

Gwell Cysylltiadau Busnes Organig



Better Organic Business Links

# Making poultry feed more sustainable

The potential for oil seed crops to replace soya in organic poultry feed

Author

Rebecca Nelder  
Organic Research Centre, Elm Farm

June 2012

### **Acknowledgements**

The completion of this project would not have been possible without the significant help and support received from numerous individuals and organisations, including the BOBL team at OCW, project lead partner organisations and all those who developed and delivered such a breadth of innovative local initiatives.

The Better Organic Business Links (BOBL) project, run by Organic Centre Wales, is a four year project designed to support the primary producer in Wales and grow the market for Welsh organic produce in a sustainable way.

The aim is to develop markets for organic produce whilst driving innovation and promoting sustainable behaviours at all levels within the supply chain, to increase consumer demand and thence markets for organic produce, especially in the home market, and to ensure that the primary producers are aware of market demands. The project provides valuable market information to primary producers and the organic sector in general.

Delivery of the project is divided into five main areas of work:

1. Fostering innovation and improving supply chain linkages
2. Consumer information and image development of organic food and farming in Wales
3. Market development
4. Providing market intelligence to improve the industry's level of understanding of market trends and means of influencing consumer behaviour
5. Addressing key structural problems within the sector.

In all elements of the work, the team are focused on building capacity within the organic sector, to ensure that the project leaves a legacy of processors and primary producers with improved business and environmental skills, able to respond to changing market conditions, consumer demands and climate change.

The project is funded under the Rural Development Plan for Wales 2007-2013, in turn funded by the Welsh Government and the European Agricultural Fund for Rural Development

## Table of Contents

<b>Acknowledgements .....</b>	<b>2</b>
<b>Table of Contents.....</b>	<b>3</b>
<b>1 Executive Summary .....</b>	<b>4</b>
<b>2 Introduction .....</b>	<b>4</b>
<b>3 Nutrition and rationing.....</b>	<b>4</b>
3.1 Factors affecting inclusion rates of oil seed rape and sunflower.....	4
3.2 Potential for soya substitution .....	5
3.3 Whole seed vs compound feed.....	6
<b>4 Current and potential production .....</b>	<b>8</b>
4.1 Current UK areas.....	8
4.2 Production potential .....	8
4.2.1 Sunflower.....	8
4.2.2 Oil Seed Rape. ....	12
<b>5 Conclusions.....</b>	<b>14</b>

## 1 Executive Summary

Organic poultry rations are heavily dependent on imported soya to meet the protein requirements of the birds. However, organic and GM-free soya is becoming increasingly difficult, and therefore expensive, to source, and relying so heavily on imports is not in keeping with the organic ethos. This report looks at the potential to substitute soya with UK grown organic oil seed crops, specifically oil seed rape (OSR) and sunflower. From a nutritional point of view both sunflower and certain varieties of OSR can make a useful contribution to organic poultry rations. However, a number of agronomic, economic and infrastructural limitations mean the contribution from UK grown OSR is likely to be remain small for the foreseeable future.

Sunflower has more potential. It is much easier to produce under organic conditions, and is grown quite widely in Europe. Meteorological data suggest that it could be grown successfully in many areas in the UK. This includes SE Wales and small pockets of land in Pembrokeshire, Anglesey and NW Wales.

## 2 Introduction

Soybeans and more importantly soybean meal has long been a staple component of the monogastric diet. It has a complimentary relationship with cereal grains in meeting the amino acid requirements of farm animals and is therefore used as a standard to which all other plant based proteins are compared<sup>i</sup>. It is estimated that the UK imports 800,000 tonnes of beans and 1,075,000 tonnes of soybean meal annually.<sup>ii</sup> The increased global requirement for animal protein, and therefore high quality livestock feeds, has led to high demand and high prices for soybeans and soybean meal. The environmental and social impacts of the growth of soybeans, not to mention worries from an organic producer's perspective of contamination with genetically modified soy has led to a greater interest in what can be grown in the UK to feed our monogastric animals. This report looks into the feasibility of using organically grown sunflower and oil seed rape (OSR) as a feed stuff for poultry in Britain.

