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Willow Varietal Identification Guide




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Acknowledgement

The 'Willow Varietal Identification Guide' was originally written by Kevin Lindegaard from Crops for Energy. Kevin Lindegaard is an internationally-recognised biomass energy expert who continues to raise awareness of biomass farming and energy generation techniques and execute operations in the biomass field for Crops for Energy. Kevin joined the UK's Long Ashton Research Station in January of 1996. The joint UK/Swedish European Willow Breeding Partnership was an ambitious project at the Long Ashton Research Station to which Kevin Lindegaard significantly contributed. Kevin is credited with effectively breeding at least seven new strains of high-yield, disease-resistant willows. Willows are one of the chief plants used for biomass fuel, so Kevin's new varieties immediately contributed to the field of alternative energy exploration and generation.

This guide was jointly produced by Teagasc and the Agri-Food and Bio-sciences Institute. Teagasc is the agriculture and food development authority in Ireland. Its mission is to support science-based innovation in the agri-food sector and the broader bioeconomy that will underpin profitability, competitiveness and sustainability. Teagasc is funded by the Department of Agriculture, Food and the Marine. Teagasc in collaboration with AFBI and Crops for Energy are bringing together the best available information on willow variety breeding. Teagasc and AFBI staff will endeavour to update this publication based on research findings.

Research carried out by the Agri-Food and Biosciences Institute (AFBI) on biomass crops including Short Rotation Coppice (SRC) willow is financially supported by the Department of Agriculture and Rural Development, Northern Ireland (DARD). AFBI is a non-departmental body sponsored by DARD. The AFBI contribution to this guide was undertaken as part of the Answer project. This project is part-financed by the European Union's European Regional Development Fund through the INTERREG IVA cross-border programme managed by the Special EU Programmes body.

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September 2012

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ISBN: 10 1-84170-590-X

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Introduction

Willow genetic improvement programmes in Sweden and the UK have made significant progress in breeding short rotation coppice (SRC) willow. However, to expand production, cultivars suited to a wider range of European environments and future climates will be needed.

Willow breeding programmes were initiated in Sweden in 1987 and the UK in 1996. The primary aims of these programmes are to produce high yielding disease and pest-resistant varieties with a growth habit that facilitates mechanical harvesting. The majority of the crosses made by the Swedish breeding programme at Svalöf-Weibull AB have involved *S. viminalis, S. dasyclados* and *S. schwerinii*. The original parental material was based on Swedish and central European collections, later supplemented by collecting expeditions to central Russia and Siberia. The UK breeding programme based at IACR-Long Ashton (funded by the European Willow Breeding Partnership) utilised over twenty different species held at the UK National Willows Collection. These included exotic equivalents of *S. viminalis* and *S. caprea* such as *S. rehderiana, S. udensis, S. schwerinii, S. discolor* and *S. aegyptiaca*.

The progeny of crosses are initially raised as seedlings in a breeding nursery and subsequently as cuttings in field based observation trials. At each stage 5-10% are selected for further evaluation. Following the second observation trial, selections are included in yield trials at four or five locations in the UK and Sweden.

UK willow variety trials were planted at four sites at IACR-Long Ashton in Bristol, Markington in North Yorkshire, North Molton in Devon and Loughgall in County Armagh. The trials normally comprise between five and ten elite willow lines including two yield controls (L78183 and '*Tora*'). Between 1991-95, the trial design included 10 replicates of 10 plants (double rows of five) planted at a stocking rate of 20,000 cuttings per hectare. Subsequent trials included three replicates of each variety (52 plants per plot) in a randomised plot design. Typically, the duration of a trial is 6 years comprising an establishment year followed by a two-year harvest and a three-year harvest. In 2001, the first yield trials involving willows bred by the European Willow Breeding Partnership (EWBP) were harvested.

All new willow plantations now involve newly bred varieties, which are more productive and have greater resistance against pests and diseases. These factors will bring about more stable yield levels. Until recently there has been a lack of frost tolerant material for certain areas in Sweden. The varieties Gudrun and to a lesser extent *Tora* can be used in areas that have a high risk of frost. The choice of variety depends on the specific need of the grower and the climatic conditions of the site. It is also dependent of the availability of cuttings from the producers. Cutting producers need at least one years lead time in order to be able to provide sufficient cuttings of each variety. Once they know which varieties are required they can cut back their plantations to produce one-year old shoots for cutting production the following winter.

Crosses are generating about 10,000 plants per year. It takes approximately 10 years to develop a new willow variety. There are presently 24 certified EU varieties available. There are only about 10 of those in mainstream commercial use today. Approximately one – two new varieties are developed annually.

Contents

How to use this booklet

This booklet is the first definitive collation of short rotation coppice (SRC) willow varieties produced by UK and Swedish breeding programmes. All the principal varieties presented in this booklet are currently available and have been thoroughly tested in UK and Irish conditions over the last 10-15 years. Many have been grown commercially for at least a decade and have shown consistent yield and resistance to disease and pests.

Pedigrees

We have presented as definitive a pedigree as possible for each variety in some cases going back to great grand parents. The top parent, grand parent and great grand parent in the grid are female and the bottom is male.

Variety	Parents	Grand parents
Tora	L79069 *S. schwerinii* ♀	Unknown
		Unknown
	Orm ♂	L78195 *S. viminalis* ♀
		L78101 *S. viminalis* ♂

The colours in the grids give an indication of similarity between different varieties. There are several varieties that have common ancestry.

Colour code	Common ancestor(s)	Related varieties (currently available)	Related varieties (available 2013 onwards)
	S. viminalis L81102	*Beagle*, *Jorr*, *Endeavour*, *Inger*, *Tordis*	*Klara*, Roth Cotswold
	Bowles Hybrid	*Olof*, *Terra Nova*	*Klara*, *Meteor*
	S. schwerinii L79069 *and S. viminalis* Orm	*Olof*, *Resolution*, *Sven*, *Tora*, *Tordis*, *Torhild*	*Advance*, Dimitrios, *Klara*, Roth Chiltern, Roth Cotswold, Stina
	S. viminalis Jorunn	*Resolution*, *Sven*	
	S. viminalis Pavainen	*Advance*	Roth Chiltern

Mixtures

A farmer considering growing SRC in Ireland should be looking to grow at least six varieties in a mixed clonal plantation. It is important to choose a diverse mixture that has a wide genetic background as well as the potential for high yield and good quality wood chip. Maximum genetic diversity could be achieved by picking one variety each from the following six categories:

- *Olof* or *Resolution* or *Sven*
- *Tora* or *Torhild* or *Tordis*
- *Endeavour* or *Inger*
- *Gudrun*
- *Beagle* or *Jorr*
- *Terra Nova*

However, such a prescribed mixture may not produce maximum yield of the plantation. Nevertheless, there are a number of varieties with a common heritage and it would he a high risk strategy to pick a mixture comprising *Olof*, *Resolution*, *Sven*, *Tora, Torhild* and *Tordis*.

In order to make the choice easier there is a section for each variety which suggests possible partners in a mixed clonal plantation. Varieties coloured blue share some common ancestry whilst those coloured red are completely unrelated

Yields

For each variety yield results are presented from both the first and second rotation for Irish trials and all trials carried out in the UK. In some cases there have only been a couple of trials involving a certain variety in Ireland so the addition of yield information from other trials should provide a useful indication of its performance and iron out any extreme results.

Each variety is compared to the industry standard *Tora*. This variety was released in 1996 and has performed well in trial for 20 years. Each variety is given a % yield of *Tora* as well as a record of wins, losses and draws against *Tora* in all trials.

Quality issues

It is important to remember that yield isn't everything. The variety *Endeavour* has an average performance of 93% compared to *Tora*. However, it performs much better in fuel quality tests. At harvest chip produced from *Endeavour* has 7% more dry matter (i.e. 7% less moisture) and has 5% higher bulk density. This means that it should dry sooner, take up less space and require fewer vehicle movements. In addition, its

calorific value is 11% higher than *Tora* which means its wood chip has superior heat content.

There is still only limited information on the combustion characteristics of different willow varieties. The figures for bulk density, lignin and calorific value presented in this booklet are based on one study[1]. The intention is for Teagasc and AFBI to routinely test for dry matter and bulk density as part of ongoing yield evaluations. Further information on calorific values will be published in subsequent volumes. Further detailed information on growing willows can be obtained from the Willow Best Practise Guidelines which are available on the internet at http://www.teagasc.ie/publications/view_publication.aspx?PublicationID=314

SRC Variety Descriptions

Beagle

Breeding number: LA960326
Sex: Female
Pedigree:

Variety	Parents	Grandparents
Beagle	Astrid	L810203 *S. viminalis*
		L81102 *S. viminalis*
	S. viminalis	Unknown
		Unknown

Breeder: European Willow Breeding Partnership
Release date: 2001

Description

Leaves: Lance shaped, 15-19 cm long and 2-2.5 cm wide; silvery grey undersides, wavy margins with no teeth. Leaf stalks 1-1.5 cm long.
Stems: Downy grey at the tip becoming olive green. Grey white buds at tip.

