WASTEWATER BIOSOLIDS TO GARDEN CENTRE PRODUCTS VIA COMPOSTING

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ABSTRACT
Thames Water Utilities has been developing the composting of dewatered biosolids since 1987. In 1993 growing trials started to test the suitability of the matured compost as a base material for making growing media. The paper describes the trials programme and marketing which lead to the TERRA ECO·SYSTEMS range of peat free growing media launched in September 1996. The Multi-purpose compost, Growing bag and Soil improver perform as well as the brand leading peat based products.

INTRODUCTION
Little Marlow sewage treatment works serves a population equivalent of about 90,000. It is a conventional design with preliminary treatment, primary settlement, and biological filters but without any form of treatment for the biosolids (sewage sludge). Thames Water Utilities Ltd began research into composting the dewatered raw biosolids cake in 1987. The annual make, including imports from other works, is about 12,000 tonnes of cake at 25%DS. The objective was to control odour and pathogens so that the composted biosolids could be used in agriculture without offence and in compliance with the "Directive on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture" (86/278/EEC).

Both aerated static pile and turned windrow composting were tested. Composting needs a bulking agent to increase air permeability and to provide additional carbon; straw and woodchips were tested for this purpose. Chipped wood had been used extensively in USA where the static windrow process had been developed - at USDA Beltsville and at Rutgers University. Chipped wood can be recycled through the process by screening the compost, but the number of cycles is limited by gradual breakdown of the chips and new chips have to be added each cycle. A weakness of this system is that, during screening, some degraded chips break up physically exposing fresh substrate which restarts the composting and increases the oxygen demand in maturation or in bags and consequently may cause anaerobicity.

Straw is an agricultural by-product of grain production. When it falls out of the back of a combine harvester its only value is the nutrients (largely potassium) and organic matter that it contains but it also has disbenefits. Straw may carry disease and weed seeds, in addition straw incorporation involves extra work and may delay establishment of the next crop. This delay might reduce crop yield. Baling straw and transporting it off fields adds value so one has to pay for baled straw.

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Some people balk at the cost of buying bulking agent for composting biosolids and a process has been developed which comprises thermally drying extruded dewatered cake so that it has enough mechanical strength to achieve the desired air permeability in order that it will compost in a tower silo. However the design neglects the fundamental requirement for an adequate carbon to nitrogen ratio, it also neglects the large "out-turn" volume of a tonne of straw which makes it a cost-effective bulking agent. The drying/tower system has a high capital cost and double the labour requirement of our turned windrow composting for the same size of works. By forward contracting and by accepting spoilt bales, straw is very cost effective for our purposes.

The aerated static pile method was tested first. The Beltsville and Rutgers methods of aeration (i.e. blowing air into the windrow or sucking the air out of the windrow) were both tested, with thermometers controlling the blowers in both cases. Neither proved very practical because of the difficulties of the temporary air pipes and because the outside of the windrows did not compost very well.

Various designs of windrow turning were tested.. The cheapest method of turning is to use a loading shovel but this proved totally inadequate because the material clumps and the centres of these clumps are not adequately composted. When the feedstock in their centres is exposed (for example after screening) degradation starts and if oxygen is limited phytotoxic organic acids form. We have never seen top quality compost made using a loading shovel. We quickly abandoned this in favour of using purpose built windrow turners and have tested several designs. Two of the desirable characteristics of the present turner are its capacity and its mixing capability.

OPERATIONAL COMPOSTING

R&D was completed in 1992 and at the end of that year turned windrow composting became a fully operational process at Little Marlow and its management was handed over to TERRA ECO·SYSTEMS.

TERRA ECO·SYSTEMS is the team within Thames Water Utilities Ltd responsible for recycling wastewater biosolids. Biosolids (also called sewage sludge) is the inevitable consequence of treating wastewater. It comprises the solids settled from wastewater and the cells of the micro-organisms that fed on the wastewater during treatment. These micro-organisms are used to degrade soluble organic matter and eutrophying constituents.

