CROPQUEST

MINOR CROPS REPORT

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In this report as part of the DAFM funded CROPQUEST desk study, a brief description outlining the characteristics of a range of minor crops, their uses/markets and their potential, if known, for production in Ireland is presented. The crops include:

- Amaranth
- Borage
- Calendula
- Camelina
- Crambe
- Echium
- Flax / Linseed
- Hemp
- Hops
- Lentils
- Lupins
- Oats
- Poppy
- Quinoa

Amaranth (Amaranthus spp.)

Amaranth is an annual or short lived perennial plant cultivated as a leaf vegetable or cereal. The species is native to Central America and played an important role in the empires of the Aztecs and Incas. It is thought to have represented up to 80% of the calorific consumption of the Aztecs prior to the Spanish conquest (Coe, 1994).

A number of amaranth species have been cultivated throughout Europe, Africa and Asia. The tiny seeds of the amaranth plant are higher in protein, oil and minerals than many cereal grains. The leaves and young shoots are used as a green vegetable and fodder crop throughout parts of Asia and Africa (Smith et al., 1997). Amaranth has been developed as a protein rich grain for popping and

flour production which is finding increasing uses in products such as breakfast and snack foods with growing interest in products developed for the gluten free market (Coe, 1994; Inglett et al., 2015; Machado Alencar et al., 2015).

The growing crop may reach a height of 3m dependent on species, planting density and growing conditions. When the crop is dry the grain may be harvested using standard combine harvesters. Amaranth grain is typically composed of 13.1 to 21.0% crude protein; 5.6 to 10.9% oil; 48 to 69% starch and 3.1 to 5.0% dietary fibre (Mlakar et al., 2010). Proteins found in Amaranth grain have a high digestibility score (>90%) and are high in lysine. The balanced amino acid composition is close to the optimum protein reference pattern for the human diet according to FAO/WHO (WHO & FAO, 1991). Combining Amaranth flour with maize flour in a 50:50 ratio provides a well-balanced diet (Mlakar et al., 2010).

Yields of Amaranth grain in European conditions of between 500 – 3,800 kg ha^{-1} have been reported and are strongly influenced by growing conditions, site suitability and fertilizer inputs (Mlakar et al., 2010). Above ground biomass yields of Amaranth greens are also influenced by growing conditions and fertilizer inputs, with yields of between 14,000 – 49,000 kg ha^{-1} being reported (Mlakar et al., 2010). The by-products remaining after harvest can be used as a feed for animals.

Figure 1: Amaranthus being grown in Canada (Source: Ontario Ministry of Agriculture, Food & Rural Affairs (OMAFRA)).

Borage (Borago officinalis)

Borage, also known as starflower, is a herbaceous annual plant grown as an oilseed crop (Berti et al., 2010). Interest in cultivating borage is largely due to the high gamma–linoleic acid (GLA) content of the oil (Berti et al., 2010; Gilbertson et al., 2014) which can be beneficial in nutrition and human health applications. Borage seed oil is the richest plant source of GLA, which is used as dietary or food supplement alternative to fish oils (Asadi-Samani et al., 2014). The plant is a traditional medicinal and culinary herb native to the Mediterranean area. GLA is an omega-6 essential fatty acid which is occasionally prescribed as anti-inflammatory drug as it lacks some of the common side- effects of other anti-inflammatory drugs. GLA can also used in the treatment of multiple sclerosis, diabetes, heart diseases, arthritis, eczema, autoimmune disorders, cancer and premenstrual syndrome (Asadi-Samani et al., 2014; NNFCC, 2008).

Borage can grow in a range of conditions and climates but will not tolerate excessively dry soils (Asadi-Samani et al., 2014). Borage has been cultivated in the UK for centuries from the south coast to mid–Scotland with the oil profile from seeds grown in cooler northern regions more favourable (NNFCC, 2008). In these climates, Borage is sown into a fine firm seedbed once soil temperatures have reached 10°C, typically mid– April targeting a plant density of 70 – 80 plants m^{-2}. Borage requires a low level of crop inputs with 75 – 80 kg N ha^{-1} applied to the seedbed. Flowering commences around mid–June and may continue through to September. The plant is self-incompatible, requiring pollinating insects (El Hafid et al., 2002). To minimise seed loss, swathing is carried out once seed begins to shed from the second or third most forward flower/pod sets.. The crop is then combined 7 – 10 days after swathing using a conventional harvester with pick–up header. Typical yields of borage seed in the UK is 0.4 t ha^{-1} with yields of 0.7 t ha^{-1} achievable in optimum growing conditions (NNFCC, 2008). Contract prices for Borage seed in the UK has been in the region of £2,300 t^{-1} (2010). Oil content of borage seeds fluctuates between 30% and 38% of which, 20% to 23% is GLA with a premium paid for GLA contents above 22% (Berti et al., 2010).

Figure 2: Field of Borage in flower (Source: OMAFRA).

