Invited Address

Problems and progress for organic seed production

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Abstract

In the mid-1990s the organic agriculture movement started a drive for only organically grown seed to be used in organic agriculture due to its growing commercialisation, the advent of transgenetic crops and to ensure authenticity. 'Organic seed' is a multi-level concept. At its most simple, it just refers to 'certified' planting seed produced according to organic standards, then as a proxy for organic cultivars and breeding approaches, and finishing with political and philosophical issues such as food sovereignty. The International Federation of Organic Agricultural Movements (IFOAM) finally adopted a formal position on organic seed in 2011. The drive for organic planting seed in the developed world has mostly been fulfilled through the use of progressive implementation systems whereby the amount of non-organic seed that is permitted is slowly reduced. However, these systems have had some perverse outcomes, at least initially, and the management of their implementation is somewhat hampered by only collecting data on approvals to use non-organic seed, and not collecting data on how much organic seed is used. The drive for certified organic planting seed has also often had the undesirable effect of reducing the range of cultivars available to producers, which is contrary to organic objectives. This has complicated the drive for 100% organic seeds. However, this has also spurred breeding of cultivars optimised for organic systems, both in centralised institutional settings and decentralised farmer and grower undertakings. The production of organic planting seed, especially for crops such as vegetables, is probably the most difficult of all farming activities. However, there continue to be significant technological and intellectual production improvements that are not only making organic farming and growing easier, but also helping mainstream production systems address their challenges as well.

Additional keywords: IFOAM, organic cultivar, diversity, seed quality, derogation, breeding

Introduction

Around the mid-1990s the worldwide organic movement started a drive for only organically produced seeds and other propagation material, to be allowed in organic agriculture. The principle push for this change came from Europe and the USA, being driven by issues such as:

(1) the rapid growth of organic agriculture which resulted in more financially focused and less 'philosophically committed' producers becoming involved,
(2) the introduction of transgenic (genetically 'engineered') crops, and the need to 'ring fence' organic production from transgenics (Anon, 2004) once the decision was made to prohibit such technologies and,
(3) the then standard practice among organic producers of using non-organically produced seeds, but without xenobiotic (agrichemical) seed dressings, was open to the charge of being hypocritical, a less than ideal position for an ethically driven agricultural system.

Organic seed

The concept of 'organic seed' can mean quite different things to different people making the topic rather more complex than it may first appear (Horneburg, 2011).

At the simplest level 'organic seed' means planting seed[1] (i.e. 'certified' seed) that is produced and audited to internationally recognised organic agricultural production standards, i.e. is 'certified organic'. Typically these are seeds of cultivars produced by mainstream agricultural breeding programs or companies, for mainstream agriculture (i.e. optimised for production using soluble fertilisers and agrichemical pesticides) and include F1 hybrids, but exclude cultivars produced by transgenetic and related breeding techniques, which are prohibited under organic certification. It is only the last step in this system, i.e. the final multiplication of breeders or foundation seed to planting seed that is done under organic conditions. The rest of the process is under mainstream agricultural conditions and control.

The next level is seed that has been completely produced under organic conditions, including the production of breeders seed.

At the next level there is a conceptual step-change: 'organic seed' is a synonym for 'organic cultivar' i.e. cultivars that have been bred for optimum performance in organic and similar agricultural systems, i.e. with limited soluble fertilisers and no xenobiotic pesticides. Attributes such as ability to 'scavenge' nutrients, especially nitrogen, and having high disease and pest resistance and competitive ability against weeds are all attributes that are considered important for cultivars in organic agriculture, but have been of limited concern for mainstream agricultural breeding programs, at least until recently. (It is inherent in this meaning of 'organic seed' that breeding is undertaken under organic conditions.) Organic breeding is undertaken in both commercial, research and government sectors, and distributed among farmers and growers. It is an increasingly vibrant and active area.