Similarity to other varieties

In the genotype L81102, *Beagle* shares a common ancestry with the varieties *Jorr* and Ulv. It therefore shares a common grandparent with *Inger*, *Endeavour* and *Tordis*.

Possible partners in mixed clonal plantations

Olof or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Gudrun
Terra Nova

Yield results and comparison to industry standard (*Tora*)
From all trials planted in the UK *Beagle* has an overall mean yield of 9.46 odt/ha/yr. The best yields have been achieved in moist lowland areas in the west of England and Wales.

Typically *Beagle* is lower yielding than *Tora*. However, it does achieve a good yield in the first rotation but unlike most varieties does not increase its yield as much in subsequent harvests. In all UK and Irish trials it has an average performance of 88% of the yield of *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	2	2	3	3	0	0	**5**	**5**
Beagle	8.03	9.05	11.64	12.54	/	/	**10.20**	**11.14**
Tora	9.87	12.83	10.95	13.05	/	/	**10.52**	**12.96**
% of Tora	81%	71%	106%	96%	/	/	**97%**	**86%**
Trial results vs Tora (W- L-D)	0-4-0		3-3-0		0-0-0		**3-7-0**	

Typical Yield Parameters (first rotation)
First year height after cutback: 4 m
Number of shoots per stool: 8-10
Mean stem diameter at 1m: 1.3 cm

Climate conditions in which it has high/low productivity
As yet there is no data on the performance of *Beagle* in the east of England so we do not know how it fares in drier soils.

Susceptibility/resistance to diseases and pests
- Moderate susceptibility to leaf rust.
- The level of shoot tip damage caused by gall midges and lepidopterans is currently being researched.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form
97% strike rate from 20cm cuttings (365/378).

Fuel details

Avg. dry matter content:	48% (30 samples)
Bulk density:	157 kg/m^3
Lignin content:	19.7%
Calorific value:	17.7 MJ/kg
Ash content:	No information

Suitability for self supply
Beagle has a higher than average dry matter content at harvest so would be more suited to chip production than many varieties. It has a lower than average bulk density and therefore the chip would take up more storage space.

Endeavour

Breeding number: LA970164
Sex: Female
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Endeavour	Hilliers *Salix schwerinii*	Unknown	Unknown
			Unknown
		Unknown	Unknown
			Unknown
	Jorr	L820332	L78198 *S. viminalis*
			L81092 *S. viminalis*
		L81092 *S. viminalis*	Unknown
			Unknown

Breeder: European Willow Breeding Partnership
Release date: 2005

Description

Leaves: Very dark green. Lance shaped, 16-20 cm long and 2.5-3.5 cm wide; grey green undersides, wavy margins with no teeth. *Endeavour* loses its leaves by late October – earlier than other varieties.
Stems: Dark brown/black with down at the tip to olive green at base. Slightly bowing at the base.

Similarity to other varieties
Jorr is the male parent of both *Endeavour* and *Inger*. Also, in the genotype L81102, *Endeavour* shares a common grandparent with the varieties *Beagle* and *Tordis*.

Possible partners in mixed clonal plantations

Olof or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Gudrun
Inger
Beagle
Terra Nova

Yield results and comparison to industry standard (*Tora*)

From all trials planted in the UK *Endeavour* has an overall mean yield of 9.82 odt/ha/yr. Its best yields have been achieved in moist lowland areas in the west of England and Wales. It was also found to be one of the best performers at higher altitudes in Wales. It has topped the rankings on four occasions and been second three times.

Endeavour is one of the highest yielding varieties in the second rotation. On average its yield from the second harvest is 50% higher than the first. In Ireland, Wales and the west of England it performs well against *Tora*. In all UK and Irish trials it has an average performance of 93% of the yield of *Tora*. However, *Endeavour* has a significantly higher calorific value than *Tora* (10%) so in real terms it could be higher yielding than *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	2	1	3	3	4	0	**9**	**4**
Endeavour	8.79	11.87	10.11	14.35	8.47	/	**9.09**	**13.73**
Tora	11.13	10.27	10.13	13.76	10.14	/	**10.36**	**12.88**
% of Tora	79%	115%	100%	104%	84%	/	**88%**	**107%**
Trial results vs Tora (W- L-D)	1-1-1		3-2-1		1-3-0		**5-6-2**	

Typical Yield Parameters (first rotation)

First year height after cutback: 4.0 m
Number of shoots per stool: 4-8
Mean stem diameter at 1m: 1.5 cm

Climate conditions in which it has high/low productivity

Endeavour achieved its lowest yield in a trial on Orkney suggesting it might struggle to deal with high salinity.

Susceptibility/resistance to diseases and pests

- Very low incidence of leaf rust.
- Moderate susceptibility to leaf beetles.

Quality aspects

Endeavour cuttings have a lower moisture content than other varieties meaning that they could be more prone to drying out in storage or failing to establish in drier soils. Nevertheless, trial results indicate a high strike rate of 96% (372/388).

Fuel details

Avg. dry matter content:	51% (34 samples)
Bulk density:	179 kg/m^3
Lignin content:	19.4%
Calorific value:	18.6 MJ/kg
Ash content:	No information

Suitability for self supply

Endeavour has the highest dry matter content at harvest than all other commercial varieties. This means that it is more suitable for wood chip production than other varieties. In addition, *Endeavour* has a high bulk density and the highest calorific value of all the varieties tested. This means that wood chip will take up less storage space and burn for longer.

Gudrun

Breeding number: SW940598
Sex: Female
Pedigree:

Variety	Parents	Grandparents
Gudrun	Helga *S. dasyclados*	Unknown
		Unknown
	LV Rod *S. dasyclados*	Unknown
		Unknown

Breeder: Svalöf-Weibull AB
Release date: 1999

Description
Leaves: Broad leaves
Stems: Grey green and covered with fine hairs

Similarity to other varieties
Gudrun is not related to any currently available varieties. The mostly closely resembling variety is *Klara* which has the *S. dasyclados* variety Ivar as a grandparent.

Possible partners in mixed clonal plantations
Olof or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Beagle or *Jorr*
Terra Nova

Yield results and comparison to industry standard (*Tora*)
From all trials planted in the UK *Gudrun* has an overall mean yield of 9.33 odt/ha/yr. It has topped the rankings on three occasions. Its best yields have been achieved in moist lowland areas in Wales and Northern Ireland. It also ranked highly in altitude trials in Wales.

Gudrun is one of the highest yielding varieties in the second rotation. On average its yield from the second harvest is 57% higher than the first. In Ireland and Wales it performs well against *Tora*. In all UK trials containing *Gudrun* and *Tora* it has an average performance of 79% of the yield of *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	2	2	3	3	0	0	**5**	**5**
Gudrun	7.65	14.27	8.93	10.94	/	/	**8.42**	**12.27**
Tora	9.87	12.83	12.18	13.02	/	/	**11.26**	**12.94**
% of Tora	78%	111%	73%	84%	/	/	**75%**	**95%**
Trial results vs Tora (W- L-D)	2-1-1		1-5-0		0-0-0		**3-6-1**	

Typical Yield Parameters (first rotation)

First year height after cutback: 2.7 m
Number of shoots per stool: 5-8
Mean stem diameter at 1m: 1.6 cm

Climate conditions in which it has high/low productivity

Excellent tolerance to frost. As yet there is no trial data for *Gudrun* in the east of England so we do not know how it fares in drier soils.

Susceptibility/resistance to diseases and pests

- Almost completely free of leaf rust.
- Low level of shoot tip damage caused by gall midges and lepidopterans.
- Largely resistant/tolerant to leaf beetles.
- Preferred by browsing animals.

Quality aspects e.g. strike rate of cuttings, growing form

99% strike rate from 20cm cuttings (220/222). In the establishment year *Gudrun* is slower growing than other varieties so it is very important to keep the plantation free of weeds during the first year of cultivation.

Fuel details

Avg. dry matter content:	49% (28 samples)
Bulk density:	No information
Lignin content:	No information
Calorific value:	No information
Ash content:	No information

Suitability for self supply

There is less information available regarding the fuel quality of *Gudrun* than other varieties. However, the high dry matter of harvested wood means that it should dry more easily than other varieties.

