Maize

A GROWER'S GUIDE

INTRODUCTION

The amount of maize grown in the UK has risen tremendously over the past twenty years. The benefits of improved animal performance through feeding maize silage in rations has led to a huge increase in the amount of dairy and beef units growing the crop. This has been made possible by the breeding of maize varieties suitable for the UK's relatively marginal growing conditions.

In 1990, just 33,000ha of maize were grown in the UK. However, following the introduction of earlier maturing varieties like LG2080 and Melody, the area grown had more than tripled to 105,000ha by 2000. The arrival of even earlier maturing varieties like Crescendo, Destiny and Artist have contributed to the fact that in 2010, there were 160,000ha of maize grown in the UK.

As the largest maize breeder in Europe, Limagrain has been leading the market by breeding early maturing and high yielding varieties specifically for the UK climate.

This technical Guide includes an overview of the LG (Limagrain Genetics) breeding programme and outlines the key essentials for success when selecting varieties, and growing and harvesting the crop.

Sections are also included on growing maize under plastic, feeding maize silage, and maize for grain and biogas production.

Whether you are a first-time or an experienced maize grower, this Guide provides information and advice on how to maximise crop yield and quality, and reap the benefits of this high energy and very palatable cost-effective forage.






CONTENTS


LAWSON

1. THE LG MAIZE BREEDING PROGRAMME

The breeding and selection of early maturing forage maize varieties suitable for the UK and Irish climate is a key focus of the LG (Limagrain Genetics) maize programme.

Over the past 20 years, the number of early maturing varieties with excellent yield and quality has increased. Growers now have a very wide choice. Advances in breeding mean that maize can now even be grown successfully in the open in the warmer parts of Scotland and Northern Ireland.

LG BREEDING OBJECTIVES

The LG breeding programme focuses on the selection of maize varieties with the following characteristics, specifically for growing in the UK and Ireland:

Earliness – early vigour, early flowering and early ripening are essential characteristics for most areas.

High yield potential – older generations of early maturing varieties could sometimes be more than 15% lower yielding than later maturing varieties. But, thanks to Limagrain's focused research, the difference in yields achieved with modern LG varieties is now minimal. Growers can now choose varieties for earliness without compromising on yield.

High starch content – this determines the feeding quality of the resultant silage. Where crop area is limited, the starch content is an important factor in maximising the energy value of the silage.

High cell wall digestibility – UK and Irish growers tend to focus on the three characteristics: earliness, dry matter yield and starch content. However, on the Continent, the digestibility of the crop is regarded as being equally important. Varieties with higher cell wall digestibility have potentially higher metabolisable energy levels, increasing the overall energy yield available from a crop.

Yield stability – varieties need to be robust and provide consistent yield across years and sites.

Lodging resistance – it is essential that maize crops remain standing until harvested.

Left: The LG breeding programme requires pure inbred lines of parent varieties to be developed. To achieve this, paper bags are put over the tassels and silks of each plant. The pollen collected is then shaken onto the silks of the same plant to ensure 100% self-pollination.

Disease resistance – in the more marginal climate of the UK and Ireland, varieties that are less susceptible to diseases such as *Fusarium spp* and common smut are required.

Stress resistance – for example, cold tolerance is another important attribute.

Healthy leaf and stover – breeders are looking for varieties that are mid stay-green types. This means the leaf stays green until the cobs have matured, and only then does the plant senesce (die) and dry down ready for harvesting.

LG ANIMAL NUTRITION

On the Continent, Limagrain is evaluating varieties across a number of performance traits to identify the very best forage maize varieties. Factors such as improved cell wall digestibility, high starch content, disease resistance, and overall crop energy yield are collectively taken into account. Feeding trials are also carried out to quantify the extra nutritional value to be gained over key competitor varieties in the market.

The best LG varieties are then accredited with the Limagrain Animal Nutrition logo, as a mark of their nutritional superiority.

THE BREEDING PROCESS

As with any crop breeding programme, the development of new maize varieties is a long process. From an original starting number of around 2,500 potential varieties, it can take ten years of research and development to bring one new variety to the point of commercialisation and its first appearance on the NIAB Descriptive List.

The LG maize breeding programme concentrates on crossing inbred parent lines of 'flint' and 'dent' types of maize to produce new hybrid varieties. Flint types contribute the characteristics of earliness and cold tolerance, while dent types bring high yield potential. By crossing the two separate types, the resultant flint-dent hybrid has a combination of the beneficial characteristics of both its parents plus 'hybrid vigour' which allows it to outperform its parents.

Photo: Watier Visuel

As the name suggests, the dent types can be identified by the obvious 'dent' in the kernels or grains which occurs when the soft starch shrinks. Flint types have no such depression, and cobs are very hard.

The Limagrain 'early maize' breeding programme is based at the Company's research facility at Rilland, in the south west of The Netherlands. Thanks to its latitude and location, Rilland enjoys a similar maritime climate to the main maize growing areas of the UK and Ireland.

The breeding process starts with the crossing of different flint and dent types to identify which combinations give the best performance. These are selected and self-pollinated for eight generations to produce pure inbred lines which will ultimately have a 100% homozygous genotype. To speed up this process, seed is sent down to nurseries in Chile for trials straight after harvesting in Europe, so that two generations can be grown per year.

Pure inbred lines of flint and dent types are crossed together to produce new hybrid varieties. The most promising are put forward into further screening trials. The best varieties from these are entered into NIAB National List trials and the best of these will appear on the NIAB Descriptive Lists for forage maize.

SEED PRODUCTION

The production of maize seed is very labour intensive and complex to manage. When crossing the two chosen inbred lines, the plants which will carry the hybrid seed (the female plants) have to be de-tasselled to prevent self-pollination. The plants which will be the pollinators (the male plants) will need to be removed from the field before the seed harvest begins, to avoid their cobs being harvested with the seed from the female plants.

The 'male' row of plants (pictured centre) will pollinate the de-tasselled 'female' plants in the next rows, and then be removed from the field before harvesting.

So that cross-pollination can take place successfully, knowledge is needed of when the male plants will flower and when the female plants will produce silks. Rows of male and female plants are then drilled at separate times in the field to synchronise the times of pollination and silking. For example, the male inbred line may require drilling 14 days after the female inbred line for cross-pollination to successfully take place.

LIMAGRAIN UK RESEARCH

UK maize trial sites

The strong focus on developing varieties specifically for the UK's challenging environment means that new lines are grown, tested and selected here in the UK, rather than relying on evaluations at other European sites.

Limagrain has a range of UK trial sites where the performance of new material is assessed under different conditions. These stretch from Cornwall, through Worcestershire to North Wales, Lincolnshire and Nottinghamshire. In fact, Limagrain has the biggest maize breeding programme in the UK. For example, over 1,500 potential new varieties were trialled in 2010.

Once a variety has proven its worth over two to three years in Limagrain UK's development trials, it is submitted into the BSPB/NIAB official trials programme. This evaluates varieties at more locations around the UK. After three years of these official trials, the performance of the variety is published in the NIAB Forage Maize Descriptive List. By this time Limagrain UK will actually have five or six years of performance data for a variety.

Early generation seed productions, i.e. producing the inbred parent lines, are carried out by Limagrain trials personnel in Longue (Anjou/Central West France) and Nerac (SW France).

The commercial production of the hybrid seed is contracted to very experienced growers who are members of the Limagrain Co-operative. These are based in the Auvergne (Clermont-Ferrand) and Anjou (Angers) in France.

All these locations have the climate and soil types suitable for producing large quantities of uniform, high quality seed.

SEED QUALITY

Once harvested, the seed is tested at Limagrain's central processing laboratory in France. There it is assessed for moisture content, germination and vigour.

Cold testing involves incubating trays of seed at 6-10°C for two weeks before raising the temperature and assessing subsequent germination rate.

Before being bagged and shipped, the seed is 'cold tested'. This ensures that only vigorous seed lots of each variety are selected for sale in the relatively marginal growing conditions of the UK and Ireland. In fact, all LG maize seed undergoes rigorous testing procedures in addition to meeting the minimum standards that are laid down in current EU regulations.

As maize originates from Central America, the seed is susceptible to fungal attack if cold temperatures (below 8°C) occur at drilling. So, except for seed destined for organic use, all UK and Irish seed is routinely treated with a fungicide. In certain cases seed is also treated with an insecticide.

FAST-TRACKING TO MARKET

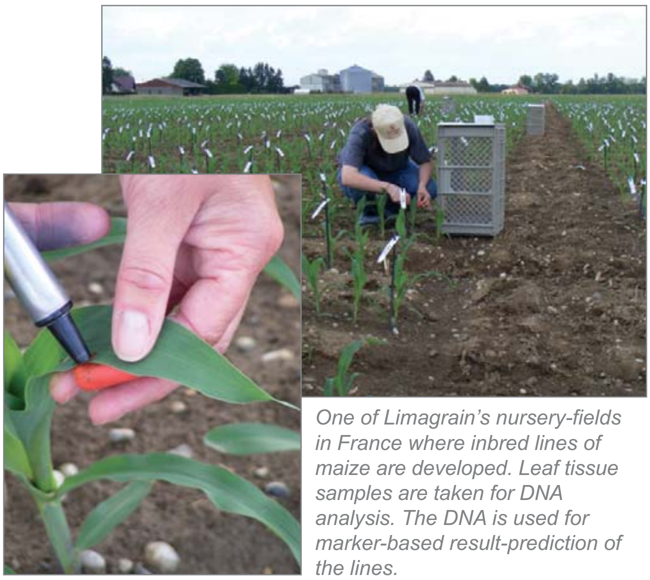
The huge scale of the LG breeding programme, and the investments made in technology, allow promising varieties to be identified and fast-tracked into commercial use quickly and efficiently.

For example, the trials harvesters are fitted with online NIRS (Near Infra Red Spectrophotometry) systems which assess the quality of each plot, as it is harvested.

Online NIRS systems on trials harvesters enable quality assessments to be made as plots are harvested.

This information – including dry matter content, starch content and metabolisable energy – is automatically transmitted back to The Netherlands, where the data can be reviewed. Previously samples had to be dried, milled and sent to the laboratories where it took several months to carry out the quality analyses. This delay in identifying the best new hybrids meant seed could not be sent to Chile to speed up the process. But with the online NIRS systems, seed can be sent to the southern hemisphere straight after harvest for seed production. This allows two generations of maize to be grown in one year, speeding up the breeding programme.

Limagrain also holds a data bank of all the varieties trialled over the past years, detailing their quality, disease resistance and yield potential, along with their DNA profile. By 'fingerprinting' each variety (using the DNA profile) it is possible to correlate their performance with their genotype and so make informed predictions about how new hybrids will perform. This is known as 'Association Genetics' and means high performing varieties can be identified sooner, i.e. with less data. Conversely, poor varieties are discarded without further trialling. This speeds up identification of potential new hybrids and improves the efficiency of the breeding programme.



One of Limagrain's nursery-fields in France where inbred lines of maize are developed. Leaf tissue samples are taken for DNA analysis. The DNA is used for marker-based result-prediction of the lines.


LG
TRIUM

2. SELECTING THE RIGHT VARIETY

There are two key factors to consider when choosing which maize varieties to grow:

1. **Whether to use early or later maturing varieties**
2. **The growing conditions of the site.**

EARLY VS. LATE MATURING VARIETIES

Maize is a sub-tropical plant and a minimum number of heat units are required by the crop to reach maturity by harvest time, i.e. to produce fully ripened, starch-rich cobs by early October. Some varieties require fewer heat units and so mature earlier than others. These are known as early or very early maturing varieties. This earliness is a key focus in the Limagrain maize breeding programme.

To find out how fast a particular variety will reach maturity compared to other varieties, growers can use the data from the independent trials programme carried out by BSPB/NIAB. A variety is first listed on the NIAB List, after three years of trials in which a range of performance traits are evaluated at different UK sites. These include maturity, dry matter yield, starch yield, metabolisable energy yield, early vigour and standing power. As more trials are carried out, further data is included into the performance figures so that on a rolling basis, each variety's results are the average of the previous five years of trials.

Crops should only be harvested once they have matured and produced fully ripened, starch-rich cobs.

Varieties are then classified into different maturity classes which reflect the time taken to achieve a 30-35% dry matter content. Varieties are described as being 'very early' maturing, 'early' or as 'later' maturing types. The earlier maturing a variety, the shorter the growing season required, and the higher the maturity class number.

Left: Every year Limagrain establishes a number of trials and demonstration sites at which commercially available and near-market maize varieties are sown. In the run-up to harvest, these sites which contain both LG and competitor varieties, allow visitors to visually inspect and compare the cob sizes and crop bulk of different varieties across a range of maturity classes.