TERRA ECO·SYSTEMS manages more than 30% of all the biosolids used in agriculture in the UK, and does this in the most populous corner of the UK. This activity is controlled by legislation to protect the environment. The Sludge (Use in Agriculture) Regulations 1989 is the UK's implementation of Directive 86/278/EEC "On the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture". The UK was the first member state to implement this Directive it is also one of a small minority of members to comply with the reporting requirements of the Directive. Thames Water is very proud of its record of 100% compliance with all legislative aspects associated with biosolids recycling, an achievement that reflects its commitment to Quality Management. This performance is ranked number 1 by OFWAT the industry regulator.

Every year Thames Water Utilities (which was privatised in 1989) treats a total of about 15,000 hectares of land, with more than 220,000 tonnes dry solids (1.4 million m^3) of various products derived from treating the urban wastewater. This is from a population equivalent of about 7.5 million people at more than 80 biosolids production centres in the most populous area of the UK. These products comprise treated and untreated liquid, treated and untreated dewatered cake and even drier products in the form of air dried, composted, and lime stabilised material. The only type of treatment we do not use is thermal drying. Mesophilic anaerobic digestion is the most widespread biosolids treatment technology, it makes methane-rich biogas which is burnt to generate electricity that is sold to the supply companies and forms part of their non-fossil fuel obligation. TWUL currently supplies about 200GWh of electricity per year. The biosolids products are traded as TERRA *organic fertiliser*, TERRA *lime-plus*, TERRA *soil-builder*, and TERRA *compost*.

TERRA ECO·SYSTEMS' team members have made the cultural change from "sludge disposal" to "biosolids recycling" and from apologetic free-give-away to charging customers for treating their land. The prices paid by farmers range from £25 to £120 per hectare depending on the product and the location of their farm. Team members have all been trained in giving fertiliser advice and are equipped with notebook PCs running the quality and marketing database under a GIS. It is called TERRA *data systems* and which is the hub of the Quality Assurance system.

We currently compost about 12,000 tonnes of cake (at 25% dry solids) per year with cereal straw. We forward contract for the straw which is delivered in nominal 0.2 tonne bales and are happy to receive the spoilt bales from the tops and bottoms of stacks but insist that the straw when it was baled was in good condition. In addition to creating the desired air permeability, straw provides carbon to balance the high nitrogen content of the cake. We are also composting biomaterials for other people. The most established of these is source separated domestic waste for the local council. The scheme has been limited to 1000 households to test people's level of co-operation but it is planned to be progressively rolled out to the rest of the borough by 1999. We are now in a position to consider extending biomaterial (for example papermill sludge) composting both at Little Marlow and at other sites.

The process currently employed at Little Marlow comprises laying out a line of big-bales, removing the strings, running through them with the turner to break them up and then placing cake on top of the fluffed up straw. The windrow is then turned twice to incorporate the cake. The temperature reaches 55°C after about 5 days and windrows are turned 3 times per week for about 6 weeks. Windrows shrink to half their size after about 2 weeks and two windrows are then combined into a single windrow. The history of each windrow is documented and temperatures are recorded at 3 locations in each windrow daily. Occasionally the atmospheric composition inside windrows is measured. The chemical composition of both the raw cake and the composted material is tested on monthly samples. After 5 weeks composting on the windrowing pad the high rate processes are complete and the compost has been sanitised but it is still not fully stabilised. Full stabilisation is achieved in maturation stockpiles over a period of 6 to 12 months. This fully composted and very stable material is the raw material from which garden centre products are now being manufactured.

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PRODUCT DEVELOPMENT

Many have erroneously thought that they will find a ready market for bags of composted material, sometimes not even very well stabilised, without considering either the requirements of the market or the performance of their product. We have taken a very rigorous approach to developing bagged horticultural products based on TERRA *compost*.

TERRA ECO·SYSTEMS started testing of formulations of growing media in 1993. This was a "spare time activity" to see if it was possible to formulate a potting medium based on TERRA *compost* which contained no peat but which would perform as well as commercially available peat-based or "John Innes" media. This was a randomised trial with triplicate replication. The test subject was Impatiens and the height, spread and flower number on each plant were measured over a 12 week period from potting up the mini-plants. Over this period one of the formulations matched the performance of the brand leading peat-based multi-purpose medium and was far superior to the soil-based one. Tissue analysis showed the nutrition was adequate from the nutrient reserves in the TERRA *compost*. Comparing the analysis of the unused medium with that after 12 weeks' growth confirmed that nutrient reserves were very good.