## 3 Nutrition and rationing

### 3.1 Factors affecting inclusion rates of oil seed rape and sunflower

The nutritional composition of OSR and sunflower in various forms is shown in Table 1 below.

**Table 1 Basic Nutritional Composition of Organic and Conventional Sunflower Meal and Conventional OSR Meal and Bean<sup>iii</sup>**

	Sunflower Meal		Oil Seed Rape	
	Conventional	Organic	Bean	Meal
<b>Dry Matter</b>	89.0	94.0	93.0	91.0
<b>Protein</b>	31.0	30.5	20.5	33.9
<b>Oil</b>	1.5	10.0	40.5	3.5
<b>ME (adult)</b>	6.5	9.0	18.5	7.0
<b>Lysine</b>	1.1	1.1	1.2	1.8
<b>Methionine</b>	0.7	0.7	0.4	0.7

A number of factors influence the maximum inclusion rates of sunflower and OSR in poultry diets including:

- Amino acid (AA) availability. Methionine and cystine are the sulphur containing amino acids (SAA). The first limiting amino acid for poultry, whether they are breeders, layers or table birds is methionine. It is used for growth in all animals but is particularly important to poultry because it is vital for egg and feather production
- Metabolisable energy (ME) content
- Fibre content,
- Digestibility;
- The type and quantity of anti-nutritional factors (ANF). These are compounds that reduce the nutritive value of the feed in one way or another
- The type of bird (i.e. table birds, layers or breeders) and stage of production.

### 3.2 Potential for soya substitution

Although sunflower meal is deficient in lysine it is very rich in SAA. Its inclusion rate in organic diets for laying hens may be limited less by its ANF's than by its moderate metabolisable energy.<sup>iv</sup> Rape cake has a high crude protein content. The lysine and methionine contents are comparable to those of soybean meal. The metabolisable energy value of OSR is low.

The inclusion rate of OSR in poultry rations is limited by the presence of high concentrations of ANF's.<sup>v</sup>, specifically glucosinolates and uric acid which affect palatability and can negatively affect intake levels. It also contains sinapine which is converted to trimethylamine in the gut and can cause a fishy taint in eggs of birds that lay brown eggs. Interestingly, white shelled layers have the ability to break down the trimethylamine into an odourless oxide that does not result in the problem<sup>vi</sup>. It has therefore been suggested that OSR meal should not be fed to chicks or breeders and kept to low levels, such as 2.5%, for broilers and 5% for layers<sup>vii</sup> of brown eggs.

However, the problem has been addressed, to a large degree, by the development of 'Canola'. Canola was registered in Canada in 1979 and is the name used to describe varieties of oil seed rape low in both glucosinolates and uric acid (they are therefore also referred to as 'double-low' varieties. For these varieties, the extracted oil will contain less than 20g/kg of uric acid and the air dried meal less than 30 µmol of glucosinolates per g of air dried material. Conventional canola meal is required to have a minimum of 350g/kg crude protein and a maximum of 120g/kg crude fibre<sup>viii</sup>. Canola, or double low varieties, may be a suitable type of OSR for poultry diets.

Sunflower meal does not contain ANF's such as those found in soybean and OSR<sup>ix</sup>. Although Baines reports a slightly laxative affect when used in high quantities, this is not backed up by other authors.

When looking at substitution of soy with UK grown protein in conventional poultry diets,

Table 2, Baines<sup>x</sup> found OSR meal has the lowest substitution value (1.63:1) compared to Hipro soy beans and each kg included in the ration would increase energy by 4MJ ME.

This is closely followed by sunflower (1.86:1) which would increase the net energy per kg inclusion by 1.21.

Baines goes on to suggest the following inclusion levels for poultry based on consideration of ME and ANF's: OSR; Broiler 2.5%, Layer 5% Sunflower; Broiler 5%, Layer 10%, Breeder 10%.

Jacob et alxi found body weight gain of broilers to 42 days of age was not affected by total replacement of soybean meal with sunflower seed meal but concluded a good substitution level was 67% based on gaining a satisfactory level of energy in the diet. Serman et alxii suggest that sunflower meal can be used as the protein source for laying birds as long as the dietary lysine and energy values are maintained.

