Cropping for Biogas

A Practical Guide

KWS ENERGY

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Biogas Cropping

High output feedstock crops are a key prerequisite for any biogas farmer. At the same time, for the grower with a plant in the near neighbourhood, biogas cropping represents a useful source of income.

While it would be easy for both to compromise and utilise currently grown crops, this commonly results in a reduced methane yield and poor use of the land available.

Continental experience shows clearly that the selection and growing of crops for biogas needs as much careful thought, planning and husbandry expertise as cropping for food.

This the fourth edition of our Biogas in Practice Guide – updated in 2019 – aims to provide biogas entrepreneurs, and those who support them, with the latest advice on biogas cropping in the UK.

“It examines the potential of a range of crops and crop mixes as feedstocks in a biogas plant – providing advice on which crops will provide maximum methane yields per tonne of dry matter and, more importantly, per area of cropped land.

It then looks at the prospects for these crop mixes across UK conditions and their sustainability in a typical rotation, before finally assessing the individual needs of those crops most suited to drive methane yield.

The guide draws on the research and experiences of our colleagues in continental Europe, but also our own product development trials and the growing expertise of current biogas producers in the UK, with whom we have close working relationships.

KWS funds what is believed to be the only long-term energy crop breeding programmes across Europe. Our focus is on providing varieties that maximise methane outputs and are sustainable in a UK biogas rotation and we look forward to helping you do likewise.

Feedstock Prospects

Ideally, biogas production would benefit from a consistent mix of feedstock materials, chopped and blended to ensure optimum methane yield.

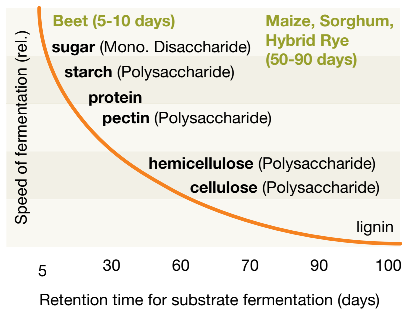
In practice, Anaerobic Digester (AD) units may also rely on a proportion of food waste. This is largely beneficial to the environment; however as a single feedstock, food waste and industrial by-products can present challenges in the consistency of gas output and therefore income.

A base feedstock from break crops, or energy crops grown as part of a farm rotation, is an ideal solution for farmers and helps provide an alternative income stream alongside standard combinable and commodity crops.

Yield is the overriding consideration for efficient energy crop production. The key is to use a feedstock mix that allows the digestion process to function effectively, and maximise methane output, given the size, layout and capability of the operation.

The digestion rate of different feedstocks within a biodigester varies from two days to two months. Material that has a high level of sugar or starch is quicker to ferment than feedstocks which have more lignin or cellulose (Figure 1).

Figure 1. Biogas: Relative Fermentation Characteristics by Crop



Data source: KWS SAAT AG.

Thus, material like energy beet will have a shorter retention time in the digester and release more gas over a shorter period of time than wholecrop cereals or maize.

However, in terms of total methane yield; both wholecrop cereals and maize, while slower to release gas, can be just as effective as energy beet (Table 1).

Table 1. Feedstock Characteristics

Feedstock Yield (t/ha)	Fresh Weight Yield	Dry Matter (%)	Biogas Yield Conversion m³/t	Methane (%)	Methane Yield m³/t
Energy Maize Silage	45-60	27-31	200	53%	105
Ensiled Beet	70-100	22-24	180	55%	99
Fresh Beet	70-100	22-23	170	51%	86
Wholecrop Cereals*	35-45	33-36	200	54%	108
Hybrid Rye	35-45	33-36	200	54%	108
Grass Silage	25	25-28	160	53%	90
Sunflower Silage	12	22-26	105	57%	60
Cattle Manure	-	8-10	24	40%	12

* Wheat, Barley, Triticale.
Data source: KWS SAAT AG.

Each individual feedstock component has advantages and disadvantages.

Feedstock	Advantages	Disadvantages
Energy Maize	High methane yield/ha Easy storage and feedout	Relatively slow retention time
Energy Beet	Highest possible yield/ha Fastest possible retention time	Needs careful storage
Grass	High DM – but 20% lower gas yields/t fresh weight than wholecrop	Low methane yield/ha
Hybrid Rye	High wholecrop yield with high DM Good for drought prone areas Good feedstock partner for maize	Needs short chop length at harvest
Manure	Useful starter and mixer product	Low methane output – so may not suit larger plants

Data source: KWS SAAT AG.

Table 2 illustrates some examples of potential mixes in the biogas plant. This shows that, per tonne of fresh weight produced, the most effective mixes for maximum methane yield should comprise maize and wholecrop cereals. However, when you look at the methane yield per hectare, utilisation of 10-30% energy beet alongside these two crops has a positive effect on output from the land area.

Care does need to be taken to ensure that the viscosity of the mix enables good functionality of the plant. So called 'wet' or 'dry' plant designs often specify feedstocks to ensure the retention time and buffering capacity is adequate.

The fast conversion rate of the beet helps to buffer the gas production, raising the pH inside the plant, encouraging bacterial conversion of the complete feedstock to methane. Furthermore, beet produces a cleaner source of methane than other feedstocks which enables more efficient conversion from methane to electricity, through the combined heat and power (CHP) unit, or biomethane.

Plant operators will also find that there are significant benefits from the synergies provided from using beet. Such synergies are difficult to quantify and will vary with plant type. However, continental experience strongly suggests that use of wholecrop cereals with maize does provide a higher yield per tonne of material than maize alone.

Table 2. Potential Crop Based Feedstock Mixes

Example Feedstock Mixes	Methane Yield m³/t (Fresh)	Methane Yield m³/ha (Fresh)†
Maize 100%	105	6300
Maize 90% + Beet** 10%	100	6360
Maize 70% + Beet** 30%	96	6480
Maize 70% + Hybrid Rye 30%	112	5544
Maize 40% + Hybrid Rye 30% + Beet** 30%	106	5724

** Assumes ensiled beet. † Doesn't take into account synergies of the various feedstock mixes.
Data source: KWS SAAT AG.

The Rotational Mix

It is important that whatever crops are selected across the rotation, when used in combination they provide secure yields every season and so do not limit the supply of feedstock.

Low risk crops – e.g. hybrid rye – are well suited to UK-wide conditions on all bar the driest and wettest sites respectively.

Geographical and Soil Type Limitations

Maize
Maize requires high temperatures over a long summer period for maximum yield and maturity.