At the highest level 'organic seed' takes on a more metaphorical meaning/becomes an emblem relating to issues such as food sovereignty and farmers as stewards of global genetic resources (Shiva, 2007). For those people with a more mechanistic or 'scientific' psychology, such concepts can appear esoteric and sentimental. However,

[1] The term 'certified' is used both in organic agriculture (meaning audited to organic standards (rules)) and seed production (to represent the final stage of seed multiplication (seed certification classes) from breeder's seed through, foundation, registered, to certified seed). To minimise confusion in this address, certified refers to certified organic and 'certified seed' will be referred to as planting seed.

these are valid political and philosophical positions, particularly in relation to agriculture in developing countries, and these issues are also becoming more visible within mainstream agriculture in developed countries, though still as a minority position.

IFOAM position on the use of organic seed

Due to the complexity of the issues surrounding organic seed in all its meanings, The International Federation of Organic Agricultural Movements (IFOAM) which is the single, international, non-governmental organisation that represents the global organic agricultural movement, took a considerable time to produce an official position on organic seed, finally publishing it in 2011 (Anon, 2011), some eight years after the joint IFOAM and FAO first world conference on organic seed.

However, despite the delay, perhaps even as a result of the delay, as a formal IFOAM position, it commands significant deference within organic agriculture. It is therefore worth reproducing the executive summary of the position paper (Anon, 2011), to create a foundation for the complexities, and competing objective of organic seed, that are discussed in this address. This executive summary is as follows:

“1. The choice of high quality organic seed and plant propagation material of suitable varieties is an important key to successful organic farming, allowing for improved yield and product quality, for crop resilience, considerate use of non-renewable resources and for increased genetic and species diversity.
2. The overall goal of IFOAM is to increase the proportion of organically propagated plant material, the number of crops and varieties available as organic seed, and the quality of organic seed with respect to purity, seed health and vigour.
3. The organic sector together with committed organic seed suppliers need to take responsibility to ensure that the organic propagation and seed market becomes more independent from the market dominating companies and can further grow.
4. IFOAM recommends seed production to be done with greatest experience and care and under favourable climatic conditions as well as in the respective regional context. Seed production should be combined with on-farm variety testing in order to provide as much information for farmers as possible.
5. IFOAM acknowledges variety protection as long as breeder exemptions and farmers’ privilege are guaranteed. IFOAM will strongly advocate against the patenting of living organisms that violate these rights.
6. IFOAM will promote the coexistence of the formal seed sector and informal farmer based organic propagation in order to favour the diversity of Organic Agriculture and to help farmers to better adapt to local conditions.
7. IFOAM supports all initiatives to improve the legal situation for farm-saved seeds and plant material as well as for the propagation of old and modern landraces, populations, and other accessions that are useful for organic cultivation but do not pass the present variety registration process or have lost variety protection.
8. In places where certified organic seeds of suitable varieties are not available in sufficient quantity or quality the use of

non-organic seeds should be allowed. As a first step, IFOAM strongly recommends the use of seed treatments that comply with organic principles.

9. IFOAM recommends the training of farmers, farmer groups, seed processors, and organic seed traders in all aspects of organic propagation and maintenance breeding."

Implementation of 100% organic planting seed

Despite the strong desire for change, the practical implementation of 100% certified organic planting seed and propagation material faced a classic 'chicken or the egg' causality dilemma. Until there was a good range of quality seed of suitable cultivars produced organically, farmers and growers were unwilling to use organic seed, especially if it put them at a financial or other disadvantage with their competitors, and in turn, seed producers were not willing to go to the considerable expense and complexity of setting up certified organic seed production systems, if there was not a 'guaranteed' market for their seed.

In addition there is considerable variation in the difficulty of producing seed organically (as there is in mainstream production); for example, in cereals, the final 'consumer' product is seed, so organically certified cereal planting seed is only slightly more difficult to produce than the food crop, while for vegetables, seed production is often utterly different from food crop production, requiring very different production systems which are often much more technically challenging. It is therefore simply not possible to apply blanket rules across all types of crops regarding the use of certified organic seeds and propagation material.