FAVOURABLE VS. MARGINAL SITES

It is essential to consider the growing conditions of the site where the maize is to be grown. In addition to simply ranking varieties by their earliness of maturity, the BSPB/NIAB trials programme is conducted at sites which vary in their location and climate, so that varieties can also be selected according to how they performed in different growing conditions.

The published NIAB List categorises varieties as suitable for growing in either 'favourable' sites, or more marginal, i.e. 'less favourable' sites.

Favourable sites can be sub-divided into 'very favourable', typically, those found in the central southern and south eastern parts of the UK, where the climate is influenced by the Continent, and 'favourable', found in more central parts of the UK.

The relatively few maize growers in very favourable locations are not restricted by maturity class. They can trade earliness of harvest for increased yield and successfully grow the later maturity types, for harvesting.

Growers in 'favourable' locations should choose early maturing types and aim to optimise both quality and yield from an early October harvest.

Marginal sites are, typically, found in the north and north-west of England and in Cornwall and Devon. In these areas, the weather conditions are cooler and less sunny, so the choice for growers is more limited. Only varieties that have the ability to mature relatively early should be grown.

In very marginal conditions such as in south west Scotland, only the earliest maturing varieties should be chosen. The Limagrain breeding programme has produced excellent very early maturing varieties. Even earlier maturing varieties from the LG programme are undergoing official trials. These new varieties allow maize to be grown successfully in the open in the very marginal areas of south west Scotland.

At marginal and very marginal sites, failing to select a variety with sufficient earliness for the cooler growing conditions will result in the crop not reaching maturity by harvest in October. The choice is then to harvest an unripe crop and miss out on energy potential, or to harvest late in the autumn when the crop may have reached maturity but weather conditions may have deteriorated. Harvesting in wet conditions can result in contaminated silage, soil compaction and problems with mud on the roads.

FEED QUALITY CHARACTERISTICS

Maize silage is a high energy forage. Its nutritional value is primarily derived from its starch content, and, to a lesser degree, its digestible fibre content.

Rations are usually formulated to include maize silage so that it can be fed through as much of the year as possible. This is to gain the year-round benefits of extra milk yield and good cow health.

Low inclusion levels – on some farms, maize silage inclusion in the ration may be limited by the availability or ability of the land to grow the crop. Typically this type of farm will rely on a high proportion of grass silage in the diet and cows fed on this type of ration will benefit from a high level of starch in the maize.

So, as a guide, where maize silage inclusion is limited to a maximum of 50% of the forage component of the ration, then the feed quality of the silage, i.e. its starch content and yield, has more importance than its overall dry matter yield.

High inclusion levels – on farms with favourable growing sites, maize silage can account for a major part of the forage ration (as high as 90%). So it is best to select varieties that have a combination of high starch yield, improved cell wall digestibility (CWD) plus high yield potential. These variety types will have both a high starch content and a high metabolisable energy content, which will enable an energy dense diet to be made.

The flow diagram below provides a guide to variety selection for growers of forage maize. An example of a very marginal area would be south-west Scotland, and

For rations with a low maize silage inclusion rate, it is best to use varieties with a high starch content.

marginal areas are typically found in Cheshire and south-west England. Favourable areas include Gloucestershire, Somerset and Dorset. The very favourable areas are confined to good growing sites in Hampshire, Sussex and the south-east of England.

For specific information on which forage maize varieties to select visit www.limagrain.co.uk/maize.

Variety selection chart for forage maize (open sown)

What are the growing conditions for the site?

Very marginal	Marginal	Favourable	Very favourable
Only grow the earliest maturing varieties	Only grow very early maturing varieties	Early maturing varieties can be grown	Later maturing varieties can be grown

High ------------➤ **MATURITY CLASS NUMBER** ------------➤ **Low**

3. GROWING A MAIZE CROP

3. GROWING A MAIZE CROP

In addition to variety selection, being successful in growing maize is also dependent on following good agronomy and management practices.

SELECTING THE RIGHT SITE

When choosing where to grow maize on the farm, attention should be paid to the following factors when selecting the specific growing sites.

Altitude – Avoid high altitude sites which will be colder. As a rule of thumb, growers should consider 600 feet (180 metres) above sea level to be very marginal. However, individual fields above 600 feet with lighter, drier soil types that will warm up quickly in spring can be considered.

Aspect – Ideally, any fields selected for maize production should face south, and be sheltered from wind. Fields to avoid are those which are very exposed, or have heavy, poorly drained soils, and any locations which are known to be ‘frost pockets’. An established crop at 2-6 leaf stage can be set back 2-3 weeks by a late May frost. Avoid steeply sloping fields, especially near to water courses to reduce the risk of nitrate leaching from runoff.

Soil depth – To support its bulk and height, a maize plant requires a very extensive root system. Ideally, crops should be grown where there is at least 2m of soil. If soil depth is less than 1m, then root development is impaired and crops are stunted, with resultant lower yields. Crop maturity can also be delayed. The same effects can occur where soil is compacted.

Weed control – Maize suffers badly from weed competition during the early growth stages. Ideally, a clean, weed-free site should be chosen. A weed control programme applying either pre-emergence and/or post-emergence herbicides can be followed.

Environmental considerations – Harvesting maize in wet conditions can lead to surface compaction. Maize stubble left uncultivated over the winter months can result in surface water runoff and nitrate leaching into waterways. There is also a particularly high risk of soil erosion where fields are sloping and have sandy soil.

Previous page: To maximise maize crop yield, it is essential to select an appropriate growing site, ensure a sufficient supply of nutrients in the soil, and only sow seed into a well-prepared seedbed once weather conditions become suitable. Weed control in the early months is also important.

As part of the cross compliance required in order to claim the Single Farm Payment, land must be kept in a ‘Good Agricultural and Environmental Condition’. Growers must comply with specified legal requirements known as Statutory Management Requirements.

An annual Soil Protection Review is also required. This requires three options to be carried out on the maize crop where there is a high risk of runoff or soil erosion (two options where the risk is moderate). The options are:

- Maintain land drainage
- Harvest earlier by choosing earlier maturing varieties
- Cultivate immediately after harvest
- Rough plough after harvest
- Sow another crop within 10 days of harvest
- Undersow maize
- Sow with a temporary cover crop throughout the winter.

Principles of good soil husbandry for maize are outlined in Defra’s Cross Compliance for Good Soil Management – or visit www.crosscompliance.org.uk for more information.

PRINCIPLES OF GOOD SOIL HUSBANDRY FOR MAIZE

- Avoid growing maize on land where the chances of runoff and erosion are high.
- On fields that are vulnerable to compaction, runoff and soil erosion, choose early-maturing maize varieties to allow an early harvest in the drier month of September.
- Where necessary, cultivate as soon as conditions are suitable after harvest to remove wheelings and compaction.

(Adapted from Defra’s Cross Compliance for Good Soil Management)

Crop rotation

Where suitable maize-growing land is limited, then the crop can be grown repeatedly on the same ground, as long as soil pH and nutrient content are maintained. Any compaction issues need to be resolved before each sowing.

However, maize also fits well into a crop rotation with cereals or grass. By selecting earlier maturing varieties, harvested in September, follow-on crops of wheat or grass can be sown. Maize also serves as a useful break crop for cereal growers, especially to break the cycle of blackgrass contamination.

When maize is sown after grass, wireworm infestations can be damaging to the root systems of the following crop. To combat this pest, maize seed that has been treated with Poncho® should be sown.

SOIL NUTRIENT REQUIREMENTS

In what is a relatively short growing season, maize will achieve huge dry matter yields of up to 15-20t/ha. So an adequate supply of nutrients and water is essential to ensure the crop reaches its full performance potential.

Soil pH

Soil tests should be carried out routinely to check nutrient levels and pH. For growing maize, a pH of 6.8 is ideal, although crops can tolerate a relatively low pH. To maintain the correct soil pH, lime should be applied on an 'as needed' basis. This should be done the year before growing maize, so that there is time for it to be incorporated into the soil.

Soil nutrients

The key nutrients for maize are phosphate, potash and nitrogen. Much of the crop's requirements can be met through applications of FYM or slurry. As part of cross compliance and good management practice, the nutrient content of organic manure should be estimated, and quantities spread recorded, so as not to exceed recommended levels of P and K. Further applications of inorganic manures can then be tailored to any shortfalls in N, P or K relative to the crop's needs (see tables below).

Nutrient requirement for high and low yielding maize crops (kg/ha)

Yield level	N	P	K
Low (11.2t/ha of DM)	120	75	190
High (14.8t/ha of DM)	150	115	235

Source: MGA [N.B. these are the maximum levels allowed according to the nutrients manual (RB209)]

Available nutrients in organic manure

Type of manure	Normal amount spread/ha	Average value of available nutrients kg/ha		
		N	P	K
Cattle FYM	40 tonne	22	84	288
Cow slurry	83 m^3/ha	80	50	260
Pig FYM	25 tonne	17	100	112
Pig slurry	63 m^3/ha	80	60	140
Poultry manure	8 tonne	80	62	65

Source: MGA

Nitrogen

Nitrogen can be applied to the crop either as organic manure or slurry or inorganic fertiliser. However, beware that too much nitrogen will delay crop maturity, and cause lodging.

Organic manures represent a 'free' source of nitrogen. These are best applied just before ploughing – in February or early March – to reduce ammonia losses to the air, so more will be available to the plant. Ensure that FYM is not over applied as excess levels, when ploughed in, will lead to an anaerobic layer being formed in the soil which maize roots will struggle to grow through.

Organic manures should be applied in such a way, and at application rates, that will not lead to water pollution through leaching or surface runoff. Refer to NVZ rules for application of manures (www.netregs.gov.uk). If applied in late winter, care is needed to avoid the risk of compaction and damage to the soil structure.

Inorganic nitrogen should be applied, if necessary, before sowing in the early spring. Alternatively the dressing can be split, applying half before sowing and the balance 30-35 days after sowing. Trials have shown that splitting nitrogen application so that 50% is applied after drilling can boost yields. This should be done at the 2 leaf stage, and before the 4 leaf stage when nitrogen prills can get caught in the leaves leading to crop scorch.

Inorganic fertiliser should never be broadcast onto a crop (after the 4 leaf stage) as granules can drop down through the leaves and 'burn' the plant's growing point. This will stress the plant and lead to leaf loss and crop damage, and potentially to yield losses.

During the first seven to eight weeks of growth, there may be some slight yellowing or purpling of the crop. In most cases this is the result of 'stress' associated with low soil temperatures in June/July, which inhibit the uptake of N, P, and K. As the soil temperature improves, nutrients will once again be taken up by the maize plant, so it may not be necessary to apply additional fertiliser.

Phosphate
Phosphate is essential for vigorous root development, which improves establishment, cob weight and dry matter yield of the crop. As with most crops, a base application of phosphate is required for adequate growth. The phosphate that is contained within FYM or slurry is only released very slowly and may not benefit the current maize crop. Phosphate levels in the soil can be boosted by using a starter fertiliser of MAP 12-52-0 (mono-ammonium phosphate) or DAP 18-46-0 (diammonium phosphate) (see later).

Potash
Maize has a huge demand for potash, with an average crop needing around 225kg/ha to ensure adequate nutrition. A good application of organic manure should deliver sufficient supply of this nutrient.

Crops which receive insufficient levels of potash may show a number of symptoms including later maturity, poor fertilisation, irregular cob formation and may have an increased risk of lodging.

Trace elements
It is quite rare in the UK to see maize crops which have been seriously affected by any trace element deficiencies. However, shortfalls of the following elements can occur:

Magnesium – crops which are seriously short of this element may be stunted with leaves hanging down. The leaves at the base are likely to be yellow with the possible presence of black or green spots on the leaf surface.

Zinc – very pale looking leaves which may also show deep discolouration of the veins – typically red or purple and these colours may also be banded by translucent areas.

Sulphur – although quite rare, sulphur deficiencies have occasionally been seen in maize crops. The symptoms are yellowing of the leaf, and the new leaf being a pale-green/yellow in colour. This element should, however, be in adequate supply if organic fertilisers have been used.

Copper – deficiency can lead to a ‘rat-tail’ appearance of the cobs as this element is important for pollen formation and fertilisation, affecting the number of kernels formed on the cobs.

If crops are looking poor and lack of soil nutrients is suspected then seek advice from an agronomist. Fertiliser foliar feeds which contain key trace elements, can be best applied at the 4-8 leaf stage to remedy the situation.

SEEDBED PREPARATION
The elimination of soil compaction and preparation of a fine seedbed are essential for successful crop growth.

Maize is a deep rooting plant and therefore sensitive to any soil compaction as this will prevent its roots from penetrating deep enough to reach water and nutrients. This stresses the crop and reduces yield. It will also delay maturity. Maize grown in compacted soils normally suffers from stunted growth leading to several small ears instead of one large one on each plant.

