Challenges of Organic Arable Farming

4th module
Technical tools, strategies and machineries to control weeds in organic arable farming

Module objectives

Most of the biological diversity in our crop fields comes from the presence of weeds. They provide habitat for both beneficial insects and mycorrhiza fungi. However, weeds may cause a real yield loss and managing them using non chemical control strategies includes many challenges.

This module aims at providing general information about common weeds, by presenting basic knowledge to be acquired before designing a plan for weed suppression (e.g. intercropping options). It also tries to rise the awareness about different mechanical weed control options and cropping systems that suppress weed incidence.

Provided tools explain the factors that should be considered when you select a weed control strategy. The main weed control methods and future perspectives will be discussed.

Module outlines

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2	**Key weeds in Mediterranean and European areas**	
3	**Weed management methods**	3.1. Preventive methods 3.2. Cultural methods 3.3. Direct methods
4	**Key factors in the selection of a weeding strategy**	4.1. Time 4.2. Livestock 4.3. Crop 4.4. Weed type
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1. Introduction

- Before thinking of how to suppress weeds, it is fundamental to collect information about weeds biology and ecology.

- The main issue in weed management under organic systems is the typology of prevailing weeds and their relationship with the cropping system.

- In organic farming, we cannot use synthetic chemical herbicides, therefore the management practices aim at keeping the weed population at a level that does not result in the economic loss of the crop or affect its quality.

- The goal is not to completely eradicate all weeds, as they also have a role to play on farm. For example, weeds contribute to reduce soil erosion phenomena.

1. Introduction

- It is important to distinguish between annual and perennial weeds because the currently available solutions, including recent innovations, are developed accordingly.

- The same is true when we distinguish between livestock-based and stockless systems.

- Weeds in organic farming are considered a component of natural biodiversity. Hence, an optimum balance between weed control and crop tolerance can be perfectly feasible through rotations and by adopting crops that sufficiently suppress weeds.

2. Key weeds in Mediterranean and European areas

The most commonly occurring weeds across Europe and Mediterranean areas are:

Thistle (*Cirsium*)

Couch grass (*Elymus repens*)

Fat hen (*Chenopodium album*)

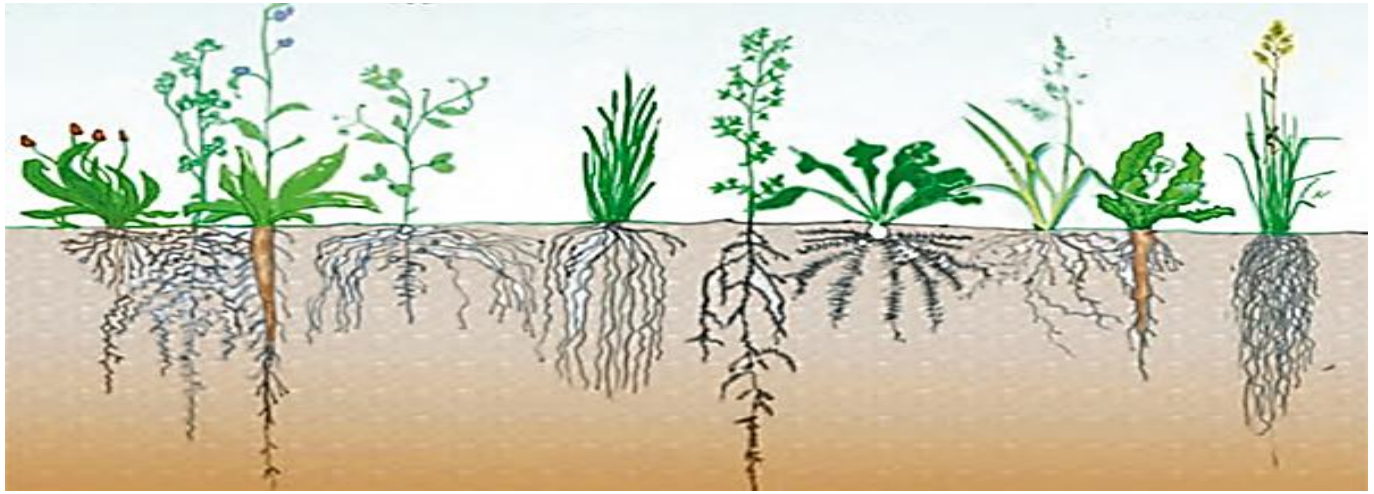
Wild oat (*Avena*)

Docks (*Rumex* L.)