**Table 2 The substitution ratio for alternative protein feeds compared to Hipro soybean meal for poultry and the net change in metabolisable energy as a result.**

Feed	Energy ME/MJ/kg/DM	Protein % DCP	Hipro Soybean meal substitution ratio	Net change in ME
Hipro soybean meal	12.0	52	1	0
Lopro soybean meal	10.7	47	1.1	-0.23
Full fat soy	16.9	38	1.37	11.15
Field beans	13.5	26	2	15.0
Dried Peas	13.0	23	2.26	17.38
Lupin (white)	11	28	1.86	8.46
Oilseed rape meal	10.5	32	1.63	5.12
Sunflower	7.1	28	1.86	1.21
Linseed	20.5	18.5	2.81	45.61
Dried Lucerne	6.0	12	4.33	13.98
Dried Grass	6.0	17	3.06	6.36
Naked oats	12.5	9.4	5.53	54.63

Adapted from Ewing 1997<sup>xiii</sup>

### 3.3 Whole seed vs compound feed

From a commercial point of view sunflower and OSR meal is more likely to be available for use in livestock and poultry feeds. This is because the oil is of high value, and therefore likely to be extracted and sold onto other markets. In addition, high levels of oil in feed stuffs can cause them to become soft, difficult to pellet and prone to rancidity. Pelleting of sunflower meal has been found to be beneficial in helping to overcome its the bulkiness in the diet.<sup>xiv</sup>

Full fat canola has to mechanically disrupted and heat treated to allow glucosinolate destruction and maximum nutritional benefit to be obtained<sup>xv</sup>. Once ground the oil becomes susceptible to rancidity very quickly; a practical solution is to simply grind enough

for immediate use. This poses the obvious problem of on-farm machinery. Work in Saudi Arabia showed that a 50-100g/kg inclusion of whole seed OSR did not affect hen-day egg production, egg mass, feed conversion efficiency or egg weight<sup>vi</sup>. Talebali and Farzinpour reported that broilers grew well on diets containing up to 120g/kg OSR seed as a replacement for soybean meal<sup>xvii</sup>.

## 4 Current and potential production

### 4.1 Current UK areas

The Farm Business Survey (FBS)<sup>xviii</sup> provides information on the physical and economic performance of farm businesses in England, to inform policy decisions on matters affecting farm businesses. It is intended to serve the needs of government, government partners, farming and land management interest groups, and researchers. The 2009/10 data shows no organic farms growing OSR, either double low or other varieties. Sunflowers do not have their own category and are included as 'other crops,' again this suggests that areas grown are very small.

### 4.2 Production potential

#### 4.2.1 Sunflower

##### *Climatic conditions*

Sunflower (*Helianthus annuus*) establishment and growth are very dependent on temperature. Soil temperature needs to be between 6-8°C in the top 10cm for drilling. Figure 1<sup>xix</sup> shows the average soil temperature on the first of May. For growth of the plant sunflower requires a base daily air temperature of above 6°C. Figure 2<sup>xx</sup> shows areas that have achieved an accumulative 1400 day degrees between 1971 and 2000 (yellow, orange and red).

