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Number 47

Improving the yield and quality of arable crops in organic production systems

Grass / Clover
N + OM build-up

Winter Wheat
High response

Potatoes
Mineralise N

Oats
Low fertility

Legume
Replace N

Spring Barley
Start grass/clover

Teagasc
Agriculture and Food Development Authority
CROPS RESEARCH CENTRE, OAK PARK

IMPROVING THE YIELD AND QUALITY OF ARABLE CROPS IN ORGANIC PRODUCTION SYSTEMS

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CONTENTS

SUMMARY

Ireland's ability to supply organic arable products to meet future market requirements depends on the provision of scientific quantitative information on the production of these crops. The conversion of an 8-ha site at Oak Park is described. The establishment of a single stockless 7-year rotation (wheat, potatoes, oats, legume, spring barley followed by two years' grass/clover lea) with three replicates is described. The results of the first series of experiments are presented and the possible implications discussed.

INTRODUCTION

Organic farming offers some solutions to the problems currently facing agriculture in developed countries. It has the potential to limit environmental damage, conserve non-renewable resources and reduce surpluses. It can meet consumer demands for wholesome food products produced in a chemical-free environment. In recognition of these potential benefits, all EU Governments including Ireland are encouraging farmers to adopt organic farming practice through financial incentives, as well as funding research, advisory and marketing initiatives.

In Ireland, only 29,850 hectares are farmed organically (Franklin Research Ltd., 2002) with demand outstripping supply; up to 70% of organic food and animal feed requirements are imported. While in Europe meat products are a relatively small category, in Ireland organic meat (beef and lamb) is the primary product. Most organic units are primarily beef production units with a small tillage area. Overall, the growth in demand for organic food is expected to increase by a minimum of 10% per year, with faster growth rates expected in the meat sector. With Ireland's infrastructure in beef and lamb production, there is an opportunity for Irish producers to participate in this growing market.

Developments in organic meat production will increase the demand for organic cereal and protein crops for the animal feed market. The opportunities for expansion of the organic tillage sector already exist, with up to 80% of the animal feed concentrate market supplied by imports (Teagasc, 2000). The ability to supply cereal/protein products to meet future market demands will ultimately depend on large-scale cereal growers converting to organic production. Some conventional tillage farmers in traditional arable areas will need to convert to organic if supply is to meet demand.

Organic farming has traditionally been based on animal production units. In Denmark, development has centred on dairy production (Olesen *et al.*, 2002). In Ireland and the UK, development has concentrated on beef, with some cereal production to provide organic straw for animal bedding and home-produced concentrate feed. The assumption that organic farms must contain animals has led to very few all-arable farms converting to organic production, yet arable organic farms are needed for the efficient production of animal feed concentrates to meet the demands of an expanding market (Teagasc, 2000).

Stockless arable organic systems are technically possible. The use of green manures/cover crops for cutting and mulching makes the nutrients directly available to the following crop rather than being recycled through an animal (Lampkin and Measures, 1999). The wider use of grain legumes in stockless systems can improve the supply of nitrogen to the system, having a positive effect on the following cereal as well as supplying a non-GMO protein source (Schmidtke and Rauber, 2000). The desirability of this type of organic system is disputed by many organic traditionalists and little research on stockless systems has been carried out. In the last ten years, only four studies have been published in the UK. Reviewing the data, Leake (2001) concludes that those soils that can produce high yields and support extended rotations will sustain profitable organic cereal and protein grain production despite any future down-turn in prices.

In the light of demands from organic cereal producers and the recommendation for increased research in organic farming, it was decided that a research programme on organic cereal and protein crops should be established at Oak Park, beginning in 1999. The primary objective of the Oak Park proposal was to provide a field facility for research on the production of a range of arable crops within an organic environment. The full list of objectives were as follows:

- To develop and maintain a field facility for research on organic production of arable crops, with particular emphasis on animal feed crops.

- To establish base-line site data against which any long-term changes from organic production systems could be evaluated.

- To establish good agronomy practices for the cereal, legume and grass crops included in the rotation.

- To collect input-output data to allow the production costs of organic crops to be established.

- To research key agronomic factors by conducting component trials within the existing rotation.

MATERIALS AND METHODS

The existence of the Organic Dairy Unit at Johnstown Castle, Co. Wexford, allowed some preliminary trial work to begin in 1999, while the Oak Park site was being prepared during the years 1999 to 2001. A number of old pasture fields that required renewing were ploughed and sown to cereals trials over the two years 2000 and 2001.