Chickweed (*Stellaria media*)

2. Key weeds in Mediterranean and European areas

- Knotweed (*Fallopia*)
- Mayweed (*Matricaria*)
- Perennial ryegrass (*Lolium*)
- Charlock (*Sinapsis arvensis*)
- Ragweed (*Ambrosia*)
- Annual meadow grass (*Poa annua*)
- Blackgrass (*Alopecurus myosuroides*)
- Quick weed (*Galinsoga*) particularly for vegetable farms



3. Weed management methods

The strategies that maintain weed abundance below the 'threshold' of acceptable damage can be used. Usually, more than one approach is necessary in practice. First, we interfere using Preventive methods before growing our crop, aiming to reduce in-crop weed emergence. Cultural control increases crop competitive ability against weeds. Here, we look at how growing practices, such as crop rotation and tillage, can control weeds. Then Direct control methods include mulching or mechanical removal of weeds.

The table below shows examples of agricultural practices that may have more than one classification as weed management methods:

Examples	Preventive	Cultural	Direct
Soil tillage	√		√
Cover crops	√	√	
Mulching	√	√	
Flame-weeding	√		√

This module focuses on mechanical means (Direct), crop rotation (Preventive) and some cultural measures.

3.1. Preventive methods

- Prevention is the most effective method of dealing with weeds. Once a weed invades the orchard and becomes established, eradication becomes expensive and requires more resources to control and reduce its impact.
- Many ways can be adopted as preventive methods:

1. Restricting the opportunity for new weeds to invade and spread (e.g. limiting the movement of vehicles, trying to buy certified weed-free fodder)
2. Restricting the spread of existing weed infestations (e.g. working in the clean area first and in the infested area last)
3. Quarantine (e.g. holding the livestock that may be infested with seeds in a single location)
4. Monitoring (e.g. continually monitoring weed infestations)

3.1. Preventive methods

Crop rotation is the most common preventive measure

- Being a cornerstone in organic farming, crop rotations are the pivotal element of weed control.
- The crop rotation design strongly influences the diversity and abundance of the weed flora (Bond and Grundy, 2001), especially of perennial weeds.
- Crop sequence that keeps the soil covered for a long period has a significant role in the weeds establishment.
- Weed growth cycles are adapted to the cultivated crops and the associated agricultural practices. In addition, crops are different in their germination and growing periods (spring or autumn crops). Therefore, shifting between crops helps reduce weed pressure.
- Generally, the weed severity increases with a higher share of grains and a lower share of grass-clover leys in crop rotation.
- Bi- or multi-annual crops in the rotation can effectively suppress perennial weeds by 71-98%, in comparison to a rotation with annual crops only.

3.2. Cultural methods

3.2.1. Genotype choice

- The use of competitive cultivars could be an option, especially in small grain cereals (Andrew *et al.*, 2015), but they are not always easily available everywhere.

3.2.2. Planting pattern

- Crop management must be integrated with weed control means. The way we manage the crop may be a tool for weed control, basically by adjusting the sowing date, the sowing density and by optimizing crop nutrition to enhance crop competitiveness.

3.2.3. Intercropping

- Although some classic solutions for narrowly-spaced crops (e.g. barley-pea mixture) are still used, the intercropping system is yet to be fully assessed.

3.2.4. Cover crops

- "Grass clover leys" are usually mentioned as a key strategy to control annual and perennial weeds.

3.3. Direct methods

Mechanical methods

- There is a general trend towards mechanical weeding especially for perennial weeds and for selective weeding between crop lines. Check this real-life case.

- The cost of specialized machinery is the major barrier to implement this strategy. It can be bypassed by sharing such equipment among neighbor farms.

- There is a trend towards low "inversion tillage" and the use of machinery other than a plough to perform cultivations. With the growing importance of reduced tillage in organic farming, the use of mulches and cover crops is more and more frequent. However, they have to be well-managed in order to allow "non-inversion tillage" to impede weed proliferation (Anderson, 2015).

- Under these conditions, improved equipment (e.g. roller crimper) to terminate cover crops while impeding regrowth is needed (Davis, 2010).