Having established the potential the next step was to work with professionals from the growing media industry to develop the concept further and if possible bring it to a market. Rainbow Wilson Associates were brought into the project at this stage. The programme was pragmatic so that the cost could be minimised at any stage if results indicated that a credible marketable product would be unachievable.

More analytical work was undertaken including the physical characteristics. TERRA *compost* was also one of three test materials in a European Standards interlaboratory exercise to test methods being developed by CEN/TC 223 "Soil improvers and growing media". Nineteen laboratories participated and TERRA *compost* gave the most consistent results, the other products were a peat-perlite and a bark based commercial growing medium.

In order to be credible in the market it was agreed that we needed to have a multi-purpose compost together with complementary products to complete the range. Growing trials began at Levington Agriculture's research facilities early in 1995. By the end of that season our results showed that there was a very strong possibility of success.

For 1996 the products were reformulated based on the results from 1995 and a much more extensive range of growing trials was undertaken. Market research was also undertaken to test whether consumers were ready for such products, whether they would be compatible with and worthy of their Thames Water parentage, and to develop the packaging design. The target was to launch the products at the Gardening and Leisure Equipment Exhibition in September 1996 (GLEE'96) at the NEC.

Analytical Results

Tables 1-6 show analyses of the three products. The water soluble and DTPA-extractable nutrients are comparable with good peat-based products, but the "totals" (i.e. aqua regia extractables) could give the misleading impression that the products are too rich. This high lights a difference between these new products and peat, coir or timber based ones. The new

ones are inherently fertile with large reserves of nutrients that are gradually released. This means that feeding is not as critical with TERRA ECO·SYSTEMS media.

The physical analysis shows the good air-water relationship.

Seed Germination Trials
This was very demanding. To create a multipurpose compost from an inherently fertile starting material meant that the readily available nutrients had to be diluted and amended. The trials were conducted in a heated greenhouse at Levington Agriculture as a randomised block design with 3 times' replication. Seeds were surface sown on the test formulations and compared with brand leading products based on peat, coir, bark, timber and loam (John Innes). Germination and growth of lettuce, stock, pansy, Antirrhinum, and petunia were tested. Seedlings in the TERRA formulations performed better when the trays were on open staging rather than when they were watered by capillary matting. The formulation that has become the TERRA ECO·SYSTEMS *Peat-Free* Multi-Purpose Compost performed as well overall as the brand leading peat-based multi-purpose compost and better than the other branded products, some of which were spectacularly poor.

Growing Trials
A wide range of plants was grown to maturity in containers to test the suitability of the multi-purpose compost, these are listed in Table 7. Many of the plants were displayed on the product launch stand at the NEC. Their quality, even of difficult subjects, was excellent.

Growing Bag Trial
Trials have been made growing Shirley, Marmande and Gardeners' Delight tomatoes. The largest was the trial with Shirley which again was conducted at Levington against the brand leading peat-based bag. The cumulative yield of good ripe fruit (figure 1) was that same from both products but that from the TERRA bags was spread a little more evenly across the growing season. This was even more marked in the trial with Marmade. Technicians managing the trial observed that the TERRA bags were easier to water than the peat bags where it is well known that the added wetter washes down into the bag leaving the surface hydrophobic. The trial also confirmed that the start of feeding could be delayed for 4 weeks compared with the peat-based bag. In a blind flavour tasting the fruit from the TERRA bags was rated better which is a consequence of the higher conductivity of the medium.

Market Research
The question of fundamental importance was "would gardeners use growing media based on recycled material of human faecal origin?" Our market research showed that 90% of gardeners found no problem with this, and when they saw samples of the products they found them very pleasant and easy to handle. In focus group interviews we tried to get people who were sceptical about privatisation and about Thames Water, this proved surprisingly difficult. Although Thames Water has no recent record in horticulture gardeners felt that if the company was involved in the project the products would be safe and of a high standard.

Gardeners have received a lot of persuasion not to use peat but despite this peat alternatives only account for 3% of the market, having peaked at 5%. Our market research found that 30% of

compost users had tried peat free media but it had not come up to the expectations of our interviewees, however 23% said they would be willing to try again. Gardeners were well disposed towards green products, but their prime concern was that they must perform and also that they must be good value for money and be easy and convenient to use.