A single stockless rotation was set up on an 8-ha site in Oak Park. While rotation is the key to successful organic farming, there is no blueprint rotation. There are as many different types of organic rotation as there are conventional systems. In all cases, however, nitrogen supply is the major limiting factor and all rotations depend on legumes, either forage or grain, to supply nitrogen to the following crop (Lampkin and Measures, 1999). The restricted nitrogen supply means that in practice no more than two cereal crops can be successfully grown without a legume or root crop break. Taking the above into consideration, and to allow all five of the major tillage crops to be represented, a seven-year rotation was chosen (Crowley, 2002). The rotation was wheat, potato, oats, legumes (peas, beans or lupins), spring barley followed by a two-year grass/white clover break, all to be sown with three replicates, giving a total of 21 individual blocks. The area of each block was approximately 0.4 ha, large enough to conduct a fully randomised field experiment within each block.

The 8-ha area selected for the organic unit was in permanent grass for the previous ten years. It was harvested twice each year for silage and had very little clover present. The whole area was ploughed on 1 July, 1999 and re-seeded in early August with a ryegrass/clover mixture containing 4 kg/ha of the Oak Park-bred white clover varieties Avoca and Susi. Establishment was quick and even over the 8 ha sown. To encourage a good clover development the sward was maintained by cutting every two to three weeks throughout 2000, leaving the cuttings on the sward. In autumn 2001, the area was divided into the 21 experimental blocks required to accommodate the 7-year rotation with three replicates. This allows each of the five crops to be sown each year along with the two grass/clover lea breaks included to rebuild the nitrogen status of the soil before the start of the second rotation cycle. The seven treatments were allocated at random in each of the replicates to start the process of establishing the single organic rotation. The first sowing of the two winter crops, wheat and oats, took place in late October 2001, followed by the spring crop sowings (potatoes, lupins and barley) in March/April 2002.

The area was managed and operated according to the *Standards for Organic Agriculture* (1999) of the Irish Organic Farmers and Growers Association Symbol Scheme. The unit was operated on the basis of "Best Practice" as set out by MacNaeidhe *et al.* (1998). The grass-clover swards in the rotation were cut regularly (every two-three weeks) leaving a stubble height of 10 cm, as were the surrounds. The cut material was left to rot back into the sward. A 2-3 metre strip around the perimeter was left uncut at all times to encourage an increase in beneficial ground beetles and spiders (Hall, 2001). A perimeter hedge made up of beech, black alder and whitethorn was planted in early spring 2000.

In organic farming, soil cultivation should aim to maintain the biologically active layers in the top 20 cm. Shallow ploughing is the general practice. However, Kouwenhoven *et al.* (2002) concluded that, while shallow ploughing seems to be the best reduced tillage system, weed populations can increase when the ploughing depth is less than 20 cm. Ploughing was carried out with a two-furrow reversible plough to a depth of 15-20 cm. Ploughing was carried out 3-4 weeks ahead of the planned sowing date, allowing a stale seedbed system of weed control to be practiced.

The approach to crop establishment varied according to the crop being sown. In all cases, the stale seedbed technique was employed. Winter cereals were sown late (end of October into early November), to avoid the flush of autumn weed establishment and reduce the risk of BYDV infection. Crop competition in spring contributed to maintaining low weed numbers in these crops. The reverse applied to spring sowing. Early sowing ensured that the crop was well established ahead of the main flush of weed germination as well as reducing the incidence of BYDV infection. Mechanical weed control, using a light tined harrow, was used as a back-up.

Immediately following the harvest of all crops, the straw was chopped and spread over the plot. The plots were then lightly cultivated with a disc or tine harrow to encourage weed and volunteer germination, and produce a green cover on the plots for the winter period. This ensured that the flush of nitrate released from the soil in September/October was stored for the following crop. A green crop cover can also help reduce soil erosion and phosphate losses over the winter.

Export of plant nutrients is unavoidable in any organic production unit. Any product sold off the farm will remove nutrients from the system. The potato plots received 50 t/ha of composted farmyard manure each year. The material was obtained from a conventional sheep farm in January/February each year and stored under cover. The heap was turned two to three times before spreading on the potato plots the following March and ploughing-in immediately. Potatoes were planted in destoned beds and harvested with a commercial harvester.