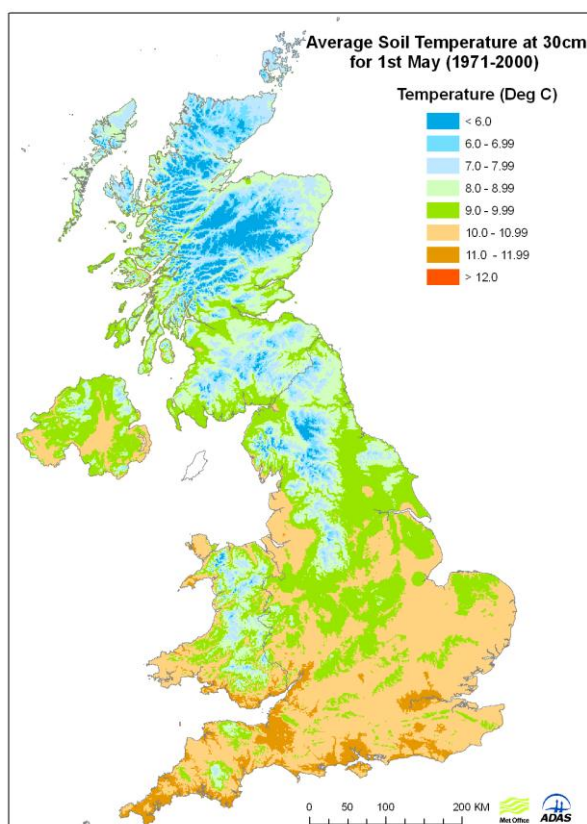


Figure 1 Average Soil Temperatures at 30cm for 1<sup>st</sup> of May (1971-2000)

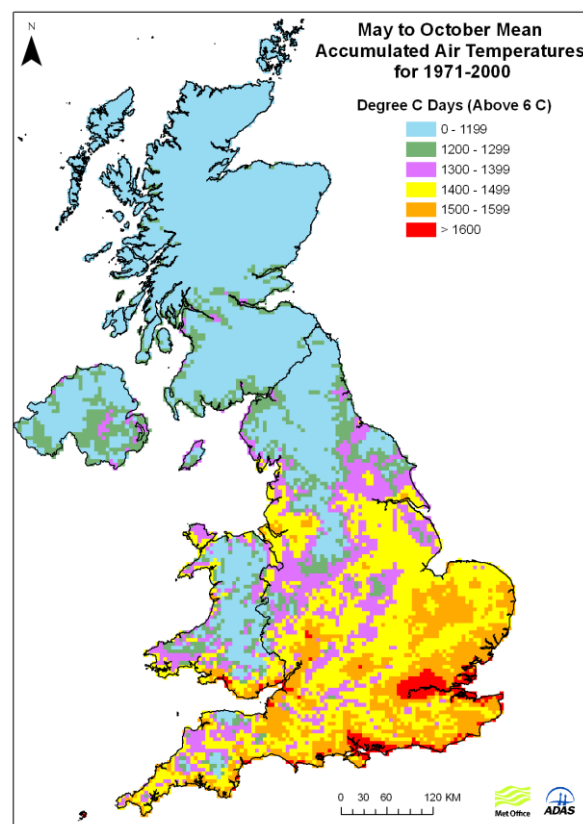


Figure 2 May to October Accumulated Days Air Temperatures above 6°C (1971 – 2000)



These areas, generally south of a line between the Humber and Severn estuaries, are best suited to production in the UK. Current weather conditions in the UK mean successful sunflower crops could be achieved in southern England in 9 out of 10 years. The map also suggests that they could be grown successfully in the SE corner of Wales and pockets of land in Pembrokeshire, Anglesey and the extreme NE of Wales.

### **Agronomy**

The following agronomic advice is from HGCA<sup>xxi</sup> and has been adapted to take into account organic standards and practices.

Sunflowers are planted at the end of April and grow rapidly given warm conditions. Buds begin to form in mid June and begin to show colour during the second week of July. Flowering lasts for approximately 2 weeks and then the crop begins to senesce ready for harvest in early October. In the UK water availability is not limiting, but excess rainfall will tend to result in taller crops. Predictions of global warming would bring drilling and harvesting dates earlier. Sunflowers can be grown on a wide range of soil types. However, a well-drained soil that will warm up rapidly in spring is preferred. The drought-tolerance of sunflowers also makes them suitable for growing on more drought-prone soil types. The optimal pH range is from 6.0 to 7.5. Seedbed preparation is crucial for sunflowers and a fine firm seedbed, similar to that for sugar beet and peas, should be prepared.

Seed is the most expensive input and there is no scope for home-saved seed as the crop is a hybrid. They yield between 1.5-2.5 t/ha when grown conventionally in the UK, organic data is unavailable but de Ponti et al (2012)<sup>xxii</sup> using a meta analysis of mostly North-American data suggest that organic yields are 77% of conventional, but can range from 54–114%. Plant population is an important factor in the production of a sunflower crop since it can affect a variety of yield components. Low populations result in plants with large heads, these tend to ripen slowly. An established plant population of between 80,000 and 110,000 plants/ha with a row width of 34 cm is optimal. Actual sowing rates should be between 10% and 20% higher than the target plant population to allow for losses during establishment. The lower figure applies to later sowings, light soils, warm seedbeds and conditions generally favourable to germination; the higher figure to heavy clay soils under less favourable conditions. Due to the nature of the sunflower crop there are no opportunities for reductions in seed rate.