Inger

Breeding number: SW950506
Sex: Female
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Inger	SW911066 *S. triandra*	Unknown	Unknown
			Unknown
		Unknown	Unknown
			Unknown
	Jorr	L820332	L78198 *S. viminalis*
			L81092 *S. viminalis*
		L 81102 *S. viminalis*	Unknown
			Unknown

Breeder: Svalöf-Weibull AB
Release date: 2001

Inger was produced from a cross between a willow collected from Siberia and the Swedish variety *Jorr*. The variety is more tolerant to dry conditions than other varieties. *Inger* is a good complement in mixed plantations as *Inger* has a different gene background than many other varieties. It has been observed that *Inger* is sensitive to Bank Vole damage.




Description

Leaves: Lance shaped, undersides, wavy margins with no teeth. *Inger* retains its leaves later into the year (similar to *Tordis*).

Stems: Grey-green and covered with fine hairs. Has side shoots but these tend to fall off during the growing season.

Similarity to other varieties

Inger's male parent is the variety *Jorr*. It is therefore a half sib of *Endeavour*. In the genotype L81102, *Inger* also shares a common grandparent with the varieties *Beagle* and *Tordis*. The only other variety with *S. triandra* in its background is *Terra Nova*.

Possible partners in mixed clonal plantations

Olof or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Endeavour
Gudrun
Beagle
Terra Nova

Yield results and comparison to industry standard (*Tora*)

From all trials planted in the UK and Ireland *Inger* has an overall mean yield of 9.38 odt/ha/yr. In most trials its performance has been middle ranking although it ranked second at one trial in Ireland.

In moist lowland areas in Wales and Northern Ireland it performs quite well against *Tora* but was lower yielding in altitude trials. In all UK trials containing *Inger* and *Tora* it has an average performance of 82% of the yield of *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	1	0	2	2	0	0	**3**	**2**
Inger	14.60	/	9.37	12.59	/	/	**11.11**	**12.59**
Tora	12.80	/	10.03	14.45	/	/	**10.95**	**14.45**
% of Tora	114%	/	93%	87%	/	/	**101%**	**87%**
Trial results vs Tora (W- L-D)	1-0-0		1-3-0		0-0-0		**2-3-0**	

Typical Yield Parameters (first rotation)

First year height after cutback: 4.2 m
Number of shoots per stool: 4-8
Mean stem diameter at 1m: 1.6 cm

Climate conditions in which it has high/low productivity
Although this variety has not been tested in the drier soils of the east of England it is believed that this variety performs well in such conditions.

Susceptibility/resistance to diseases and pests
- Low incidence of leaf rust.
- Medium level of shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form
98% strike rate from 20cm cuttings (201/206).

Fuel details

Avg. dry matter content:	47% (17 samples)
Bulk density:	176 kg/m^3
Lignin content:	17%
Calorific value:	16.6 MJ/kg
Ash content:	1.47-1.63%

Suitability for self supply
Inger has above average figures for dry matter content and bulk density so could be suitable for wood chip production. However, this variety has a low calorific value (5% lower than the average and 11% lower than *Endeavour*) so a greater quantity of wood chip would be required to provide the same heat output.

Jorr

Breeding number: SW880013
Sex: Male
Pedigree:

Variety	Parents	Grandparents
Jorr	L 820332	L78198 *S. viminalis*
		L81092 *S. viminalis*
	L 81102 *S. viminalis*	Unknown
		Unknown

Breeder: Svalöf-Weibull AB
Release date: 1996

Description
Leaves: Lance shaped, wavy margins with no teeth
Stems: Green with downy hairs on young shoots.

Similarity to other varieties
In the genotype L81102, *Jorr* shares a common parent with the old varieties Astrid and Ulv. It therefore shares a common ancestry with *Beagle*, *Endeavour* and *Tordis*. It is a grandparent of the variety *Klara*.

Possible partners in mixed clonal plantations
Olof or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Gudrun
Beagle
Terra Nova

Yield results and comparison to industry standard (*Tora*)
Jorr was first included in trials in 1992 and as a result the majority of results are based on an old plantation design which tended to exacerbate competition effects. As a result the best varieties produced higher yields at the expense of the weaker

ones. From all trials (new and old) planted in the UK, *Jorr* has an overall mean yield of 9.95 odt/ha/yr. Its best yields have been achieved in moist lowland areas in the west of England and Wales.

Typically *Jorr* is lower yielding than *Tora*. In all UK trials it has an average performance of 70% of the yield of *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	2	2	5	3	3	2	**10**	**7**
Jorr*	11.48	11.47	8.30	10.15	7.60	10.09	**8.73**	**10.51**
Tora*	13.63	16.73	12.68	15.29	10.19	14.13	**12.12**	**15.37**
% of Tora	84%	69%	65%	66%	75%	71%	**72%**	**68%**
Trial results vs Tora (W- L-D)	0-4-0		0-7-1		0-5-0		**0-16-1**	

Typical Yield Parameters (first rotation)
Number of shoots per stool: 6-10
Mean stem diameter at 1m: 1.2 cm

Climate conditions in which it has high/low productivity
Relatively susceptible to frost.

Susceptibility/resistance to diseases and pests
- Moderately susceptible to leaf rust. Often shows stem cankering caused by the stem infecting form of rust.
- Medium level of shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form
Straight stems.
Typically high strike rate.

Fuel details

Avg. dry matter content:	46% (35 samples)
Bulk density:	No information
Lignin content:	No information
Calorific value:	No information
Ash content:	No information

Suitability for self supply
There is little information available on the combustion qualities of *Jorr*. It generally has thinner stems than other varieties and therefore the bark:wood ratio is likely to be high causing a high ash content. It is possible that the wood has a high calorific value as bark tends to be higher in lignin. In addition, cankering caused by rust tends to increase the proportion of lignin in the wood which in turn leads to higher calorific values.

Olof

Breeding number: SW930387
Sex: Male
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Olof	Bowles Hybrid *S. viminalis*	Unknown	Unknown
			Unknown
		Unknown	Unknown
			Unknown
	Bjorn	L79069 *S. schwerinii*	Unknown
			Unknown
		Orm	L78195 *S. viminalis*
			L78101 *S. viminalis*

Breeder: Svalöf-Weibull AB
Release date: 1998

Olof is a cross between the old varieties Bowles Hybrid and Björn. *Olof* has lancet shaped leaves and a straight stem with few shoots similar to *Tora*. It is sometimes branched and has displayed a good resistance to leaf rust.

Description
Leaves: Lance shaped, wavy margins with no teeth. Leaves are slightly twisted at the tips of the stem.
Stems: Straight stems. More branched than other varieties. Large yellow buds at tip covered by swollen yellow leaf stalks.

Similarity to other varieties
Olof's parents Bowles Hybrid and Björn have been used extensively in breeding. *Olof* has two half siblings: *Meteor* and *Sven*. It also shares a common grandparent with the varieties *Resolution*, *Tora*, *Torhild*, *Tordis* and *Terra Nova*.

Possible partners in mixed clonal plantations
Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Gudrun
Beagle or *Jorr*
Terra Nova

Yield results and comparison to industry standard (*Tora*)

Olof seems to do much better in the lowland areas of Wales and West England. In these trials it has frequently outyielded *Tora*. The yields attained in Ireland have been much lower. From all trials planted in the UK *Olof* has an overall mean yield of 10.80 odt/ha/yr. From twenty results it has been the top ranking variety on four occasions and second three times. In all UK and Irish trials *Olof* has achieved a mean yield of 90% compared to *Tora*.

Typical Yield Parameters (first rotation)

First year height after cutback:	4.6 m
Number of shoots per stool:	4-7
Mean stem diameter at 1m:	1.5 cm

Climate conditions in which it has high/low productivity

Relatively susceptible to frost.

Susceptibility/resistance to diseases and pests

- Low incidence of leaf rust.
- Low-medium level of shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	4	3	5	4	4	1	**13**	**8**
Olof	9.13	8.88	12.36	12.58	7.88	11.39	**9.99**	**11.04**
Tora	11.15	13.16	11.83	12.71	7.76	11.95	**10.37**	**12.78**
% of Tora	82%	67%	104%	99%	102%	95%	**96%**	**86%**
Trial results vs Tora (W- L-D)	0-6-1		6-3-0		3-2-0		**9-11-1**	

Quality aspects e.g. strike rate of cuttings, growing form
Slightly wavy stems and somewhat side branched. 92% strike rate from 20cm cuttings (367/400).