The soil in all 21 plots was sampled once a year and soil structure changes monitored. The average soil analysis over the 21 blocks is presented in Table 1 for 2002 and 2003. Key fauna constituents were also monitored. In addition to recording yields from the various crops, seedling, tillers, heads and seed numbers/head as well as thousand grain weights were recorded. The various grain quality parameters were also included in the analysis. Potatoes were graded into four grades <40, 40-45, 45-60 and 60-80. During the growing season pest and disease levels were recorded.

Table 1: Average soil analysis figures for 2002 and 2003

Year	P	K	pH	Mg	Cu	Zn	Mn	% OM
2002	11.6	120.8	6.9	195.6	3.5	3.3	351.7	5.7
2003	10.9	123.7	6.9	200.00	3.6	3.8	366.1	6.0
Mean	*11.3*	*122.2*	*6.9*	*197.8*	*3.5*	*3.5*	*358.9*	*5.8*

RESULTS

On the Organic Dairy Unit at Johnstown Castle, Co. Wexford, three cereals (winter barley, spring barley and triticale) were sown using undressed commercial seed. The two winter crops, Opal winter barley and Taurus triticale were sown on October 18 into a stale seedbed. The spring barley, Newgrange, was sown on March 15, 2002, again into a stale seedbed. No interventions were carried out on these crops. Establishment was very good, with minimum losses from bird attacks. The results are presented in Table 2.

Table 2: Yield and screenings of three organically grown cereal crops, Johnstown Castle

Crop	Variety	Yield (t/ha @ 14% m.c.)	Screenings (%)
Winter barley	Opal	2.96	35.3
Spring barley	Newgrange	4.46	1.4
Triticale	Taurus	4.47	1.8

The poor performance of the winter barley was due to the high level of foliar diseases recorded in the crop from early summer and was reflected in the very high level of screenings recorded post harvest. The diseases included barley blotch, mildew, rhynchosporium and ramularia. Plant counts were good at $350/m^2$ and weed levels were low across all the crops at $< 15 /m^2$. The very high levels of screenings recorded for the winter barley suggests that leaf disease was the main cause of the poor performance. Disease levels in the spring barley and particularly in the triticale were very low, indicating that triticale may be a safer option where the seed is being kept for on-farm feeding.

Mechanical weed control trials were carried out with a light harrow in both winter barley and triticale. The treatments included one, two and three passes, both along and across the crop rows, in early March. None of the treatments had a significant effect on either crop yield or seed quality.

The experience to date has not been encouraging. These harrows are only effective on very small weeds (from germination to the appearance of the first true leaves), and then only when a few dry days follow the tilling operation.

A winter wheat trial was planned for autumn 2001. The area was ploughed and roughly tilled in September with a view to creating a stale seedbed and sowing in late October. Unfortunately, the very wet autumn and early winter delayed sowing until January 16, 2002. The area was re-tilled and sixteen varieties were sown at 400 seeds/m^2. The results are presented in Table 3.

Despite the late sowing (January 16), the yields recorded were good for organic wheat at 6.47 t/ha (14% m.c.). No weed problems were encountered, apart from a few docks. Disease levels were very low; this was generally the case for all cereals in 2001. As in 2000, the triticale varieties produced yields equivalent to winter wheat in what was a disease-free year. As expected, hectolitre weight and protein content were significantly lower in triticale than in winter wheat; Rialto gave the highest yield, with Rialto, Richmond, Access and Exsept producing above average yields.

In Oak Park, the long-term organic single rotation experiment laid out in 2000 completed its first full sowings of all five crops in 2002. Winter wheat and winter oats were sown in October/November 2001 and the three spring crops, potatoes, spring lupins and spring barley, were sown during March/April 2002. Being the first year of a seven-year rotation, all five crops were sown into the ploughed grass/white clover ley established in July 1999. For this reason, only the winter wheat crop sown in November 2001 was in its correct rotational position. Nevertheless, useful experience in handling organic crops was gained. A short summary of each of the crop performances is presented below.