Most specialist energy hybrids have a very high dry matter yield but are relatively late to mature. So while these crops will suit favourable sites in current maize growing regions, earlier hybrids will be required if production is to be considered further north.

Energy Beet
The only limitation to energy beet production is the ability to be able to get on the ground to plant and then harvest the crop.

Thus, geographically, UK growers could grow energy beet across the UK, but production is more limited on those soils that are still at field capacity in mid April and/or return to field capacity at around the end of October.

Hybrid Rye
There are no geographical limitations to where hybrid rye can be grown successfully. It will perform better on heavy land sites with adequate moisture that promotes good grain fill which will maximise DM yields.

Geographical Suitability

Rotational Balance

Maize
Maize suits most rotations including continuous cropping, though care needs to be taken when grown in close association with cereals due to the increased spread and risks of Fusarium.

Late harvesting can be an issue, but in most situations growers should be able to follow with autumn sown hybrid rye or grass crop. When considering planting energy beet after maize, growers will need to consider soil conservation and cross compliance issues as a consequence of leaving maize stubbles over winter.

Energy Beet
Like maize, highest yields of energy beet can be taken from lifting the crop as late as possible with yields peaking in mid-late November. In milder parts of the UK the crop could be left in the ground over winter.

Close cropping of energy beet should be avoided or growers could create a build-up of Rhizomania, or Beet Cyst Nematode (BCN).

The crop shouldn't be grown at a greater interval than one in three.

Hybrid Rye
Can fit behind maize or early lifted beet and thus provide both a winter cover crop and high yielding biogas crop. If used in a cereal rotation best drilled as a 2nd cereal.

In warmer, more southerly locations it can be used for double cropping, with the rye being followed by an ultra-early maturing maize hybrid.

Table 3. Example Rotational Performance

Potential Example Rotation and Yield Performance	Likely Situation/Location	Combined 3 Year Yield (t/ha)
Year 1-3	Favourable conditions – eastern half of England – suits large 1 mW plus plants	165
2 Year Rotation: Year 1 Maize (55t/ha) Year 2 Hybrid Rye (40t/ha)	Favourable conditions – where beet doesn't suit (e.g. vegetable production regions) – suits 1 mW plants	127
Year 1 Maize (45t/ha) Year 2 Hybrid Rye (40t/ha) Year 3 Grass† (15t/ha)	Ideal for livestock areas or smaller 650-750 kW biogas installations	100
Year 1 Beet (70t/ha) Year 2 Hybrid Rye (40t/ha) Year 3 Maize (55t/ha)	More sustainable rotation – suits all biogas plant sizes	155
Year 1 Beet (70t/ha) Year 2 Hybrid Rye (40t/ha) Year 3 Grass – 2 year ley (30t/ha)	Where maize cropping is not possible – e.g. Northern Britain	130

† Assumes first cut grass silage only.
Data source: KWS SAAT AG.

Table 3 illustrates the likely yield over some example three year rotations of biogas crops.

Continuous maize produces the highest yields that will ensure a good supply of material for larger biogas plants (1 mW and above).

A rotation where maize is joined by hybrid rye and energy beet may be a better approach and one that is more sustainable.

Finally, the use of energy beet, hybrid rye and then grass will also provide a more tenable yield of material for those in Northern Britain where maize cropping has been less successful.

Other Issues

Soil Erosion

Growers need to ensure they maintain good soil health and minimise the risks of erosion and soil loss especially over winter and between crops.

Risks are greatest in maize or late-lifted beet and growers may need to consider tined cultivation post harvesting to break up any surface compaction and improve water infiltration through the soil to minimise run-off.

There may be benefits from including hybrid rye, planted in the winter, as part of the feedstock cropping mix. Hybrid varieties are fast growing and tiller strongly, utilising any nutrient reserves and reducing potential leaching losses.

Growers are also leaving a proportion of their energy beet in the ground through to the spring, which also helps minimise potential soil loss in at risk fields.

Alternatively, the use of cover crops after later harvested maize or sugar beet may be necessary and could provide additional material for the digester.

Spreading of Digestate

Care needs to be taken to ensure that the use of any slurry and digestate fits in with cross compliance guidelines.

Spreading or injecting of digestate would be best carried out in the spring immediately prior to the drilling of a spring crop.

Growers should also consider the effects of a mix of winter and spring crops within the rotation. The harvesting of rye, for example, in June, gives growers an ideal opportunity in good summer conditions, to apply digestate before any following crop.

A period of fallow may be beneficial and in certain situations, particularly where grass weed control is increasingly difficult, the use of a spring crop can help growers get on top of grass weeds.

Finally, where large areas of monocropping, e.g. maize are proposed, there will be a noticeable change in the visual appearance and often the aesthetic appeal of the countryside. This does need to be considered. To counter this, growers can consider catch crops or headland mixes of sunflowers, phacelia or wildflowers.

Digestate Values

The nutrient content and the value of the digestate also vary according to rotational feedstock mix (Table 4).

However, whatever the cropping pattern and subsequent analysis, significant amounts of N, P & K plus valuable rates of other nutrients can be returned to soils when digestate is spread at reasonable rates/t (Table 5).

Long term use of biodigestate provides significant improvements in soil physical condition, workability and fertility.

Table 4. Feedstock and Digestate Value

Feedstock	Digestate Value (kg/t)		
	N	P	K
Maize Silage	3.7	2.4	4.5
Ensiled Beet	2.2	1.0	2.2
Fresh Beet	1.2	0.6	1.9
Hybrid Rye	5.9	3.7	7.3
Grass Silage	5.3	2.9	9.4
Sunflower Silage	4.5	2.2	5.7
Cattle Manure	4.5	3.6	7.9

Data source: KWS SAAT AG.

Table 5. Typical Digestate Nutrient Value

	kg/t (Fresh)	Potentially Available (Spread at 40t/ha)
N	4.7	113kg/ha
P	1.8	43kg/ha
K	5.2	125kg/ha
Mg	0.8	19kg/ha
Ca	2.1	50kg/ha
S	0.34	8kg/ha

Analysis based on 75% maize & 25% fresh manure.
Data source: KWS SAAT AG.

Energy Maize

Advantages	Disadvantages
High DM yield	Later harvest – soil damage and risk of compaction
Black grass control and wide herbicide spectrum	Following winter crop options can be limited
Low cost per tonne	Ideally needs to be balanced with other crop substrates to encourage a faster retention time
Can be grown continuously	
High yield potential on lighter land	
High biogas yields	

Geographic Potential

The KWS North European maize breeding programme continues to develop, assess and introduce maize varieties that are adapted to UK conditions.