Fuel details

Avg. dry matter content:	45% (25 samples)
Bulk density:	161 kg/m^3
Lignin content:	18.5%
Calorific value:	17.7 MJ/kg
Ash content:	No information

Suitability for self supply
The wood chip produced from *Olof* is wetter at harvest than many varieties which makes it more problematic to dry. It also has a lower bulk density which means chip will take up more storage space. The calorific value of the wood is average.

Resolution

Breeding number: LA980414
Sex: Female
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Resolution	SW930812	Jorunn	N81102 *S. viminalis*
			L830201 *S. viminalis*
		Bjorn	L79069 *S. schwerinii*
			Orm *S. viminalis*
	Quest	Pavainen *S. viminalis*	Unknown
			Unknown
		Björn	L79069 *S. schwerinii*
			Orm *S. viminalis*

Breeder: European Willow Breeding Partnership
Release date: 2002

Description
Leaves: Lance shaped, 17-22 cm long and 1.5-2 cm wide; greyish green undersides, wavy margins with no teeth. Leaf stalks 1.5-2 cm long. Relatively low leaf area index of (1.20). Leaves turn mustard yellow in autumn.
Stems: Slightly wavy but less than *Resolution*. Downy light brown at tip grading through chestnut brown to dark olive at the base. Light pink buds at tip.

Similarity to other varieties

This variety is a complex hybrid. The male parent 'Quest' is a sibling of the variety '*Advance*' whilst the female parent SW930812 is a sibling of *Sven*. As a result of this heritage *Resolution* has common grandparents in the old varieties Jorunn and Björn. It shares great grand parents with *Tora*, *Torhild*, *Tordis* and therefore is more distantly related to these varieties.

Possible partners in mixed clonal plantations

Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Gudrun
Beagle or *Jorr*
Terra Nova

Yield results and comparison to industry standard (*Tora*)

Resolution has performed well in all regions with an overall mean yield of 10.60 odt/ha/yr. From 24 results it has topped the rankings seven times with two second places. It has produced its highest yields in the lowland areas of west England and Wales but also has an above average yield in the drier east. It tends to produce very high yields in the first rotation and although there is a general yield increase in the second harvest it is slightly lower than other varieties. *Resolution* has performed well against *Tora* and in all trials has a relative yield of 97% compared to the industry standard.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	4	1	6	5	7	1	**17**	**7**
Resolution	10.46	8.05	11.86	14.13	9.40	10.41	**10.53**	**12.73**
Tora	11.80	10.27	11.19	14.44	8.91	11.95	**10.22**	**13.49**
% of Tora	89%	78%	106%	98%	105%	87%	**103%**	**94%**
Trial results vs Tora (W- L-D)	1-4-0		6-4-1		5-3-0		**12-11-1**	

Typical Yield Parameters (first rotation)

First year height after cutback:	4.6 m
Number of shoots per stool:	3-6
Mean stem diameter at 1m:	1.6 cm

Climate conditions in which it has high/low productivity

Resolution has performed well in most locations. It has ranked well in the drier soils of the east of England.

Susceptibility/resistance to diseases and pests

- Very low incidence of to leaf rust.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form

94% strike rate from 20cm cuttings (483/516).

Fuel details

Avg. dry matter content:	47% (42 samples)
Bulk density:	161 kg/m^3
Lignin content:	16.1%
Calorific value:	16.8 MJ/kg
Ash content:	No information

Suitability for self supply

Resolution has a medium dry matter content at harvest so drying the wood chip should be easier than with some varieties. However, the chip has a low bulk density so will take up more storage space and the calorific value of the wood is below average so a greater quantity of wood chip would be required to provide the same heat output.

Sven

Breeding number: SW930824
Sex: Male
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Sven	Jorunn	N81102 *S. viminalis*	Unknown
			Unknown
		L830201	L78090 *S. viminalis*
			L78013 *S. viminalis*
	Björn	L79069 *S. schwerinii*	Unknown
			Unknown
		Orm *S. viminalis*	L78195 *S. viminalis*
			L78101 *S. viminalis*

Breeder: Svalöf-Weibull AB
Release date: 1997

Description
Sven is a cross between the varieties Jorunn and Björn. *Sven* has lancet shaped leaves and a straight stem and few shoots similar to *Tora*. The variety has a high yield and has displayed good resistance to leaf rust.

Leaves: Lance shaped; wavy margins with no teeth. Leaves are very erect on the stem.
Stems: straight stems, few in number.

Similarity to other varieties

Sven is most closely related to its half sib *Olof* and its nephew *Resolution*. It shares grand parents with *Tora*, *Torhild*, *Tordis* and therefore is more distantly related to these varieties.

Possible partners in mixed clonal plantations

Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Gudrun
Beagle or *Jorr*
Terra Nova

Yield results and comparison to industry standard (*Tora*)

Sven has yielded well in both Ireland and the West of England and Wales. Like *Resolution* it produces excellent first harvest yields but there is less of an increase in the second harvest than other varieties. From all trials planted in the UK and Ireland *Sven* has an overall mean yield of 11.02 odt/ha/yr. From 23 results *Sven* has been top ranked five times and second on four occasions. In all trials it has an overall yield of 96% compared to *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	5	2	6	4	5	1	**16**	**7**
Sven	11.81	12.96	11.80	13.25	8.12	12.68	**10.65**	**13.09**
Tora	12.62	13.97	11.20	13.53	8.28	11.95	**10.73**	**13.43**
% of Tora	94%	93%	105%	98%	98%	106%	**99%**	**97%**
Trial results vs Tora (W- L-D)	4-3-0		6-3-1		3-2-1		**13-8-2**	

Climate conditions in which it has high/low productivity

Relatively susceptible to frost.

Susceptibility/resistance to diseases and pests

- Almost completely free of leaf rust.
- High level of shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form
Excellent upright form. 93% strike rate from 20cm cuttings (327/350).

Fuel details

Avg. dry matter content:	44% (23 samples)
Bulk density:	184 kg/m^3
Lignin content:	20.7%
Calorific value:	16.9 MJ/kg
Ash content:	1.1% - 2.9%

Suitability for self supply
The wood chip of *Sven* has a higher moisture content than other varieties so will be more difficult to dry. Furthermore, it has a below average calorific value so more wood chip will be required for the same output. However, it has the highest bulk density so less space will be required to store the fuel.

Terra Nova

Breeding number: LA980132
Sex: Female
Pedigree:

Variety	Parents	Grandparents
Terra Nova	LA940140	Bowles Hybrid *S. viminalis*
		Dark Newkind *S. triandra*
	Shrubby Willow *S. miyabeana*	Unknown
		Unknown

Breeder: European Willow Breeding Partnership
Release date: 2005

Description
Leaves: Lance shaped, 14-18 cm long and 3-4 cm wide; green undersides with prominent veins, toothed margin. Relatively high leaf area index of (1.93). Keeps its leaves late into season (December).
Stems: Downy grey at tips grading through dark yellowy green to deep orange red at base. Buds are yellow at top and orange/red lower down the stem.



Similarity to other varieties
With Bowles Hybrid as its female grandparent *Terra Nova* is related as a nephew to *Olof* and Meteor. The only other variety with *S. triandra* in its background is *Inger*.

Possible partners in mixed clonal plantations

Olof or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Gudrun
Beagle or *Jorr*

Yield results and comparison to industry standard (*Tora*)

Terra Nova is one of the lowest yielding varieties with an overall mean yield of 8.71 odt/ha/yr. In all UK and Irish trials it has an overall yield of 80% compared to *Tora*. Nevertheless, *Terra Nova* performs best in more difficult conditions where other more productive varieties struggle. For instance, in altitude trials in Wales conducted at sites 228 and 296 metres above sea level, *Terra Nova* had the highest average yield of currently available varieties. Similarly in the drier soils of eastern England, it has produced above average yields, ranking third behind *Resolution* and *Tora* of the currently available varieties.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	3	1	4	4	5	1	**12**	**6**
Terra Nova	10.43	6.50	7.73	9.09	9.09	9.11	**8.97**	**8.66**
Tora	11.69	10.27	10.81	14.31	9.81	11.95	**10.61**	**13.24**
% of Tora	89%	63%	72%	64%	93%	76%	**85%**	**65%**
Trial results vs Tora (W- L-D)	1-3-0		0-8-0		1-5-0		**2-16-0**	

Typical Yield Parameters (first rotation)

First year height after cutback: 3.7 m
Number of shoots per stool: 5-10
Mean stem diameter at 1m: 1.4 cm

Climate conditions in which it has high/low productivity

Interest is being shown in *Terra Nova* by Southern European growers following successful trials in Portugal and Spain.

Susceptibility/resistance to diseases and pests

- Resistant to leaf rust.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form

95% strike rate from 20cm cuttings (416/438).