Table 3: Yield and quality of 14 winter wheat varieties and two triticale varieties, Johnstown Castle

Variety	Yield (t/ha @14% m.c.)	T.G.W. (mg/grain)	Protein (gm/kg)	Hectolitre wt (kg/hl)
Rialto	6.75	57.0	9.83	75.3
Madrigal	6.29	44.3	8.88	74.3
Buchan	5.95	48.3	8.61	75.3
Equinox	6.25	59.0	9.44	72.6
Falstaff	6.21	54.0	9.32	72.8
Option	7.29	48.0	8.91	75.2
Claire	6.14	47.0	8.77	73.7
Richmond	6.75	51.2	9.24	76.7
Macro	6.11	60.5	9.00	72.3
Access	6.80	49.8	8.46	73.6
Tanker	6.24	55.7	9.32	72.8
Exsept	6.80	55.3	9.77	76.1
Ellipse	6.29	50.5	9.56	74.2
Deben	6.28	58.8	8.54	70.2
*Taurus	6.35	50.5	6.76	67.6
*Fidelio	7.09	56.0	6.62	66.2
SE	1.21	1.5	0.09	1.68

*Triticale varieties

Winter wheat/triticale

The three replicates were ploughed in early October 2001 and sown on November 1 into the stale seedbed. All plots were sown at 400 seeds/sq. m using an Oyjard plot drill. Plots were virtually weed-free throughout the season. Total biomass samples, taken in July, showed a negligible weed content. Component research trials were carried out in two of the three blocks. Ten wheat and two triticale varieties were evaluated in a fully randomised trial along with a seed rate trial using the variety Soisson. A summary of variety trial the results are presented in Table 4.

Table 4: Yield and quality of 15 winter wheat and two triticale varieties

Variety	Yield (t/ha @ 14% m.c.)	Septoria resistance	Protein (g/kg)	Hectolitre wt. (kg)	TGW (g)	Vigour score 01/12/01
Tanker	4.07	4.3	117	65.2	29.0	6.3
Milestone	5.91	5.8	107	70.6	32.3	7.5
Carlton	4.98	5.3	94	71.8	32.5	8.0
Goodwood	5.22	6.8	90	73.0	31.1	7.0
Savannah	5.13	4.8	103	72.8	33.0	6.3
Marshall	5.20	5.3	115	68.6	31.5	6.3
Xi 19	5.71	4.5	97	73.2	35.8	8.3
Claire	5.43	7.0	93	74.5	33.1	7.8
Deben	5.83	7.5	93	72.5	35.1	8.3
Exsept	8.15	7.8	82	73.7	44.4	6.0
*Taurus	8.75	7.8	82	73.7	44.4	6.0
*Fidelio	6.18	8.5	79	72.6	53.0	7.3
Trust	5.53	7.3	97	74.5	35.5	8.3
Ld 91-59-1	4.46	3.8	98	69.2	33.6	2.8
Equinox	4.24	3.0	112	66.5	26.5	3.0
Madrigal	5.50	4.8	102	75.5	33.6	7.3
Falstaff	4.65	3.8	106	70.1	31.8	9.8
S.E.	1.42	0.92	0.08	1.55	1.02	2.10

*Triticale varieties

Leaf diseases were a significant problem in 2002; in particular *Septoria* spp. reduced the green leaf area to practically zero by mid-July. The only exceptions were the winter wheat variety Exsept and the two triticale varieties, Taurus and Fidelio. All three showed a very high level of field resistance (Table 4). Deben, Claire and Goodwood scored well for septoria resistance in July, but broke down by early August. This is reflected in the high TGW figures for these varieties (Table 4) when compared to the trial mean of 32.5 g. Of the twelve varieties evaluated, only four (Exsept, Milestone, Debon and Xi 19) produced yields significantly higher than the trial mean (5.58/ha at 14% m.c.) (Table 4). Exsept and the triticale variety, Taurus, produced 146% and 157% of the trial mean.

The variety Soisson was sown at five rates in a randomised block design with four replicates. A summary of the results is presented in Fig.1 below.