Earlier maturing hybrids that are more suited to northern, colder and heavy soil sites are being developed and these are helping extend successful energy maize production into new regions.

Physiological Requirements

Germination	Soil Temperature >8°C
Young Plant Development	Soil Temperature >10°C*
	<10°C – leaf tissue becomes shrivelled
	Late frosts of -3°C or below lead to plant death
Maturity	Autumn temperatures of 6.5°C or below, halt growth

Maize heat unit and soil temperature tools
Two 'free to access' services are available from KWS. Simply enter your post code to interrogate the latest data. The Soil Temperature Tool – (updated daily) helps assess best maize drilling time. Our Heat Unit Tool – will help to assess the likely performance of maize with different maturity characteristics by post code region.

To try out these services visit **www.kws-uk.com**

Soil and Site Potential

Soil Type	Advantages	Disadvantages
Light	Warm and easy to work Allows earlier drilling of later, higher yielding varieties	Droughty and liable to erosion
Medium	Good water supply, fertile and easy to work	
Heavy	Good water supply, fertile Later drilling of earlier varieties is recommended	Slow to warm, dense/compact structure, silts are likely to cap
Organic	Good water supply, fertile	Slow to warm, low pH (<7), suffer from late frost

Energy Maize Breeding

KWS breed hybrids for biogas that maximise yields and provide a low production cost per tonne. High cold tolerance and vigour, standing ability and an improved earliness/yield ratio are all key attributes of our material.

Maize grown for biogas requires different characteristics compared to maize for forage. Forage maize produced for ruminants (dairy and beef cattle) requires high energy content in the form of starch and the appropriate dry matter content to encourage feed intake. For energy varieties starch content is less important than dry matter production.

Maize grown for biogas focuses on maximum yield, and a lower dry matter content, to encourage fermentation. Using a short chop length will help speed the process. Maize will have a long retention time of up to 100 days.

Forage Maize (Cattle Feeding)	Energy Maize (Biogas Output)
Minimum methane production in the rumen	Maximum methane production per ha
Dwell time: 5-10 hours	Dwell time: 50-100 days
Maximum feed value (starch and whole plant digestibility)	Maximum biomass (yield and dry matter)
Sufficient dry matter for feed intake (30-35%)	Sufficient dry matter for fermentation (27-31%)
Long chop length for rumen degradability (12-15mm)	Short chop length for surface area (7-10mm)

Data source: KWS SAAT AG.

A standard forage maize hybrid (left) and a high biomass energy maize (right).

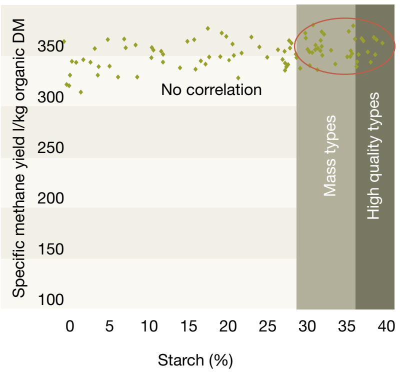
Our work, and that of our research partners, has clearly shown that biomass yield/ha correlates strongly with biogas production and is the key to high biogas yields.

Research from the University of Hohenheim, for example, confirms that the key to high methane yield is dry matter and that starch content and plant digestibility have only a minimal effect on methane output.

The study, which analysed the gas output from 10,800 plots testing 600 hybrids and 300 inbred maize lines confirmed a direct correlation between dry matter yield and methane output.

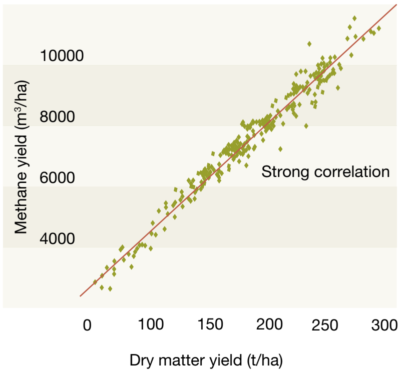
This relationship is very strong with little variance around the straight line plot and statistical analysis giving a near perfect 0.98 R2 correlation – i.e. over 98%. In all tests, all hybrids produced a narrow band of 300-330l methane/kg of dry matter.

Chart 1. Starch and Methane Yield



Data source: University of Hohenheim.

Chart 2. Dry Matter Yield and Methane Yield



Data source: University of Hohenheim.

Yield Reference Table

Fresh Yield (t/ha)	Dry Matter (%) & DM Yield (t/ha)						
	27%	28%	29%*	30%*	31%*	32%	33%
45	12.2	12.6	13.1	13.5	14.0	14.4	14.9
47	12.7	13.2	13.6	14.1	14.6	15.0	15.5
49	13.2	13.7	14.2	14.7	15.2	15.7	16.2
50	13.5	14.0	14.5	15.0	15.5	16.0	16.5
51	13.8	14.3	14.8	15.3	15.8	16.3	16.8
53	14.3	14.8	15.4	15.9	16.4	17.0	17.5
55	14.9	15.4	16.0	16.5	17.1	17.6	18.2
57	15.4	16.0	16.5	17.1	17.7	18.2	18.8
59	15.9	16.5	17.1	17.7	18.3	18.9	19.5
61	16.5	17.1	17.7	18.3	18.9	19.5	20.1
63	17.0	17.6	18.3	18.9	19.5	20.2	20.8
65	17.6	18.2	18.9	19.5	20.2	20.8	21.5
67	18.1	18.8	19.4	20.1	20.8	21.4	22.1
69	18.6	19.3	20.0	20.7	21.4	22.1	22.8
71	19.2	19.9	20.6	21.3	22.0	22.7	23.4
73	19.7	20.4	21.2	21.9	22.6	23.4	24.1
75	20.3	21.0	21.8	22.5	23.3	24.0	24.8
Dry Matter Yield/ha = Methane Yield/ha							

Forage Maize (FAO 150-210) Energy Maize (FAO 220-260) * Optimal harvest dry matter.

Data source: KWS SAAT AG.

Energy Potential

With its versatility, very high fresh yield potential and relatively easy cultivation, maize has become the main substrate for the ever increasing number of biogas plants, particularly in Germany, and elsewhere in North West Europe.

Gas Output

The following factors all play a critical role in optimum methane yield, and all are directly linked to the management of the crop in the field and at harvest.