- The chisel ploughing and sub-soil ploughing are used in minimum/conservative tillage, which is considered as a way to discourage the germination of annual weed seeds. Check here how no-tillage succeeded in organic.

3.3. Direct methods

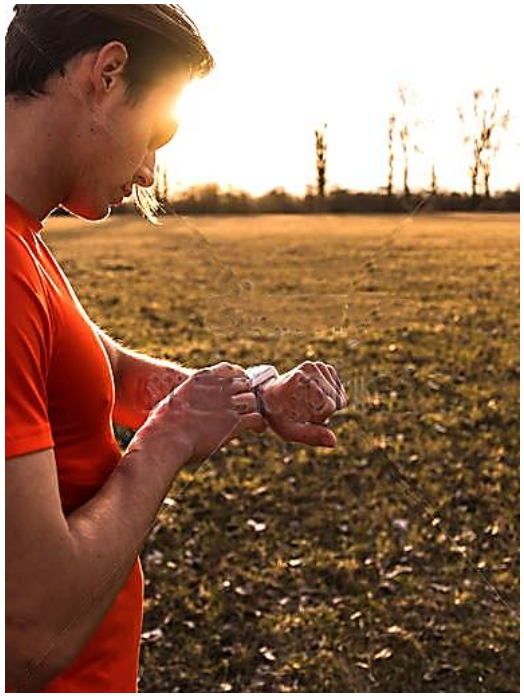
- The "Finger weeder" has reached some popularity as intra-row mechanical weed control method, also due to its reduced cost.
- It is likely that improving control strategy may be achieved through the organized use of tillage that, however, may not be in agreement with other important management goals (e.g. the need to keep soil cover in wintertime).
- Both mechanical control and herbicide treatments can be equally efficient in terms of crop yields. However, mechanical weed control does not negatively influence weed diversity and species richness like herbicides do (Armengot *et al.* 2012). Check this paper.
- We might need to introduce row crops in our rotation to apply inter-row hoeing as weed control strategy.
- The efficacy of direct control methods depends on the composition of the weed flora, timing, environmental conditions and the frequency of the applied technique.

4. Key factors in weeding strategy selection

Weed control strategies are farm specific and dependent on: present weeds, farming system, climate, soil moisture and many other factors such as:

4.1. Time

- The timing of mechanical weed control is important (pre-crop emergence, early or late post-crop emergence).
- Early harrowing can slightly reduce yield because it harms crop seedlings (Mangerud *et al.*, 2007).
- For a single pre-crop emergence and early post-crop emergence harrowing, weed reduction was found to be around 40% (Mangerud *et al.*, 2007), whereas variance can range from 5% to 90% depending on weed species (Davis and Welsh, 2002).
- The second, late mechanical weeding significantly reduced weeds compared to one single early weeding (Lukashyk *et al.*, 2005; Lundkvist, 2009).

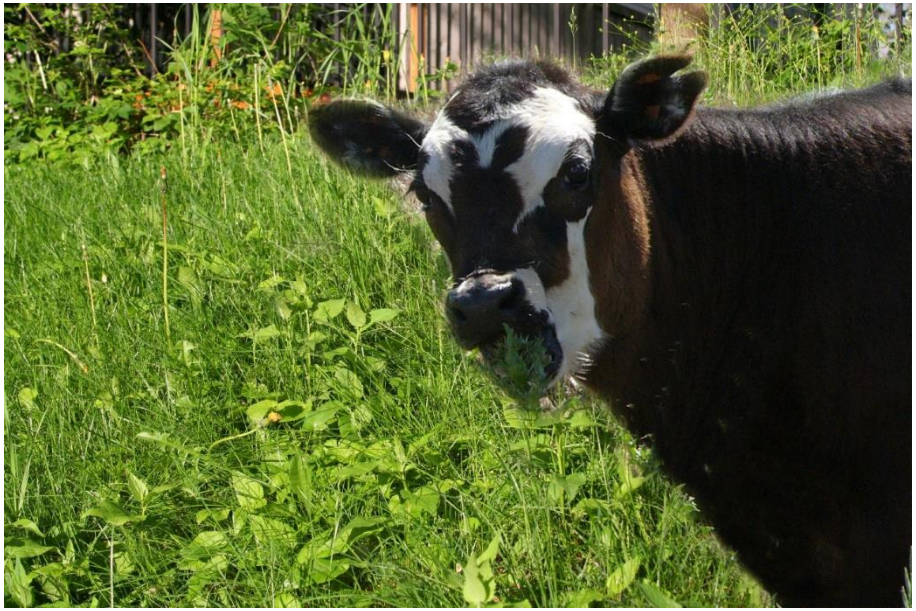


4. Key factors in weeding strategy selection

4.2. Livestock

In livestock systems:

- Annual weeds are relatively easy to control by appropriate mowing regimes of the grass.
- Cutting grass-clover or similar leys usually breaks the life cycle of annual weeds before setting seeds, determining their development over the crop rotation.
- The use of “flex tine harrows” like “Treffler” would result in better annual weed control (Huiting *et al.*, 2014).
- Docks (*Rumex* spp.) are major perennial weeds.



4. Key factors in weeding strategy selection

4.2. Livestock

In stockless systems:

- The control of annual weeds introduces greater challenges. Among preventive methods, the use of the "false seedbed" technique is still perceived as important. However, the increased climate unpredictability may reduce the use of this technique due to the higher risk of delaying crop sowing as result of adverse weather conditions.

- Species mixtures may increase weed suppression and simultaneously enhance the array of genotypes with the right traits available for different environments.

4. Key factors in the selection of a weeding strategy

4.3. Crop

- Cultural and direct control measures in any weed management approach vary from crop to crop. Some crops were derived from weedy plants and may create local conditions that favor the growth of a specific weed. Furthermore, control strategies vary among crops (e.g. higher value vegetable tending to be mulched and manually weeded).

4.4. Weed type

- Thistles (mainly *Cirsium arvense*) are the major perennial weeds in most European organic stockless arable systems. Their control is currently targeted either through stubble cultivation, the use of competitive cover crops, or through the introduction of a ley phase (Lukashyk *et al.*, 2008), but effects are not always outstanding.

5. Future perspectives, what is next?

Despite the progress in the basic and applied knowledge on:

- Weed community dynamics
- Crop/weed interactions and
- Weed management tools

there is still a gap to be filled in, before saying that new scientific evidence would straightforwardly become a potential innovation for organic arable farmers.

Participatory research is still sparsely used, determining a potential mismatch between farmers requirements and scientists preferences.

5. Future perspectives, what is next?

- New methodological approaches based on the multi-actors engagement like ‘mental models’ have been recently applied to weed management issues under organic conditions (Jabbour *et al.*, 2013).The knowledge gained from such ‘mental models’ might lead to more appropriate extension work and might be worth to be implemented in different countries. You are invited to read more here and here.

- In general, holistic (system-based) weed management (Bàrberi, 2002) is yet to be fully implemented in organic arable systems. Research was carried out on ecological weed management, which means the use of methods that eventually reduce the weed seed bank by investing ecological interactions (Bastiaans *et al.*, 2008).

- This includes: rising up the decay of weed seeds and the severity of insects and rodents attacks to weed seeds. Both strategies might be possible through an appropriate management of field and field borders (Davis *et al.*, 2013).

5. Future perspectives, what is next?

- The ecological branch of weed research is still at the beginning but it is expected to become progressively more important, especially for application in organic systems.

- Adoption of high-tech solutions like "camera-guided, semi-automated systems" for mechanical weeding is expected to increase (Bakker *et al.*, 2010, Shah and Lee, 2015), but it may increase the gap among European farmers due to the different attitude to innovation and budget availability in different countries.

- Recently, localized hot water injection has been proposed as an effective method of direct weed control for docks (Latsch and Sauter, 2014)

6. Brainstorming questions

6.1. Is it always necessary to control weeds? What are the weeds benefits?

- Although weeds can be significantly reduced by different direct control strategies, a negative impact of weeds on the crop yield is not always found (Popay *et al.*, 1992; Samuel and Guest, 1990; Peruzzi *et al.*, 1993).
- In a recent study, it was found that weed incidence under organic reduced tillage schemes may be increased by 50% compared to plough systems, without necessarily threatening the yield.
- Wheat yields under reduced tillage and plough system were similar.

6.2. Do we need to combine methods?

- Improved management of perennial weeds may require tillage – mainly ploughing – to gradually reduce the load of vegetative reproductive propagules (seed bank). Combinations of tillage and the use of improved tools for direct non chemical weed control are needed to inhibit creeping perennials.