Fuel details

Avg. dry matter content:	45 % (39 samples)
Bulk density:	170 kg/m^3
Lignin content:	23.3%
Calorific value:	18.4 MJ/kg
Ash content:	1.39-2.45%

Suitability for self supply

Terra Nova has one of the highest calorific values (10% higher than *Tora*) which goes some way to compensating for it's lower than average yield. It has average performance for bulk density and dry matter. By having many, thinner shoots it has a higher bark:wood ratio and therefore also has higher ash content. *Terra Nova* retains its leaves later into the Autumn than other varieties so could be problematic with early harvesting.

Any general information on its use as biofilter or in bioremediation

There is some unpublished data that suggests that *Terra Nova* can perform well on sites contaminated with heavy metals. It was found to maintain relatively high yields (over 9 odt/ha/yr) and was particularly useful in taking up cadmium from the soil.

Tora

Breeding number: SW910007
Sex: Female
Pedigree:

Variety	Parents	Grandparents
Tora	L79069 *S. schwerinii*	Unknown
		Unknown
	Orm	L78195 S. *viminalis*
		L78101 S. *viminalis*

Breeder: Svalöf-Weibull AB
Release date: 1996

Tora originates from a cross between a Siberian basket willow and a Swedish variety called Orm. The variety has long shoots but less number of stems than other varieties. From the Swedish variety perspective *Tora* is considered the most sustainable high yielding variety in various climatic conditions with the exception of very warm climates. *Tora* is almost free from leaf rust attack from gall midges and other insects damaging the shoot tips are less common.

Description
Leaves: Dark green, glossy leaves; lance shaped, 20-22 cm long and 2-2.5 cm wide; greyish green undersides, wavy margins with no teeth. Leaf stalk 2 cm long, swollen at the base. Relatively low leaf area index of (1.26)

Stems: Slightly wavy (a feature that it inherits from a variety Orm). Unequal size stems –some are thick whilst others are thinner. Dark olive at the tip grading to light olive at base. Less downy at tips than *Resolution*. White buds.

Similarity to other varieties

The variety *Tora* and its sibling Bjorn have been used extensively in plant breeding programmes in both Sweden and the UK. *Tora* is the female parent of *Tordis* and *Torhild*. Björn is the male parent of *Sven* and *Olof* and grandparent of *Resolution*.

Possible partners in mixed clonal plantations

Olof or *Resolution* or *Sven*
Endeavour or *Inger*
Gudrun
Beagle or *Jorr*
Terra Nova

Yield results

Tora has produced consistently high yields in all regions. From all trials planted in the UK and Ireland *Tora* has an overall mean yield of 11.05 odt/ha/yr. From 49 results it has ranked first in seven trials and second 19 times. It also has produced higher than average yields in altitude trials in Wales and exposure trials on Orkney. *Tora* has an exceptional record against the other currently available varieties. Although, it has been out yielded in the first rotation on many occasions it typically yields higher in its second rotation. For overall combined yield across all sites and years it is most closely matched by *Resolution* (97%), *Sven* (96%), *Endeavour* (93%) and *Tordis* (93%).

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	9	7	13	10	9	1	**31**	**18**
Tora	10.90	12.44	11.23	13.14	9.10	11.95	**10.52**	**12.80**
Trial results vs all other available varieties (W-L-D)	31-15-4		67-43-4*		24-16-2		122-74-10	

*Includes altitude trials in Wales

Typical Yield Parameters (first rotation)

First year height after cutback:	4 m
Mean number of shoots per stool:	3-6
Mean stem diameter at 1m:	1.6 cm

Climate conditions in which it has high/low productivity

Medium tolerance to frost.

Susceptibility/resistance to diseases and pests

- Resistant to leaf rust.
- Low -medium level of shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.
- Less preferred by browsing mammals.

Quality aspects e.g. strike rate of cuttings, growing form

95% strike rate from 20cm cuttings (706/742).

Fuel details

Avg. dry matter content:	44% (129 samples)
Bulk density:	171 kg/m^3
Lignin content:	21.3%
Calorific value:	16.8 MJ/kg
Ash content:	1.5%

Suitability for self supply

Tora has a higher moisture content at harvest than most other varieties. This means it is particularly bulky when freshly cut and will be more difficult to dry. It has an average bulk density but has a low calorific value. As a result more chip will be required to produce the same heat output.

Tordis

Breeding number: SW960299
Sex: Female
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Tordis	*Tora*	L79069 *S. schwerinii*	Unknown
			Unknown
		Orm	L78195 *S. viminalis*
			L78101 *S. viminalis*
	Ulv	Rot7 *S. viminalis*	Unknown
			Unknown
		L81102 *S. viminalis*	Unknown
			Unknown

Breeder: Svalöf-Weibull AB
Release date: 2000

Tordis is a cross between the varieties *Tora* and Ulv. *Tordis* has a high yield and has not shown much damage from leaf rust. *Tordis* seems to be one of the best varieties both for cutting production and in productivity of biomass.

Description

Leaves: Lance shaped, greyish green undersides, wavy margins with no teeth. The leaves turn yellow in autumn and persist on the stems longer than other similar varieties

Stems: Stems are straight and tend to be of equal thickness.

Similarity to other varieties

Tordis is most closely related to *Tora* (its female parent) and *Torhild* a half sibling. The new variety Roth Cotswold is a cross between *Tordis* and Björn. *Tordis* is also closely related with *Sven* and *Olof* (first cousins) and *Resolution* (first cousin once removed albeit as a result of the pairing of two half siblings). Another new variety Roth Chiltern is a cross between Discovery and Quest and therefore also has this relationship. In the genotype L81102 *Tordis* shares a common heritage with the varieties *Jorr*, *Beagle Inger*, and *Endeavour*.

Possible partners in mixed clonal plantations

Olof or *Resolution* or *Sven*
Endeavour or *Inger*
Gudrun
Terra Nova

Yield results and comparison to industry standard (*Tora*)

Tordis has achieved its highest yields in the lowland areas of the west of England and Wales. It has also performed well in Ireland although there is limited data from second harvests. From all trials planted in the UK and Ireland *Tordis* has an overall mean yield of 10.13 odt/ha/yr. From 17 harvests *Tordis* has topped the rankings on four occasions and been second on six occasions. On good arable land *Tordis* is a very good match for *Tora* but fares less well on more exposed sites. As a result when all UK trials are considered *Tordis* has an overall yield of 93% compared to *Tora*.

Typical Yield Parameters (first rotation)

First year height after cutback:	4.0 m
Number of shoots per stool:	3-6
Mean stem diameter at 1m:	1.6 cm

Climate conditions in which it has high/low productivity

Performs well in dry soils.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	4	1	4	4	3	1	**11**	**6**
Tordis	13.15	9.30	10.59	13.42	7.74	9.69	**10.74**	**12.11**
Tora	12.41	11.70	10.65	14.19	7.28	11.95	**10.37**	**13.40**
% of Tora	106%	79%	99%	95%	106%	81%	**104%**	**90%**
Trial results vs Tora (W- L-D)	2-3-0		4-4-0		2-1-1		**8-8-1**	

Susceptibility/resistance to diseases and pests

- Very low incidence of leaf rust.
- Medium level of shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form

99% strike rate from 20cm cuttings (357/360).

Fuel details

Avg. dry matter content:	45% (24 samples)
Bulk density:	138 kg/m^3
Lignin content:	20.6%
Calorific value:	17.7 MJ/kg
Ash content:	No information

Suitability for self supply

Tordis has a significantly lower bulk density than any of the other varieties tested. This means that the wood chip would take up a much greater storage space. It has a slightly higher dry matter than *Tora* and an above average calorific value.

Torhild

Breeding number: SW930725
Sex: Female
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Torhild	*Tora*	L79069 *S. schwerinii*	Unknown
			Unknown
		Orm	L78195 *S. viminalis*
			L78101 *S. viminalis*
	Orm	L78195 *S. viminalis*	Unknown
			Unknown
		L78101 *S. viminalis*	Unknown
			Unknown

Breeder: Svalöf-Weibull AB
Release date: 1997

Torhild is a cross between the varieties *Tora* and Orm. *Torhild* has lancet shaped leaves and a straight stem with few shoots similar to *Tora*.

Description
Leaves: Lance shaped, greyish green undersides, wavy margins with no teeth.
Stems: Straight stems but not as thick as *Tora*.

Similarity to other varieties
Torhild is most closely related to *Tora* (its female parent) and *Tordis* (a half sibling). *Torhild* is also closely related with *Sven* and *Olof* (first cousins) and *Resolution* (first cousin once removed albeit as a result of the pairing of two half siblings).