### **Sowing**

Seed should be sown to a depth of 2.5 - 5.0 cm (1 to 2 inches), according to seed size and soil type and condition. In dry conditions, seed should be sown more deeply into moisture. Most seed-drills can be adapted for use with sunflower but seed rate, seed spacing and row width are critical. Sunflower is a non-branching crop and cannot compensate for uneven plant-spacing and low plant populations. Accuracy of drilling has an important bearing on yield and quality. Pneumatic disk drills, belt drills and pneumatic cereal drills have all been used to establish successful sunflower crops. Near optimal seed spacing can be achieved with the precision drills. With a pneumatic cereal drill optimal row spacing can be achieved by blocking-off alternate coulters, but these drills are not well adapted to the low populations required by the crop. Plant spacing within the rows can be very uneven.

For drills of all types, accurate calibration is essential, both to achieve the optimal plant population and to conserve expensive seed. Grower experience has shown that best results are achieved by calibrating the drill over a full hectare. Unless the drill has a press-wheel behind the seeder unit, the seed bed should be consolidated immediately after drilling, using a Cambridge roller, this conserves moisture and improves seed-soil contact.

### ***Plant nutrition***

The deep-rooting nature of sunflower can remove nutrients from depth in the soil profile. As a result the crop will yield satisfactorily at quite low levels of soil nitrogen so could be grown in the second and possibly the third year after a legume based fertility break. High levels of nitrogen can lead to excessive vegetative development, encouraging disease, delaying maturity and reducing seed oil content. UK experience indicates that N applications of more than 25-50 kg/ha are rarely required.

Phosphate is required at relatively low levels by the crop so a targeted adjustment is not likely to be needed. If soil phosphate levels are particularly low the farm should have a programme of rock phosphate application in place. Sunflowers require a relatively high level of potassium but most of this is returned to the soil after harvest. Potassium levels should be adequate in an active soil with a good clay content but could be a problem on lighter soils. Applications of potassium sulphate are permitted under organic standards but a very good case needs to be made (soils must be close to deficient and have less than 20% clay). A light application (10-15t/ha) of green waste compost could supply sufficient potassium and phosphorus without causing problems with nitrogen levels as a significant proportion is tightly bound.

Sunflowers are sensitive to boron deficiency, and can be a particular problem on calcareous or sandy soils where boron levels are often naturally low. Boron is taken up chiefly during the vegetative period prior to heading and signs of deficiency usually become apparent during flowering and seed maturation. A characteristic feature is poor seed-set, with many heads having large areas of hollow seeds. Other symptoms are red-brown necrotic patches and abnormal head and neck development. Organic standards will allow the use of soluble inputs to address trace element deficiencies but once again a strong case has to be made. Boron deficiency can be addressed through the use of borax (sodium tetraborate) at rates of 5-10kg/ha. In the case of sunflowers a single application of 5kg/ha could be used where levels are marginal but be aware that the gap between deficiency and toxicity is relatively small.

### ***Pest disease and disease management***

The height and broadly spreading leaf-canopy of sunflower enables it to compete very effectively with weed growth from as early as the fourth week from emergence. Despite this the crop is highly sensitive to competition during establishment. The effects of early competition are particularly marked where low soil temperatures and/or poorly aerated soil slow the growth of the crop relative to that of the weeds and where low plant populations or uneven drilling delay canopy closure. Maturity can be delayed and this can cause harvesting problems. The late drilling date of sunflowers allows ample opportunity to control weeds by cultivation and if conditions allow for a stale seed bed and weed strike the opportunity should be taken. Sunflower crops grown in wide rows allow an ideal opportunity for weed control through cultivation. A tractor mounted steerage hoe or other inter-row weeders (brush hoe, finger hoe, etc.) can be used successfully in the UK.