Subsoiling will remove compaction and ensure maize plant growth is not limited.

Maize crops sown continuously on the same field are likely to be most at risk from compaction. The harvesting of crops in wet conditions, or muck spreading in mid-winter, can exacerbate the problem.

To avoid compaction becoming an issue, the soil structure needs to be checked immediately after the previous crop and then sub-soiled as required. Sub-soiling operations are best carried out in the previous autumn – under dry conditions to encourage the maximum amount of ‘shattering’ of the soil. Ideally, subsoiling should be done after the spreading of FYM or slurry, and then the field be ploughed.

Seedbed cultivation can be left until immediately prior to drilling in April or May. The top layer of fine soil needs to have a depth of about 5cm.

WEED CONTROL (PRE-EMERGENCE)
It is important to know the likely weed burden of land on which maize is to be grown, and then prepare a strategic weed control programme. Herbicides should be selected according to the weed species that are likely to be present. For maize, a range of approved pre-emergence and post-emergence herbicides are available. However, where heavy infestations of weed, for example, couch are present, these are best controlled by applying glyphosate before any cultivation.

Growers should also be aware that where FYM or slurry has been applied, future crops of maize may be infested with other annual/biennial weeds such as black nightshade, fat hen, orache, knotgrass and bindweed.

However, some maize varieties are also susceptible to damage by certain herbicides. With so many options and possible varietal restrictions over use of some products, advice should be sought from a BASIS registered agronomist in order to make the right choice.

SOWING MAIZE

The best time to sow

Do not be tempted to drill too early – as this may expose the crop to frost damage if the growing point is above the soil surface. Maize seed should not be sown until the soil temperature has stabilised to a minimum of 8°C. A soil temperature probe can be used to determine the temperature at seed depth. Nor should seed be drilled if night frosts are still anticipated.

In most years, temperatures reach suitable levels between mid April through to early May, depending on the location. In a good season, all maize crops would be in the ground by the first week in May and no later than mid-May. Maize can also be drilled following an early first cut of silage. However, this later drilling will result in a later harvest and reduced yield potential. In these situations very early maturing varieties should be selected, and seed should be treated to combat leatherjacket and wireworm attack (see later in section).

Maize seed should not be sown until the soil temperature has stabilised to a minimum of 8°C.

Seed depth

A drilling depth of 3-5cm will normally ensure that seed has adequate moisture for germination. The higher figure will be the maximum depth for drilling in light, dry soils, whilst a 3cm depth is typically used in heavier soils. However, drilling into soil moisture is more important than the specific depth. So in some cases it may be necessary to drill a little deeper to find moisture.

Crops in the UK are typically drilled in 75cm (30in) rows. On most farms growing maize, a contractor with a special drill is hired in to sow the crop. The seedbed should have been worked down to a firm fine tilth to ensure consistent seed depth and spacing is achieved. A poor seedbed and/or drilling too fast will result in a crop with variable maturity and depressed yields.

Starter fertiliser

It is recommended that a starter fertiliser is used at drilling. An application of 65kg/ha of MAP or DAP will provide extra support to the early growth of the crop, improving dry matter yields, and can also bring crop maturity forward. However, where the field has previously received high levels of FYM, then the starter fertiliser application rate can be halved.

A blocked spout on the drill meant only one row of seed received starter fertiliser in this field.

Seed rate

Another factor which is important when growing maize is the plant population. Under good growing conditions the ideal sowing rate is 110,000/ha (44,500 seeds/acre). Allowing for a realistic ‘loss’ of 10%, this should result in a final stand of 40,060 plants/acre (99,000/ha). A lower sowing rate is required for maize grown under plastic as plant losses are less (see section 7).

Calculation of plant density achieved

Seed rate used		100,000/ha (40,400/acre)	110,000/ha (44,500/acre)	120,000/ha (48,600/acre)
Average number of seeds sown/metre		7.6	8.3	9.3
Achieved plant density at field emergence	95%	95,000/ha (38,450/acre)	105,000/ha (42,490/acre)	114,000/ha (46,150/acre)
	90%	90,000/ha (36,420/acre)	99,000/ha (40,060/acre)	108,000/ha (43,700/acre)
	85%	85,000/ha (34,400/acre)	94,000/ha (38,040/acre)	102,000/ha (41,300/acre)

(Row width = 75cm)

To calculate plant population see table on page 13.

Sowing at a higher seed rate can increase dry matter yields but only if growing conditions are very good.

At locations with ideal growing conditions, a higher seed rate and higher plant density can be supported. Raising the seed rate from 111,000-121,000 seeds/ha (45,000-50,000 seeds/acre) can increase yields by up to 10% with no loss of quality or delay in harvest. However at poorer locations, raising the seed rate can result in a lower dry matter content and forage quality may suffer. This is due to interplant competition which leads to poor ear development and lower starch levels. A higher plant population will also encourage the production of taller thinner stems and this, in turn, may well increase the risk of lodging.

At marginal sites seed rates are typically reduced to between 99,000-100,000 seeds/ha (40,000-43,000 seeds/acre) and at very marginal sites 94,000-99,000 seeds/ha (38,000-40,000 seeds/acre). This helps bring forward harvest and/or improve feed quality.

From population trials conducted at Limagrain's trial sites over the past ten years, the conclusion is that site location and growing season are the main factors that determine how well maize crops perform. These outweigh any trends that may be due to sowing rates.

Calculating plant population

To calculate the plant density that is achieved, count the number of plants found in a 5m run of 10 separate rows in the field. Divide this number by 10 to get an average, and use the table below to determine the plant population.

Average number of plants per 5m of row	Plant population	
	per hectare	per acre
28	74,000	30,000
30	81,500	33,000
32	84,000	34,000
34	89,000	36,000
36	95,000	38,500
38	100,000	40,500
40	105,000	42,500
42	110,000	44,500
44	116,000	47,000
46	121,000	49,000

(Row width = 75cm)

WEED CONTROL (POST-EMERGENCE)

Weeds can easily out-compete maize crops, swamping them during the early establishment phase in May and June.

Post-emergen herbicides should be applied as soon as possible after the crop has emerged, as early weed competition has a big effect on final yields. Post-emergence herbicides can be applied up to a plant size of 8 leaves. If left any later, it also becomes more difficult to move through a crop without damaging it.

For information on choice of herbicide, growers should seek an agronomist's advice.

Broad-leaved weeds will become a problem if left untreated.

PEST CONTROL

There are a number of pests which may attack the maize plant.

Photo: Watier Visuel

Wireworms

The shiny golden brown larvae of click beetles (*Agroites* and *Athous spp.*) can be a problem – particularly when the crop follows grassland. The pesticides which are available to control this problem are normally incorporated into the soil just before drilling. Some wireworm control can also be achieved by using seed dressed with the insecticide Poncho®.

Photo: Watier Visuel

Leatherjackets

Leatherjackets are the larvae of crane flies (*Tipula spp.*), and just as with wireworms, the most serious damage often results when maize follows grass. Leatherjackets feed on the roots and stems of the maize plant just below the soil surface. Ploughing out old grassland before early August will remove the egg laying sites of the flies, and should reduce damage to any spring-sown crop. If chemical control is deemed to be appropriate, then seed treated with the insecticide Poncho® can be used.

Photo: Watier Visuel

Frit fly

Frit fly (*Oscinella frit*) larvae will cause the leaves enfolding the growing shoot of the maize to twist and pucker. They burrow into the plant, which then leads to a condition known as 'deadheart'. A severe attack may kill the growing point, and lead to secondary tiller production. The extent of any damage is likely to vary depending on the time of peak egg-laying in relation to the growth stage reached by the maize crop. If growing conditions are good then the plants will often grow away from any attack.

Frit fly is a common pest, and so seed supplied in the UK has normally been treated with Mesurol® to protect against attack.

Photo: Tom Hlavaty, USDA Agricultural Research Service, www.bugwood.org

Diabrotica (Western corn rootworm)

The adult beetles of the Western corn rootworm (*Diabrotica virgifera virgifera*) lay eggs which hatch into larvae that feed on the roots of maize plants, reducing yield and causing lodging. Crop rotation is the most effective means of control, as this helps break the Diabrotica's life cycle.

In 2003, the first Diabrotica beetles to reach the UK were found on several farms in the vicinity of London Heathrow and Gatwick airports. They are believed to have arrived in the country as stowaways on planes. A statutory regime of crop rotation was issued by DEFRA for maize fields within 2,500m of airports, and annual beetle surveys instigated. Surveys in 2008 and 2009 did not detect presence of Diabrotica however annual checks continue. Maize crop rotation is required around certain airports (Heathrow, Gatwick, Stansted, Bristol and East Midlands) where the risk of introduction of Diabrotica is high.

For up-to-date information on *Diabrotica virgifera virgifera*, visit the Defra website.

Birds

Pheasants, rooks and other birds can cause considerable damage to fields of maize, especially during the period of early emergence. Birds are also attracted to fields that have been ploughed out of grassland as there tends to be a high level of insects in the soil. This increases the chances of birds also eating the maize seed. It is essential in high risk situations, such as these, that appropriate measures to control bird damage are taken. Solutions include regular patrols over a two to three week period, automatic bird scaring guns, kites and similar devices.

Badgers

Badgers are very attracted to the starchy maize cobs and will push the plants over to get at them. Low level, single strand badger fencing is available; alternatively electric rabbit fencing is an effective deterrent. This should be put into place from late August as the cobs on the plants develop.

Slugs

Another potential threat to the crop in warm wet weather is the slug. Seed dressed with Mesurol® has some deterrent activity. However, where weather conditions have created a challenge, slug pellets should be applied to the field without delay. Consult your agronomist for further information on chemical control to combat these pests.

DISEASE CONTROL

Maize crops can be attacked by a number of diseases, but under normal UK growing conditions the resultant damage does not normally represent a major problem. The main diseases are as follows:

Damping-off/seedling rot

Damping-off (caused by *Pythium spp.*) could potentially be prevalent in early sown crops, especially in a cold, wet spring. However, conventional seed marketed in the UK is treated to reduce the threat of damage. Organic and natural seed is not treated and is therefore at risk.

Photo: Watier Visuel

Fusarium (Stalk rot)

Potentially, this is the most serious disease of maize in the UK. It is caused by three species of Fusarium – *F.culmorum* (this is the most common), *F.avenaceum* and *F.graminearum*. The disease attacks the stem base, usually during August and September. The stem rots or becomes very brittle, the leaves wilt, and characteristic drooping cobs appear. In severe cases, a pink fungal growth can be seen on the kernels.

In most seasons the crop will have been harvested before any serious lodging or brackling (stem breakage at the point of cob attachment) occurs. However, if the disease attacks early causing the crop to lodge, this can lead to harvesting difficulties and yield loss.

Fusarium can also cause premature death in some susceptible varieties. The leaves die off and this increases the dry matter content of the whole plant. However, as the cobs have not matured, starch yield will be low.

Smut

Smut is a soil-borne disease caused by a fungus (*Usilago maydis*). Although it is slightly alarming in appearance, it is rarely an economic problem in the UK. It only occurs when the weather is hot and dry. Smut is more frequent where maize has been grown continuously in the same field. The fungus attacks the aerial parts of the plant or the stem and causes the development of very characteristic 'galls'. These are irregular in shape, have a white skin, and produce a large mass of unsightly black spores. The spores can be blown onto other maize plants and the infection is spread further. A percentage will remain dormant in the soil and can infect the next year's crop.

To avoid smut outbreaks, select resistant varieties and rotate maize crops. Seek advice from a nutritionist before feeding silage from smut-infected crops.

Rust fungus

There have been attacks on maize by a rust fungus (*Puccinia sorghi*) which leads to small orange-brown pustules on the leaves late in the season. Attacks tend to be relatively mild and yield loss is negligible.

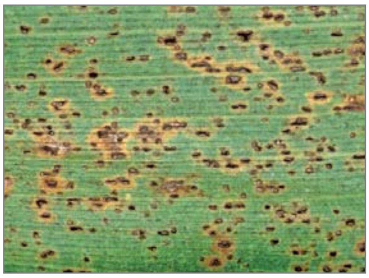


Photo: Watier Visuel

Kabatiella zeae (Eyespot)

This is not related to the eyespot disease seen in wheat crops. The first symptoms likely to be seen in a crop infected by *Kabatiella zeae* are smallish round or oval translucent spots. The spots, 1-4mm in diameter, will typically have a lightish brown centre, surrounded by a purple-brown ring with a yellow 'halo'. In many crops the lesions amalgamate and generate a necrotic area. A serious attack may result in premature senescence of the leaf.