Progressive implementation

The solution to these problems was a progressive implementation approach, whereby minimum thresholds for the use of certified organic seeds were established within different crop categories, e.g. cereals versus vegetables, often down to the individual species level. These thresholds were initially set very low, e.g. 10% organic certified seed, so that it was not an onerous burden on producers, but at the same time created a 'guaranteed' market for organic seed, so seed producers could be confident of getting a return on their initial investments in organic production systems. The aim was that as time progressed and the availability and quality of certified organic seed increased, the thresholds would be increased to match supply and demand, eventually reaching the point where only certified organic seed would be permitted for use.

While conceptually simple, the practical application of the progressive implementation approach was complex. For every crop that a farmer or grower wanted to use, they had to actively look for certified organic seed, and only if they could not find sufficient seed of suitable quantity, quality and/or cultivar, could they then apply for a 'derogation' from their certification agency to use 'untreated' (no xenobiotic seed dressings) non-certified organic seed. With thousands of organic producers in any given country, each planting tens, even hundreds of crops, with many different producers and suppliers of planting seed, often with large ranges of cultivars, and multiple organic certification agents, the management of the progressive implementation approach required top down control and was inevitably 'administratively complex'.

It was initially hoped that by 2004 all planting seed would be all certified organic

(Lammerts van Bueren *et al.*, 2003). However, that and many subsequent 'deadlines' have come and gone, with the final objective yet to be fully achieved, although for some species 100% organic seed has been fully achieved.

The application of progressive implementation

The European Union (EU) is a useful example of the practical application of progressive implementation as most other countries have similar overall approaches to the EU, but often with a lower level of complexity, as they are not faced with the EU's competing politics of subsidiary and unification/standardisation, at least to the same degree.

The solution in the EU was for the union's organic standards to state that all propagation material had to be organic (i.e. the ultimate objective), but with a system of derogations that permitted non-organic certified materials to be used when certain criteria were met. This was implemented on a country by country basis, facilitated by an internet based database of available organic seeds (www.organicxseeds.com) which was filled in on a voluntary basis by seed producers and sellers and consulted by seed purchasers. Derogations were issued to producers on a case by case basis by the government regulated certification agents (auditors) in each country, with information on derogations passed to each country's government for recording, which was then passed to the European Commission to provide centralised monitoring. Based on the collected information decisions are made as to the overall certified organic seed derogation thresholds, and the specific thresholds for individual species (Döring *et al.*, 2012).

This system has worked reasonably well, but there have been, and still are, a number of issues. For example, the databases created some rather perverse outcomes, particularly in the earlier stages, such as producers switching from their regular cultivars and seed suppliers when these were put on the database in preference for other seed companies' cultivars that were not available organically, and therefore often cheaper (Döring *et al.*, 2012). This resulted in some seed producers not listing their organic seed on the database to prevent their larger customers deserting them. This contrasts with the interesting approach taken by Bejo Zaden B.V (www.bejo.com) who made a new and highly regarded carrot cultivar only available as organic seed (G. Beemsterboer pers. comm. 2012) even for mainstream growers who had no interest in using certified organic seed, thus forcing them to use certified organic seed, or a different cultivar.

Beyond these somewhat minor issues there is a fundamental gap in the administration system (particularly in light of the primary objective of making 100% of the propagation material in organic agriculture certified organic) that there is no recording of the amount or proportion of certified organic seed used by producers. Due to the way the administration system is set up, only derogations, i.e. permissions for the use of non-organically certified seed, are recorded. This, as noted above, is tabulated at country level and then collated at EU level, for example (Atkinson *et al.*, 2012). While these reports are helpful, from a scientific perspective they are fundamentally flawed as it is not possible to calculate the amount of organic seed that is used, from the derogations for non-organic seed, as the relationship between these also depends on the total amount of seed required by organic producers, which in turn depends on the area of crops they grow. Therefore, as the number of organic producers and area of organic land is increasing the number of derogations could also be increasing even though the proportion of organic versus non-organic seed that each individual producer is using is also increasing. However, from a political perspective, the system appears to be sufficient, and there are enough alternative sources of information, e.g. through 'expert groups' and the seed trade, to allow the derogation thresholds to be increased in line with supply and demand (Döring *et al.*, 2012).