Mechanical weed control is most successful when soil conditions are dry and the weather is set fair.

In the UK the crop is most vulnerable to slugs from drilling until one pair of true leaves is visible. All soils are at risk but particularly cloddy or stony soils with high levels of organic debris. Surface consolidation can be important and there is an approved input for slug control based on ferric phosphate although the economics need to be carefully considered. Pigeons are a major pest of UK sunflowers; they graze the crop as it emerges, snipping off the growing point. Similar damage has been attributed to pheasants. Rabbits can also cause damage by grazing emerging crops. Finches can damage ripening crops, but they tend to venture only up to 24 m into the crop, because of predators. In a small field (less than 4 ha), bird damage can be considerable and the whole crop can be lost. To decrease damage to seed-heads, plant spacing should be controlled to reduce head size and increase head angle to discourage perching. Other mammals, such as mice and badgers, can also damage crops during ripening, but this is generally a localized problem. There have been reports of minor damage caused by Tortrix larvae, leaf minors and looper caterpillars, thrips and silver Y moths (*Autographa gamma* L.). Various aphids, including *Brachycaudus helichrysi*, *Aphis fabae* and *Myzus persicae* have been recorded but caused little damage.

Sunflower is host to a number of fungal, bacterial and viral pathogens that can cause varying amounts of crop damage, the two most common being *Botrytis cinerea* and *Sclerotinia sclerotiorum*. Botrytis head rot or grey mould is caused by *Botrytis cinerea*, a fungus widely spread throughout a range of crops. It occurs frequently in sunflower growing under relatively cool (15-25°C) and wet conditions and may cause extensive damage. Botrytis can develop on seedlings, stems and leaves, but only if the fungus gains entry through wounds. However, it is most damaging when it infects heads. Botrytis makes its first appearance on the back of the head as sunken brown spots. As the infection develops, the lesions spread and eventually the back of the head becomes soft and grey. A late season infection on the head can result in increased seed losses during harvest; earlier infections may reduce both yield and quality. There are no chemical options for controlling Botrytis in the sunflower crop and few management options beyond avoiding fields known to be wet or at risk of flooding. The use of dessicants is not permitted in organic agriculture although it can be a common approach in the conventional crop. Mycotoxins are not an issue for sunflowers as the husks are removed before consumption.

### **Harvesting and Storage**

Harvest should take place when seed moisture content reaches 30% or less. Oil quality does not suffer between 15-30% moisture content. A conventional cereal combine can be used with little modification, but if sunflowers are grown regularly then harvesting trays can be fitted to the cutter bar. The reel tines should also be covered to avoid impaling the flower heads. Combine settings should be similar to those used for harvesting beans and the crop should be harvested during the day and when dry. Care should be taken to avoid overloading the returns auger.

To minimize the amount of admixture with the grain, only a small amount of the stem should be cut. Some heads may fall forward, away from the combine table, when harvesting. This can be reduced by a relatively fast forward speed. The stubble can be chopped by the combine or by using a forager or heavy discs. The field can then be

ploughed and drilled if the following crop is a cereal. Volunteers may continue to appear throughout the spring.

Sunflower seed dries quickly but the seed should never be stored wet. Sunflower seed will heat up if allowed to stand while wet. Use of a drying floor is the safest method and the seed should be at a maximum depth of 1 metre. The best method of drying is to use cold air until the moisture content falls to 15 per cent. The seed can then be cleaned and sufficient heat applied (using the same temperature as for oilseed rape) to reduce the moisture to 9 per cent for long term storage. The seed should be left for seven days to allow the seed moisture to equalize before drying again if necessary.

The seeds of sunflower can persist in the soil for up to five years and have the ability to germinate at a considerable depth and over a long period. At ADAS Boxworth, on a clay soil susceptible to cracking, sunflowers were found to germinate in the cracks and appear in following crops. The growth of these volunteers was more vigorous where the crop was less competitive, especially on headlands and in gateways. On an organic farm volunteers in headlands and gateways could be looked on favourably as a valuable source of feed for wild birds and insects.

#### **4.2.2 Oil Seed Rape.**

Demand for organic OSR seems to be high and OSR offers some advantages from a rotational point of view. However, there are a number of issues that mean that organic producers do not appear to be very interested in growing it.