Figure 3: Borage flower (Source: OMAFRA)

Calendula (Calendula officinalis)

Calendula is native to the Mediterranean region. It is grown globally as Marigolds. Calendula is a member of the Asteraceae family, which includes sunflowers and daisies. The crop is an annual, which typically reaches heights of between 50 and 80 cm. The crop has been used in traditional medicine for thousands of years as a method of treating burns and wounds to the skin (Khalid & Teixeira da Silva, 2010; Smith et al., 1997). There has been growing interest from industry due to the calendic acid component (60%) of the oilseed which contain ~20% oil. Calendic acid has numerous uses as drying agents in coatings, paints and cosmetics due to its rapid oxidation (Cromack & Smith, 1998; Wilen et al., 2004).

Cromack and Smith (1998) conducted a study in southern England to determine the suitability of the crop for this region. They reported seed yields of between 2 and 2.5t ha^{-1} in the years of 1994 and 1995. These yield values are similar to values reported by Smith et al. (1997). The flower heads can be used to create dyes which range in colour from bright yellow to gold. Dried Calendula petals are

used in the spice trade as an inexpensive alternative to saffron and are used in many ointments to enhance their appearance by adding a gold colour (Khalid & da Silva, 2012).

Calendula can be grown as a dual purpose crop where the flowers are harvested for use in the food and pharmaceutical industries and the seeds are harvested for use as an oilseed (Wilen et al. 2006). Multiple harvest of flower heads can be obtained from the crop with little effect on the seed yield in low yielding regions.. This study harvested 1.7t of flower heads ha^{-1} and maintained a seed yield of 700 kg ha^{-1}. In similar trials where the flower heads were not removed seed yields of 765 kg ha^{-1} were reported. However the yields of these crops grown in western Canada were very low. Further trials of Calendula as a dual purpose crop in climates similar to Ireland would need to be conducted to determine if flower head removal affects seed yield at the higher yields obtained in European situations.

Figure 4: Field of Calendula officinalis in bloom.

Camelina (Camelina sativa L.)

Camelina is a crop native to Finland, Romania and regions east of the Ural mountains. The crop has been an important oil crop for centuries with references to its cultivation in the Rhine valley region of Germany as far back as

600 BC. Camelina is an annual crop member of the Brassica family similar to both oilseed rape and flax crops. The crop is sometimes referred to as false flax and reaches a height of approximately 90 cm. Camelina is regaining prominence as a health product due to the high contents of the omega-3, alpha-linoleic acid (ALA) content. Reports from the Centre for alternative land use (CALU) found Camelina oil contains 45% ALA compared with 10% ALA in rapeseed oil and virtually none in sunflower oils (CALU, 2007).

A study conducted by Teagasc reported average seed yields of 2.5t ha^{-1} over a three year period with oil contents of between 42 – 47% (Crowley & Frohlich, 1998; Dobre et al., 2014). Camelina is a crop that requires very little inputs of fertiliser and is suitable for use on more marginal land. CALU (2007) report sowing dates in Wales from April to mid-May and fertiliser inputs of 75 kg ha^{-1} of nitrogen, with higher levels of N leading to problems with lodging. These values for fertiliser inputs are in line with results obtained by Teagasc during trials of Camelina in 1994 (Crowley & Frohlich, 1998). The crop can be harvested using traditional combine harvesters.

Camelina oil contains high levels of gamma-tocopherol (Vitamin E) and anti-oxidants which confers a reasonable shelf life without the need for special storage conditions. Stems of the Camelina crop can be used as a packaging material (Smith et al., 1997).

Figure 5: Camelina sativa plants in a trial plot (Source: OMAFRA).

Crambe (Crambe abysinnica Hochst.)

Crambe (more commonly known as Abyssinian mustard) is an annual spring sown herb from the mustard family originating from the Mediterranean regions. Crambe has been grown successfully for industrial use in North America for a number of years and more recently has proved to be successful in the UK since 2001 as an alternative oil crop (NNFCC, 2006).

The crop contains an inedible oil that has numerous industrial applications. The oil is used as an industrial lubricant, a corrosion inhibitor, and as an ingredient in the manufacture of synthetic rubber. The oil contains 50 to 60% erucic acid from which erucamide is derived, a long chain fatty acid, which is used in the manufacture of plastic films as a slip agent, plasticizers, nylon, adhesives, and electrical insulation (NNFCC, 2006; Oplinger et al., 2015; Rogerio et al., 2013). Since the development of low erucic acid varieties of oilseed rape the supplies are less plentiful (Oplinger et al., 2015), as cross-contamination with food- oil is seen as a risk. As crambe is not related to oilseed rape there is no risk of cross contamination making it suitable for inclusion in crop rotations which contain oilseed rape (NNFCC, 2006).

Crambe has a short growing cycle, around 90 – 100 days; reaches plant heights ranging from 70 – 90 cm; can flower as soon as 35 days after sowing, and has 35 – 60% of seed oil content (Rogerio et al., 2013). Crambe seed yields in our climate average around 2 – 2.5t ha^{-1} (NNFCC, 2006).