6. Brainstorming questions

6.3. Is it true that one weed type always requires a specific control method?

- There is no clear trend towards one strategy or another depending on the weed type, although perennial weeds require a combination of all strategies including mechanical weeding.
- However, there are similarities in the major weed species across Europe (docks, thistles, couch, fat hen, wild oats), and common control methods and barriers (such as machinery cost and lack of knowledge) applied by farmers.

6.4. What are the farmer perspectives concerning the following issues?

- Seed persistence in soils
- The role of weed diversity
- The economic consequences of weeds (e.g. high labor against yield losses)
- The use of weeds as indicator for soil nutritional status

7. Conclusions

- Weed control is a challenge for researcher-advisor-farmer cooperation and mutual learning.
- In stockless arable systems, the control of annual weeds introduce greater challenges. Among preventive methods, the use of “false seedbed” technique is really important.
- In both livestock and stockless systems, perennial weeds can be effectively managed by using stubble cultivation, competitive cover crops and a ley phase.
- In most systems, economic issues and unfavorable weather conditions limit preventive and sometimes mechanical measures.
- In mechanical weed control, farmers play a very active role, investing their observation to help engineers. The result is professional machinery with craftsmanship.
- New production systems like reduced tillage require modification of the weeding techniques.
- Precision farming and robots might revolutionize weed control in organic arable cropping systems to compensate the prohibition of chemical herbicides.

7. Conclusions

- Despite the innovative research on direct weed control methods such as robotic and site-specific weeding (López-Granados, 2011), there is a little novelty in “low-tech solutions” that would be more easily adopted by a larger number of farmers across Europe.

“A strong weeding strategy can be achieved if we keep in mind the following issues:

- ❑ Acquiring knowledge of your weeds and their weak points
- ❑ Building up a sound and diversified crop rotation
- ❑ Applying preventive methods (e.g. cover crop)
- ❑ Choosing competitive cultivars and creating competitive crop stands
- ❑ Choosing the direct method best suited to your crop, soil and weeds
- ❑ Bing ready to change”

prof. Paolo Bàrberi

Further tools

Here there are some further tools in the context of this module available in other languages

- Demonstration of Hoeing Machines in Arable Farming (video) / French.
- Dock plant control (Use preventive possibilities) (leaflet) / German
- Weed Cutter CombCut in Use (video) / German

Linkography

- How do I manage weeds?
- Weed control in Vegetable Cultivation
- Weed Management in Organic Agriculture
- Non-chemical weed management in organic farming systems
- Weed management in organic agriculture: are we addressing the right issues?
- An Agricultural Mobile Robot with Vision-Based Perception for Mechanical Weed Control

Linkography

- The effect of sowing date, stale seedbed, row width and mechanical weed control on weeds and yields of organic winter wheat
- Is conservation tillage suitable for organic farming? A review
- A Survey of Weeds in Organic Farming in Sweden
- Weed Seedbank Dynamics in Three Organic Farming Crop Rotations
- Innovation in mechanical weed control in crop rows
- Effect of tillage intensity on weed infestation in organic farming

References and further readings

- Anderson R. (2015). Integrating a complex rotation with no-till improves weed management in organic farming. A review. Agronomy for Sustainable Development 35, 967-974.

- Andrew I.K.S., Storkey J. and Sparkes D.L. (2015). A review of the potential for competitive cereal cultivars as a tool in integrated weed management. Weed Research 55, 239-248.

- Armengot, L., José-María, L., Chamorro, L. and Sans, F.X (2012). Weed harrowing in organically grown cereal crops avoids yield losses without reducing weed diversity. Agronomy for Sustainable Development. DOI 10.1007/s13593-012-0107-8

- Bàrberi P. (2002). Weed management in organic agriculture: are we addressing the right issues? Weed Research 42, 176-193.

- Bastiaans L., Paolini R. and Baumann D.T. (2008). Focus on ecological weed management: what is hindering adoption? Weed Research 48, 481-491.

- Böhrnsen A. (1993). Several years results about mechanical weed control in cereals. Communications of the fourth International Conference IFOAM – Non-Chemical Weed Control, Dijon. 93100.