This pathogen over-winters in crop debris and the spores, which then develop, can transfer to a new crop via rain splash. Spores are also wind borne. Although the disease can attack a maize crop throughout the growing season, it tends to be associated with plants that are nearing maturity. Research has shown that damp conditions are needed to 'trigger' the onset of symptoms, hence coastal areas can be at particular risk.

Recent high rainfall years have caused disease outbreaks near the coast resulting in significant yield and quality losses in maize crops.

Stubble hygiene is very important – eyespot attacks can be greatly encouraged if debris from the previous maize crop is left on the soil surface over the winter months. Some other pathogens and physiological disorders that can affect maize may well give rise to very similar 'spotting' symptoms to those found in a genuine infection of *K.zeae*.

To reduce the impact of an eyespot infection in high risk areas and seasons, a fungicidal spray can be applied in the early growth stages.

Seek professional advice if infection is suspected.

COB DEVELOPMENT

Between 80 and 95 days after sowing, the maize plant produces a flower (or 'tassel'), which is the male part of its reproductive system. About halfway down the stalk the plant produces the 'silks' which is the female part of the system. Pollen from the tassel is released and falls naturally onto the silks enabling pollination of the grain sites on the spindle.

A 'tassel'.

A 'silk'.

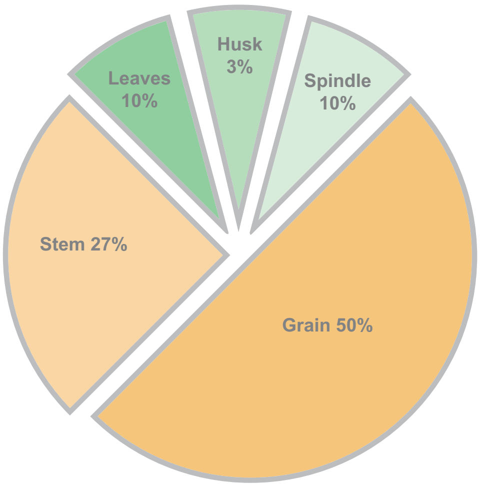
The weather plays an important role in the fertilisation process. The earlier a plant flowers, the sooner the grains are formed.

Heavy rain at the time of pollination may hinder fertilisation of the silks leading to blind ears and missing kernels. Poor weather or stress at flowering can also lead to multiple, poorly-filled ears being formed.

Grain sites in the middle of the cob are fertilised first, followed by those in the base and finally the tip. Blind sites in the tip can be due to poor weather at the end of flowering or the pollen burning off before all grain sites have been successfully fertilised. Under these circumstances the formation of starch is also impaired.

Ideally, one large well-formed and mature ear (or cob) per plant is the optimum. This will account for around 50% of the mature plant's dry matter yield.

The maize cob is 50% of the crop's dry matter yield



Sugars formed by photosynthesis in the leaves and stover are translocated to the cobs. Here, starch is laid down as the cobs mature and the plants senesce.

When the cob reaches between 50 and 55% dry matter, approximately 50 to 60% of the plant's energy is available as starch in the cob. It forms the largest part of its feeding value. The remaining sugars in the leaf and stover provide sufficient energy for fermentation when the crop is ensiled.

Varieties that mature early and have a high cob ripeness score tend to achieve higher ear starch contents than later maturing varieties.

Temperatures generally fall in the autumn, from about 1st October onwards, and the process of leaf sugar to ear starch formation slows down. Plant dry matter continues to increase as it matures and although frosts may increase dry matter content artificially, starch content and feeding quality plateau.

Plants gain approximately 2% dry matter each week during the latter stages of the growth cycle, up to early October. As the weather then cools, dry matter gains halve to 1% or less per week. To achieve a maximum starch content it is important to select a variety which achieves 50-55% dry matter in the ear (30-32% dry matter for the whole plant) before early October. Maize plants cannot withstand frost and will start to die. So even if the crop is still immature, it must be harvested immediately as the plants will already have started to deteriorate.

ORGANIC MAIZE

The main difference with maize grown in organic systems is that seed is not treated, and the use of chemicals to control weeds and pests is not permitted. This means that organic maize crops need to be managed differently.

When choosing where to site an organic maize crop, choose 'clean' weed-free fields where possible. In the early stages of maize establishment, the ground between the rows should be tractor-hoed regularly to reduce weed competition.

Since organic seed will not have been fungicide-treated against damping off, it should ideally be sown later – in May rather than April – when weather conditions are less cold and damp, and establishment is faster.

Birds can be more of a problem in organic crops – the placing of bird-scarers in the field until the crop is established is essential.

A limited number of maize varieties are available as organic seed. However, the same principles regarding variety selection as for conventional seed, should be applied.


CLAAS
JAGUAR

4. HARVESTING THE MAIZE CROP

The ideal time to harvest maize is when the cobs are mature and have reached maximum starch yield, but the crop still contains sufficient moisture to compact easily in the clamp. This is when the crop is 32-35% dry matter.

Harvesting a crop at a dry matter level which is lower or higher will reduce the feed value and/or quality of the silage.

Growers should aim to produce silage with a starch content of at least 30% in order to provide a quality feed at a cost-effective price.

Factors such as chop length and clamp management also play a role in how effectively the maize silage is utilised by the cow.

THE BEST TIME TO HARVEST

Close co-operation and communication with the contractor is essential as the crop nears maturity.

Given the choice, it is better to harvest maize slightly too late rather than slightly too early, to ensure the maximum feed value is obtained.

Harvest too early, when the crop is below 25% dry matter, and not only will feed value be lost through effluent wastage, but sugars will not have converted into starch in the cobs and so energy potential is compromised.

There will also be penalties if the crop is allowed to get too dry before it is harvested. At dry matter levels of 35% or above, palatability is reduced leading to lower feed intakes.

Once the crop reaches 40% dry matter, the fibre content increases and so does cell lignification, decreasing overall digestibility. At this level of dry matter it may also prove difficult to consolidate the crop properly in the clamp once the clamp has been opened resulting in aerobic spoilage.

Left: The decision on when to harvest a maize crop should be made based on crop maturity not contractor availability. Once ensiled, the sugars in maize are lost in fermentation. However, starch levels remain constant. So only harvest when crops have reached maturity.

Disadvantages of harvesting an immature crop

Harvesting too early (below 28% DM)		Correct harvesting (between 32-35% DM)
High freshweight yield, but not maximum DM yield. Storing water is an expensive use of clamp space.	**Fresh yield and DM yield**	Maximising DM yield reduces harvesting costs per tonne of DM ensiled, and makes economic use of clamp space.
Harvesting before optimum grain fill compromises starch content and starch yield.	**Crop quality (starch yield)**	Maximising starch content and yield maximises the energy content of the silage.
Fibre:starch ratio of 6:1, making this a fibre rich crop.	**Fibre:starch ratio**	Fibre:starch ratio near 1:1, making this an energy-dense crop.
The maize compacts easily and ensiles well, but potentially loses nutrients through effluent production.	**Ensiling characteristics**	Good ensiling techniques with plenty of rolling are key to good silages and only very dry silages (>35%DM) will be difficult to ensile.

Frost

Very severe frost will kill the maize plant. This will lead to a rapid increase in the dry matter content of the maize and also reduce the amount of plant sugars. This will be more apparent in crops which are relatively immature.

A frost with ‘killing’ power will also encourage the development of many moulds and yeasts. At a later date these undesirable organisms will trigger heating at the face of the clamp as soon as it is opened.

So, as a general rule, all maize should be harvested within 7 days of a really hard frost, before it can deteriorate further.

ASSESSING CROP MATURITY

The start of the forage maize harvest in the UK is influenced by a number of factors: the geographical area, the site, the variety, and the dry matter content of each individual crop.

From September, the maize crop will start drying down at a rate of approximately 2% per week. So from this time, crops should be inspected every week to establish an accurate harvest date.

When assessing a crop, walk well into it and look at plants in several locations within the main body of the field. Do not evaluate plants near the perimeter of the field as these will not be typical of the crop.

The first thing to assess is the green part of the plant, the stover (leaves and stem). This makes up 50% of the crop's bulk and is a substantial proportion of the energy.

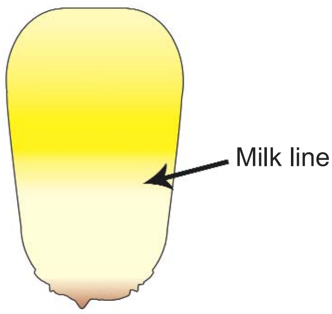
The aim is to harvest when the stover has a DM% of about 24% – this is when the leaves level with the cob are beginning to turn brown and the leaves at the top of the plant are becoming pale and papery. When a plant is picked and the stem twisted, no juice will emerge.

Leaf description	Stem moisture	Stover dry matter %
Green	Juice emerging	18
Starting to turn yellow	Stem wet	21
Brown	Stem dry	24

The most accurate way of assessing cob maturity is to put 500g of chopped cob in the microwave, along with a beaker of water to prevent the forage from igniting. Then heat the sample until its weight remains stable, but before it chars. The dry matter can then be calculated: DM% = final weight/original weight x 100.

For a quick in-field assessment of crop maturity use the 'Thumb Nail' test or the 'Milk Line' test.

Thumb Nail test:
Take a representative cob and peel back the sheaths. The grains at the top of the cob should have a consistency which is comparable to soft cheese, whilst the grains at the bottom should be like hard cheese. Grains in the middle should just be able to take the imprint of a thumbnail.



Milk Line test:
Break the cob open half way down and remove one of the grain kernels. The milk line is where the solid starch ends and the liquid milk begins. The ideal is to have 75-100% of the kernel yellow in colour (starch) instead of being milky, and for no liquid to be excreted when pressed.

Harvesting should take place when the overall crop dry matter is 32-35% which is when the dry matter of the cob is nearing 55% and the stover dry matter is around 24%.

Relationship between grain ripeness and dry matter

	% DM plant	Leaves above the ear	% DM ear	Grain	Ear content	Clamp loss*	Quality loss*
Milk ripe	18-21%	Green	25-35%	Grain crushes easily + milk	25-35%	15-20%	17-25%
Soft dough	21-24%	Starting yellow	35-40%	Grain crushes + milk	35-45%	10-15%	12-18%
Dough	23-27%	Starting yellow & drying out	40-45%	Grain crushes	43-49%	8-10%	10-12%
Hard dough	26-30%	Drying out	45-50%	Grain crushes difficult + nail notch	47-53%	6-8%	7-10%
Fully mature	>30%	Dry	>50%	No nail notch possible	>53%	4-6%	5-8%

*Clamp loss includes silage effluent and fermentation losses.
**Quality losses through lack of starch assimilation or starch production.

IMPORTANCE OF CROP MATURITY

The metabolisable energy (ME) from maize is derived from three carbohydrate sources: digestible fibre, sugars and starch.

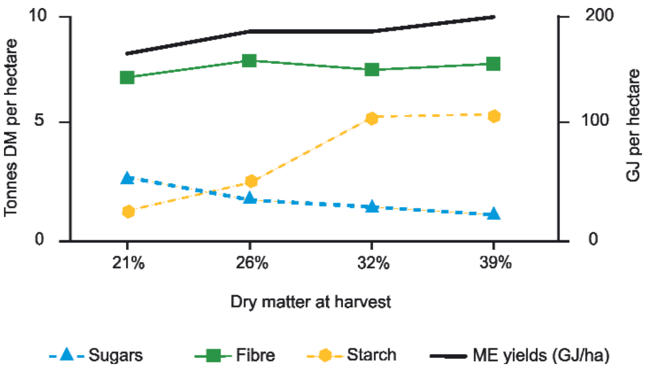
The relative proportions of the sugars and starch change, not only as the crop matures, but also once the crop is ensiled.

Fibre is mainly found in the leaves and stem. Once the crop is fully grown the amount of fibre changes very little, irrespective of when the crop is harvested.

However, as the crop matures, sugars from photosynthesis are deposited in the grains as starch, so as starch levels rise, sugar levels fall.

Despite the change in starch and sugar levels, the overall energy yield from a standing crop of maize only increases slightly as the crop matures (see figure below).

Energy yield change as maize crop matures



However, once maize is ensiled, the levels of sugars present will fall. This is because micro-organisms convert the plant sugars into organic acids, which help preserve it in the clamp.

Up to 95% of the sugar in a maize crop is utilised by these micro-organisms during the ensiling process, and energy is lost during their conversion to organic acids. This means that very little of the energy in maize silage comes from sugar.

Starch, however, remains relatively stable in the ensiling process. So the principal energy sources once the crop is ensiled, are the fibre and starch.

This is why it is essential to ensure that crops have reached maturity before harvesting, or risk losing out on the energy potential of the crop. This was demonstrated in research commissioned by Limagrain, at CEDAR (see panel).

