	Effect (-) (-)	biological_control Abundance, Yield Abundance, Yield Abundance
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		2011			Wheat		China	Sitobion avenae Fabricius	Pest	(·)	Populations density, Parasitism rates, Yield
		2011			Wheat	Strip cropping	China	All stages of Lady beetles	Predator	(•)	Populations density, Parasitism rates, Yield
		2011			Wheat	Strip cropping	China	aphid mummies	Parasitoid	(•)	Populations density, Parasitism rates, Yield
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						Strip cropping				Θ	Populations density and biological control index (BC
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	Economic profit of in	2007			Cotton		China			(•)	Abundance, damage, Yield
		2007			Cotton	Relay cropping	China			(•)	Abundance, damage, Yield
Maletial., 2007a	Economic profit of in	2007			Cotton	Relay cropping	China	spiders		(+)	Abundance, damage, Yield
	Effect of Brassica St	2012			Wheat	Strip cropping	Pakistan	Wheat aphids		Θ	Abundance, yield
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Sherawat et al., 2012	Effect of Brassica St	2012			Wheat	Strip cropping	Pakistan	Lady beetles		(+)	Abundance, yield
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## PART III

## **ANALYSE YOUR DATA**

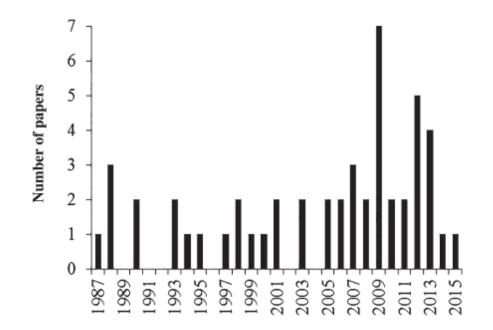
### **Step 7: Perform data description...**

Type of intercropping	Crops associated with wheat	Number of papers	References
Strip cropping	Alfalfa (Medicago sativa L.)	4	70-73
	Garlic (Allium sativum L.)	2	74,75
	Mung bean [Vigna radiata (L.) Wilczek]	2	76,77
	Oilseed rape (Brassica napus L.)	7	42,66,74,78-81
	Pea (Pisum sativum L.)	4	82-85
	Chili pepper (Capsicum frutescens L.)	1	86
Relay cropping	Cotton (Gossypium sp.)	10	44,45,87-94
	Field bean (Phaseolus vulgaris L.)	1	95
	Sorghum (Sorghum bicolor L.)	1	96
	Soybean [Glycine max (L.) Merr.]	2	97,98
Mixed cropping	Oilseed rape (Brassica napus L.)	4	99-102
	Bean (Vicia faba L.)	1	103
Strip and mixed cropping	Pea (Pisum sativum L.)	2	43,104
Non-specified	Chickpea (Cicer arietinum L.)	3	105-107
-	Cotton (Gossypium sp.)	2	108,109
	Bean (Vicia faba L.)	1	110
	Mustard (Sinapis alba L.)	3	111-113
	Sugarcane (Saccharum officinarum L.)	1	114

### **Step 7: Perform data description...**

		Effect			
Сгор	()	(0)	(+)	Number of papers	References
Pest abundance					
Bean	•		_	1	103
	•		•	1	95
Chickpea	•			3	105-107
Chili pepper	•			1	86
Cotton	•			10	44,45,87,88,90-94,10
	•		•	2	89,109
Mustard	•			2	112,113
		•		1	111
Oilseed rape		٠		3	99-101
	٠			2	79,102
Pea	٠			1	104
Sorghum	٠	٠		1	96
Soybean	٠			2	97,98
Sugarcane	٠	٠		1	114
Wheat	٠			15	66,71-78,80-85
Wheat and alfalfa	٠			1	70
Wheat and bean	٠			1	110
Wheat and pea	٠			1	43
Predator abundance and predation rate					
Cotton			٠	5	89,91,93,108,109
		٠		2	44,45
		<b>é</b>	٠	2	92,94
Oilseed rape	٠			1	42
Sorghum		٠		1	96
Wheat		-	٠	8	66,72,75,76,78,80,83,8
		٠		2	74,81
		<b>é</b>		1	73
Wheat and alfalfa	٠	-		1	70
Wheat and pea				1	43
arasitoid abundance and parasitism rate	-				
Cotton		٠		1	45
		•	٠	2	92,93
Oilseed rape	٠	٠	•	1	102
Wheat	•			1	80
			۵	1	74
		•	Ĭ.	8	66,71,75,76,78,82,83,8

### **Step 7: Perform data description...**

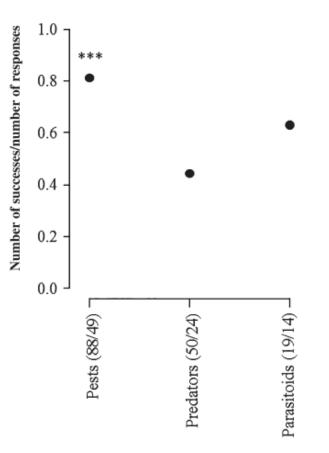


**Figure 2.** Evolution through time of the number of papers published on the effect of wheat-based intercropping on pests and their natural enemies.