We also tested the acceptability of the pack design and the message that it conveyed. A selection of six design elements was tested and the designs that are now being used are the product of that research.

Getting The Products To Market

This involved another set of skills that were new to TERRA ECO·SYSTEMS as composters and biosolids recyclers. A Quality Assured manufacturing process had to be developed involving blending ingredients, bagging the products, and distributing them. To ensure that the products are safe "due diligence testing" in comparison with other products from garden centres and garden soil, etc. has been undertaken. Selling to garden centres is not the same as selling to farmers and a new language had to be learnt. Farmers are interested in how a product works and its benefits, retailers of fast moving consumer items are also interested in whether they will indeed move fast!

CONCLUSIONS

The proof came over the Easter weekend (March 28-31, 1997). Traditionally Easter is the start of the gardening year and we aimed to get product to as many retail outlets as possible. The response was tremendous and on the first working day retailers were placing repeat orders.

Composted wastewater biosolids can be turned into high quality garden centre products but only with a lot of effort and a rigorous development programme that involves skills that the wastewater treatment operator almost certainly does not possess. These include horticulture, marketing, design, brand management, process engineering and selling. Any change in feedstock to the composting process may significantly change the characteristics of the compost and necessitate re-formulation and further testing of the products. Since the ultimate test of a growing medium is growing plants this takes appreciable time. Three essentials are that the compost feedstock has an adequate available carbon to nitrogen ratio, the composting process achieves adequate time/temperature for pathogen control and that the composted material is fully matured and stabilised. TERRA ECO·SYSTEMS with Rainbow Wilson Associates has achieved these requirements.

Table 1 TERRA ECO•SYSTEMS *peat free* Multipurpose Compost

bulk density		560 g/litre	
moisture content		60 % m/m	
dry matter		40 % m/m	
air-filled porosity		11 % v/v	
water-holding capacity		60 % v/v	
organic matter		45 % m/mDM	
carbon:nitrogen ratio		10	
pH		6.5	
electrical conductivity		600 μS/cm	
	water-extractable (w-e) mg/litre	total mg/litre	w-e/total %
nitrogen as N	200	4000	5.0
phosphorus as P	16	4500	0.35
potassium as K	400	1100	36.4
calcium as Ca	500	8000	6.25
magnesium as Mg	50	800	6.25
sulphur as S	300	900	33.3
iron as Fe	0.2	1500	0.01
copper as Cu	0.4	150	0.27
manganese as Mn	0.1	60	0.17
zinc as Zn	0.3	100	0.3
boron as B	0.7	8	8.75
molybdenum as Mo	0.6	6	10.0

Table 2 TERRA ECO•SYSTEMS *peat free* Soil Improver

bulk density		680 g/litre	
moisture content		60 % m/m	
dry matter		40 % m/m	
air-filled porosity		15 % v/v	
water-holding capacity		77 % v/v	
organic matter		42 % m/mDM	
carbon:nitrogen ratio		9	
pH		6.5	
electrical conductivity		900 μS/cm	
	water-extractable (w-e) mg/litre	total mg/litre	w-e/total %
nitrogen as N	400	5500	7.3
phosphorus as P	10	7000	0.14
potassium as K	500	1500	33.3
calcium as Ca	1000	15000	6.7
magnesium as Mg	100	1100	9.0
sulphur as S	700	1600	43.7
iron as Fe	0.3	2500	0.01
copper as Cu	0.6	300	0.2
manganese as Mn	0.1	100	0.1
zinc as Zn	0.5	200	0.25
boron as B	0.4	12	3.3
molybdenum as Mo	1.0	10	10.0

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Table 3 TERRA ECO•SYSTEMS *peat free* Growing bag			
bulk density		660 g/litre	
moisture content		60 % m/m	
dry matter		40 % m/m	
air-filled porosity		12 % v/v	
water-holding capacity		75 % v/v	
organic matter		44 % m/mDM	
carbon:nitrogen ratio		8	
pH		6.5	
electrical conductivity		900 µS/cm	
	water-extractable (w-e) mg/litre	total mg/litre	w-e/total %
nitrogen as N	240	5000	4.8
phosphorus as P	25	6000	0.42
potassium as K	500	1100	45.0
calcium as Ca	600	12000	5.0
magnesium as Mg	80	1000	8.0
sulphur as S	400	1200	33.3
iron as Fe	0.3	2000	0.01
copper as Cu	0.5	250	0.2
manganese as Mn	0.2	80	0.25
zinc as Zn	0.5	180	0.28
boron as B	1.0	10	10.0
molybdenum as Mo	0.8	8	10.0