LIMAGRAIN UK RESEARCH

Energy value maintained by ensiling a mature crop

The importance of harvesting a maize crop only when maturity has been reached was demonstrated in trials at CEDAR, University of Reading. Maize that had been harvested and ensiled three weeks before maturity had half the starch yield and the metabolisable energy yield was 34 GJ/ha lower than that harvested later.

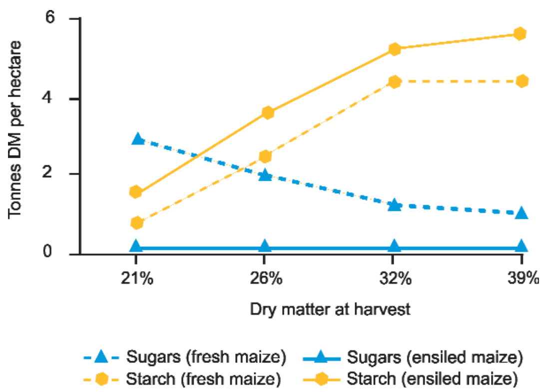
Six varieties of maize were each harvested on four different occasions as the crop approached maturity. The dry matter percentages at harvest were 21, 26, 32 and 39%. The energy components of the maize were compared straight after harvest, and then again after 3 months in the clamp.

The water soluble concentrate fraction (sugars) in the fresh samples decreased over the harvests from 1.59t/ha to 0.76t/ha. However, once the maize was ensiled, fermentation in the silo resulted in sugar levels falling below 0.1t/ha (see figure below).

Meanwhile, average starch yields rose from 2.91t/ha to 4.59t/ha as the plants matured, and once ensiled, these starch yields remained stable.

In the fresh samples taken at harvest, the metabolisable energy yield rose 15 GJ/ha between the first and last harvest, whereas that of the ensiled maize increased by 34 GJ/ha. This difference was due to sugars being lost during fermentation, demonstrating the importance of energy gained from starch and fibre.

Energy yield – ensiled vs fresh maize



THE HARVESTING OPERATION

Cutting Height

For maize crops, the optimum cutting height for the forage harvester is 20cm above the ground level. The lower part of the stalk contains little feeding value and a high proportion of water.

If forage yields look to fall short of expectations, the cutting height can be lowered, but to no lower than 12cm. Below this there is no real nutritive value in the maize stalk.

Length of chop

The chop length, to which the forage harvester is set, has a major impact on the level of 'effective' fibre ultimately provided in the maize silage. The optimum chop length for a particular situation will vary according to target feeding rates, the characteristics of the accompanying forage, and level of concentrate feeding.

Longer chop* suitable for:	Shorter chop best suited for:
Lower dry matter %	High dry matter %
Narrow/low clamp face	Wider/high clamp face
Excellent clamp management	Poorer clamp management
Dairy cows/beef cattle	Young cattle/sheep
High concentrate diets	Low level of concentrate feeding

**A typical 'longer chop' is 20-25mm.*

Nutritionists advise that for dairy cows, short chop material, less than 20mm, will have insufficient effective structural fibre to maintain rumen health in dairy cows. A longer chop (>25mm) will have a positive impact on rumination time and rumen function. However, other sources of fibre in the diet can be used to improve rumen function.

Consolidation and clamp management are undoubtedly easier with short chop, but many producers have seen positive changes in rumen health and milk quality resulting from increasing chop length.

Cracking the kernels

The most nutritious part of maize is the grain kernels, which hold the starch. These need to be 'damaged' or cracked during the harvesting process so that they can be digested. Forage harvesters are fitted with kernel processors – also known as 'corn crackers' – which ensure that the grain is cracked by rollers during the harvesting operation. Cracking is very advantageous if a crop has to be harvested at a relatively mature stage of development (when the grain is hard and the potential for wastage and feed inefficiency in the animal is increased).

ENSILING MAIZE

Maize can produce a well fermented silage due to its high level of soluble carbohydrates and low buffering capacity. However, the use of a maize silage additive may enhance fermentation and reduce the losses during ensiling. An additive can be especially useful where silage is to be stored for a long period, also where stock are feeding from a wide face.

The ensiling process itself affects the quality of the resultant maize silage. These points should be observed:

- To minimise loss of quality once the silage face is opened, a long narrow clamp is better than a short wide one.
- Roll the clamp continuously for optimum consolidation. Aim to limit each successive layer to 25-30cm. With deeper layers, it is harder to consolidate the crop.
- Fill the clamp and seal it as quickly as possible. If the ensiling process is likely to take more than 1 day then sheet down the clamp overnight.
- Soil contamination of the crop must be avoided. Pay attention to the harvesting operation in the field and to the wheels of the tractor(s) operating on the clamp.
- Salt spread on top of the silage (and worked into a shallow depth) will improve the sealing of the clamp. A dressing of around 3kg/m^2 should be sufficient in the main body of the clamp. For high risk areas like the shoulders of the clamp, increase rate to 5kg/m^2.

The fermentation process should be complete within 6 weeks. However, if necessary, the silage can be fed almost immediately.

ENVIRONMENTAL CONSIDERATIONS

Where maize stubble is left uncultivated over the winter months, heavy rainfall can cause soil erosion and leaching of nitrogen into nearby waterways, particularly where fields are sloping.

This can be avoided by selecting early maturing varieties of maize which can be harvested in time to sow a follow-on crop of cereals or new grass ley.

Alternatively, maize crops can be undersown with grass in June. Limagrain has carried out trials to demonstrate this (see panel opposite).

Farmers in England and Wales can earn points in agri-environment schemes such as the ELS (Entry Level Stewardship) scheme and Tir Gofal (or Glastir, from 2012), by adopting certain maize management practices which protect against soil erosion and nitrate leaching. For example: harvesting maize by 1st October, sowing a follow-on crop straight after harvest.

LIMAGRAIN UK RESEARCH

Options for managing maize stubble

To avoid leaving bare maize stubble over the winter months and the risk of soil erosion and water runoff, maize growers have several options to establish winter ground cover.

These are:

- undersow the young crop
- sow a follow-on crop straight into the maize stubble after harvesting
- cultivate the ground and sow a follow-on crop.

At Limagrain UK's Lincolnshire research site, trials have investigated how best to establish a grass ley by either undersowing the maize crop or broadcast sowing onto stubble.

Undersowing maize

The advantage of undersowing a maize crop with a grass ley mixture is that immediately after harvesting, ground cover is already established, and no further work is needed.

Three weeks following the sowing of an early maturing maize a range of herbicides were applied. After allowing a further three weeks for the post-emergence herbicides to work, the young maize crop was then undersown at the end of June with a grass/red clover mixture.

To achieve this in commercial situations, a cereals drill could be used with its coulters removed where they coincide with the maize rows.

Harvesting took place in early October once the crop was judged to have reached 32% dry matter.

Undersowing in this trial was not detrimental to the quality, yield or maturity of the maize crop and at harvest gave some protection from damage to the land.

However, in commercial situations a reduced seed rate is advised to allow light down to reach the grass.

Undersown maize plots in November.

An assessment of the new leys the following spring, revealed ground cover scores ranging from 76% to 86% demonstrating the effectiveness of this method in achieving good winter ground cover and minimising the risk of soil erosion and runoff.

Stubble sowing

Broadcast sowing a new crop onto the stubble immediately after harvest (on the same day) was also investigated as an alternative to undersowing.

Seed was simply broadcast sown onto a dry seed bed with no tilth or cultivation. Two mixtures were applied: a grass/clover seed mixture treated with Headstart®, a seaweed extract which helps boost early vigour and establishment, or the same seed mixture untreated.

Stubble sown plots in November.

In this trial, at an assessment the following spring, seed treated with Headstart® had achieved 14% more ground cover (80%) than untreated seed. This demonstrated that for the best results, a seed mixture which has been treated to boost seed germination and establishment rates should be used as conditions are less ideal than in normal reseeding.


897

5. FEEDING MAIZE SILAGE

Maize silage is a cost-effective, high energy, starch-rich forage which is reliable, consistent and helps support high levels of animal performance.

A COST-EFFECTIVE FORAGE

The value of good quality maize in rations is significantly higher than the cost of producing it.

Maize growing costs/ha are relatively fixed, leaving minimal scope to significantly reduce establishment or harvesting costs. Consequently, the aim should be to pay attention to variety choice, agronomy and crop nutrition, in order to maximise dry matter yield and forage quality (visit www.limagrain.co.uk/maize for information on varieties).

As a single harvest crop, most of its costs are directly attributable to the total crop dry matter yield. The cost of land, cultivation, seed, fertiliser and chemicals can be recorded, and divided by the fresh weight or dry matter tonnage harvested, less expected in-silo losses, to give an accurate cost per tonne.

The following simple example illustrates the impact of dry matter yield on the actual cost of the forage in the clamp.

Effect of DM yield on forage production costs

	Average yielding crop	High yielding crop	Difference
Freshweight yield/ha @32% DM & 30% starch	35	45	+10
DM yield of silage produced (15% in silo losses)	9.5	12.25	+2.75
Growing cost/ha	£800	£800	=
ME MJ/kg DM	11.2	11.2	=
Cost/t DM of silage	£84	£65	-£19

Left: Maize silage is a high energy starch-rich and very palatable forage which is ideal for including in ruminant rations. It can be used to complement high protein forages like grass silage or grazing, or fed as the sole forage in rations balanced for protein, long fibre, minerals and vitamins.

NUTRITIONAL CHARACTERISTICS

The main characteristics of maize silage are relatively consistent from year to year. It is a low protein forage with energy derived from three primary sources.

1. Starch
2. Sugar – which is largely converted to lactic acid when ensiled
3. Digestible cell wall material (fibre).

The total energy yield of a crop and the relative proportions of energy from each source will vary depending on the variety grown, the quality of the standing crop, and the stage of maturity at harvest (see page 20).

Forage maize is a palatable, high energy, starch-rich, but low protein, feed. It is an ideal complement for high protein silages and grazing, and can be fed as the sole forage provided it is correctly balanced with protein, long fibre, minerals and vitamins.

Typical composition of UK maize silage

	Typical value	Range
Dry matter %	30	25-38
ME MJ/kg DM	11.2	10.5-12.0
Crude protein %	8	6-9
NDF %	45	38-48
Starch	28	38

Energy

The key energy sources in maize are digestible fibre and starch.

Maize starch characteristically supplies a combination of:

- Rumen fermentable energy – which fuels the microbial population
- ‘Rumen bypass’ starch – which is converted to glucose which is absorbed and utilised directly by the animal.

The proportions of each are determined by the genetic make-up of the plant, the stage of maturity, and level of grain processing at harvest.

Cereals, such as wheat, contain ‘simpler’ starch which is largely rumen available and can cause rapid pH drops as a result of fast fermentation. Maize starch therefore is a ‘safer’ source to feed since fermentation rates in the rumen are slower, and not all the starch will be degraded. This reduces the rate and quantity of volatile fatty acid production, and decreases the risk of rumen acidosis.

High production dairy and beef diets will typically contain up to 20-25% starch. Milk protein improvements are usually seen where increased levels of safe starch are fed in a balanced dairy ration. There is also evidence that higher starch rations can improve body condition and fertility in dairy cows.

The table below shows the effect of feeding maize silage of different starch levels, in a ration which has a forage component of 20kg DM per day. If maize silage with a 20% starch content, is fed in a 50:50 mix with grass silage, it will only make up 10% of the ration's starch content. However, if the maize is harvested at a 30% starch content, then the same forage mix will supply 15% starch into the overall ration. By feeding this higher starch maize silage, less starch is needed from concentrate or cereal sources, cutting costs and generally improving rumen health.

Effect of maize silage inclusion and starch % on total diet starch content

	% maize in total ration	20% starch maize	25% starch maize	30% starch maize
4kg DM maize	20%	4%	5%	6%
6kg DM maize	30%	6%	7.5%	9%
8kg DM maize	40%	8%	10%	12%
10kg DM maize	50%	10%	12.5%	15%
15kg DM maize	75%	15%	18.75%	22.5%

Digestible fibre is key to good rumen health and efficient digestion. Again there are varietal and agronomic factors which determine fibre levels and fibre digestibility. Fibre digestibility will decline as the crop matures (much like grass), but the speed of decline and fibre characteristics can be determined largely by plant breeding. Over-mature crops with woody stems will have very poor digestibility due to the lignification of cell wall material. This is typical of crops harvested very late, and reduces the energy density of the silage.

Protein

Maize silage rarely contains above 9% crude protein. The fermentable starch and fibre sources in maize silage require a corresponding supply of rumen degradable protein in order to provide the microbial population of the rumen with a balanced and synchronised fuel stock. So protein supplementation is key to unlocking the feeding potential of maize.