- **Harvest date** (lignin %, dry matter %, chop length)
- **Storage** (fermentation, absence of air)
- **Dwell time** (substrate mix, plant design)

Shorter chop lengths (typically 7-10mm) are desirable, so as to maximise surface area and assist rapid substrate breakdown. Clamping is also critical; securing an airtight seal will encourage maximum clamp stability and minimise losses.

	Energy Maize	Forage Maize
Fresh Weight Yield (t/ha)	60	45
Dry Matter %	27-31	28-35
Biogas Yield m³/t Tonne (Fresh)	200	200
Methane Conversion	53%	53%
Methane Yield m³/t	105	105
Methane Yield m³/ha	6300	4725

Data source: KWS SAAT AG.

Hybrid Characteristics

- Very high fresh yield potential (55-65t/ha)
- Large structured hybrids with excellent standing ability
- Safe maturity for the majority of mainstream sites (28-31% dry matter)
- Moderate stay green (recommended chop length 7-10mm)

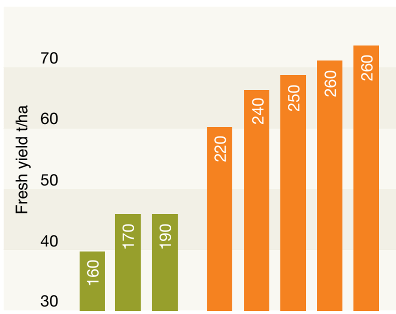
Variety Selection

- Variety selection should be based on the estimated level of heat units and field and soil conditions
- The FAO number is a measure of the relative earliness of the variety and represents the number of days a variety will take to reach a specific grain moisture
- The earliest varieties, now more commonly grown for fodder maize in marginal conditions, have low FAO ratings of around 150-160. They take fewer days from planting to maturity and require up to 20% fewer heat units than medium early hybrids but have a lower absolute yield potential
- Over recent years yield development has been greater in energy maize than silage maize

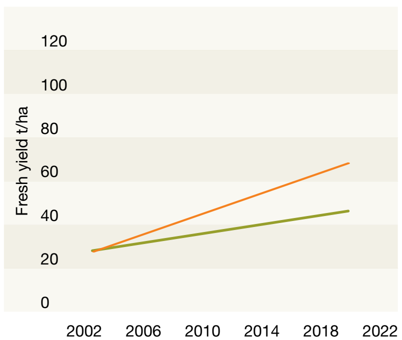
FAO	Maturity	Yield Potential
170	Short season/ Late Drilling	++
220	Early	+++
250	Mid Early	+++++
260	Late	++++++

Data source: KWS SAAT AG.

Yield Potential by FAO Number



Yield Progress



Agronomics

Drilling, Seed Rates and Row Width

Trials have established a methane yield gain from closer rows. Typically the standard row width of 75cm (30") used for forage maize can be reduced to 50cm (20") or 37.5cm (15").

Closer rows produce a denser crop with higher fresh weight yields and tend to promote a slightly faster dry down at harvest. Consideration should be given to deeper and earlier drilling, where soils are lighter.

Recommended seed rates

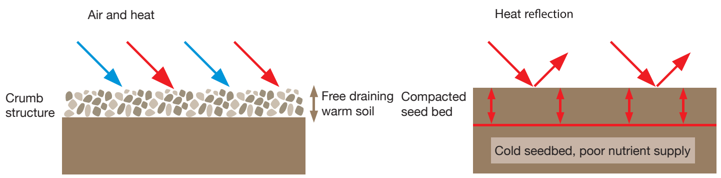
Plants/ha (acre)	Units*/ha (acre)	Deposition distance (cm) at 75cm (30")	at 50cm (19")
85,000 (34,000)	1.8 (0.72)	14.9	22.4
90,000 (36,000)	1.9 (0.76)	14.1	21.2
95,000 (38,000)	2.0 (0.81)	13.3	20.1
100,000 (40,000)	2.1 (0.85)	12.7	19.0
105,000 (42,000)	2.2 (0.89)	12.1	18.1
110,000 (44,500)	2.3 (0.93)	11.5	17.3
115,000 (46,500)	2.4 (0.98)	11.0	16.6

Considerations:

- Yield response is highest with earlier varieties (FAO >200)
- Energy maize suits lighter soils and earlier drilling – drill deeper into moisture if needed
- Earlier varieties will have a fast dry-down at harvest leading to an increased dry matter %
- There is an increased risk of lodging/plant competition with late varieties (FAO <240), so ensure you select an appropriate variety split, for your conditions

Soil Structure

Maize requires a well structured topsoil and well prepared seedbed. Compaction has a marked effect on crop growth and yield.



Nutrient Use

Maize has a high nutrient demand, particularly for potash. Assess soil reserves and tailor fertiliser applications to match site/field potential, for maximum yield.

Nutrient Removal

Harvest Date	FAO Maturity	Drilling Order	Fresh Yield Potential	Nutrient Removal (kg/ha)		
				N	P	K
Early (mid Sept)	170-200	Last	45t/ha	110	75	210
Mid (late Sept)	220-240	Mid	55t/ha	125	85	230
Late (mid Oct)	240-260	First	65t/ha	165	95	270

Data source: KWS SAAT AG.

Typical Fertiliser Recommendations

	Rate (kg/ha)	Timing
Nitrogen (N)	100-150	Pre-emergence
Phosphorus (P)	80-110	50kg/ha prior to drilling the rest at drilling
Potassium (K)	250-350	Autumn or spring
Sulphur	20-30	To the soil before drilling
Magnesium	40-60	To the soil before drilling

Herbicide Use

Pre-emergence and post-emergence applications should be used to minimise weed competition which can significantly reduce early growth. Effective utilisation of maize herbicides will help provide good grass weed control, effectively boosting control of problem weeds such as black grass or annual meadowgrass within a following cereal crop.

Fungicide Requirement

Eyespot is increasingly an issue, particularly in cool, wet summers and in regions where maize crops are more concentrated and grown in tighter rotation.

At the same time be aware that the disease control and physiological benefits of this chemistry could delay both maturity and harvest.

Later maturing hybrids (FAO 200 or later) are considerably less susceptible compared to early maturing hybrids (FAO 150-180).

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Harvest, Maturity and Clamp Management

When considering the total cropped area, growers should take into account the need for a wide drilling and harvesting window. The key is to secure high yields and the right level of plant dry matter (27-31%). Lower dry matter levels increase the risks of leaching losses in the clamp – higher levels increase the risk of moulds and spoilage on the clamp face and reduced methane yields (see graph).