Growing bag trial TERRA vs brand leading peat-based bags

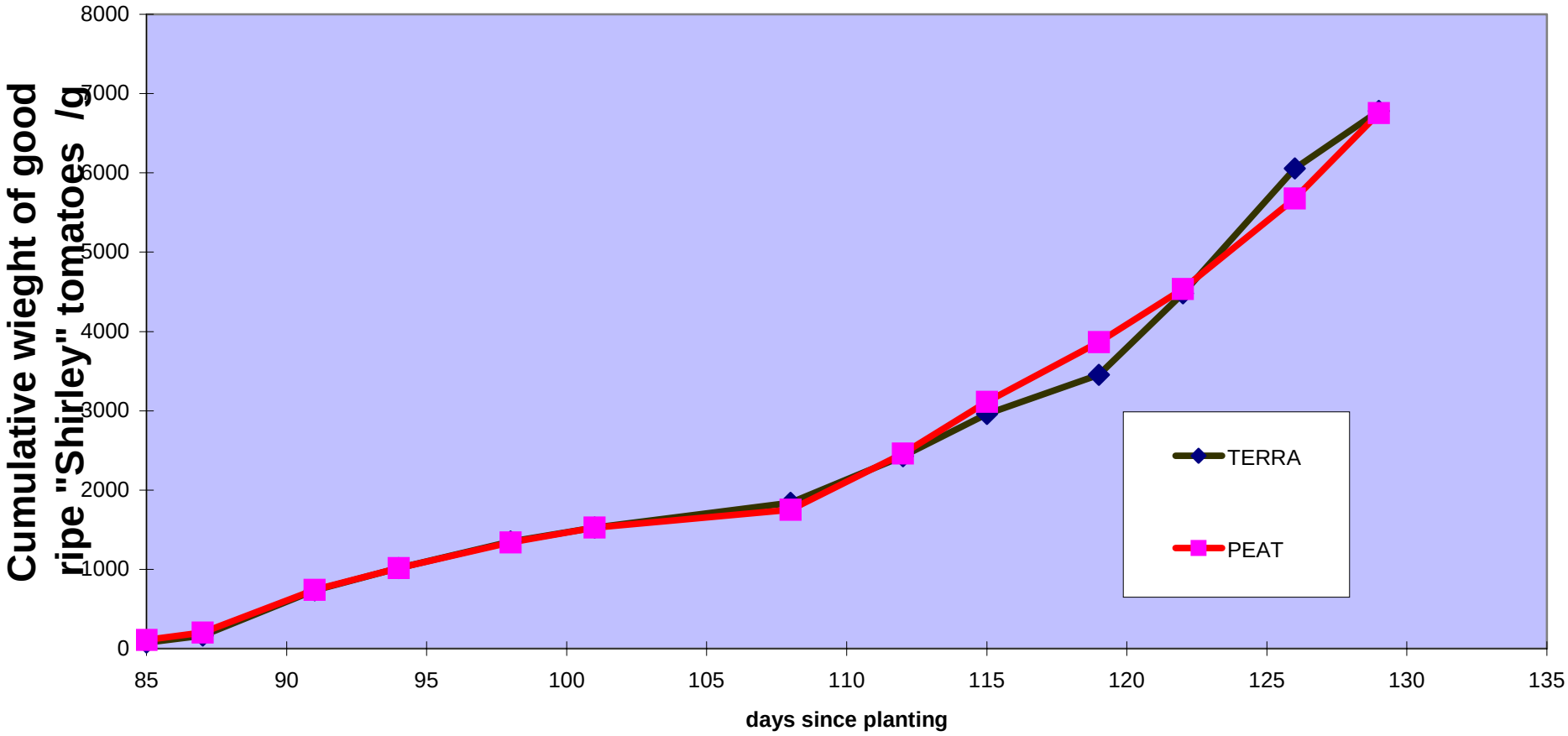

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Table 4 TERRA ECO·SYSTEMS *Peat Free* Multi-Purpose Compost has been used to raise the following varieties in the course of product development. TERRA ECO·SYSTEMS is very grateful to Thompson & Morgan and to Unwins for their advice and support