The main reason for this is that the risk of attack from insect pests is high and there are few successful non-chemical control measures available. Weed control is also difficult and, being a relatively hungry crop, it can be difficult to grow from a nutritional point of view. The lack of a dedicated organic market and supply chain and the lack of examples of good practice are additional structural reasons. There is also little organic OSR grown in other countries, with the largest areas in Switzerland and Germany, but both only comprise a few hundred hectares.

#### **Agronomy**

Depending on plant density and year, the impact of some major pests, such as the pollen beetle, can pose high risks for organic OSR farmers because direct control options are not economically viable and experience with indirect pest control (such as trap cropping) is currently limited. On the plus side, several authors highlight the high competitiveness of OSR plants against weeds<sup>xxiii</sup>. For example, Freeman & Lutman<sup>xxiv</sup> report that “in the three seasons studied, oilseed rape growth was particularly vigorous in the autumn and, as a consequence, the competitive impact of the weeds was lower than anticipated.” A prerequisite for high competitiveness is good establishment and strong early development; therefore OSR depends on a high plant density and sufficient plant nutrition to withstand significant weed pressure.

In comparison with many other crop species, OSR requires relatively high levels of nitrogen. When supply is limited, it tends to lead to thin plant stands and reduced competitiveness of the crop against weeds. For optimal N supply, organic OSR should be the first crop after legume or grass-clover mixtures as shortage of nitrogen supply for the OSR plants can be expected if it is the last crop in an organic rotation. From the beginning of OSR development, until about 6 weeks after sowing, the competitive strength of weeds

against the crop is potentially very high. Ground cover can increase rapidly in autumn to shade out weeds. As a consequence, a decisive criterion for the choice of OSR varieties is a fast autumn and spring development.<sup>xxv</sup>

### ***Harvesting and Storage***

Compared to cereals, rapeseed presents two to three times the resistance to airflow. Thus dryer bed and store depths need to be reduced by a factor of two to three, unless facilities are purpose-built.

Before harvest, stores should be thoroughly cleaned and disinfested. The small size of rapeseed means it can easily leak from bins or into ducts. Therefore, thorough store inspection pre-harvest and maintenance throughout the storage period is essential. Rapeseed should be cooled rapidly to maintain oil quality and minimise the threat from moulds and mites. Cooling can be achieved using ambient air. Cooling is best achieved in stores specifically designed for rapeseed. In stores designed for cereals, adequate airflows are maintained by reducing bed depth. Alternatively, the aeration period can be increased to two to three times that used for cereals (e.g. it would take some 900 hours to reduce rapeseed temperature to 5°C). Storage at low temperatures helps protect against increased free fatty acid (rancidity) levels due to broken seed and the build-up of mites and moulds.

## 5 Conclusions

From the point of view of poultry nutrition, both OSR and sunflower have the potential to help replace soya in UK poultry diets. However, from an agronomic and economic perspective the potential for UK grown OSR to contribute to poultry rations is low. Advances need to be made agronomically for OSR to reach its full potential for inclusion as almost none is grown in the EU.

Sunflower, on the other hand, is more promising prospect. From the point of bird nutrition, is a useful ingredient in feed. It grows readily in Europe and has the potential to do well organically in the UK including SE Wales and part of Pembrokeshire, Anglesey and NE Wales.