Figure 6: Crambe abysinnica in flower (Source: OMAFRA)

Echium (Echium plantagineum)

Echium is a spring sown annual oilseed crop closely related to borage and grows to a height of 50 – 80 cm. Echium seeds contain about 27% oil. Echium seeds contain a speciality oil which is high in alpha linolenic acid (ALA), gamma linolenic acid (GLA) and stearidonic acid (SDA) (NNFCC, 2009). These fatty acids are rare in plants and highly valued in the health and personal care industries (NNFCC, 2009). SDA acid, in particular, is an essential ingredient in anti-wrinkle cosmetics, and both SDA and GLA provide health benefits analogous to fish oils (Eberle et al., 2014).

Echium is a low input crop with agronomic characteristics similar to Borage. Prior to harvest the crop is usually swathed to encourage uniform ripening, however seed loss can be a risk so the timing of harvest is crucial. The crop will usually be harvested 7 – 10 days after swathing in August using a conventional combine harvester with a pick up draper header (NNFCC, 2009). Yields of Echium seeds in the UK can be variable depending on soil type and weather but typically range between 0.2 – 0.3 t ha^{-1} (NNFCC, 2009).

Prices for Echium seeds on a contract basis are in the region of £3,500 t^{-1}, however, as the market is small but expanding prices can vary (NNFCC, 2009). The market outlook for echium seed oil is strong, particularly if its use in the functional food market is developed.

Figure 7: Field of Echium in flower (Source: innovationfarm.co.uk).

Flaxseed (Linum usitatissimum)

The seed of the flax plant is linseed (Linum usitatissimum L.). It is an oil seed and fibre crop that has been used by humans from more than 6,000 years and is among one of the first plants to be domesticated (Jhala & Hall, 2010). The utilization of flax for various purposes including industry, nutraceutical, bio-pharmaceutical, fiber, animal feed and human food is continuing to develop (Jhala & Hall, 2010; Soto-Cerda et al., 2014; Thompson et al., 2015).

Flax was traditionally grown in Ireland as a fibre crop for the production of linen, however this industry declined with the development of synthetic fabrics and the expansion of cotton production.

In recent times there has been growing interest in the use of flaxseed oil as an oil for human consumption and for industrial purposes due to the high ALA content of the oil with ~57% of the oil content being ALA (Jhala & Hall, 2010; Thompson et al., 2015). The plant oil, high in omega-3 ALA, is a sustainable, vegetarian alternative to fish oils (Jhala & Hall, 2010; Thompson et al., 2015). There is limited use of flax oil for human consumption due to problems associated with the oxidation of the oil, however, the oil properties of flax are so unique that considerable effort is being expended to emulate the fatty acid profile (Jhala & Hall, 2010). A recent study conducted by Paschos et al. (2007) in Europe indicated that the consumption of one tablespoon flaxseed oil (providing 8 g ALA day^{-1}) for 12 weeks in a daily diet lowered blood pressure significantly in middle aged men with high blood cholesterol levels.

Flaxseed is also the most abundant plant source of lignans; it has concentrations of 50 – 800 times greater than other lignan containing foods (Shim et al., 2015). Lignans act as antioxidants in humans. Partially defatted flaxseed meal, containing ~10% oil, is reported by Shim et al. (2015) to be an excellent gluten replacer in gluten free breads. Flaxseed mucialge has been reported (Jhala & Hall, 2010; Thompson et al., 2015), to have emulsifying properties better than gum Arabic with potential for both industrial and bakery uses

As industrial oil, flaxseed is used as a drying agent in resins, paints, printers' ink and varnishes (Jhala & Hall, 2010; Thompson et al., 2015). Flaxseed oil is also the most important raw material used to make the traditional flooring product linoleum. In the process of linoleum manufacturing, oxidized linseed oil is mixed with rosin and other raw material to form linoleum granules, which are pressed onto a jute backing, making linoleum sheets (Jhala & Hall, 2010).

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Figure 8: Flaxseed plants in flower (Source: easywildflowers.com).

Hemp (Cannabis sativa)

Industrial hemp is distinct from the illicit drug form of cannabis as it has been bred to contain < 0.2% of the tetrahydrocannbinol (THC) compound. THC is the compound responsible for giving cannabis its psychoactive effects. Industrial forms of hemp have been used for millennia for a diverse range of products such as rope, textiles, oil, food, energy and construction materials. In fact the word canvas derives from the Latin for hemp, cannabis. According to Caslin (2007) hemp products can be associated with over 50,000 different product applications across an array of industries. Modern varieties of hemp have been developed which can be grown for both fibre and seed production thus increasing the economic competitiveness of the crop.