There are also a number of other problems and successes with progressive implementation in the EU, such as some countries not having databases, the large differences between countries derogation reports, lack of data standardisation, harmonisation between agronomically and climatically similar countries, especially those sharing land boarders, e.g. France, The Netherlands and Germany, the existence or lack of and different composition of expert groups, price differences, different 'carrots and sticks' used by different countries, derogation categories and seed mixtures (Döring *et al.*, 2012), many of which are symptoms of the competing politics of subsidiarity and unification/standardisation. Other jurisdictions also suffer from similar or related issues.

However, overall, the view from the EU and other countries is that progress is being made: certification bodies continue to push producers to increase the proportion of organic seed they use. The percentages of non-organic seed that are permitted continue to be slowly decreased, the range (number of species and cultivars, and total amount) of organic seed continues to increase, to the point that the range of species where only organic seed is permitted continues to expand (Lammerts van Bueren *et al.*, 2003; Dillon and Hubbard, 2011).

Gathering accurate information - surveys

This lack of data on the amount and proportion of organic and non-organic seed used is not unique to the EU, and it appears pretty much ubiquitous in other countries using progressive implementation approaches, e.g. the USA. Without the collection of primary data, the alternative information gathering approach is producer surveys. Unfortunately these are mostly not undertaken on a regular/systematic basis, so they are not as rigorous as ideal in determining trends over time, but they do give a useful snapshot of the situation 'on the ground' (Lammerts van Bueren *et al.*, 2003; Dillon and Hubbard, 2011). Some of the key points from these surveys are:

(1) Arable crops have the highest use of organic seed, followed by pasture and then vegetables, which is expected from the nature of the crops, as already discussed.

(2) Smaller scale producers tend to use more/100% seeds than larger scale farms. This could be interpreted as smaller producers being more philosophically committed than larger producers who are more financially motivated. However, smaller producers also tend to have more direct sales, which means they have the ultimate choice over cultivar and therefore seed selection, while larger producers are more likely to have their cultivar choice dictated by the market, e.g.

processor or supermarket, so they have less autonomy in being able to select organic seeds. Teasing out these issues requires more details than surveys generally provide.

(3) In all cases where producers were not already using 100% certified organic seed the certification (audit) organisations continue to pressure producers to increase the proportion of organic seed used.

(4) In terms of the concerns that producers have, the availability of a desired cultivar is still the major barrier to uptake of organic seed, especially for vegetables, and again, this is often related to market demands, especially for producers supplying processors and multiples.

(5) Although organic seed rules and legislation often state that cost should not be taken into account when comparing organic versus non-organic seed options, cost is an issue for a significant proportion of farmers (e.g. 41%, Dillon and Hubbard, 2011).

(6) In comparison, concerns about quality have become a minor issue with 73% of respondents in the USA saying they had the same level of quality problems with organic and non-organic seed (Dillon and Hubbard, 2011). Issues around quality were a major concern in the early days of promoting organic seed with the issue of whether lower 'seed certification' standards should be permitted for organic seed coming under intense discussion (Groot *et al.*, 2004; Larinde, 2004).

Organic planting seed reduces cultivar diversity

For countries that control the marketing of plant cultivars through legislation, including transnational schemes such as the OECD Scheme for the Movement of Seed in International Trade, the push for certified organic planting seed has often resulted in a reduction in the diversity (range) of cultivars that organic producers can access - which is the complete opposite of organic agricultural objectives which promote diversity in all its forms including cultivars. This situation mostly arises where only seed from cultivars that are registered/approved through legislation are permitted to be sold. The costs of registration are often considerable so only commercial breeders have the financial capability and profit motive to list cultivars. This means that older breeds and 'heirloom varieties' are not registered and therefore illegal to sell. Certified organic planting seed therefore has a 'double' filtering, by cultivar registers and organic certification, resulting in a reduced selection of cultivar choice (Micheloni and Giubilato, 2004; Stannard and Toledo, 2004). This can also be compounded by plant variety rights and other forms of intellectual property protection afforded in different legal jurisdictions, in that cultivars are often only available from the original breeders, so they are not sold by multiple seed production companies.