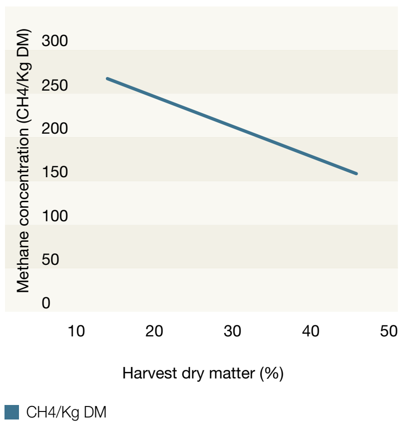
Total Cropping Area (ha)	Variety Planning Suggested % Breakdown of Maturity Early	 Mid Early	 Late
150+	40	35	25
350+	35	30	35
550+	35	25	40

Increasing the proportion of later maturing hybrids provides a wide window for establishment and harvesting capacity.

Data source: KWS SAAT AG.

Aim for a chop length of 7-10mm to maximise compaction in the clamp and optimum surface area for bacterial activity.

Optimal Harvest Window



Data source: KWS SAAT AG.

Biogas plant ©Agrafern Technolgoies

Energy Beet

Advantages	Disadvantages
Suitable for UK soils	Relatively high production and processing cost
Established agronomic knowledge	Requires a relatively wide rotation >3 years
Consistently high DM yields	Storage requires careful clamping
Complete crop can be used	
Very fast biodigestion	
High and clean methane yields	

Geographic Limitations

Energy beet is suitable for cultivation across most of the UK.

It has a low transpiration rate – around 300-500l of water/kg dry matter – and can withstand periods of drought.

Optimum yield requires 180-220 days growth and an accumulated 2500-2900°C heat units.

Optimal germination occurs when soil temperatures at 10cm reach 5°C and above.

Sunny days and cool nights during August/ September provide the highest yields, helping to maximise dry matter production and root weight.

Energy Potential

	Fresh Weight Yield (t/ha)	Dry Matter %	Biogas Yield m³/t (Fresh)	Methane Conversion	Methane Yield m³/t (Fresh)	Methane Yield m³/ha
Energy Maize	45-60	27-31	200	53%	105	6300
Energy beet*	65-100	22-24	180	55%	99	7722

* Assumes ensiled beet.
Data source: KWS SAAT SE.

Energy beet is one of the most highly efficient crops by land area in terms of sustainability and maximum methane output. KWS' energy beet feature higher dry matter yields than beet grown for sugar.

The sugar in energy beet ensures extremely fast fermentation – taking less than 14 days. Maize, in comparison takes 50-90 days. This makes energy beet an ideal partner for maize or hybrid rye. Furthermore, 95% of the complete beet plant can be converted into biogas.

By using a mix of both maize and beet – with beet as the faster fuel conversion source – producers can sustain high loads and methane production in the biodigester over a prolonged period.

The fast conversion rate of the beet helps to buffer the gas production, raising the pH of the biodigestate mix, encouraging bacterial conversion of the complete feedstock to methane.

Beet also produces a cleaner source of methane than other feedstocks which enables more efficient conversion from methane to electricity through the combined heat and power (CHP) unit.

Agronomics

As with fodder or sugar beet, a minimum three year rotation is advisable. More regular growing of beet will lead to increasing problems with soil pests and diseases.

In particular, be aware that beet cyst nematodes are also hosted by the oilseed rape crop, so growing energy beet and oilseed rape in the rotation could see the pest proliferate.

Biogas producers looking to grow beet will need to ensure they have a comprehensive soil management programme that restructures the soil.

Beet is particularly sensitive to soil compaction. If following cereals, deep loosen or plough the ground prior to winter and allow it to weather down before preparing a seedbed in the spring. On light land a plough and press prior to winter may allow drilling straight onto ground in the spring.

Soil structural damage is likely to be worse when beet and maize are grown in the same rotation. Both crops can be harvested when soil conditions are less than ideal leading to subsequent structural deterioration.

Best practice when cropping beet after maize may be to leave land uncultivated over-winter and wait for soil conditions below any soil pan to dry in the spring before deep loosening and restructuring the ground. Rough tining may be required to reduce erosion risks or potential soil loss from maize stubble.

Energy beet production fits in well alongside cereal production, including the use of hybrid rye. Energy beet can either follow early harvested crops of rye, or rye can be planted immediately post lifting of the beet.

Seedbeds need to be well structured, ensuring sufficient seed to soil contact to enable good moisture conservation for fast germination and emergence.

Beet is particularly sensitive to soil acidity and soils should be limed to pH 6.5-7. Slightly alkaline soils are less of an issue, but care should be taken not to restrict availability of nutrients such as phosphorus, manganese and magnesium. On peats, aim for a pH of 6-6.5. Drill at 2-3cm depth when soils have warmed up to at least 5ºC in March or the beginning of April.

Care should be taken to avoid drilling on land likely to cap or slump if heavy rainfall is likely to occur within 24 hours.

To achieve maximum dry matter yield, aim to achieve a stand density of 85,000-100,000 plants/ha using a seed rate of 110,000 seeds/ha (1.1 units/ha).

Energy beet Drilling Table

Plant spacing (cm)	Units/ ha*	45cm Rows Target based on 45cm rows – 000's				Units/ ha*	50cm Rows Target based on 50cm rows – 000's			
		60%	70%	80%	90%		60%	70%	80%	90%
15	1.48	88	104	118	133	1.33	80	93	107	120
16	1.39	83	97	111	125	1.25	75	88	100	113
17	1.31	79	92	105	118	1.18	71	82	94	106
18	1.23	74	86	98	110	1.11	67	78	89	100
19	1.17	70	82	94	105	1.05	63	74	84	95
20	1.11	67	78	89	100	1.00	60	70	80	90
21	1.06	64	74	85	95	0.95	57	67	76	86

Optimal plant population (85,000-100,000 plants/ha) * 1 unit = 100,000 seeds.

Data source: KWS UK.

Fertiliser Guidelines

Energy beet requires relatively low supplies of nitrogen and phosphorus, but utilises a significant amount of potassium. Base requirements on soil analyses and take into account expected yield and uptake.