Underfeeding protein can severely limit the productivity of maize-based diets as rumen function will be restricted. This usually leads to slow starch degradation, and increased faecal starch losses. Products such as rapemeal, soyabean meal, high clover silage and urea-based liquids make ideal complements to maize silage. These provide a readily available source of nitrogen, which the rumen microbes will use to produce microbial protein. This is then used for maintenance, milk protein synthesis and muscle development.

High protein silages containing legumes feed well alongside maize. The same is true when maize is used alongside high quality grazing. Protein utilisation is improved, and rumen function and feed conversion efficiency are improved.

Fibre

Maize silage will typically have a neutral detergent fibre content (NDF) of between 40 and 50%, which is well above the target minimum for ruminant diets. However, the harvesting process has a major impact on the level of 'effective' fibre. Short chop material (<20mm) will have insufficient effective structural fibre to maintain rumen health in dairy cows. Longer chop (>25mm) will have a positive impact on rumination time and rumen function. The optimum chop length for a particular farm situation will vary according to target feeding rates, the characteristics of the other forages fed, and level of concentrate feeding.

In most cases, additional structural fibre sources should be fed to dairy cows alongside maize silage. Longer chop grass silage and chopped straw are commonly used, and the quantity fed can be adjusted according to animal performance. The need becomes more critical as maize inclusion rates increase, and where very short chop lengths are used.

Minerals and vitamins

Maize silage is low in all major minerals, vitamins and trace elements. Calcium levels are commonly around 0.4%/kg DM which necessitates using either a specific maize balancer mineral, or straight calcium carbonate (limestone flour). Calcium supply is critical for lactating cows and in lamb ewes since skeletal stores will become depleted leading to subclinical and/or clinical hypocalcaemia. Grass, grass silage, sugar beet pulp, and calcium soap-based protected fats in the diet will also provide additional calcium to counteract the deficit found in maize silage.

Phosphorus supplementation will depend on the other ingredients in the diet, e.g. soya, and cereals are relatively good sources of phosphorus and will reduce the levels required from mineral sources. Phosphorus is not as critical as calcium, but requirements must be met and an appropriate Ca:P ratio must be maintained.

Ensiled maize is a very poor source of vitamin E and so diets should be balanced with a high quality trace element and vitamin supplement with particular attention paid to selenium and vitamin E content. Vitamin E is an antioxidant, which boosts immune function and can impact on reproductive function, somatic cell counts and general animal health.

MAIZE IN DAIRY SYSTEMS

The advantages of including maize silage in dairy rations to provide higher dry matter intakes, high energy levels and reduced forage costs are widely acknowledged. Inclusion rates have steadily increased over recent years with many producers now feeding between 60 and 90% of their forage in the form of maize silage, for at least part of the year or lactation.

High output dairy systems

High yielding dairy cows require daily dry matter intakes of at least 22-26kg DM and forage intakes of 12-15kg DM. A mixed forage diet is essential in order to consistently meet these targets. High maize inclusions are widely used as a means of producing an energy dense, and stable diet.

Failure to achieve high dry matter and energy intakes in early lactation will:

- Limit peak yield
- Increase body condition losses
- Limit yield persistency
- Severely impair fertility
- Limit milk protein output.

Consequently maize silage has become the first choice forage in many high output herds with grass silage being made as a means of managing grazing and as a long fibre source to complement the maize.

Example ration of maize-based TMR for an 8,000-9,000 litre herd

Feed	kg fresh	kg DM
Maize silage	35	10.5
Long chop grass silage	10	3
Chopped straw	0.5	0.45
Rolled wheat	2	1.7
Molassed beet pulp	2	1.8
44% protein molasses	1	0.66
Soya/rapemeal blend	5	4.5
Minerals/vitamins	0.15	0.15
Limestone flour	0.1	0.1
Total	**56**	**23**

Maize provides the major forage energy source in this example and at 30% starch will provide over 3kg of starch per head per day.

Including maize in dairy rations enhances dry matter intakes and boosts milk yield and protein levels.

Low input/high forage dairy systems

The lower cost per tonne of dry matter and increased forage intakes when feeding maize silage can significantly improve returns in these systems. When fed along with simple protein balancers, maize silage can be used as the main winter forage, and its low protein and high starch content make it a perfect buffer feed post turnout.

Example diet for an autumn calving 6,000-7,000 litre herd with limited parlour feed

Feed	kg fresh	kg DM
Maize silage	30	10
Long chop grass silage	12	3.5
Soya	1.5	1.25
Rapemeal	2.5	2.2
Minerals	0.15	0.15
Limestone flour	0.1	0.1
Total	**46**	**17**

Buffer feeding

The role of maize silage in grazing systems is well recognised. Spring calving cows in pure grass-based systems have major energy challenges in early lactation, particularly if weather conditions are less than ideal. The introduction of maize into many grazing systems has occurred as a result of producers trying to:

- Maintain high early lactation energy intakes at grass.
- Improve the utilisation of grass protein which is often as high as 30% crude protein in the spring/early summer.
- Produce a low cost, reliable and palatable forage buffer to carry minerals and other supplements.
- Increase milk yields and milk protein from grazing cows without incurring high feed costs.

Well-managed grass is a highly nutritious and palatable feed, but grazing conditions especially in the spring and late autumn can often severely restrict intake.

The introduction of a complementary buffer of maize silage will help to maintain feed intakes and address the nutritional imbalances found in grass.

Early spring growth tends to have low levels of effective structural fibre, low dry matter and very high soluble protein content. Buffer feeding maize offers an opportunity to add more fibre, help boost intakes, and help 'mop up' excess rumen degradable protein thanks to its slow release starch content.

Feed rates will typically be 3-4kg DM/day with good grazing, with the buffer providing the equivalent of 5-6 litres of milk.

Example diet aimed at spring calving 6000-7000 litre herds with high level grassland management

Feed	kg fresh	kg DM
Grazing	100	15
Maize silage	10	3.0
Sugar beet pulp/cereals	1.5	1.35
Minerals	0.15	0.15
Calcined magnesite (magnesium)	0.05	0.05
Total	**112**	**19.3**

The above diet is designed to optimise energy intake, and provide a carrier for magnesium to help prevent grass staggers. The additional energy and fibre will also help boost milk fat and protein.

With many spring calving herds on milk constituent based contracts, even slight improvements in milk solids output can have a major impact on the milk price achieved. Milk protein can often be a limiting factor, especially if grass sugar levels are low. The addition of some good quality maize silage will boost total energy input and add starch and sugar to the diet.

MAIZE FOR BEEF

Feed inputs account for a major proportion of the variable costs in intensive beef production. High cereal prices put pressure on margins, so feeding more home-grown forages like maize silage can improve profitability.

The high energy level and palatability of maize silage means it can be used alongside cereals in intensive systems to reduce ration cost, and improve rumen function and feed conversion efficiency.

Using maize silage in bull finishing rations can reduce feed costs, improve feed intakes and liveweight gains, and allow slaughter weights to be reached sooner.

Maize cropping can be integrated well into grass-based and arable-based beef systems, and offer significant savings provided that high yields of quality material can be consistently grown.

Improved performance with maize silage

The benefits of including maize silage in beef rations have been demonstrated in feeding trials. Two examples are provided below.

In a trial at Harper Adams University College, in Shropshire, feed costs were reduced and margins increased by increasing the level of maize silage in the bull finishing ration.

In the first three to six months of life, the dairy-bred bulls were reared on a cereal-based diet to achieve a daily liveweight gain of 1.6kg per day and to allow rumen capacity to develop before feeding the forage-based diet.

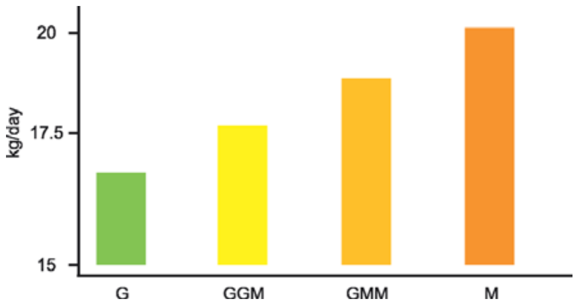
At six months of age and weighing 225kg, bulls were then fed a TMR of either 75:25 or 50:50 maize silage:concentrates (rolled barley, rapeseed meal and minerals) on a dry-matter basis. Bulls finished on maize silage reached slaughter weights of 585kg at 15.2 months old which was heavier, but later compared to bulls typically finished at Harper Adams on ad-lib cereals, finishing at 13.5 months old weighing 540kg.

Bulls fed the 75% maize silage ration achieved an improved gross margin of £55/head compared to bulls fed the 50% maize silage ration.

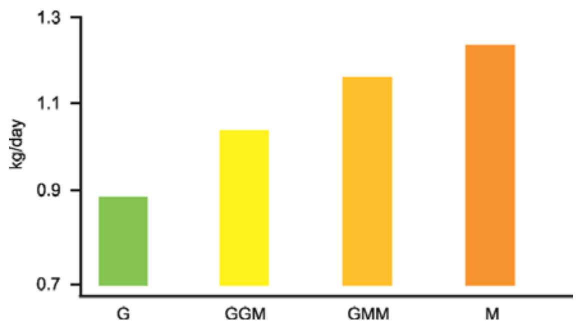
In another beef finishing trial, at CEDAR, University of Reading, bulls fed a 100% maize silage ration reached slaughter weights 40 days sooner than those fed a 100% grass silage ration. This saved around £30 in feed costs per animal.

Simmental bulls were fed a ration consisting of 83% forage and 17% concentrate. The forage component was either 100% grass silage (G), or 67:33 grass:maize silage (GGM), 33:67 grass:maize (GMM) or 100% maize silage (M). The start weights averaged 424kg and the target slaughter weight was 560kg.

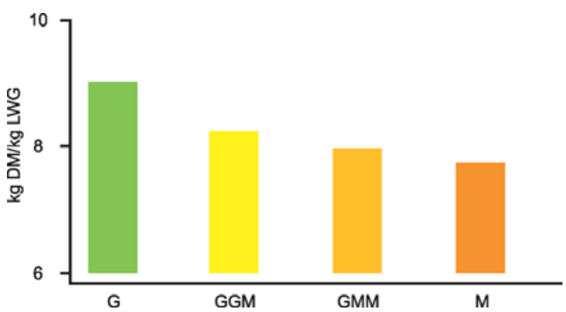
The higher the inclusion of maize silage in the forage component of the ration, the higher the dry matter intakes and liveweight gains and the better the feed conversion efficiency, as shown in the graphs below.



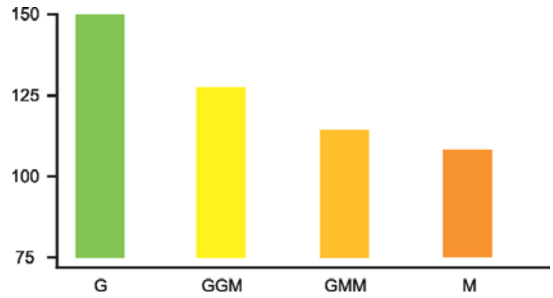
Increasing maize silage inclusion increased DM intakes



Increasing maize silage inclusion increased daily liveweight gain



Increasing maize silage inclusion improved feed conversion efficiency



Slaughter weight reached earlier with higher maize inclusion (days from 424kg to 560kg)

Finishing rations for beef units

Some example rations for intensive bull beef finishing are shown below.

Example ration for intensive bull beef finishing

Feed	kg fresh	kg DM
Maize silage	15	4.5
Chopped straw	0.5	0.45
Rolled barley	4	3.3
Rapemeal	1.5	1.25
Minerals	0.15	0.15
Total	**21**	**10**

This produces a 14% protein diet capable of supporting maintenance and in excess of 1.5kg/day liveweight gain whilst maintaining good rumen health in intensive bulls.

Example ration for forage-based steer/heifer finishing system

Feed	kg fresh	kg DM
Maize silage	20	6
Grass silage	5	1.25
Rolled barley	3	2.4
Rapemeal	1.5	1.25
Minerals	0.15	0.15
Total	**30**	**11**

Rations for young growing cattle

Care must be taken when feeding maize silage to younger, growing cattle, especially to heifers. Due to its high energy and low protein content, animals will tend to lay down fat over a prolonged period and this may lead to carcass weights which are below target, and penalties for excess fat cover.

If maize is fed to growing stock, it is vital that protein is correctly balanced and advisable to include a lower energy forage, e.g. hay or straw to reduce the energy density and provide gut fill. This also applies where maize is fed to dairy heifers.

MAIZE FOR SHEEP

Although not widely used in the UK, maize silage is a perfectly suitable forage base for both in-lamb ewes and finishing lambs/hoggets.