This dilemma was recognised in the earliest stages of the drive for organic seed, being addressed through the derogation system whereby the percentage of certified organic seed for a particular species is managed so as not to restrict the cultivar choice 'too much'. However, for some in the organic movement, the restriction of cultivars to approved cultivar lists represents too much restriction in and of itself, even without the extra filter of organic certification. This has resulted in there being both official and unofficial seed markets, (Micheloni and Giubilato, 2004; Döring *et al.*, 2012) particularly among farmers and also in the non-commercial/avocation sector, e.g. home gardeners. The problem with unofficial seed markets is that they operate completely outside of the organic seed databases, and therefore no data, for example, on their size is captured. Also such unofficial markets are also outside seed quality testing systems, such as the International Seed Testing Association (ISTA), meaning that they can be sources of pathogens, dissemination of weed seeds and all the other problems seed testing systems have been set up to address.

This 'cultivar issue' is therefore a key driver behind the objective of organic breeding programs and 'organic cultivars'.

Organic cultivars

Beyond the first level of 'certified organic planting seed' and the second level where the entire seed production system is managed organically is the third level of 'organic seeds' where new cultivars are being bred specifically for and within organic farming systems. This 'third level' is an increasingly vibrant area, even in developed countries which have the most commercialised and regulated seed and cultivar industries. For example:

(1) The European Consortium for Organic Plant Breeding (ECO-PB, www.eco-pb.org) was founded in 2001 and continues to be a key driving force behind organic seed, in all its forms, within the EU.

(2) Strategies for Organic and Low-input Integrated Breeding and Management (SOLIBAM, www.solibam.eu) which is supported by the European Commission under the seventh framework programme.

(3) In the USA, the Organic Seed Alliance (OSA, www.seedalliance.org) "advances the ethical development and stewardship of the genetic resources of agricultural seed".

Centralised versus distributed breeding

In the developed world, organic breeding can be viewed as having two main thrusts, formal centralised breeding programs within institutions such as universities and agricultural research centres, e.g. ECO-PB, and decentralised farm based farmer led breeding. This is not to say these areas are separate, as organic philosophy is not in favour of the division between academia and practical farming that has happened in many developed countries. Rather, even where breeding is occurring in an institutional framework, there must be strong linkages with the organic farming community to help give direction and also for evaluation of cultivars. Indeed, farmers and growers undertaking breeding, multiplication and cultivar evaluations on working farms, is a vital part of, and inherent in, the concept of organic cultivars.

Contrariwise, in producer led on-farm breeding and multiplication efforts, there is often considerable institutional support for farmers, typically from universities, government bodies, and organic organisations. With the dominance of the commercial seed industry in the developed world over the last half century, most breeding and multiplication knowledge has been lost from living memory among producers, so farmers and growers are having to relearn the skills of their forebears. In addition, in the intervening years, science has developed both a deep fundamental understanding of plant reproduction and breeding (and also animals) as well as a diverse range of ‘tools’ to help speed up and facilitate the breeding process. Many of these would be inconceivable to previous generation of farmer-breeders. Scientists and extension agents therefore have a vital role in helping producers gain such knowledge and use such tools, for example, “Breeding organic vegetables: A step-by-step guide for growers” (White and Connolly, 2011) which offers wide ranging and quite advanced advice, for example, “making an F1 hybrid”.

The concept of organic breeding, also extends beyond the mainstream view of single ‘pure-bred’ cultivars to much broader concepts, for example landraces and composite cross populations (Phillips and Wolfe, 2005).

One issue with the institutionalised breeding programs in the developed world is a lack of systems for taking new breeds and getting them widely distributed among farmers (E.T. Lammerts van Bueren pers. comm. 2012). In the developed world the distribution systems are mostly dominated by commercial companies, who may be reluctant to multiply and sell cultivars they have not bred themselves as these may well displace sales of their own cultivars, and therefore affect profits, even if no royalties are payable. Clearly having a breeding program with no multiplication and distribution systems is not ideal. However, following organic philosophy, decentralised farmer-to-farmer multiplication systems could be an alternative to the current commercial system.