Hemp is a tall annual crop reaching height of up to 4m. The dual-purpose varieties of hemp typically reach heights of 2m. A report from the NFCC (2010) reported yields from fibre hemp of 7.5 t ha^{-1} with yields of 10 t ha^{-1} possible. Yields from the dual-purpose varieties reported were 5 t ha^{-1} for the fibre portion and 1.25 t ha^{-1} for the seed fraction. Typical values for the fibre fraction were given as £132.50 (€184.50, converted using a conversion rate of £1 = €1.39) t^{-1} and £450 (€626) t^{-1} for the seed. This provides a 23% higher return from dual-purpose varieties of hemp over traditional fibre varieties and is confirmed by a report from ADAS (2008).

The seed is harvested using conventional harvesting machinery set to the highest height. The straw fraction is then allowed to ret for a few days before being harvested and baled. Retting is a process employing the action of micro-organisms and moisture on plants to dissolve, or rot away, much of the cellular tissues and pectins surrounding bast-fibre bundles, and so facilitating separation of the fibre from the stems.

Figure 9: Field of industrial hemp (Source: OMAFRA).

Hops (Humulus lupulus)

Hops are the female flowers from the hop plant. They are primarily used as a flavouring and stability agent in beer production but can be used for medicinal purposes to treat anxiety, restlessness and insomnia. The EU is the primary producer of hops globally accounting for 50% of the supply to world markets (Europa, 2009) with Germany and the Czech Republic accounting for 80% of the EU supply. The hop plant is a vigorous, climbing, herbaceous perennial, usually trained to grow up a mesh suspended between wooden or concrete poles in fields known as hop-yards. Many different varieties of hops are grown by farmers around the world, with different types being used for particular styles of beer. Flowers from the female plants are used as an essential part of the brewing process of beer with the essential oils contributing to the bitterness, flavor, aroma, and foam (head) characteristics, and to the preservative qualities of the beer (Pavlovic, 2012).

As the crop is a perennial that requires support during the growing season, establishment costs of a hop-yard are significant. Pavlovic (2012) estimates that the initial capital cost of establishing a hop-yard in the EU amount to approximately €15,000 ha^{-1}. Once established, the hop rootstock will produce indefinitely, although industry practice is to rotate plantings every 15 – 20 years. The majority of hops are grown on a contract basis for the major brewers, which

leads to a relatively stable price being achieved over time. Europa (2009) reports that prices for hops remained stable at ~€4,000 t^{-1} between 2000 and 2007. Prices for hops which are not grown on a contract usually follow the contract prices closely except for in 2007 when the crop failed and prices of up to €14,000 t^{-1} were achieved. Given these prices of establishing a hop-yard growers still can find profits being returned after 3 years depending on the yield achieved in the first year (Europa, 2009; Pavlovic, 2012).

Figure 10: Hops plants at full height on trellis (Source: OMAFRA).

Figure 11: Hop cone ready for harvesting (Source: OMAFRA).

Lentils (Lens culinaris)

Lentils are a pulse vegetable similar to peas and beans and are among the most ancient cultivated crop among the legume family (Abraham, 2015; Cokkizgin & Shtaya, 2013). It is indigenous to South Western Asia and the Mediterranean region. There is archaeological evidence of lentil dating back to 7,500 – 6,500 BC.

The lentil is one of the most important grain legumes, ranking sixth in terms of production worldwide. Of the production, 70% is small-seeded with red cotyledons, 25% green large-seeded and 5% brown lentils (Lizarazo & Stoddard, 2012). As lentils are imported to the EU there may be scope to develop a market. The main producers of lentils include Canada, India and Turkey, with Canada producing 2 million tonnes of the 4.2 million tonnes produced globally in 2010 (Abraham, 2015; Cokkizgin & Shtaya, 2013).

Seed yields from lentils vary globally with an average yield of 1.5 t ha^{-1} in France, Canada and the USA but yields of up to 2.8t ha^{-1} have been reported in Armenia (Cokkizgin & Shtaya, 2013). Lizarazo and Stoddard (2012) reported an average lentil yield of 1.5 t ha^{-1} in Finland during the 2010 growing season with a maximum yield of 1.87 t ha^{-1}. Higher seed yields are achieved on sandy-loam soils as opposed to heavier textured soils (Cokkizgin & Shtaya, 2013). Lentils are a nitrogen fixing crop with a potential of fixing up to 107 kg N ha^{-1} (Abraham, 2015). Their suitability for the Irish climate has not been evaluated.

Figure 12: A field of Lentils in USA (Source: US Dry Pea and Lentil Council).

Figure 13: Different types of lentils; brown, green and red lentils

Lupins (Lupinus angustiflius)

Lupins (Lupinus) are a member of the legume family, Fabaceae. The genus contains some 400 species, of which only 4 are of agronomic interest (Kohajdova). These include; *L. albus* (white lupin), *L. angustifolius* (blue or narrow-leafed lupin), *L. luteus* (yellow lupin) and *L. mutabilis* (pearl or tarrwi lupin). These species are known as 'sweet lupins' due to their low levels (0.003%) of bitter-tasting and potentially toxic alkaloids (Crowley, 1998; Kohajdova et al., 2011). Wild lupins, and those used as ornamentals, are poisonous, containing high levels of toxic constituents (ACAF, 2000).