P, K or Mg Index	0	1	2	3+
Phosphate (P_2O_5)	110	80	50	0
Potash (K_2O)	160	130	100	0
Magnesium (MgO)	150	75	0	0
Na_2O (use K Index)[a]	200	200	100	0

Data source: RB209 Beet Fertiliser Recommendation.

Potash is best applied prior to planting,taking care to avoid a high salt concentration around the seed, which will impact on germination. Fertiliser timing also needs to take into account the risks of leaching on lighter land.

N requirements should be assessed based on N-min tests prior to drilling in February/March. Typical N-use is around 80-120kg/ha with the nitrogen applied early to promote early crop growth. Care should be taken not to use more than 100kg/ha at any one time as this can lead to salinity issues.

Even if manure or digestates are used as the main source of N for growing energy beet, trials suggest that using 20-30kg/h of mineral fertiliser-N is important to ensure good availability and to promote early growth and establishment.

Compared to growing beet for sugar, amino-N and other impurities (e.g. K and Na content) are not important so growers can use additional fertiliser to push fresh weight yields 10-15% higher than they secure with conventional varieties while keeping within N-max limits.

Boron and manganese are key micronutrients and foliar applications will be needed where deficiencies are likely or seen.

Energy beet Nutrient Removal

	70t/ha Crop	
	Tops + Crowns Ploughed in kg/ha	Tops + Crowns Taken Off kg/ha
N	98	280
P_2O_5	42	91
K_2O	126	329
NaCl	35	315
MgO	28	49
CaO	119	168
SO_3	70	112

Data source: Adapted from Sugar beet Reference Book 2010, BBRO.

Seed treatments should be selected to match regional needs and minimise risks from soil pests and aphids.

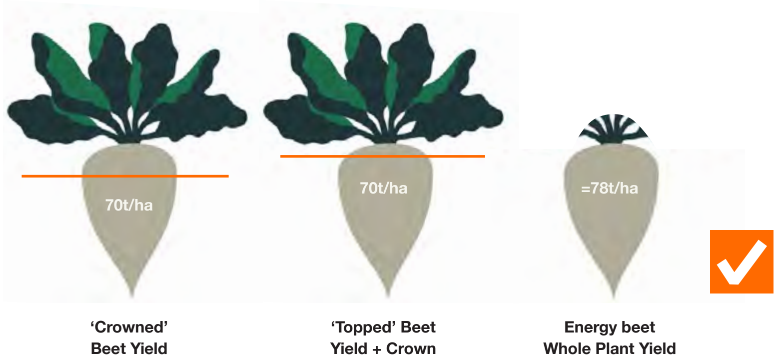
Weed control is essential. Pre-emergence and post-emergence applications should be timed to minimise weed competition which can significantly reduce early growth and canopy closure, thereby restricting yield production.

Powdery mildew and rust are the key diseases and maintaining a disease free crop during the summer maximises crop output and dry matter yield. If crops are to be left to bulk for as long as possible during the late autumn and winter, then green leaf retention is particularly important to maximise sugar and dry matter yield.

Harvesting

By utilising the whole beet plant, including the leaves, relative gas productivity for energy beet compared to maize rises to 143%.

While it is not always practical to harvest the leaf as well as the root due to lifting machinery limitations, the leaf material does contribute to the total energy harvested.



As a result, the output of these specialist high dry matter biogas beet varieties is around 400 l/methane per tonne of dry matter – approximately 100 l/kg dry matter more than that of specialist biogas maize varieties.

Care does need to be taken with dirt tare levels. German operators suggest a dirt tare of 5-8% causes no problems, though this tends to be soil type dependent.

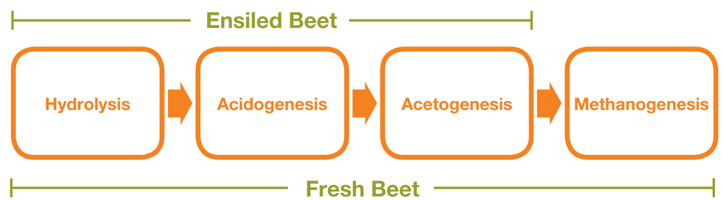
Silt and clay soils tend to stay in solution and move through the digester with the digestate, whereas sand particles will drop to the bottom of the liquor and may necessitate the use of sand traps to collect and remove soil and sediment. A number of modern AD plants will now have inbuilt sediment removers to alleviate this issue.

Other approaches are to mechanically clean beet at loading or to use specialist beet cleaning equipment prior to ensiling the beet.

Introduction:

Storage systems need to be designed and managed to ensure provision of top quality feedstock across 12 months. While energy beet can be fed fresh into the AD plant, after around three months beet will start to deteriorate if left open to the elements.

Biogas Process



In fact, ensiled beet will work faster in the AD plant as the ensiling process moves through three of the four steps to methane production, whereas fresh beet will undergo all four processes in the AD plant.

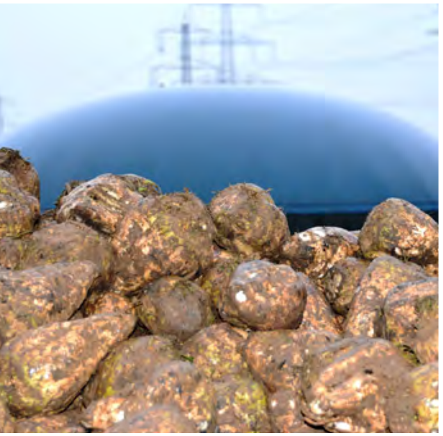
The key is to minimise any storage losses or to ensure that any leachate is captured and used in the biodigester.

While some continental growers have developed systems that store the whole beet as a mashed pulp in a lagoon, gaseous losses from this approach can be as high as 25-50%.

Another option is to mix maize silage with whole or chopped beet into the clamp, with the resultant beet runoff being absorbed by the high dry matter maize. However, this means that the harvest of both crops has to coincide and, in practice this means lifting beet before it has reached maximum yield potential. There are also problems when feeding a mixed silage into the digester with resultant swings in gaseous output as a result of utilising a non homogeneous mix.

Experience has taught us that ensiling whole beet is probably the simplest, most efficient means of storage and is best achieved by following the guidelines below:

Firstly, it is important to minimise the levels of dirt tare and stones in the clamp. While the harvesting, transport and ensiling process helps to reduce the level of soil, cleaning of the beet is an option. Cleaning may either be a wet or dry process depending on soil type and conditions at harvesting.