Cultivar performance under different systems

There is also a growing body of literature showing that cultivars that perform best in mainstream farming systems are not always those that perform best in organic and related systems, though there are also standout cultivars which perform well in both systems (Horneburg, 2011). This is to some extent not surprising, as cultivars are often bred for specific climatic areas or production systems, so a cultivar that works well for one producer may not perform for growers in different climates. However, considering that there can be as much variation within mainstream and organic production systems (e.g. in regard to nutrient availability, pests and weed control), as are there are differences between the two production systems, the fact that the literature indicates that there are good cultivars for organic systems and other cultivars optimised for mainstream systems could therefore be considered to be surprising and it may be an area that is in need of deeper theoretical conceptualisation as much as empirical research.

Yield is not the only metric

To generalise, the focus of much mainstream breeding of the last half century, has been on maximising yield, particularly for the staple crops such as cereals and rice. Within the non-staple foods, such as vegetables, there has also been a focus on cosmetic appearance, particularly in the developed world with supermarket dominated sales channels. However, bundled up in the concept of an organic cultivar is all the philosophy of organic agriculture, which has a much wider focus than just yield and visual appearance.

An illustrative example of this is the issue of micro-nutrients. The focus on increasing crop yield, has often been achieved by increasing the proportion of energy bearing components of crops, such as carbohydrates, resulting in a reduced proportion of other components such as vitamins and phytonutrients (Lairon, 2009). Organic agriculture was founded in the 1930s on the issue of 'fresh, wholesome, healthy food' that would be now referred to as a wholefood diet. The reduction in the nutritional value of food is a minor but important concern for the organic movement, and in its more extreme forms, the issue of 'empty calories' and its relationship with obesity is a concern among the medical profession and also at the political level due to the associated health costs (Pollan, 2008). The opposite of empty calories are 'nutrient dense foods' and a key aim of organic breeding programs is to increase the nutritional content of foods.

There are many other aspects of food, and therefore breeding, that are of importance within organic agriculture, that have mostly been of low importance in mainstream breeding, such as food culture, cultivar diversity and taste. However, when these 'end user' requirements are then coupled with producers' requirements, for traits such as nutrient scavenging, insect and disease resistance and weed competitiveness the challenge facing organic breeders is clearly very substantial as breeding for just two or three traits can be difficult enough, let alone a multitude of possibly competing traits.

Therefore while there is considerable desire and hope tied up in the concept of an 'organic cultivar' it is a very large and complex concept and one that can be very challenging to implement in its entirety, especially in a short time.

Intellectual property

As stated in the IFOAM position paper, organic philosophy is against some of the more stringent intellectual property constraints associated with the commercial seed industry such as patents. This is where organic philosophy and politics is linked to issues such as food sovereignty and the slow food movement. For example, most of the breeding that has been undertaken in the 10,000 year history of agriculture has been undertaken by farmers. It is only in the last one hundred years that breeding has become a specialised job and a business in its own right. In addition most of the fundamental breeding was undertaken in 'pre-history', prompting Claude Lévi-Strauss to point out that we are still coasting on the Neolithic. Therefore, there is a desire within organic philosophy to return the 'ownership' and 'control' of genetic resources, the symbol of which is 'seed' back to farmers. Examples of this are a renewed interest in open-pollinated cultivars to allow farmers to maintain their own seed stock, and or use them in breeding programs. To illustrate the strength of such concerns, the issue of whether F1 hybrids should be prohibited from organic production has been extensively debated and is still a live concern (Lammerts van Bueren *et al.*, 1999; Horneburg, 2011). However, in the developed world, at a practical level, the utility of having specialised plant breeders and multipliers, can still be significant compared with the extra work for a producer to maintain their own cultivars and seed production. In the developing world often the opposite is often true with cultivar and seed maintenance and production just part and parcel of 'normal' farming practices with the purchase of seed from specialists being an unusual procedure.