Possible partners in mixed clonal plantations
Olof or *Resolution* or *Sven*
Endeavour or *Inger*
Gudrun
Beagle or *Jorr*
Terra Nova

Yield results and comparison to industry standard (*Tora*)

Torhild is the lowest yielding of the varieties with a Björn/*Tora* heritage. In all UK and Irish trials it has an overall mean yield of 9.50 odt/ha/yr with its best results in Ireland. From 18 results it has zero first places and three second places. On good arable land it generally yields 12% less than *Tora* but the difference is extenuated on more exposed sites. As a result in all trials it has a yield of 82% compared to *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	4	2	5	4	3	1	**12**	**7**
Torhild	10.39	12.89	8.99	12.21	8.26	8.25	**9.27**	**11.84**
Tora	12.70	13.97	10.87	13.53	9.36	11.95	**11.10**	**13.43**
% of Tora	82%	92%	83%	90%	88%	69%	**83%**	**88%**
Trial results vs Tora (W- L-D)	3-3-0		0-9-0		0-4-0		**3-16-0**	

Typical Yield Parameters (first rotation)

Number of shoots per stool: 3-6

Climate conditions in which it has high/low productivity

Relatively susceptible to frost.

Susceptibility/resistance to diseases and pests

- Very low incidence of leaf rust.
- Medium-high level of shoot tip shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form

Excellent upright form. 95% strike rate from 20cm cuttings (332/350).

Fuel details

Avg. dry matter content:	44% (23 samples)
Bulk density:	169 kg/m^3
Lignin content:	19.4 %
Calorific value:	17.6 MJ/kg
Ash content:	1.1 %

Suitability for self supply

Like *Tora*, *Tordis* and *Sven*, *Torhild* has a low dry matter so it will be more difficult to dry. It has average results for bulk density and calorific value but has a lower proportion of ash in the fuel.

New & Emerging Varieties

Advance

Breeding number: LA960226
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Advance	Pavainen *S. viminalis*	Unknown	Unknown
			Unknown
		Unknown	Unknown
			Unknown
	Bjorn	L79069 *S. schwerinii*	Unknown
			Unknown
		Orm *S. viminalis*	L78195 *S. viminalis*
			L78101 *S. viminalis*

Breeder: European Willow Breeding Partnership
Release date: Possibly in 2014

Description
Leaves: Lance shaped, 12-16 cm long and 1-2.5cm wide; greyish green undersides, wavy margins with no teeth.
Stems: Olive green stems with chestnut buds.

Similarity to other varieties
This variety shares a common ancestry with the old variety Quest. In having Bjorn as its male parent it is closely related to the varieties *Sven*, *Resolution*, *Olof* and the future release Roth Chiltern. Björn is a sibling of *Tora* so *Advance* is more distantly related to *Torhild* and *Tordis*.

Possible partners in mixed clonal plantations

Tora or *Torhild* or *Tordis*
Endeavour or *Inger*
Gudrun
Klara
Beagle or *Jorr* or Meteor
Terra Nova

Yield results and comparison to industry standard (*Tora*)

Advance is a new variety and there is only limited trial data. In the two trials in Northern Ireland and Bristol is has shown high productivity. From all trials planted in the UK *Advance* has an overall mean yield of 11.95 odt/ha/yr. Typically *Advance* is lower yielding than *Tora*. In all UK trials it has an average performance of 87% of yield of *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	0	1	0	1	1	1	**1**	**3**
Advance	/	14.11	/	14.44	10.62	8.63	**10.62**	**12.39**
Tora	/	18.06	/	14.47	14.86	7.91	**14.47**	**13.48**
% of Tora	/	78%	/	100%	71%	109%	**71%**	**92%**
Trial results vs Tora (W- L-D)	0-1-0		0-0-1		1-1-0		**1-2-1**	

Typical Yield Parameters (first rotation)

First year height after cutback: 4.2 m

Climate conditions in which it has high/low productivity

Advance has only been tested on good arable land where it has performed well. As with most other varieties it has performed best in the wetter west compared to the dry east.

Susceptibility/resistance to diseases and pests

- Low susceptibility to leaf rust.
- Moderate susceptibility to leaf beetles.

Fuel details
Avg. dry matter content: 49 % (6 samples)

Suitability for self supply
There is a suggestion that *Advance* has a higher than average dry matter at harvest although this needs to be verified by more sampling. This means that wood chip could be easier to dry. There is as yet no information on combustion characteristics.

Endurance

Breeding number: LA980442
Sex: Female
Pedigree:

Variety	Parents	Grandparents
Endurance	*S. redheriana*	Unknown
		Unknown
	S. dasyclados 77056	Unknown
		Unknown

Breeder: European Willow Breeding Partnership
Release date: Possibly in 2015

Description
Leaves: Dark green and broadly lance shaped, 17-19 cm long and 4-5 cm wide; downy grey undersides, wavy margins with no teeth. *Endurance* loses its leaves in December which is later than other varieties.
Stems: Green with downy grey hairs.

Similarity to other varieties
Endurance comes from a unique cross between the Asian species *S. redheriana* and the European *S. dasyclados*. The closest related varieties to *Endurance* are *Gudrun* and *Klara* which also have *S. dasyclados* in their parentage. The old varieties Ashton Stott and Ashton Parfitt were derived from a cross with a similar male *S. dasyclados* clone.

Possible partners in mixed clonal plantations
Advance or *Olof* or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Gudrun
Klara
Beagle or Meteor
Terra Nova

Yield results and comparison to industry standard (*Tora*)

From all trials planted in the UK *Endurance* also has the highest mean overall yield of 11.53 odt/ha/yr. *Endurance* has the highest mean yield for performance in the second rotation with 14.3 odt/ha/yr. On average its yield from the second harvest is 35% higher than the first. From 20 trials it has topped the rankings on eight occasions and been second on two occasions.

Endurance is the only variety that consistently outyields *Tora* in most trial sites. In all UK trials containing *Endurance* and *Tora* it has an average performance of 106 % of the yield of *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	**1st**	**2nd**
No of trials	4	1	4	3	7	1	**15**	**5**
Endurance	10.80	14.59	12.03	14.53	9.63	13.43	**10.60**	**14.32**
Tora	11.80	10.27	11.29	13.78	8.86	11.95	**10.39**	**12.71**
% of Tora	92%	142%	107%	105%	109%	112%	**102%**	**113%**
Trial results vs Tora (W- L-D)	2-2-1		6-1-0		5-2-1		**13-5-2**	

Typical Yield Parameters (first rotation)

First year height after cutback: 4.3 m
Number of shoots per stool: 8-9
Mean stem diameter at 1m: 1.64 cm

Climate conditions in which it has high/low productivity

Endurance has achieved high yields in all locations tested. Although its best yields have been in Ireland and the West of England and Wales it is also the best performer in the drier soils in the East of England. It has not been tested at altitude or on Orkney.

Susceptibility/resistance to diseases and pests

- Resistant to leaf rust.
- Low susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form

In most trials *Endurance* has achieved a good establishment with 93% establishment. However, in two trials it has only achieved 52-54% establishment. *Endurance* retains its leaves later than any other variety (usually December) so could be problematic with early harvesting.

Fuel details

Avg. dry matter content:	50 % (27 samples)
Bulk density:	172 kg/m^3
Lignin content:	21.6 %
Calorific value:	18.3 MJ/kg
Ash content:	No information

Suitability for self supply

Endurance has a high % dry matter content at harvest meaning that it should be more suitable for wood chip production than other varieties. In addition, it has a higher than average bulk density and one of the highest calorific values of the varieties tested. This means that wood chip will take up less storage space and burn for longer.

Klara

Breeding number: SW010350
Sex: Female
Pedigree:

Variety	Parents	Grandparents	Great Grandparents
Klara	SW__	SW__	SW911310
			Jorr
		Ivar *S. dasyclados*	Unknown
			Unknown
	SW__	Bowles Hybrid	Unknown
			Unknown
		Bjorn	L79069 *S. Schwerinii*
			Orm *S. Viminalis*

Breeder: Svalöf-Weibull AB
Release date: 2008

Klara has a genetic background that combines a Russian willow collected from the area of Kirov and a Swedish breeding line. The variety has narrow leaves like *Tora*. *Klara* is very frost tolerant. Based on Swedish yields *Klara* seems to be the higher yielding than any other of the frost tolerant varieties.