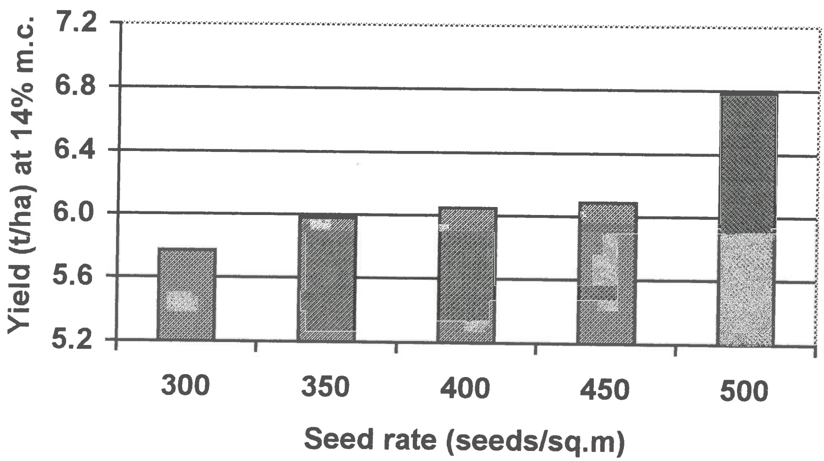

Fig. 1: The effect of seed rate on the yield of the winter wheat variety Soisson

The results show an increase in yield up to the highest seed rate treatment used. This is probably a reflection of the severe septoria damage suffered in 2002 rather than a direct effect of seed rate.

Winter oats

The three winter oat replicates were ploughed in early October and sown on November 4 into a stale seedbed. Establishment was quick and even across all the plots. The early spring growth of the crop smothered any weed development and the crop was weed-free up to harvest. Little or no disease was recorded except for a late rust attack which did very little damage. The winter oat crop was the easiest of the organic crops to manage. The yields from the three plots were 7.21, 6.49 and 7.14 t/ha at 14% m.c. Within one of the winter oat plots a fully randomised seed rate trial was carried out. The results are presented in Fig. 2 below.

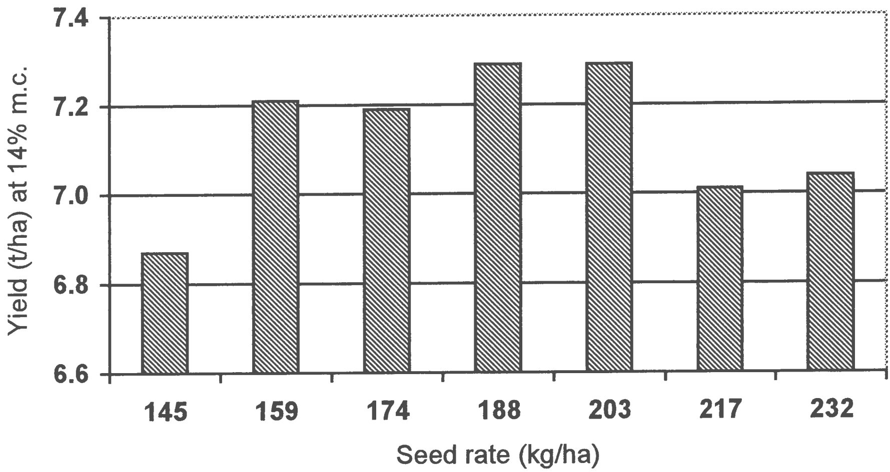

Fig. 2: The effect of seed rate on the yield (t/ha at 14% m.c.) of the winter oat variety Barra sown in November 2001

The results indicate that for winter oats a seed rate of 159 kg/ha is sufficient to achieve maximum yield; increasing the rate above 203 kg/ha can result in a significant loss in yield.

Spring lupins

The crop chosen for the legume part of the rotation was the spring lupin species *Lupinus angustifolius* (Blue lupin). Although there is limited information on this new crop in Ireland, it does appear to be a safe choice for legume grain production on organic farms. Limited data suggest grain yields of 3.2 to 3.8 t/ha at 14% m.c., with a very low disease threat compared to peas or field beans. With two variety types available, single-stem or spike type and a multi-branched type, the three legume plots were split and both variety types grown in each of the three blocks. The crops were sown on April 20, using a Fiona corn drill, into a stale seedbed. The sowing was delayed by weather conditions; sowing in early April would be more desirable. The results are presented in Table 5 below.

Table 5: The seed yield of two contrasting blue lupin varieties grown organically in 2002

Variety	Type	Yield (t/ha @ 14% m.c.)	Harvest m.c. (%)
Prima	Single stem	3.13	21.9
Bordako	Multi-branched	3.51	38.3
S.E.	-	1.10	2.02

Despite the very cold and wet season, both varieties grew well throughout the season. Weeds were not a serious problem for either variety. As expected, the branching type variety, Bordako, was practically weed-free due to the dense canopy structure of the crop. In contrast, the open canopy structure of the spike type, Prima, allowed some weed development. The only disease recorded was *Botrytis*. Infection occurred on both main stems and branches. The yield data (Table 5) is consistent with previous results under conventional production systems. Bordako showed a higher yield potential but with a significantly later maturity date. Very high seed moistures (Table 5) were recorded despite delaying the harvest of Bordako to September 21, three weeks after the Prima harvest. The late-maturing date of the branched type, Bordako, could create difficulties. This type of lupin could be useful for whole-crop harvesting and ensiling.