Breeding ewes

A high energy, palatable and consistent diet is essential for in-lamb ewes. Again, protein is the first limiting factor and must be supplemented in order to provide for the needs of the developing foetus and impending milk production. Additional long fibre is not usually necessary, but calcium supplementation is critical since pre-lambing ewes are extremely susceptible to hypocalcaemia, which leads to loss of appetite and subsequent metabolic disorders such as ketosis or twin-lamb disease.

Example ration for twin-bearing 70kg ewes in late pregnancy

Feed	kg fresh	kg DM
Maize silage	5	1.5
Beet pulp pellets	0.2	0.18
Soya	0.4	0.35
Minerals	0.03	0.03
Limestone flour	0.01	0.01
Total	**5.65**	**2.1**

Finishing lambs/hoggets

The basic requirements for intensively finishing lambs in the autumn are no different to those of finishing beef cattle. They require a high energy density, moderate protein diets.

Maize has the advantage of being very palatable and its short chop length helps prevent any sorting or rejection within the diet. A combination of maize, cereals and a small amount of a protein supplement will produce a safe high quality finishing ration which will stimulate appetite and enable rapid finish.

If the aim is to delay finish to try and catch higher winter prices, maize should be restricted in the early stages with hay or straw available as belly fill. Again, mineral supplementation is important, and a specialist lamb mineral should be used in order to help prevent losses due to urinary calculi in entire males.

MAIZE FOR MILKING SHEEP AND GOATS

Maize silage is also a valuable forage for milking ewes and goats.

Like high yielding dairy cows, milking sheep have a high energy requirement in order to maximise output of milk solids. By offering a high energy, high starch forage which is both palatable and easy to mix, concentrate levels can be reduced, and/or output increased. The digestible fibre portion of the crop will aid rumen function and drive milk fat content, whilst the slow release starch will promote milk protein.

Goats on the other hand, produce higher yields of lower fat and protein milk, and again energy intake is a primary driver of yield. Starch is a glucose precursor which drives lactose synthesis and therefore promotes milk yield.

Goats' natural instincts lead to ration sorting. The use of well chopped maize silage with some slightly longer chopped grass silage or haylage will help reduce the effects of this when feeding a mixed ration.

Ensure rations for milking sheep and goats contain sufficient levels of protein and calcium.

As with dairy cows, dietary levels of protein and calcium are primary considerations when balancing maize-based lactating sheep and goat rations. Both species produce milk with a significantly higher calcium content than cows milk so any shortfalls in the diet will lead to excessive depletion of calcium reserves.

Right: Maize can also be harvested using a combine which takes only the cobs. The cob kernels can either be crimped to produce a high energy feedstuff, or dried and sold as high value grain maize for the petfood market.

6. GRAIN MAIZE FOR CRIMPING OR DRYING

Photo: Watier Visuel

6. GRAIN MAIZE FOR CRIMPING OR DRYING

As an alternative to growing maize and ensiling the whole plant for forage, the cobs can be harvested on their own. The grains are then further processed either by drying or crimping to produce high energy feed ingredients.

Grain can be dried and sold into the petfood and bird feed markets. Grain size and colour are important features. Currently, the majority of the 1 million tonnes of grain maize used in the UK is imported from the Continent, where it is easier to grow the crop. A small amount of grain maize is produced in the very favourable areas of the south and south east of the UK. Grain maize is a good spring cash crop for arable farmers.

Alternatively, grains can be treated with an additive to make crimped grain maize, which is a moist starch-rich feed for livestock rations. It can be substituted into rations to reduce the reliance on bought-in concentrates.

Growers can expect grain maize yields of 8-10t/ha off the combine, which is equivalent to dry matter yields of around 5-7t/ha.

VARIETY SELECTION

Maize varieties bred for grain and crimping differ from those for forage. They are selected for their resistance to disease and stress, good sheath cover of the cob and the ability to remain standing for the extra time required for the plant to dry down to a moisture content of 30-35%. Typically they are not early maturing forage varieties.

In the UK, the majority of maize is grown for forage and varieties are primarily bred for that purpose. Grain/crimped maize accounts for less than 10% of the area of maize grown and is therefore too small a market to warrant a breeding programme specific to UK conditions. Grain maize varieties are being selected from the LG breeding programme for north-west Europe and trialled in the UK for their suitability here. As well as in-house trials, varieties have also been submitted into MGA trials.

LIMAGRAIN UK RESEARCH

UK RESEARCH

A dual-purpose LG variety

Results to-date from joint NIAB-MGA trials reveal that maize variety Lorado has characteristics which make it suitable for growing for either grain for crimping, or for silage.

In trials it has provided over 8.4t/ha of grain and matures earlier than most grain maize varieties.

Varieties bred for forage maize may sometimes be used to produce crimped maize. However, these may not have the standing power required and may also suffer *Fusarium* infection due to the prolonged time the cobs are left in the field, so it is recommended to use varieties bred for grain.

For information on varieties suitable for grain maize, visit www.limagrain.co.uk.maize.

GROWING GRAIN OR CRIMPED MAIZE

Grain maize varieties require more heat units to reach maturity than forage maize varieties. Agronomy is critical and production is best suited to the favourable growing areas of the UK.

To help bring forward maturity and crop ‘dry down’, grain maize crops are typically sown early in April, and harvested later than forage varieties. A reduced seed rate of 90,000-100,000 seeds/ha (36,000-40,000 seeds/acre) is used so that plants have more space, which encourages the development of larger cobs. Plastic cover may be used to advance maturity, however this adds significant cost to the operation.

HARVESTING GRAIN MAIZE

Harvesting should take place when the crop has dried down to around 65-75% dry matter, i.e. 35-25% moisture. Weather permitting, harvesting can start as early as the beginning of October, however it is possible to harvest as late as January. It is important for varieties to have good standing power.

A combine harvester with a specialised 8-row maize header is used. These strip the cobs from the plant. The combine chops the stem and leaves, which are left on the field.

Maize varieties grown for grain need to have good resistance to disease and stress and the ability to remain standing for a longer period of time than forage maize varieties.

The combine and accompanying trailers travel across the field on a carpet of chopped maize plants. This reduces the risk of trailers taking mud out onto the roads. As the plant material is broken down over the winter months, nutrients are returned to the soil.

Grain maize is harvested once the crop has dried down to around 25-35% dry matter, so harvesting often takes place much later than with forage maize crops.

Yields of grain maize range from 8-10t/ha, at a 32% moisture content which produces a 5-7t/ha yield of dry matter.

PROCESSING AND STORAGE

Grain maize which is to be sold, is dried down to a 15% moisture content. High energy costs whilst drying increase the cost of the final product considerably. This is a major factor affecting the profitability of this crop, although this is offset by the premiums offered for the bird feed and pet food markets.

Maize growers intending to use the crop as a ruminant feed usually opt for moist storage after harvesting to avoid the high drying costs. The relatively high moisture content of grain maize at harvest means that it needs to be further processed so it can be stored without spoiling. This process involves crimping the grains and treating with either an acid-based or biological innoculant.

Crimped grain maize is an energy dense feedstuff: it has a 60-70% starch content in the dry matter, and a metabolisable energy content of around 14.5MJ/kg DM.

Crimped grain maize is an energy dense moist feed. It is especially high in by-pass starch. This is broken down more slowly in the rumen compared to the starch found in wheat, and therefore reduces acid-loading and the risk of rumen acidosis.

CORN-COB MIX

Corn-cob mix is a feedstuff that is an intermediate between grain maize and forage maize. It is also known as ground ear maize (GEM). A forage harvester with a picker header is used to harvest the whole cob and sheath, which are then chopped.

Varieties bred for grain or forage maize can be used to make corn-cob mix. It requires a slightly drier cob than used for silage and so is typically harvested several weeks after the same crop would have been ensiled. Corn-cob mix is a high energy feed with the leaves of the cob sheathes adding the benefit of some fibre to the diet.

Harvesting comparisons of maize products

End product	Material harvested	Moisture content
Grain maize	Kernels only	15%
Crimped maize	Kernels only	25-35%
Corn-cob mix/GEM	Whole cob + sheath	45%
Maize silage	Whole plant	65-70%

7. GROWING MAIZE UNDER PLASTIC

Sowing maize under a plastic cover allows earlier sowing and advances crop maturity so that harvesting can be brought forward. However, it does incur significant extra cost.

Establishing maize under plastic costs around an extra £300/hectare compared to sowing conventionally. So growing a crop of forage maize under plastic is something to consider only if conditions are so marginal that even a very early maturing variety would not have the warmth and sunshine to develop starch-rich cobs.

In very marginal areas, growing maize under plastic may be the only way to attain a mature crop for making silage. This system is also popular amongst growers of maize for crimped grain, as the crop is required to dry down to a 30% moisture content, and so benefits from the plastic accelerating maturity.

EFFECT ON CROP YIELD

Higher yields from sowing maize under plastic can sometimes, but not always, be achieved.

In Ireland, where the concept of sowing under plastic was first established, trials have demonstrated that dry matter yields will average an extra 1.4t/ha, but this ranges from 0.1 to 3.4 tonnes/ha. For example, in DAFF* 2009 trials, the open sown maize actually out-yielded the plastic covered by 0.1 t/ha. With maize silage valued at £90/t dry matter, then only in the very best years is it cost-effective to grow maize under plastic solely for the purpose of obtaining higher yield.

Left: Growing maize under plastic allows earlier sowing and advances harvest date, but the extra costs involved and potential weed control problems make this an option only at very marginal growing sites.

Higher yields cannot be expected when maize is sown under plastic in late April/May, or where weeds are not controlled and the seedbed is not adequately prepared.

THE 'PLASTIC SYSTEM'

A specialist contractor and drill is required for sowing seed under plastic. As the seed is drilled, a pre-emergence herbicide is applied, and then plastic cover is stretched out over the rows and weighted down with soil at either side.

The drill is designed with spray nozzles sited to apply pre-emergence herbicide to the ground before the plastic is laid down, and then again afterwards to spray the ground between the rows.

By using a plastic film cover, the soil temperature is raised, allowing the crop to establish faster, and also protecting the seedlings from frost in early sown crops.

Plastic film is available either completely un-perforated for very early sown crops, or with pinholes for later sown crops. The pinholes enable air to escape to prevent temperatures under the film reaching scorching levels as this would 'cook' the plant and check its growth. The pinholes also offer an easier route for plants to emerge through the plastic.

The plastic film is usually photo-degradable. In marginal areas with low sunlight, the photodegradable material can cause problems in subsequent crops, when plastic is ploughed under and remains undegraded in the soil. Problems can also arise as plastic fragments become attached to the plants as they grow, and are incorporated into the clamp.

Although plastic can be photodegraded so that all visual traces disappear, small fragments of plastic can remain in the soil. These may attract toxins that would otherwise exist in individual harmless quantities.

*Department of Agriculture Fisheries and Food in Eire

VARIETY SELECTION

Current maize varieties sown under plastic are those that have been bred for the Continental market which are later maturing. Late maturing varieties tend to achieve higher dry matter yields and so they better offset the extra costs of establishing a crop under plastic than early maturing types. However, Limagrain UK research has demonstrated that some early maturing varieties are also suitable for sowing under plastic.

To date, in Limagrain trials, all LG varieties – both early maturing and later maturing – have successfully emerged through the plastic and reached maturity by harvest. for information on varieties suitable for plastic, visit www.limagrain.co.uk/maize.

Currently, the only independent sources of data on how maize varieties have performed under plastic are in Ireland. In Southern Ireland, where climatic conditions are similar to many marginal maize areas of the UK, DAFF publishes recommended lists. In Northern Ireland, growing conditions are extremely marginal and comparable to Scotland. So the majority of maize has to be grown under plastic as yields from open-sown crops are uneconomic. DARD* also publishes recommended lists, however variety performance should be viewed with caution due to the extremely marginal conditions in that region.

**Department of Agriculture and Rural Development, N. Ireland*

CROP MANAGEMENT

There are some major differences in crop agronomy and management between growing maize under plastic and open sowing.

A fine tilth is essential to ensure that the plastic is properly secured down either side of each double row of seeds. As a rule of thumb, the tilth needs to be about 10cm deeper than with conventional sowing, i.e. at least 15cm deep. A clod-free seedbed is also essential to prevent the plastic from being ripped at sowing. This means very heavy soils are less suitable for plastic-based production systems.

The warmer environment created by the plastic cover improves the growing conditions for young seedlings and so a lower seed rate can be used as plant establishment rates will be higher. Typically, a rate of 99,000/ha (40,000 seeds/acre) is used, as opposed to the 111,000/ha (45,000 seeds/acre) for open-sown maize. This is also the maximum limit for the existing drill equipment.