Similarity to other varieties
Klara is a complex hybrid with the varieties Bowles Hybrid, Björn and *Jorr* in its pedigree. As a result it shares a similar ancestry with almost all of the varieties: *Olof*, *Terra Nova* and Meteor (Bowles Hybrid is the female parent); *Endeavour* and *Inger* (*Jorr* is the male parent) and *Sven*, *Advance* and *Resolution* (Björn is the male parent and grandparent). *Klara* also shares a common grandparent with *Beagle* and *Tordis* and *Torhild*.

Yield results and comparison to industry standard (*Tora*)
This variety has not as yet been trialled in the UK.

Meteor

Breeding number: LA960444
Sex: Unknown
Pedigree:

Variety	Parents	Grandparents
Meteor	Bowles Hybrid	Unknown
		Unknown
	S. viminalis	Unknown
		Unknown

Breeder: European Willow Breeding Partnership
Release date: Possibly in 2014

Description
Leaves: Lance shaped, 15-19 cm long and 1-2 cm wide; silvery grey undersides, wavy margins with no teeth.
Stems: Olive green stems. Very erect habit.



Similarity to other varieties
With Bowles Hybrid as its female parent *Meteor* is a half sibling (step sister) of *Olof*. It is much more distantly related to *Klara* and *Terra Nova*.

Possible partners in mixed clonal plantations
Advance or *Resolution* or *Sven*
Tora or *Tordis* or *Torhild*
Endeavour or *Inger*
Gudrun
Klara
Beagle or *Jorr*
Terra Nova

Yield results and comparison to industry standard (*Tora*)

Meteor is a new variety and as a result there is only limited trial data. Its best yield was recorded at a trial in Bristol. *Meteor* has an overall mean yield of 12.05 odt/ha/yr. In all UK trials it has an average performance of 87% of the yield of *Tora*.

	N & S Ireland		W of England & Wales		E of England		Overall	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
No of trials	0	1	0	1	1	1	**1**	**3**
Meteor	/	9.88	/	16.01	10.18	12.13	**10.18**	**12.67**
Tora	/	18.06	/	14.47	7.91	14.86	**7.91**	**15.80**
% of Tora	/	55%	/	111%	129%	82%	**129%**	**80%**
Trial results vs Tora (W- L-D)	0-1-0		1-0-0		1-1-0		**2-2-0**	

Typical Yield Parameters (first rotation)

First year height after cutback: 3.7 m

Susceptibility/resistance to diseases and pests

- Moderate susceptibility to leaf rust.
- Low level of shoot tip damage caused by gall midges and lepidopterans.
- Moderate susceptibility to leaf beetles.

Quality aspects e.g. strike rate of cuttings, growing form

Excellent upright growing form. 100% strike rate from 20cm cuttings (78/78).

Fuel details

Avg. dry matter content: 48% (10 samples)

Suitability for self supply

Meteor has a higher than average dry matter content at harvest so would be more suited to chip production than many varieties. Having many, thinner stems means a higher bark:wood ratio is likely which could result in a higher ash content of the fuel.

Summary of New and Outclassed Varieties

Advance (EWBP)
Pedigree: *S. viminalis* Pavainen x Björn (*S. schwerinii* 79069 x *S. viminalis* Orm)
Only one trial result suggests good performance in Irish conditions. Similar parentage to many other varieties. Possibly available 2014.

Dimetrios (SW)
Pedigree: *Tora* (*S. schwerinii* 79069 x *S. viminalis* Orm) x *S. aegyptiaca*
Not yet tested in Ireland.

Endurance (EWBP
Pedigree: *S. redheriana* x *S. dasyclados* 77056
Disease resistant variety with excellent yields in both Northern and Southern Ireland. Might be available from 2015.

Klara
Pedigree: (*S. viminalis* x *S. dasyclados) x* (*S. viminalis* Bowles Hybrid x Björn (*S. schwerinii* 79069 x *S. viminalis* Orm)
Not yet tested in Ireland.

Lisa
Lisa, one of the newest varieties it combines the genetic background from *Tordis* and *Olof*. It is also a more narrow leaf variety like *Tora*. Lisa has shown good yielding capacity also under warmer conditions like in Northern Italy and hence seems more adapted for growing regions in Central Europe.
Pedigree: *Tordis* (*S. schwerinii* 79069 x *S. viminalis* Orm) X *Olof* (*S. viminalis*)

Meteor (EWBP)
Pedigree: *S. viminalis* Bowles Hybrid x *S. viminalis*
Variety with excellent upright habit ideally suited for harvesting. Only one trial result suggests average performance in Irish conditions. Possibly available 2013.

Roth Chiltern (RR)
Pedigree: Discovery (*S. schwerinii* Hilliers x Björn (*S. schwerinii* 79069 x *S. viminalis* Orm) x Quest (*S. viminalis* Pavainen x Björn (*S. schwerinii* 79069 x *S. viminalis* Orm))
Only one trial result suggests good performance in Irish conditions. Similar to many other varieties. Possibly available 2013.

Roth Cotswold (RR)
Pedigree: *Tordis* (*S. schwerinii* 79069 x *S. viminalis* Orm) x *S. viminalis* Ulv) x Björn (*S. schwerinii* 79069 x *S. viminalis* Orm)
Only one trial result suggests good performance in Irish conditions. Similar parentage to many other varieties. Possibly available 2013.

Stina (SW)
Pedigree: *Torhild* ((*S. schwerinii* 79069 x *S. viminalis* Orm) x *S. viminalis* Orm)) x *S. aegyptiaca*
Stina was developed to be a variety better adapted for warmer and drier conditions. More details have yet to be collected to confirm expectations.
Not yet tested in Ireland.

Outclassed varieties
Several varieties have now been removed from the marketplace by crop developers. This is due to poor yields, breakdown in resistance to disease and pests, difficulties of producing good quality rods for machine planting (e.g. excessive side branching, wavy stems or terminal bud damage by pests) and other crop management issues.

Variety	Yield	Susceptibility to disease	Susceptibility to pests	Issues with multiplication	Planting/ harvesting issues
Orm					•
Jorunn	•	•			•
Björn				•	•
Sherwood			•	•	
Karin	•				
Ashton Stott		•			•
Ashton Parfitt		•			•
Quest	•				
Discovery				•	•
Nimrod	•			•	

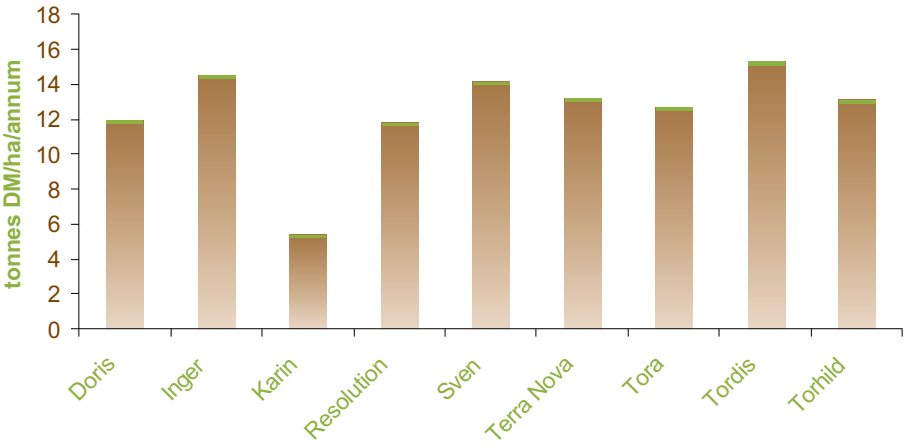
Other varieties that are no longer available include: Asgerd, Astrid, Doris, Loden, Rapp, and Ulv.

Willow Genotype Trials at Teagasc Oak Park

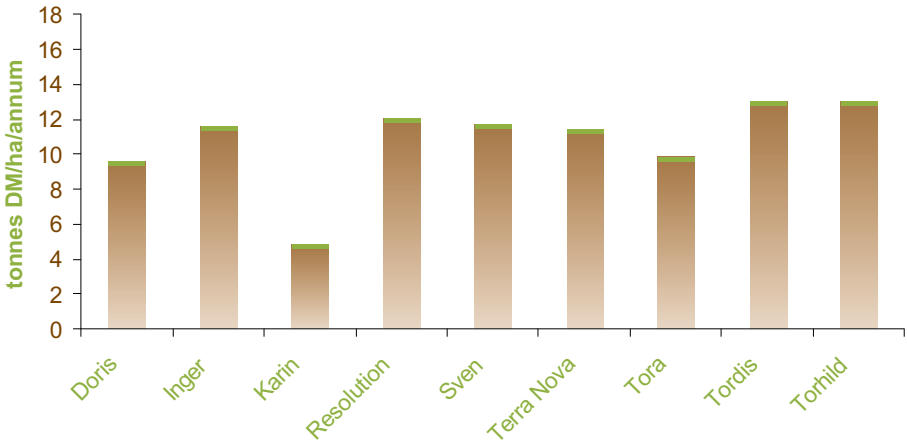
A willow genotype trial which included varieties from both the Swedish and UK breeding programmes was established at a site in Oak Park in May 2007. The trial was cut back in February 2008 before the first harvest was taken in 2010 and the second harvest in 2012. Please note that the yields provided below are plot yields and are not necessarily representative of yields that can be expected at field scale.