Generally a heavy clay based soil will have higher dirt tares which will be even higher in wet conditions. Allowing the beet to dry after lifting for a period of time, if possible, and then running over a cleaner loader will remove the majority of this soil. Likewise a sandy based soil, typically has a lower dirt tare and can be cleaned satisfactorily with a cleaner loader.

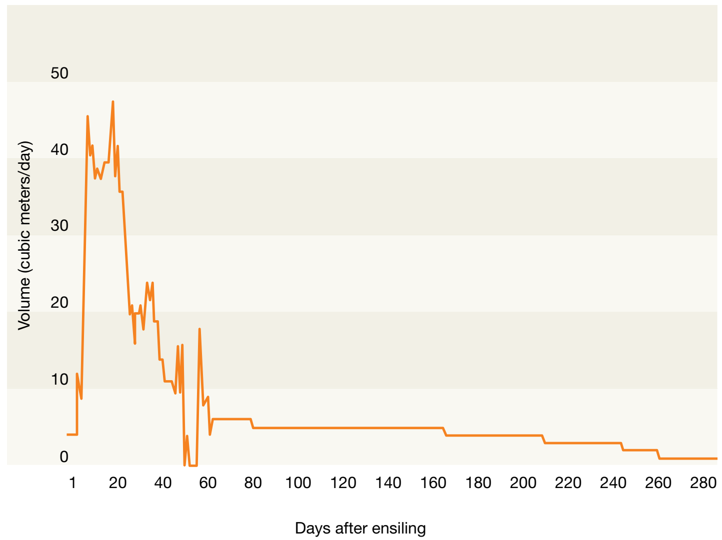
Some AD plants now have sumps or sediment removers to deal with excessive dirt tare in the plant.

Stone removal is most important as they will impact on chopping and moving machinery. Stones can typically be removed with the use of a good cleaner loader system.

The higher the heap, the greater the downward pressure on the beet and the better its compaction and anaerobic nature. Clamps will reduce in height over time; in practice a 7m high clamp will eventually fall to around a height of 4-5m after several weeks. In general, the greater the height of a clamp the better the condition of the ensiled beet.

Liquor runoff will begin almost immediately. This will comprise between 25-30% of the initial fresh weight of the stored beet and it is essential that this is captured and used in the digester to maximise gas yields.

Beet Juice from 7,500t Energy beet Clamp



Data source: KWS SAAT AG.

Large volumes run off initially, but this decreases over time until a low and stable volume of liquor is produced. The above chart, taken from a 7,500t clamp, demonstrates a typical pattern of liquid runoff measured in m3 per day and does not include the effects of rainfall.

Plastic sheeting can be used on the side of the beet clamp to help with the ensiling process and ensure capture of liquid runoff.

The clamp is best sealed with two layers of plastic sheeting with an additional outer protective layer to prevent bird and pest damage to the ensiled clamp. Weights need to be placed around the base of the clamp and preferably across the top of the clamp to help prevent wind lift and exposure to oxygen.

The clamp will initially billow out as existing oxygen is respired and an oxygen free environment is created.

It will then slump and reduce in height as liquid runoff occurs and the clamp consolidates on itself. The beet will ensile very quickly, typically within 10-14 days, reaching a steady and preserved state.

Beet will compact tightly together to provide good long-term ensiling conditions. This packing also allows for a stable clamp which holds together, reducing the risk of collapse. It also provides a solid and stable face from which to take the feedstock.

Ensiled beet is preserved perfectly. Storage can be indefinite as long as the clamp maintains an oxygen free state. This allows for year-round feeding of beet into the AD plant.

Beet is best chopped into matchbox size pieces or smaller, prior to feeding into the AD plant. This will increase the surface area of the beet accessible for bacteria and enable faster digestion.

KWS Breeding Programme

KWS has been developing new beet varieties for biogas for the last 5 years. Its research and development team have found a direct correlation between dry matter and biogas yield.

These varieties have 11-12% higher dry matter yields than standard beet for sugar production and hence produce a correspondingly higher methane yield.

As with maize the key overall goal is to produce as much dry matter per hectare as possible. There are clear differences in breeding goals for energy beet compared to sugar beet – these are detailed in the following table.

Beet Breeding Goals	
Sugarbeet	**Energbeet**
Sugar Content	Dry Matter Yield
White Sugar Yield	Dry Matter Content
Impurities	Digestibility

Common Breeding Goals
Bolting resistance
Rhizomania resistance
Beet cyst nematode resistance
Dirt Tare

Hybrid Rye for Wholecrop

Advantages	Disadvantages
Easy to manage	Need short chop length
High DM yields	Dry Matter Yield
Act as winter cover crop	Dry Matter Content
Can be drilled late after maize or beet	Digestibility
Could allow double-cropping	
Spread harvest and drilling workloads	
Improves gaseous output from maize	

Geographic Potential
Hybrid rye is highly robust and will cope with most situations, however, maximum yields come from regions with higher rainfall and heavier soils and here rye is the most appropriate biogas crop.

Rye also fits well within an energy beet or maize rotation. It can be planted relatively late and in some situations could be taken early to allow second cropping with energy beet or maize, providing a double biogas crop opportunity.

Hybrid rye is a useful substrate that can be utilised all year round in the biogas plant. It can be used to balance the high productivity of energy beet or maize substrates, providing an alternative nutrient source for the bacteria in the digester and stabilising gas output.

In this respect, used alongside maize, it has a synergistic effect in the biogas plant by improving the gas yield, as it increases the length of time for the maize to produce methane in the digester.

By mixing 25% hybrid rye with 75% maize, plant managers can increase gas output by nearly 20% more than from maize used on its own. However, combined gas yield declines when the proportion of rye used rises above this level.

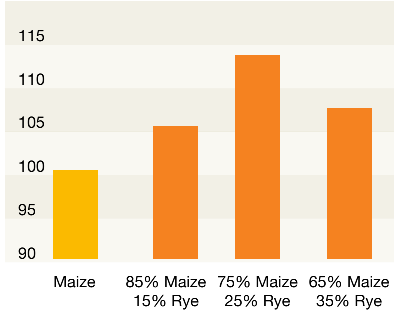
Hybrid rye also works well within the biogas rotation, complementing other crops. As it is harvested in the summer, it can be stored in empty maize or beet clamps.

Energy Potential

	Energy Maize	Hybrid Rye
Fresh Weight Yield (t/ha)	60	35-40
Dry Matter %	27-31	33-36
Biogas Yield m³/t (Fresh)	200	200
Methane Conversion	53%	54%
Methane Yield m³/t (Fresh)	105	108
Methane Yield m³/ha	6300	4320

Data source: KWS SAAT AG.