Lupins are a high protein legume containing between 30% and 43% protein (Biddle, 2008; Crowley, 1998). This is the highest protein content of legume crops grown in Europe, second only to soybeans globally. Lupin seeds also contain significant levels of oil of between 6.7 and 12.8% (Biddle, 2008) and are consequently more similar to soybeans than to either peas or beans, which contain 23 – 27% protein and no oil (Crowley, 1998). Lupins fixation of nitrogen in the soil is high among legume crops at up to 300 kg N ha^{-1} (Crowley, 1998).

Trials conducted by Teagasc in Oak Park between 1994 and 1997 reported yields from dwarf varieties of winter sown white lupins of between 3.96 and 4.84 t ha^{-1} over the trial period with an average yield of 4.54 t ha^{-1} (Crowley, 1998). Spring sown varieties of lupins have had yields of up to 2.9 t ha^{-1} achieved in the UK (Biddle, 2008). However, the number of days to ripening of spring sown lupins varied from 130 to 171 days. This may lead to problems when it comes to harvesting due to unfavourable weather conditions at the end of a growing season.

Figure 14: Trial plot of yellow Lupins (Source: Aberystwyth University).

Oats (Avena sativa)

While oats are usually considered a mainstream cereal, they are a useful break-crop in cereal rotations as they are not affected by the same variant of take-all as other cereals. Also there are a number of variants of oats and uses which warrant their consideration as an alternative crop. In Ireland, mainstream oats are grown primarily for the horse feed and milling industries (Burke et al., 2001).

The area of oats grown in Ireland has remained relatively unchanged since 2008 with between 9,000 and 11,000 ha sown. This represents approximately 9% of the area cultivated with traditional cereal crops. In recent years, there has been growing interest in oats for human nutrition including breakfast cereals, snack bars and gluten-free products. The primary protein in oats is avenalin, and it is gluten free. However, for certification for use in coeliac diets, the crop needs to be kept separate from wheat and barley so as to avoid contamination of the oats. Oat protein is similar in quality to soya protein, which WHO (2014) research has shown to be equivalent to meat, milk and egg proteins. The protein content of the hull-less oat kernel (groat) ranges from 12 to 24%, the highest among cereals (Lasztity, 1999). Typical yields for winter oats in Ireland vary from 7 – 8 t ha^{-1}.

Varieties of oat have been bred that naturally lose the husk during the combining and processing of the crop. These oats are known as naked oats (Biel et al., 2009) and they contain a higher proportion of crude protein than conventional oats and are suitable for sale as a health food or to specific equestrian markets where lower starch and higher oil contents are desired.

Oats have an oil content which typically range from 3 – 11% (Banas et al., 2007). Oat oil contains high levels of Vitamin E (tocopherols 729 mg kg^{-1} oil), twice the

level present in rice bran oil (Tong et al., 2014). Vitamin E is important in many areas; recently it has become increasingly used in skin care products for anti-aging, anti-irritation and sun-care purposes. A leading cosmetics brand, Aveeno, has built its reputation on incorporating oat compounds into skincare products.

Figure 15: Field of Oats

Poppy (Papaver somniferum)

The Papaver somniferum species of poppy plants is grown primarily for the opium laden latex contained in the seed heads of the plant (Chaturvedi et al., 2014). The word somniferum derives from Latin and translates as sleep–bringing. The plant was known in Europe at least 4,000 years ago as evidenced by fossil remains of poppy seed cake and poppy pods found in the Neolithic Swiss Lake Dwellings. The poppy is also referred to in Homer's works the Iliad and the Odyssey (850 B.C.). Hippocrates (460 – 357 B.C.) prescribed drinking the juice of the white poppy mixed with the seed of nettle.

A number of medicinal products are extracted from the latex in the seed heads of poppy and include morphine (as well as its illegal derivative heroin), codeine, thebaine, papaverine, and noscapine (Mishra et al., 2013; Simon et al., 1984; Stranska et al., 2013) which are used as active pharmaceutical ingredients in the production of drugs.

Traditionally, opium was harvested manually by scoring the seed heads with a knife and waiting for the latex to ooze out of the capsule. This method is particularly labour intensive with an estimated 350 man days of work required to harvest opium from one acre of poppy. Globally, opiates are now harvested using the concentrate of poppy straw (CPS) method (Fist, 2001). When the crop has matured and dried the seed heads along with 20cm of poppy straw are harvested, after threshing of the seed from the seed heads the alkaloids (opiates) are extracted using various solvents (Fist, 2001). CPS generally contains between 40 and 80% alkaloid. The Macfarlan Smith company has estimated the US opiate market at $400 million (Johnson Matthey, 2006).

According to the Criminal Justice Act of 2006, cultivation of the crop is currently illegal in Ireland and is considered a class C conviction. However, the crop is extensively grown in countries including Australia, France, Spain, the Netherlands and the UK.