In open-sown conditions, MAP/DAP fertiliser is added 'down the spout' at the same time as maize is sown. However the equipment used to drill and cover the seed with plastic cannot support such fertiliser placement. So it is essential to correct any nutrient deficiencies prior to drilling.

Using plastic will warm the soil up sooner than in open-sown crops and this mobilises the phosphates in the soil so that the seedlings can benefit earlier than in open-sown crops. So, given a pH of 6.5-7.0 and correct phosphate indices, using plastic will save on the use of a starter fertiliser.

Weeds and plastic residues left in the soil are two practical problems which occur when growing maize under plastic.

Weed control is an extra challenge when growing maize under plastic. Pre-emergence herbicides require moisture to be effective. However the plastic cover will prevent any rain from increasing the soil moisture levels immediately around the maize seed/seedlings. So weed problems can still occur, especially in dry sowing conditions.

Where weeds become a significant problem, then as a last resort, the plastic film can be broken so that post-emergence herbicide can be applied. This is not a straightforward process. So, growing maize under plastic at sites prone to weed problems should be avoided.

The plastic film can only protect the plants until they emerge. Once they have broken through they are subject to the same environmental conditions of wind, rain, and temperature as any other crop. These will affect crop height and eventual bulk.

In early sown crops, seedlings that have broken through the plastic may be subject to frost which will result in a severe growth check and reduce yield potential.

THE ECONOMICS OF PLASTIC

The extra cost of using the plastic cover is the main drawback of this production system making it prohibitive for the majority of maize growers.

There is also no guarantee that this extra cost will be recouped by a higher dry matter yield.

With the ongoing research and development into breeding earlier and earlier maturing varieties, it is also an unnecessary cost for growers in most areas. There is an ever increasing choice of early maturing varieties with yields very similar to late maturing varieties.

In very marginal areas, growing maize under plastic can bring harvest forward by approximately one month compared to open sown crops. This allows harvesting to take place before weather conditions deteriorate. So in some cases, the plastic system can be considered justifiable.

For higher value maize products like dried grain maize and crimped maize, the use of plastic is comparatively more cost-effective than with silage crops. However, it still increases the cost per tonne of grain produced.

In very marginal areas, sowing maize under plastic may be the only way to harvest a mature crop. However, elsewhere, the selection of early maturing varieties will be a far more cost-effective option for the majority of growers.

The pros and cons of sowing maize under plastic

Advantages	Disadvantages
Earlier sowing	Extra cost
Less fertiliser required	Frost damage to emerged plants
Earlier harvest	Weed control more difficult
Higher yields (sometimes)	Plastic residues in soil

LIMAGRAIN UK RESEARCH

UK RESEARCH

Maize under plastic trials

Limagrain's UK maize trials programme includes ongoing evaluations of how varieties perform when grown under plastic, and the cost:benefits of sowing under plastic compared to sowing in the open.

To date, Limagrain trials have proven that all LG varieties will successfully grow through the plastic covers, and so all are suitable for using in this production system.

A key finding in the research trials, and in Limagrain's demonstration trials, is that weed control can be a major challenge. In particular, when sowing is carried out in relatively dry conditions, this decreases the ability of the pre-emergence herbicide to effectively control weeds. Maize plants then have to compete against weed growth, which has also benefited from the warmer conditions under the plastic.

Each year, new LG varieties will be entered into Limagrain's plastic trials and demonstration plots will also be set up around the UK to enable growers to see first-hand the performance of the different maize varieties available – both LG and competitor varieties.

8. MAIZE AND RENEWABLE ENERGY

As well as a forage supply, maize can serve as a renewable energy source in the production of bioenergy like biogas and bioethanol.

MAIZE FOR BIOGAS PRODUCTION

Maize is a very good raw material (feedstock) for the production of biogas, using Anaerobic Digestion (AD). This is the breakdown of non-woody material by micro-organisms in the absence of oxygen. Biogas is made up of approximately 60% methane and 40% carbon dioxide. The methane produced is used in a combined heat engine and power (CHP) to create electricity and heat.

Approximately 10%, by volume, of the feedstock which goes into an AD plant is converted to biogas and the remaining 90% leaves as a liquid digestate. This digestate provides a very useful by-product as it is rich in nutrients and can be used as a fertiliser. Spreading digestate onto farm land instead of purchasing fertiliser, is estimated to save £180 per hectare.

In Europe, biogas forms a major part of the renewable energy programmes. In Germany there are over five thousand on-farm digesters which sell electricity to the country's national grid. Maize accounts for 80% of the substrate used in biogas production.

Interest in biogas production is growing in the UK. There are two main types of AD systems used. The most common is an on-farm system that utilises slurry and ensiled crops. The management of this system remains under the farmer's control.

The second type of biogas production uses a larger commercial AD system that typically relies on utilising food and other waste products. These are generally bigger, more complex and more expensive to set up and run.

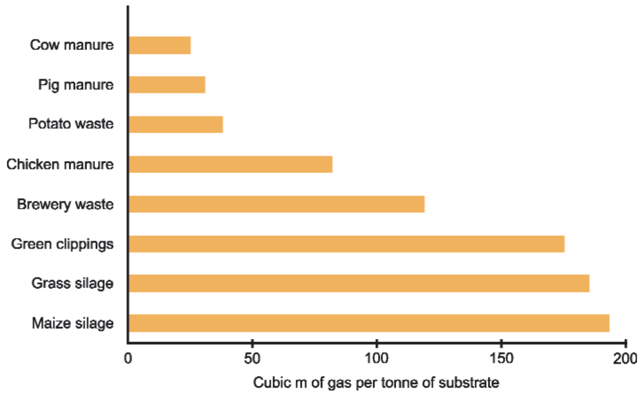
Setting up any AD system requires considerable capital expenditure and investment in time. The UK government has created incentives to encourage renewable energy production from AD. These include Renewable Obligation Certificates (ROCs), a process by which electricity produced by an AD plant receives a direct subsidy in the price paid for electricity supplied into the national grid.

Left, and above right: At this biogas production site near Nottingham, anaerobic digesters will be fed with 34,500t of locally grown maize silage and 2,500t of wholecrop silage to generate 15GWh of electricity – enough to meet the needs of 4,000 residential properties – and 20GWh of heat each year.

Feed in Tariffs (FITs) were also introduced in April 2010. An AD producer of electricity can choose either to accept ROCs, FITs, plus an export tariff, for electricity 'fed in' to the national grid. Prices for both ROCs and FITs have been guaranteed for 20 years and electricity companies are obliged to buy electricity produced in this way. In addition, a Renewable Heat Incentive is available (April 2011) for any heat exported from an AD plant for use in residential areas or by commercial operators.

The profitability of an AD plant will be influenced by both the capital cost of setting up the project and its output potential so choice of feedstock is critical to maximising output and getting a good return on investment. Output is determined by the methane producing capability of the feedstock and the consequent amount of electricity and heat produced and sold to the national grid. Maize silage produces significantly more biogas than livestock manure (see figure below).

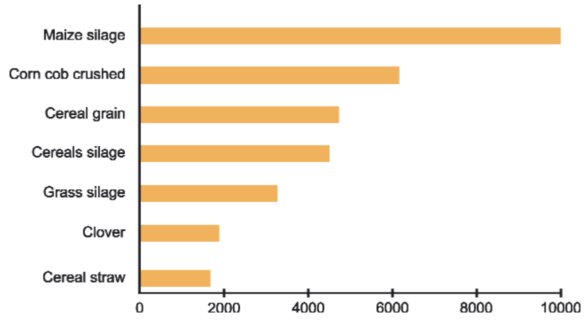
Comparative biogas yields of different feedstocks



Most farm AD systems will use a proportion of slurry. However, this has a relatively low output potential, as it has already been digested. Therefore a plant needs other, higher energy inputs like maize silage to function efficiently.

Research has shown that maize silage is very effective when used in biogas production, topping the list of crops that produce the greatest amount of biogas from each hectare grown (see figure below).

Biogas yield (in m³/ha)*



**Average data*
Source: Caussade semences

On average, one hectare of maize can produce up to 10,000 cubic metres of biogas. This compares to about 4,500 cubic metres produced by one hectare of cereals and 3,000 cubic metres from grass silage.

Typically a 500KW output AD plant would require 220 hectares of maize silage, yielding an average of 50t/ha fresh matter. An AD digester runs on a similar principle to a cow's rumen, it is the microbes that digest the organic feedstock. It follows that the feedstock should be of suitable dry matter and energy content to maximise the efficiency of this process. In addition total input will also influence total output, so crop yield is important.

VARIETY SELECTION

So what type of maize is ideal for biogas production? Variety selection is just one of the factors influencing production levels. The selection of a suitable site, the time of drilling, and subsequent management of the crop will also have a significant impact. The crop should be ready for harvest relatively early in order to avoid harvesting difficulties and the risk of damaging the soil structure.

It is vital that the crop can achieve a minimum of 28% dry matter content even in an adverse season. It is only at this stage of maturity that both the energy and dry matter yield of the crop are near their maximum potential. As for a crop grown for silage, the target harvest dry matter should ideally be between 30% and 32%. At this level the crop has formed a mature cob and maximised both its total dry matter and energy yield.

Varieties developed for biogas production in Continental Europe should be avoided as they mature too late in UK conditions to form a cob and reach the required dry matter. Typically, mid-maturing types offer the best compromise between increased total dry matter yield potential and acceptable quality.

Limagrain continues to conduct trials to identify the best varieties for use in AD systems. Typically, these are early maturing and high yielding.

BIO-FUEL PRODUCTION

These biofuels are substitutes for fossil fuels, and can be produced from a range of normal farm crops including grain maize, oilseeds, wheat and sugar beet.

Biofuels can be blended in small quantities (currently up to 5%) with petrol and diesel and used safely in today's road vehicles. In the UK, rapeseed is already grown to produce biodiesel.

In the production of bioethanol in countries like the USA and Brazil, maize and sugar cane are the most important feedstocks. In 1995 world demand for maize was 558 million tonnes, and this is expected to increase by 50% by 2020 to around 837 million tonnes.

Bioethanol processing facilities to convert wheat crops into fuels are being built in the UK. In the meantime, much of the bioethanol used in the UK is imported from major producers like the US and Brazil, where growers are subsidised to grow crops for fuel.

SUSTAINABLE BIOFUEL CROPS

Global biofuel production has increased three-fold over the last 20 years. Some media coverage about biofuels has called into question the benefits of biofuel production linking the rise in production with deforestation, food price increases, peat bog destruction and negative impacts on biodiversity.

Limagrain is committed to producing sustainable solutions through advanced breeding techniques. Research is assessing the energy return on investment as well as the environmental impacts on soil, water, climate change, and ecosystems of biofuels.

Biofuels can only contribute to energy and environmental goals as part of an overall strategy that includes greater energy efficiency and conservation, and a diversity of sustainable energy sources.

Limagrain is a fast-growing international agricultural co-operative group, specialising in both agricultural and horticultural seeds, and in cereal products.

As the largest plant breeder and seeds company in Europe and the fourth largest in the world, Limagrain employs over 6,000 people (more than 1,200 in research) and turns over more than £1.1 billion annually.

Limagrain has 3,500 farmer shareholders in France and national subsidiaries in 38 other countries.

In 2005, Limagrain acquired the business of Advanta Seeds which was a major step in its development to become a world player in seed breeding and production.

Maize seed accounts for two-thirds of the field crops turnover, so the organisation's commitment to this crop is massive. There are 20 maize breeders working in different parts of the world to develop and select varieties suitable for the climate of their local markets. The Group's critical mass also enables significant advances in maize breeding to be made through huge investments in its laboratories in Riom and Clermont-Ferrand, in France.

With maize being such an important crop for the Limagrain Group, its focus on breeding and seed production combine to give the advantage of a secure seed supply for UK farmers.

Visit **www.limagrain.com** for more information.

The UK subsidiary, Limagrain UK, is based at Rothwell in Lincolnshire. It is a £40 million business employing 180 people, and is the largest plant breeding company in the UK. It is also the largest supplier of maize in the UK, its success stemming from the scale of the LG breeding progamme and the selection of varieties bred specifically for the UK climate and marketplace.

In the arable sector, Limagrain UK has a very successful breeding programme in wheat, barley and pulses. In the livestock sector, it has an extensive forage crop portfolio which, as well as LG maize, includes: LG root crops, agricultural grass mixture brands Sinclair McGill and Monarch, amenity grass brands MM and Designer, and a game cover crops portfolio branded Hi Bird.

Visit **www.limagrain.co.uk** for more information.

BSI FM29412 UKAS QUALITY MANAGEMENT 003

Limagrain UK Limited
Rothwell
Market Rasen
Lincolnshire
LN7 6DT

Tel: 01472 371471

maize@limagrain.co.uk
www.limagrain.co.uk/maize

Oct. 2010