Relative Biogas Yield (Maize at 100%)



Data source: IBS GmbH and KWS Lochow GmbH.

Early harvesting when the crop is at 30-35% dry matter produces the best gas yields and reduces costs compared to rye produced for grain.

As a relatively low input crop, hybrid rye combines high fresh weight yields (around 40t/ha) and offers a higher dry matter content over both beet and maize. Grown in the rotation alongside maize, wholecrop hybrid rye offers an earlier harvest and significant rotational advantages.

Compared to other winter cereals, hybrid rye is extremely versatile. It has extreme winter hardiness and tolerance to very late autumn sowing as it tillers well and has strong early growth.

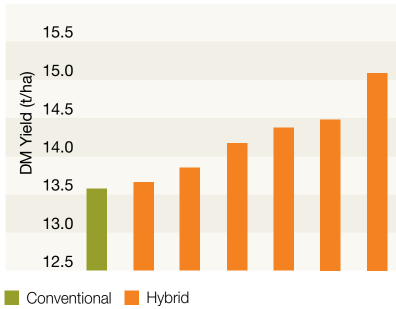
The grain is full of energy and a good feed source for bacteria with a high gaseous output.

Variety Selection

KWS' experience is that hybrid rye offers greater potential than all other cereals.

The new hybrid ryes being developed can deliver fresh weight yields as high as 50t/ha. A 50t/ha biogas crop has a biogas output of 4320 m3/ha compared to conventionally bred rye at around 3000 m3/ha.

Hybrid Rye – Yield Progression Over Time



Data source: KWS Lochow GmbH.

Our hybrid rye breeding programme focuses on high tillering types that produce a dense plant population. These varieties ensure fast early growth, production stability and consistent field performance with high dry matter yields.

KWS has also focused on providing varieties that can give a fast turnaround in the rotation – in some situations allowing an early harvest in mid May and the possibility of twin cropping with an energy beet or maize crop in the same season.

The new generation hybrid ryes have the potential to provide growers with significantly higher yields than traditionally bred material.

Agronomics

Winter rye varieties can be sown late (until the end of February) and has a well developed root system that extracts nutrients and water from greater soil depths than most cereals. This minimises N-loss during the winter and can also help minimise soil erosion.

Drill Timing	Date	Seed Rate m^2
Early	Mid Sept to Early Oct	200
Medium	October	250
Late	November onwards	300

Data source: KWS Lochow GmbH.

Common practice is to use between 120-160kg N/ha applying 40% at the start of vegetative growth and the remaining 60% at tillering. Agrochemical inputs are minimal. Brown rust is the main leaf disease that will affect Rye, between 1 and 3 fungicide applications may be required depending on growing region and rust risk.

Nutrient Use

	N/ha	P/ha	K/ha	Growth Regulator	
				Light soils	Heavy soils
Growth stage 25	60-80kg				
Growth stage 31	30-40kg			1.5-1.8l/ha	1.5-1.8l/ha
Growth stage 37	30-40kg				0.5l/ha
	120-160kg	90kg max	240kg (wholecrop) max		

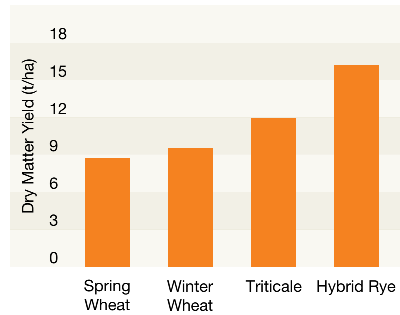
Data source: KWS Lochow GmbH.

Maximum dry matter and subsequent biogas production comes from ensiling when the grain is at the milky ripe stage. Leaving the crop to mature through to June and cutting at milky dough stage can double biogas yields compared to cutting at ear emergence.

Rye v Other Cereals?

In comparison to wheat, barley or triticale, rye produces more straw and similar grain yields. It is this higher biomass potential that makes it a better option for use in biogas production.

Hybrid Rye – Yield Comparison



Data source: KWS UK.

In order to achieve optimum mechanical shredding of the whole crop the harvester should be equipped with grain crackers with rollers that can be operated at different speeds (up to 60%). The aim is to expose as much of the crop as possible to lactic acid bacteria enabling them to propagate rapidly. This will also improve the efficiency of any ensiling agent.

As the rye stalks are essentially hollow, a lot of oxygen is brought into the silage. For this reason, the shredder should be set to achieve chop lengths of between 6 and 10mm for best results. This will help achieve a bulk density of more than 230kg of dry substances per m3 after intensive compacting in the clamp. Relatively hot harvest conditions can result in the growth of a number of micro-organisms. These may have a negative effect on the silage leading to high energy loss during storage and potential accumulation of toxic by-products in the clamp.

A suitable ensiling agent will reduce the natural growth of lactic bacteria in the plant.

Harvest/Storage

Harvesting at the late milky ripe to early dough ripe stage provides a dry matter of around 32-38% (max. 40%) and a grain-straw ratio of 1:1.

Stage of Maturity	Harvest Time	Dry Matter (%)	Biogas Yield m³/t (Fresh)
Ear tip	Beginning of May	<20%	<100
Flowering	Beginning of June	20-25%	130-160
Grain at milky ripe stage	Mid June	30-35%	200-230

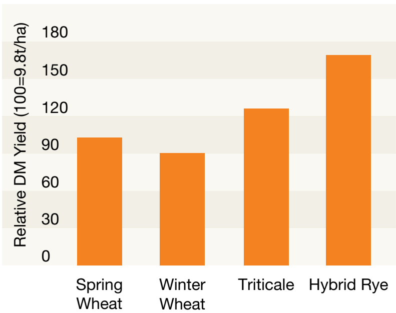
Data source: KWS Lochow GmbH.

Varieties

KWS hybrid rye varieties offer higher yields than conventional varieties and typically have achieved very high 38-45t/ha DM yields in UK situations.

The key is to select varieties with appropriate low-risk agronomy but which have consistently high yields.

Wholecrop Cereal Yield Comparisons



Data source: KWS UK.

Summary

UK biogas producers can maximise their output by establishing a cropping mix that provides a range of feedstocks to secure high gaseous output, which is also sustainable within the farm rotation.

Maize, wholecrop cereals and energy beet have the greatest potential within the majority of UK conditions. While maize is less tenable in the far north of the UK, wholecrop cereals can provide a suitable alternative.

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