Agronomic data for the production, yields and morphine content of opium poppies in an Irish or British context is scarce. Simon et al. (1984) reported that poppy can grow in a wide range of conditions: temperatures of 7 - 23 C and annual rainfalls of 300mm to 1700mm. The crop is spring sown. Mishra et al. (2013) has reported a number of agronomic factors for opium poppy in an Indian context. Opium contents of 50 – 64 kg ha^{-1}, seed yields of 1,000 – 1,400 kg ha^{-1} and morphine contents of 12 – 15% have been achieved from a number of varieties.

Poppy seeds are commonly used for human consumption of baked goods and pastries for their nutty flavour and odour (Chaturvedi et al., 2014; Simon et al., 1984). Prochazka and Smutka (2012) reported the average yield of poppy seeds in the Czech Republic from 1993 to 2010 was 0.62 t ha^{-1}. The average world prices for poppy seeds during these years (1993 – 2010) was € 1.14 kg^{-1}. Poppy seeds have been reported to contain 32% - 50% oil (Ozcan and Atalay (2006), Bozan and Temelli (2008)). Poppy seed oil has a number of uses in foods as salad dressings and also for industrial uses.

Figure 16: Papaver somniferum plants in flower and with seed capsules visible (Source: bioweb.uwlax.edu)

Figure 17: Papaver somniferum seed capsule after lancing to extract opium (Source: flickr.com).

Quinoa (Chenopodium quinoa)

Quinoa (Chenopodium quinoa Willd.) is a pseudo-cereal (i.e a grain that is treated in a similar manner to a cereal) and is a native plant in the Andean region (Nowak et al., 2015). Quinoa has been cultivated for human consumption for at least 5,000 years in many different climatic conditions of the Andes from sea level to (3,800m) the height of Bolivian Altiplano plateau (Nowak et al., 2015; Oelke et al., 2012).

Due to Quinoas highly nutritious grain and excellent protein quality it has been singled out by the Food and Agriculture Organization of the United Nations (FAO) as a food with "high nutritive value," impressive biodiversity and an important role to play in the achievement of food security worldwide (Bhargava et al., 2006; Przygoda & Wejnerowska, 2015).

Quinoa is an annual broad leaved plant which typically reaches heights of 1 – 2m and has deep penetrating roots. The plant is mainly grown for its seed, which is a gluten free and high protein (10 – 18%) alternative to maize, rice and potato (Bhargava et al., 2006; Przygoda & Wejnerowska, 2015). Studies conducted across Europe have found that Quinoa is a suitable crop for cultivation in both Denmark and the Netherlands (Jacobsen, 1997). Unpublished trials from Wageningen University using traditional cultivars of Quinoa have yielded 2 – 3t of seed ha^{-1}, however, breeding of new varities more suited to northern European climates may improve this yield.

The crop is sown from late March to early May and depending on the growing conditions of the year is typically harvested from late August to late September. Harvesting of the seed can be completed using a combine harvester with appropriate sieving, air and drum settings. The thousand seed weight of Quinoa is 2 – 3g compared with 40 – 55g for both winter wheat and winter barley. The seeds are coated in a bitter tasting saponin (a toxic glycoside) which needs to be removed before consumption. Breeding programs are working on developing 'sweet' varities of Quinoa that contain lower levels of saponins. There is also work being conducted that looks at using the saponins removed from Quinoa as an active ingredient in pesticides and fungicides for the treatment of Botrytis cinerea (grey mould) and other diseases in potatoes, pulses and wheat crops (Cantrell et al., 2012).

Figure 18: Varying colours of Quinoa seed heads (Source: OMAFRA).

Acknowledgements
The authors wish to acknowledge the support for this work provided by the Department of Agriculture, Food and the Marine through the Research Stimulus Fund.

References

Abraham, R. 2015. Lentil (Lens Culinaris Medikus) Current Status and Future Prospect of Production in Ethiopia. Advances in Plants and Agriculture Research, 2(2), 1-9.

ACAF. 2000. The use of sweet lupins in animal feed.

ADAS. 2008. A study of bio-refining oppurtunities in Ireland - A report prepared for Enterprise Ireland.

Asadi-Samani, M., Bahmani, M., Rafieian-Kopaei, M. 2014. The chemical composition, botanical characteristic and biological activities of Borago officinalis: a review. Asian Pacific Journal of Tropical Medicine, 7, Supplement 1(0), S22-S28.

Banas, A., Debski, H., Banas, W., Heneen, W., Dahlqvist, A., Bafor, M., Gummeson, P., Marttila, S., Ekman, A., Carlsson, A.S., Stymne, S. 2007. Lipids in grain tissues of Oat (Avena sativa): differences in content, time of deposition, and fatty acid composition. Journal of Experimental Biology, 58(10), 2463-2470.

Berti, M., Fischer, S., Wilckens, R., Hevia, M., Johnson, B. 2010. Borage (Borago officinalis L.) response to N, P, K, and S fertilization in south central Chile. Chilean Journal of Agricultural Research, 70(2), 228-236.