CROP	CULTIVAR	SOURCE
Ageratum	Blue Mink	TM
Anagallis linifolia	Gentian Blue	TM
Antirrhinum	F1 Chimes Bronze	O
Balsam	Baby Bush	U
Begonia	Rieger	O
Begonia semperflorens	Viva	TM
Begonia (corms)	Pastels	O
Cactus	Various	O
Canary Creeper		O
Chilean Bellflower *Nolana*	Bluebird	U
Chilean Glory Vine	Fireworks	U
Cineraria	Royalty	O
Cobaea scandens	Cathedral Bells	U
Coleus	Rainbow mixed	O
Cyclamen	F1 Laser Rose Flame	O
Dahlia	Dwarf	TM
Epipremnum aureum	Marble Queen	O
Ferns	Various	O
Ficus benjamina	Variagata	O
Fuchsia	Various	O
Hyacinthus orientalis	Various	O
Impatiens	Various cultivars	TM
Impatiens	Double flowered	TM
Impatiens	Tempo White	TM
Impatiens	F1 Accent White	O
Ipomoea	Mini Sky Blue	TM
Lilium	Various	O
Lobelia	Cascade Mixed	O
Lobelia	Blue Splash	TM
Marigold	Gold 'n Vanilla	U
Marigold	French Vanilla	TM
Marvel of Peru *Mirabilis jalopa*	Afternoon Delight	U
Narcissus	Various	O
Nasturtium	Whirleybird Mixed	U
Nasturtium	Tall climbing mix	U
Nasturtium	Dwarf semi-dbl	U
Nasturtium	Peach Melba	U
Nasturtium - dwarf	Salmon Baby	U
Nasturtium - dwarf variegated	Alaska	U
Nasturtium - variegated	Jewel of Africa	TM
Nemophila maculata	Five Spot	U
Nepeta	Trailing	TM
CROP	CULTIVAR	SOURCE
Pansy	Super Beaconsfield	U
Pansy	Love Duet	U
Pansy	Silhouette Mixed	TM
Pansy	F1 Ultima Blue Centre	O
Passiflora	Mollissima	TM

Pelargonium	Various cultivars	TM
Pelargonium	F1 Salmon Elite	O
Pelargonium - regal	Mixed	O
Pelargonium zonale	Dwarf Century	O
Petunia	Buttercream	U
Petunia	Lavender Storm	U
Petunia	Giant Victorious	O
Petunia	F1 Frenzy Red Vein	O
Polyanthus	Crescendo Blue	O
Sansevieria trifasciata		O
Saxifraga	Rock garden mixed	TM
Silene	Pink Pirouette	TM
Spathiphyllum wallisii		O
Stock	Apple Blossom	TM
Stock	Cinderella Rose	O
Stocks (column)	Giant Excelsior	U
Sunflower	Pastiche	TM
Sunflower	Moonwalker	TM
Sunflower - dwarf	Teddy Bear	U
Sunflower - dwarf	Music Box	U
Sweet Pea	9 cultivars	U
Thunbergia	Susie Mixed	U TM
Tobacco *Nicotiana*	Sensation Mixed	U
Tobacco *Nicotiana*	Little Nicky	U
Tobacco *Nicotinia*	Appleblossom	TM
Tobacco *Nicotinia*	Breakthrough Mixed	TM
Tobacco *Nicotinia*	Dwarf White Bedder	TM
Alpine Strawberry	Baron Solemacher	O
Aubergine	Slice Rite No. 23	U
Courgette	Gold Rush	U
Courgette	Zucchini Hybrid	U
Globe Artichoke	Green Globe	U
Onion	Ailsa Craig	O
Runner Bean	Scarlet Emperor	U
Runner Bean	White Emergo	U
Strawberry	Serenata	O
Strawberry Spinach		U
Tomato	Gardeners' Delight	O
Tomato	F1 Shirley	O
Tomato	Super Marmande	O
Tomato	Tumbler	U

Key:

U = Unwins

TM = Thompson & Morgan

• = Other sources