References and further readings

- Bond W. and Grundy A. C. (2001). Non-chemical weed management in organic systems. Weed Research, Vol. 41, No. 5, (October 2001), pp. 383-405, ISSN 0043-1737

- Davies, D.H.K. and Welsh, J.P. (2002). Weed control in organic cereals and pulses. In: Younie, D.; Taylor, B.R.; Welch, J.M. and Wilkinson, J.M. (Eds.) Organic cereals and pulses. Papers presented at conferences held at the Heriot-Watt University, Edinburgh, and at Cranfield University Silsoe Campus, Bedfordshire, 6 and 9 November 2001. Chalcombe Publications, chapter 5, pp. 77-114.

- Davis A.S. (2010). Cover-crop roller-crimper contributes to weed management in no-till soybean. Weed Science 58, 300-309.

- Davis AS., Taylor EC., Haramoto EC. and Renner KA. (2013). Annual postdispersal weed seed predation in contrasting field environments. Weed Science 61, 296-302.

- Dierauer H.-U. and Stöppler-Zimmer H., (1994). Unkrautregulierung ohne Chemie. Eugen Ulmer Verlag, Stuttgart, 134 S.

- Huiting H.F., Riemens M.M. and van der Weide R.Y. (2014). Practical experiences from physical and cultural weed control in reduced tillage maize growing systems. Proceedings 10th EWRS Workshop on Physical and Cultural Weed Control, Alnarp, Sweden, 16-19 March, 5.

References and further readings

- Jabbour R., Zwickle S., Gallandt ER., McPhee KE., Wilson RS. and Doohan D. (2013). Mental models of organic weed management: comparison of New England US farmer and expert models. Renewable Agriculture and Food Systems 29, 319-333.

- Latsch R. and Sauter J. (2014). Optimisation of hot-water application technology for the control of broad-leaved dock (Rumex obtusifolius). Journal of Agricultural Engineering 45, 137-145.

- López-Granados F. (2011). Weed detection for site-specific weed management: mapping and real-time approaches. Weed Research, 51, 1-11.

- Lukashyk P.; Berg B. and Köpke U. (2005). Einsatz des Striegels zur Regulierung von Vicia hirsuta in Winterweizen. [Controlling Vicia hirsuta in winter wheat by using a tine - harrow.] In: Heß, J and Rahmann, G (Eds.) Ende der Nische, Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau, kassel university press GmbH, Kassel.

- Lukashyk P.; Berg M. and Köpke U. (2005). Kontrolle von Cirsium arvense durch Stoppelbearbeitung. [The effect of stubble tillage on Cirsium arvense.] In: Heß, J and Rahmann, G (Eds.) Ende der Nische, Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau, kassel university press GmbH, Kassel.

- Lukashyk, P., Berg, M., & Köpke, U. (2008). Strategies to control Canada thistle (Cirsium arvense) under organic farming conditions. Renewable Agriculture and Food Systems, 23(01), 13-18.

References and further readings

- Lundkvist A., Fogelfors H.; Ericson L. and Verwijst T. (2011). The effects of crop rotation and short fallow on the abundance of perennial sow-thistle (Sonchus arvensis L.). Proceedings of 24th NJF Congress, Food, Feed, Fuel and Fun – Nordic Light on Future Land Use and Rural Development, p. 76, ISSN 1653-2015, Uppsala, Sweden. June 2011. 20.07.2011

- Mangerud K., Brandsaeter L. and Waernhus K. (2007). Criteria for optimized weed harrowing in cereals. European Weed Research Society. 14th EWRS Symposium, Hamar Norway, 17-21 June 2007, 82.

- Peruzzi A., Silvestri N., Gini N. and Coli A. (1993). Weed control of winter cereals by means of weeding harrows: first experimental results. Agricoltura Mediterranea, Vol. 123: 236-42.

- Popay I., Stiefel W., Sorenson E. and Popay, A.J. (1992). Tine weeding effects on cereal crops with few weeds. Proceedings of 45th New Zealand Plant Protection Conference, 93-94.

- Samuel A.M. and Guest S.J. (1990). Effect of seed rates and within crop cultivations in organic winter wheat. In: Unwin R.J. (Ed.), Crop Protection in Organic and Low Input Agriculture: Options for Reducing Agrochemical Usage. British Crop Protection Council, 49–54. 1