- 
- <sup>i</sup> Blair, R. (2008) Nutrition and Feeding of Organic Poultry. Oxford: CABI
- <sup>ii</sup> Baines, R., Jones, J., (2010) *The potential for replacing imported soy with alternative home grown protein feeds for UK livestock. Part 1: Technical feasibility and possible policy interventions.* RAC Report for Friends of the Earth
- <sup>iii</sup> Nutritional information from Humphrey's Feeds Ltd
- <sup>iv</sup> Sundrum, A., Schneider, K., and Richter, U. (2005) Research to support revision of the EU Regulation on organic agriculture ; Possibilities and limitations of protein supply in organic poultry and pig production. EEC 2092/91
- <sup>v</sup> Sundrum, A., Schneider, K., and Richter, U. (2005) Research to support revision of the EU Regulation on organic agriculture ; Possibilities and limitations of protein supply in organic poultry and pig production. EEC 2092/91
- <sup>vi</sup> Butler, E.J., Pearson, A.W., and Fenwick, G.R. (1982) Problems which limit the use of rapeseed meal as a protein source in poultry. *Journal of the Science of Food and Agriculture* 33, 866 - 875
- <sup>vii</sup> Baines, R., Jones, J., (2010) *The potential for replacing imported soy with alternative home grown protein feeds for UK livestock. Part 1: Technical feasibility and possible policy interventions.* RAC Report for Friends of the Earth
- <sup>viii</sup> Blair, R. (2008) Nutrition and Feeding of Organic Poultry. Oxford: CABI
- <sup>ix</sup> Elwinger 2003
- <sup>x</sup> Baines, R., Jones, J., (2010) *The potential for replacing imported soy with alternative home grown protein feeds for UK livestock. Part 1: Technical feasibility and possible policy interventions.* RAC Report for Friends of the Earth
- <sup>xi</sup> Jacob, J.P., Mitru, B.N., Mbugua, P.N. and Blair, R. (1996) *The feeding value of Kenyan sorghum, sunflower seed cake and sesame seed cake for broilers and layers.* *Animal Feed Science and Technology* 61, 41-56
- <sup>xii</sup> Serman, V., Mas, N., Melenjuk, V., Dumanovski, F. and Mikulec, Z. (1997) *Use of sunflower meal in feed mixtures for laying hens.* *Acta Veterinaria Brno* 66, 219-227
- <sup>xiii</sup> Ewing W., N. (1998) Feeds Directory: Commodity Products Guide. Context.
- <sup>xiv</sup> Blair, R. (2008) Nutrition and Feeding of Organic Poultry. Oxford: CABI
- <sup>xv</sup> Smithard, R. (1993) *Full fat rapeseed for pig and poultry diets.* *Feed Compounder* 13, 35-38
- <sup>xvi</sup> Huthail, N. and Al-Khateeb, S.A. (2004) The effect of incorporating different levels of locally produced canola seeds in the diets of laying hens. *International Journal of Poultry Science* 3, 490-496
- <sup>xvii</sup> Talebali, H. And Farzinpor, A. (2005) Effect of different levels of full fat canola seed as a replacement for soyabean meal on the performance of broiler chickens. *International Journal of Poultry Science* 12, 982-985
- <sup>xviii</sup> Farm Business Survey. [www.farmbusinesssurvey.co.uk/index.html](http://www.farmbusinesssurvey.co.uk/index.html) Accessed 30/03/12
- <sup>xix</sup> Cook, S K (2009) Sunflowers and climate change In. Defra project AC0302 A Research and Innovation Network Supporting Adaptation in Agriculture to Climate Change
- <sup>xx</sup> Cook, S K (2009) Sunflowers and climate change In. Defra project AC0302 A Research and Innovation Network Supporting Adaptation in Agriculture to Climate Change  
[http://www.hgca.com/publications/documents/croprosearch/SF6\\_new\\_sunflower\\_growers\\_guide.pdf](http://www.hgca.com/publications/documents/croprosearch/SF6_new_sunflower_growers_guide.pdf)
- <sup>xxi</sup> de Ponti, T., Rijk, B., van Ittersum, M.K., 2012. The crop yield gap between organic and conventional agriculture. *Agricultural Systems* 108, 1-9.
- <sup>xxii</sup> Arnold B (2011) Raps Mechanische Unkrautregulierung. <http://www.agrigatech.de/pflanzenbau/ackerbau/oel/sorten/> Accessed 15/11/2011
- <sup>xxiv</sup> Freeman SE, Lutman PJW (2004) The effects of timing of control of weeds on the yield of winter oilseed rape (*Brassica napus*), in the context of the potential commercialization of herbicide-tolerant winter rape. *Journal of Agricultural Science* 142:263-27
- <sup>xxv</sup> Döring, T.D., Pearce, H. and Howlett, S. Mechanical weed control in oil seed rape: A summary of research and recommendations for HGCA