Bhargava, A., Shukla, S., Ohri, D. 2006. Chenopodium quinoa - An Indian perspective. Industrial Crops and Products, 23, 73-87.
Biddle, A. 2008. Spring Lupins in UK Agriculture - Experiences and Challenges. Proceedings of the 12th International Lupin Conference, Freemantle, Western Australia. International Lupin Association.
Biel, W., Bobko, K., Maciorowski, R. 2009. Chemical composition and nutritive value of husked and naked oats grain. Journal of Cereal Science, 49(3), 413-418.
Bozan, B., Temelli, F. 2008. Chemical composition and oxidative stability of flax, safflower and poppy seed and seed oils. Bioresource Technology, 99(14), 6354-6359.
Burke, J., Browne, R., White, E. 2001. Factors affecting yield and quality of oats.
CALU. 2007. Technical Notes - Camelina.
Cantrell, C., Dayan, F., Duke, S. 2012. Natural Products as Sources for New Pesticides. Journal of Natural Products, 75, 1231-1242.
Caslin, B. 2007. Hemp (Cannabis Sativa), (Ed.) Teagasc, Vol. Tillage No. 6. Oak Park, Carlow.
Chaturvedi, N., Singh, S., Shukla, A., Lal, R., Gupta, M., Dwivedi, U., Shasany, A. 2014. Latex-less opium poppy: cause for less latex and reduced peduncle strength. Physiologia Plantarum, 150, 436-445.
Coe, S. 1994. America's first cuisines, Austin, Texas.
Cokkizgin, A., Shtaya, M. 2013. Lentil: Origin, Cultivation Techniques, Utilization and Advances in Transformation. Agricultural Science, 1(1), 55-62.
Cromack, H.T.H., Smith, J.M. 1998. Calendula officinalis,Äîproduction potential and crop agronomy in southern England. Industrial Crops and Products, 7(2,Äì3), 223-229.
Crowley, J. 1998. Factors affecting the yield of Winter Lupins. Teagasc.
Crowley, J., Frohlich, A. 1998. Factors affecting the composition and use of Camelina.
Dobre, P., Jurcoane, S., Matei, F., Stelica, C., Farcas, N., Moraru, A. 2014. Camelina sativa as a double crop using the minimal tillage system. Romanian Biotechnological Letters, 19(2), 9190-9195.
Eberle, C.A., Forcella, F., Gesch, R., Weyers, S., Peterson, D., Eklund, J. 2014. Flowering Dynamics and Pollinator Visitation of Oilseed Echium (Echium plantagineum). PLoS ONE, 9(11), e113556.
El Hafid, R., Blade, S.F., Hoyano, Y. 2002. Seeding date and nitrogen fertilization effects on the performance of borage (Borago officinalis L.). Industrial Crops and Products, 16(3), 193-199.
Europa. 2009. Evaluation of the CAP measures related to hops. Agriculture and Rural Development DG - Final report.
Fist, A. 2001. The Tasmanian Poppy Industry: A Case study of the Application of Science and Technology. in: Proceedings of the 10th Australian Agronomy Conference, (Eds.) B. Rowe, D. Donaghy, N. Mendham. Hobart, Tasmania.
Gilbertson, P.K., Berti, M.T., Johnson, B.L. 2014. Borage cardinal germination temperatures and seed development. Industrial Crops and Products, 59(0), 202-209.
Inglett, G.E., Chen, D., Liu, S.X. 2015. Physical properties of gluten-free sugar cookies made from amaranth,oat composites. LWT - Food Science and Technology(0).