Practical production issues

The production of certified organic planting seed is often the most technically demanding/challenging production task in farming, requiring all the know how associated with production of the food crop with the additional challenges of seed production e.g. purity, low pest and disease tolerances, and for vegetable seed, seed production is sufficiently different from food crop production that it is almost a completely different crop. Fortunately, considerable advances have been made over the last three decades in organic farming and growing, and many of the lessons and new techniques developed for food crop production are of immediate use in seed production. A couple of examples, weed and pest management, will give a flavour of this progress.

Organic weed management

Weeds are still the primary production issue for most organic annual crop producers. However new tools, such as computer implement guidance, have created a step change, even a paradigm shift, in mechanical weeding (Merfield, 2010). Computer guidance comes in two main forms, GPS and vision. GPS uses the very high accuracy RTK (Real Time Kinematic) approach, which achieves sub-millimetre position accuracy, which can be used to automatically steer tractors with a repeatability of ±20 mm and where the implements (e.g. seed drills and interrow hoes) are independently steered in addition to the tractor, even greater accuracies can be achieved. Computer vision systems 'see' the crop rows using digital cameras and using exceptionally sophisticated algorithms to differentiate the crop from soil and weeds. Computer vision is also used to steer both tractors and implements, and can achieve the same accuracy as GPS systems. These machines can outperform human guidance of machinery many fold, in just about every aspect, e.g. accuracy, speed (speeds of 20 kph are possible) and repeatability, although human visual processing still outperforms computers at present (Merfield, 2010). This turns interrow hoeing, that was previously a difficult task often requiring specialised toolcarriers tractors, almost into an everyday farming operation, such that it is becoming of increasing interest to mainstream farmers.

Organic pest and disease management

Organic pest and disease management has not been the preserve of organic agriculture for some time. To use the very nearby example, the Bio-Protection Research Centre, based at Lincoln University, has a foundational aim to use biology rather than chemistry for crop protection. This would have probably been inconceivable in the 1960s and 1970s when the solution to pest and disease management was agrichemical, but bio-protection is now very much part of the mainstream. The use of biological control for pest and disease management is the key approach within organic agriculture, so organics is benefiting considerably from biological control advances, such as those from Bio-Protection, for example using buckwheat (*Fagopyrum esculentum* Moench) for management of leafroller caterpillars in vineyards. This does not mean that biological control is a complete alternative to the agrichemical pesticides, and a number of pests and diseases continue to be difficult to manage using non-chemical techniques. However, significant progress continues to be made for the benefit of organic agriculture as a whole and for seed production systems.

The convergence of organic and mainstream agricultures

This overlap between organic and

mainstream production systems in pest and disease control is also indicative of the increasing overall overlap between organic and mainstream agricultural production systems. This is due to increasing problems being faced by mainstream agriculture such as resistance to agrichemicals, and increasing societal concerns about non-target effects of practices such as the use of soluble synthetic nitrogen and pesticides, resulting in increased legislative restrictions (McIntyre *et al.*, 2009). Therefore, techniques that have been developed within organic systems are increasingly being used within mainstream agriculture, and vice versa. Approaches such as biological control developed for mainstream agriculture are avidly taken up by organic producers.

Conclusions

It is a decade and a half since the international organic movement started its drive for all planting seed used in organic agriculture to be produced by organic agriculture, thereby making organics more self-contained and consistent. While there was much early optimism as to how quickly this could be achieved, e.g. the 2004 EU target (Lammerts van Bueren *et al.*, 1999), and with current progress 2014 may well pass without fully achieving the objective, good steady progress is being made with the number of farmers and growers who only use organic seed, both commercially and self-produced, continuing to grow. The crops for which organic certified seed is easiest to produce, e.g. the cereals, were the first to reach 100% organic status, which, *ipso facto*, means the most challenging crops, such as vegetables, are likely to be the last, and may represent a small, but quite long tail, before 100% certified organic planting seed is achieved. It will probably be some considerable time after that before the higher level definitions of organic seed, such as organic cultivars, will also achieve 100% status. In the meantime, many valuable lessons have been learnt both at the practical farming and research levels, that are not only of benefit for organic agriculture but agriculture as a whole.

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