### Step 7: ...and statistical analyses

1. Effect of intercropping on pests and natural enemies?

Positive (1) or negative/neutral (0) ?
Bernouilli test



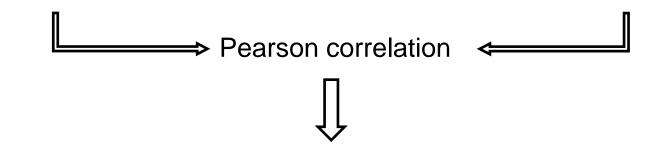
**Figure 3.** Ratio of the number of responses reporting a positive effect of wheat-based intercropping on biological control (i.e. decrease in pest and increase in natural enemy populations) on the total number of responses. The ratio given in brackets corresponds to the number of responses/number of papers. Exact Bernouilli test. \*\*\* P < 0.001.

### **Step 7: ...and statistical analyses**

2. Correlation between pest control and yield?

Positive (1) or negative/neutral (0) ?

Increased/neutral (1) or decreased (0)



Pest reduction and yield increase:  $\varphi$ =0.45, P =0.145

Increase of predator populations/predator rate and yield increase:  $\varphi$ =0.77, **P**=0.024 \*

Increase of natural enemies/rate and yield increase:  $\varphi$ =0.81, **P** =0.002 \*\*

### **Step 7: Perform statistical analyses**

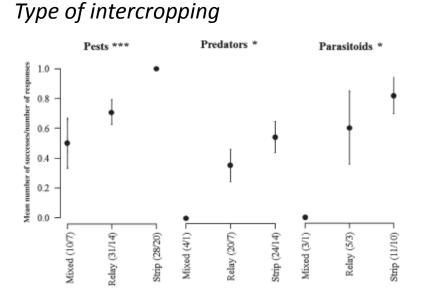
3. Where such studies took place? 4. Technical characteristics of such studied systems? 4. Technical characteristics o

**Table 2.** Effect of wheat-based intercropping on pests and natural enemies according to the countries where the studies took place, the type of intercropping and the crop of primary interest. Likelihood ratio tests on GLMs. \* P < 0.05; \*\* P < 0.01; \*\*\* P < 0.001. A dash indicates that it was not possible to perform the analysis

		Pests	Pests Predators			Parasitoids			
Predictor variables	df	χ <sup>2</sup>	Pr (> chi)	df	χ <sup>2</sup>	Pr (> chi)	df	χ <sup>2</sup>	Pr (> chi)
Country	10	19.47	0.035*	5	21.47	<0.001***	2	7.61	0.0223*
Type of intercropping <sup>a</sup>	2	18.39	<0.001***	2	6.20	0.045*	2	7.85	0.020*
Crop	11	27.63	0.004**	5	8.46	0.133	2	7.85	0.020*
Crop*type of intercropping <sup>a</sup>	-	-	-	-	-	-	-	-	_
Crop*country	-	-	-	1	1.29	0.255	-	-	-
Country*type of intercropping <sup>a</sup>	-	-	-	1	2.15	0.142	-	-	-

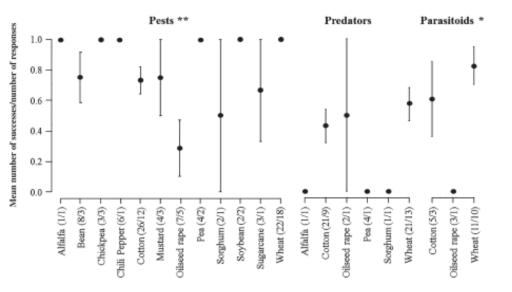
<sup>a</sup> Papers where the intercropping design was not defined were not considered in the analysis.

### Step 7: ...and statistical analyses

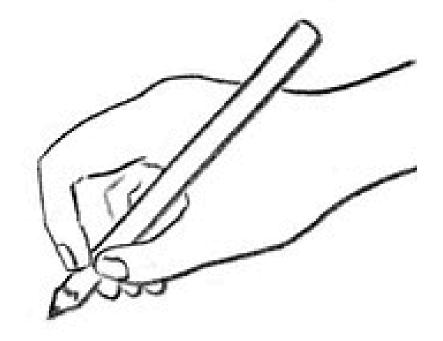


### Country Pests \* Predators \*\*\* Parasitoids\* 1.0er of resp 0.80.6 SUIC 0.4 Mean number of 0.2 0.0 ([/]) usu] (1/1) nerl USA (9/4). Belgium (8/1) 3angladesh (1/1) Belgium (4/1) Germany (3/1) Canada (2/1) China (25/14) Canada (3/1) Canada (3/3) China (47/23) Denmark (1/1) France (2/1) India (6/5) Pakistan (7/5) (TVEI) ASU Pakistan (5/2) China (15/12) Pakistan (1/1)

### Crop associated with wheat



### **Step 8: Lastly, write your review like a research paper**



## severin.hatt@ulg.ac.be