Jacobsen, S. 1997. Adaption of quinoa (Chenopodium quinoa) to Northern European agriculture: studies on development pattern. Euphytica, 96, 41-48.
Jezierny, D., Mosenthin, R., Bauer, E. 2010. The use of grain legumes as a protein source in pig nutrition: A review. Animal Feed Science and Technology, 157, 111-128.
Jhala, A., Hall, L. 2010. Flax (Linum usitatissimum L.): Current uses and future applications. Australian Journal of basic and Applied Sciences, 4(9), 4304-4312.
Johnson Matthey. 2006. Presentation to Analysts & Investors, Johnson Matthey Macfarlan Smith. Edinburgh.
Khalid, K.A., da Silva, J. 2012. Biology of Calendula officinalis Linn.: Focus on Pharmacology, Biological Activities and Agronomic Practices. Medicinal and Aromatic Plant Science and Biotechnology, 6(1), 12-27.
Khalid, K.A., Teixeira da Silva, J.A. 2010. Yield, essential oil and pigment content of Calendula officinalis L. flower heads cultivated under salt stress conditions. Scientia Horticulturae, 126(2), 297-305.
Kohajdova, Z., Karovicova, J., Schmidt, S. 2011. Lupin composition and possible use in bakery - A review. Czech Journal of Food Science, 29(3), 203-211.
Lasztity, R. 1999. The Chemistry of Cereal Proteins. Akademiai Kiado.
Lizarazo, C., Stoddard, F. 2012. Lentil - a promising new crop for Finland. Maataloustieteen Paivat http://www.smts.fi.
Machado Alencar, N.l.M., Steel, C.J., Alvim, I.D., de Morais, E.C., Andre Bolini, H.M. 2015. Addition of quinoa and amaranth flour in gluten-free breads: Temporal profile and instrumental analysis. LWT - Food Science and Technology, 62(2), 1011-1018.
McGreevy, T. 2011. Take your pulse.
Mishra, B., Rastogi, A., Siddiqui, A., Srivastava, M., Verma, N., Pandey, R., Sharma, N., Shukla, S. 2013. Opium Poppy: Genetic Upgradation through Intervention of Plant Breeding Techniques. 209-238.
Mlakar, S., Turinek, M., Jakop, M., Bavec, M., Bavec, F. 2010. Grain Amaranth as an Alternative and Perspective crop in Temperate Climate. Journal for Geography, 5(1), 135-145.
NNFCC. 2008. Borage (Borago officinalis L.) Crop fact sheet.
NNFCC. 2006. Crambe (Crambe abysinnica). Crop fact sheet.
NNFCC. 2009. Echium (Echium plantagineum) - Crop fact sheet.
NNFCC. 2010. Hemp (Cannabis sativa). in: http://www.nnfcc.co.uk/publications/nnfcc-crop-factsheet-hemp, (Ed.) NNFCC.
Nowak, V., Du, J., Charrondiere, U. 2015. Assessment of the nutritional composition of quinoa (Chenopodium quinoa Willd.). Food Chemistry.
Oelke, E., Putnam, D., Teynor, T., Oplinger, E. 2012. Quinoa. Alternative field crops manual. http://www.hort.purdue.edu/newcrop/afcm/quinoa.html.
Oplinger, E., Oelke, E., Kaminski, A., Putnam, D., Teynor, T., Doll, J., Kelling, K., Durgan, B., Noetzel, D. 2015. Crambe: Alternative Field Crops Manual. http://www.hort.purdue.edu/newcrop/afcm/crambe.html.
Ozcan, M., Atalay, C. 2006. Determination of seed and oil properties of some poppy (Papaver somniferum L.) varieties. Grasas y Aceites, 57(2), 169-174.

Paschos, G., Magkos, F., Panagiotakos, D., Votteas, V., Zampelas, A. 2007. Dietary supplementation with flaxseed oil lowers blood pressure in dyslipidaemic patients. European Journal of Clinical Nutrition, 61, 1201-1206.

Pavlovic, M. 2012. Production character of the EU hop industry. Bulgarian Journal of Agricultural Science, 18(2), 233-239.

Prochazka, P., Smutka, L. 2012. Czech Republic as an important producer of Poppy Seed. Agris on-line Papers in Economics and Informatics, 4(2), 35-47.

Przygoda, K., Wejnerowska, G. 2015. Extraction of tocopherol-enriched oils from Quinoa seeds by supercritical fluid extraction. Industrial Crops and Products, 63, 41-47.

Rogerio, F., da Silva, T., dos Santos, J., Poletine, J. 2013. Phosphorus fertilization influences grain yield and oil content in crambe. Industrial Crops and Products, 41, 266-268.

Shim, Y., Gui, B., Wang, Y., Reaney, M. 2015. Flaxseed (Linum usitatissimum L.) oil processing selected products. Trends in Food Science & Technology, 43(2), 162-177.

Simon, J., Chadwick, A., Craker, L. 1984. Herbs: An Indexed Bibliography. 1971-1980. The Scientific Literature on Selected Herbs, and Aromatic and Medicinal PLants of the Temperate Zone., Hamden, CT.

Smith, N., Maclean, I., Miller, F., Carruthers, S. 1997. Crops for industry and energy in Europe.

Soto-Cerda, B., Duguid, S., Booker, H., Rowland, G., Diederichsen, A., Cloutier, S. 2014. Genomic regions underlying agronomic traits in linseed (Linum usitatissimum L.) as revealed by association mapping. Journal of Integrative Plant Biology, 56(1), 75-87.

Stranska, I., Skalicky, M., Novak, J., Matyasova, E., Hejnak, V. 2013. Analysis of selected poppy (Papaver somniferum L.) cultivars: Pharmaceutically important alkaloids. Industrial Crops and Products, 41(0), 120-126.

Thompson, S., Groenewegen, J., Hodgins, M., Spearin, D., Yungblut, D. 2015. Investigating Value Added Potential of Flaxseed and Straw.

Tong, L.-T., Zhong, K., Liu, L., Guo, L., Cao, L., Zhou, S. 2014. Oat oil lowers the plasma and liver cholesterol concentrations by promoting the excretion of faecal lipids in hypercholesterolemic rats. Food Chemistry, 142(0), 129-134.

WHO, FAO. 1991. Protein Quality Evaluation. WHO.

Wilen, R., Barl, B., Slinkard, A., Bandara, M. 2004. Feasibility of Cultivation Calendula as a Dual Purpose Industrial Oilseed and Medicinal Crop. Acta Horticulture, 629, 199-206.