Potatoes

The three potato plots were ploughed in February and tilled and de-stoned in late March. The areas were moulded up and left until planting in mid-April. No fertiliser of any form was applied. Three Oak Park varieties (Orla, Cara and the recently-named, Setanta) were planted in a randomised layout across all three plots using a automatic planter. These varieties were selected for a combination of blight resistance and covering the maturity range from early to late main crop. Establishment was satisfactory but vegetative growth was slow throughout the season. No farmyard manure was applied. At no time did the crop achieve full ground cover. Weed invasion was minimal and one mechanical weed removal was sufficient to keep the crop acceptably clean for the season. Blight was not a serious problem, helped by the poor top growth and the application of three copper sprays from late July to the end of August. Spraying was carried out on foot of blight warnings and the level of disease present. The early crop of Orla was harvested in mid-August and the two main crop varieties in late October. This harvest was delayed due to wet weather. The results are summarised below.

Table 6: The total yield (t/ha) and dry matter contents (DM%) of three potato varieties grown organically in 2002

Variety	Yield (t/ha)	DM (%)
Orla	22.91	21.3
Cara	28.21	25.1
18/23/10	33.88	26.8
S.E.	2.28	0.12

While the yields were low, they are within the range of commercial organic yields. Setanta, a late main crop variety, with a very high rating for both foliar and tuber blight, produced a very good yield and looks a promising variety for organic growers. The distribution of tuber sizes harvested is presented in Fig. 3.

As well as showing the highest yield, Setanta had the highest proportion of marketable potatoes.

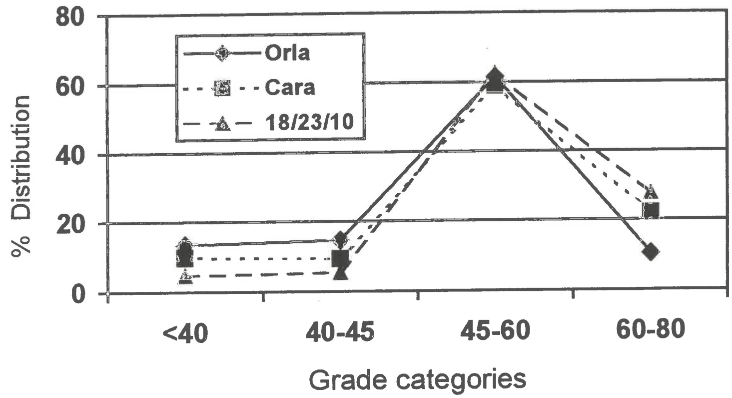

Fig. 3: The percentage distribution of tuber size for three potato varieties grown in organic field plots, 2002

Spring barley

The three plots allocated to spring barley were not sown in 2002. The very wet spring meant that the first opportunity to sow the crop did not arise until mid-May. Since these plots were to be undersown to re-establish the grass/clover break, the late sowing was unlikely to produce a worthwhile crop.

CONCLUSIONS

Setting up an organic field research facility is a slow process, taking a minimum of three years to establish. Depending on the length of the rotation chosen, it can take another three years before all the crops can be sown in their correct rotational position.

The results presented are preliminary and should be treated as such. The data indicates that crop performance under organic production may differ greatly from conventional systems. This is particularly so for variety selection, where disease resistance characteristics of the variety may have a very significant effect on the outcome. For example, the winter wheat variety Exsept, which is rated as 10-15% below the highest yielding variety in conventional trials, produced a yield of 146% of the trial mean in the 2002 organic evaluations. The triticale varieties tested in both 2001 and 2002 produced higher yields compared to winter wheat than is generally recorded in conventional trials.

Conventional trial results can be of some use to organic growers in recording variety characteristics other than yield potential. However, the extrapolation of yield results from conventional trials may not precisely define the most suitable varieties, seed rates etc. for organic production situations (Carver, 2003).

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