In 2010, the yield of all varieties with the exception of Karin exceeded 11.5 tonnes of dry matter per hectare per annum. Highest yields were obtained from the variety *Tordis* followed by Inger and *Sven*.

Willow Genotype Trial Oak Park
2010 Harvest



Willow Genotype Trial Oak Park
2012 Harvest



Yields obtained from the 2012 harvest were, in general, lower than those obtained during the 2010 harvest. It is thought that this was due to the fact that growth during 2011-2012 occurred over two dry summers. The yield of all varieties with the exception of Karin exceeded 9.5 tonnes of dry matter per hectare per annum. The highest yields were again obtained from the variety *Tordis* followed by *Torhild* and *Resolution*.

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Latest yield paper Lindegaard et al 2011 can be found at :
www.crops4energy.co.uk/files/pdfs/AAB_paper_2011_final.pdf

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Acknowledgements

Murray Carter, European Willow Breeding Programme

Ian Shield and William Macalpine, Rothamsted Research

Maurice Hinton Jones and John Valentine, IBERS, University of Aberystwyth

Fiona McKenzie and Peter Martin, Orkney College

Stig Larsson, European Willow Breeding AB

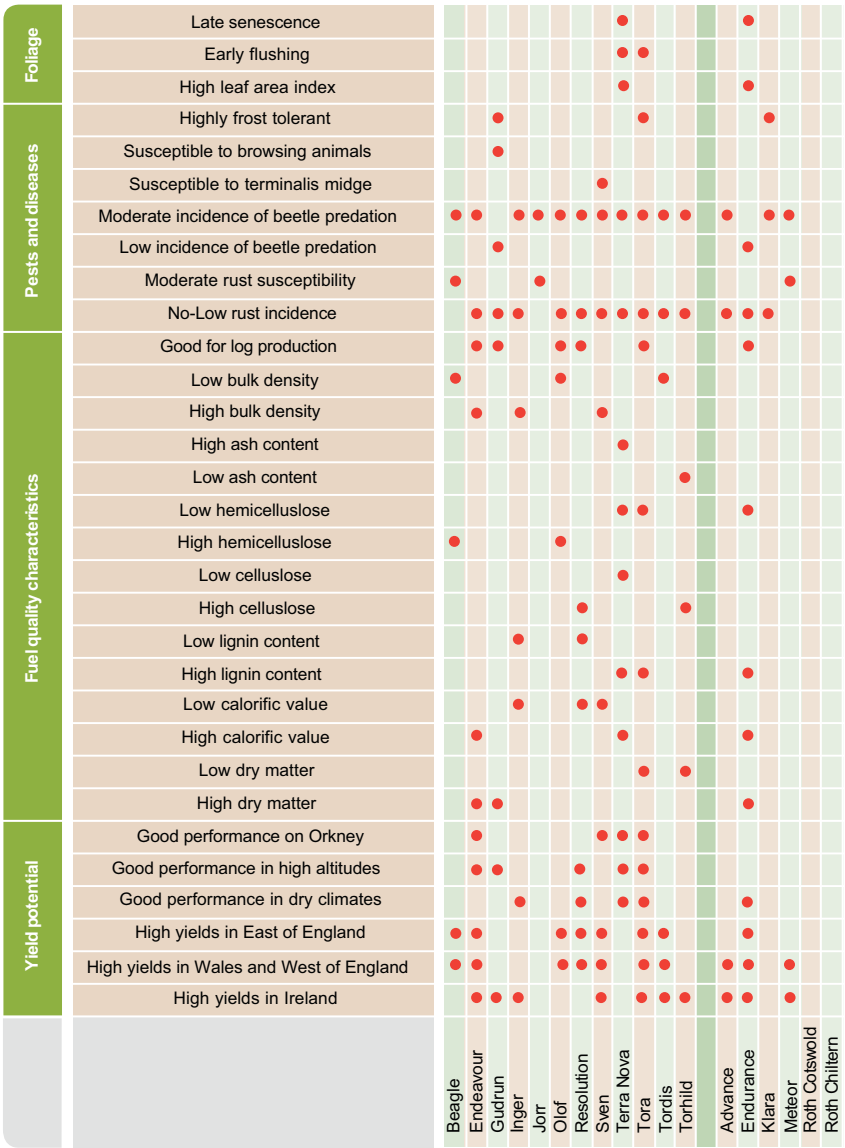
Julian Steer, Cardiff University

John Gilliland, Rural Generation

Aidan Moore, Seedtech, Irish agents for Salix Energi Sweden

Patrick Farrelly, Farrelly Willow

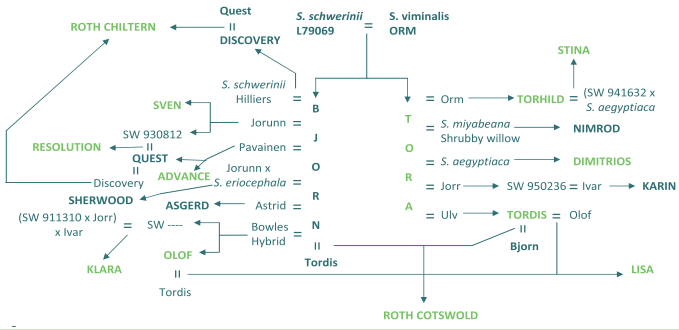
Appendix 1

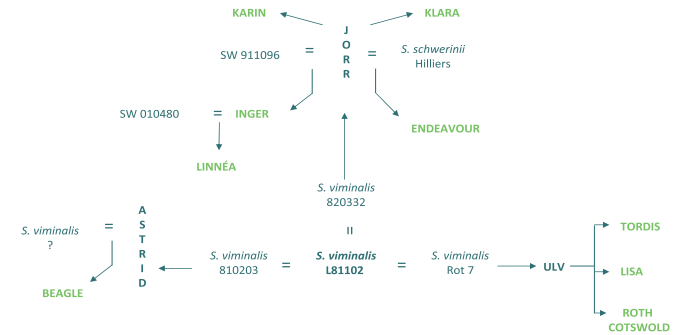

Foliage
Pests and diseases
Fuel quality characteristics
Yield potential
Late senescence
Early flushing
High leaf area index
Highly frost tolerant
Susceptible to browsing animals
Susceptible to terminalis midge
Moderate incidence of beetle predation
Low incidence of beetle predation
Moderate rust susceptibility
No-Low rust incidence
Good for log production
Low bulk density
High bulk density
High ash content
Low ash content
Low hemicelluslose
High hemicelluslose
Low celluslose
High celluslose
Low lignin content
High lignin content
Low calorific value
High calorific value
Low dry matter
High dry matter
Good performance on Orkney
Good performance in high altitudes
Good performance in dry climates
High yields in East of England
High yields in Wales and West of England
High yields in Ireland
Beagle
Endeavour
Gudrun
Inger
Jorr
Olof
Resolution
Sven
Terra Nova
Tora
Tordis
Torhild
Advance
Endurance
Klara
Meteor
Roth Cotswold
Roth Chiltern

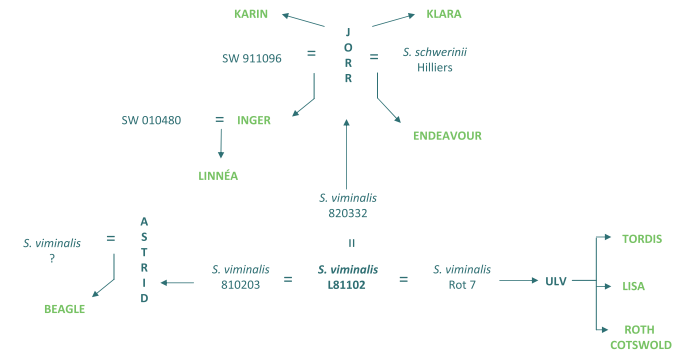
Appendix 2

The following diagrams illustrate the crosses which were used to produce the varieties currently in use. It is evident that many of the varieties which are commercially available have either a parent or a grandparent in common. In some cases, two varieties share the same parents.

Common ancestry of varieties







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ISBN: 10 1-84170-590-X

NDP
National Development Plan 2007 - 2013

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