CARROTS

INTRODUCTION

The carrot (*Daucus carota* L.) belongs to the family Apiaceae. It is related to celery, celeriac, coriander, fennel, parsnip and parsley, which are all members of this family. The carrot originated in Asia. Initially the roots were long and thin, and either purple or yellow in colour. These colours, as well as white and orange, still exist, with the orange or orange-red colours being by far the most popular today. Many shapes of roots also exist, from rather long and thin roots to shorter and thick. Roots may be cylindrical, conical, or even spherical in shape.

Carrots are particularly rich in carotene (pro-vitamin A). They are consumed either fresh, as a salad crop, or cooked. Large quantities are also processed, either alone or in mixtures with other vegetables, by canning, freezing or dehydration.

The carrot is a very important vegetable crop in South Africa. Judging by seed usage, it is among the top ten vegetable crops on an area basis. In KwaZulu-Natal it is probably one of the five most important vegetable crops grown.

The plant is a biennial, i.e. it grows vegetatively in the first season and produces seed in the second. For root production the plant is grown as an annual. Low temperatures, as well as various stress factors, will sometimes cause flower production to be initiated, particularly in certain selections of some varieties. Bolting to seed in spring is possible in carrot plantings grown over the winter period.

ENVIRONMENTAL REQUIREMENTS

Climate

Carrots belong to the moderately hardy group of plants that are not particularly sensitive to winter cold and frost. Heavy frost just before harvesting can scorch leaves. Carrots do best under cool conditions (10° to 25°C), and their seeds also germinate quite well, though slowly, under cool conditions. Crop development is much slower during colder weather than when temperatures are higher.

While carrots can tolerate low temperatures, they can also endure a considerable amount of heat. Carrot crops can thus be grown throughout the year, except in very cold areas, where there is virtually no growth during winter. In very hot areas, summer production is not easy, because it is difficult to establish a good stand. Diseases such as Alternaria leaf blight also cause more problems, usually in late summer and autumn, with warm temperatures, high humidity and heavy dew.

Temperature and soil moisture influence the shape, colour and quality of carrots. The best quality carrots are obtained when weather conditions favour regular uninterrupted growth. Plant growth is optimal between temperatures of 15° to 20°C, and the roots also develop the best colour and flavour at such temperatures. At temperatures below or above the optimum, poorer colour develops. The roots also tend to be shorter, often with a poor flavour, when high temperatures prevail. Insufficient soil moisture results in a longer and thinner root, while very wet conditions have the opposite effect and also give rise to a lighter colour. Carrots develop a rougher appearance when the temperatures are fairly high in summer and where there are varying soil-moisture conditions. Forked and cracked roots are more common in summer and the central core tends to be thicker.

Soil

The objective in growing carrots is a high yield of straight, smooth roots. The first requirement is a deep, well-drained, well-prepared soil of a loose, friable structure. Sandy loam or loam soils are most suitable. Heavy, stony, compacted or poorly-drained soils interfere with good root development and are less suitable. In fairly heavy, humus-rich soils, carrots tend to develop excessive leaf growth, and to form forked, hairy roots; they also tend to be rougher and coarser on the outside. Very light soils subject to wind erosion should be avoided. However, the lighter- textured soils are frequently preferred, if well-fertilized and irrigated, because roots then tend to be smoother, straight and have a better appearance; roots are also easier to wash clean at harvest.

Carrots grow poorly in very acid soil with a pH of 5 and lower. Carrots are also very sensitive to soil salinity, and brackish soils should be avoided.

CULTURAL ASPECTS

Soil Preparation

Carrot seeds are small and are sown directly in the field. It is therefore most important that the soil be thoroughly prepared, with a level, fine, soil surface. Deep ploughing or working to loosen the soil to a depth of at least 30 cm is important to allow good root development. Sub-soiling can be advantageous in breaking compacted soil layers. As in other crops, over-working the soil should be guarded against, because the resulting compaction and possible surface capping can seriously affect emergence and root development of plants.

Sowing times

Cold areas	(heavy frosts)	August - March
Warm areas	(light frosts)	January - November
Hot areas	(no frost)	February - September

Seeding rates

One of the major problems confronting most carrot growers is to achieve the correct plant population. Where the population is too low, roots tend to become large, are generally subject to more splitting/cracking, and marketable yields are detrimentally affected. On the other hand, where the population is excessive, roots tend to become smaller, are often twisted around one another, giving a poorer quality root, and marketable yields of good quality may also be lowered. Dense plantings could be thinned out, but this is costly, time-consuming and requires so much labour that it is seldom practical where large-scale plantings are made.

Most serious producers therefore attempt to adjust their seeding rates in such a manner that a satisfactory population is obtained without having to resort to thinning out.

Various factors must be taken into account in determining the optimum seeding rate.

The size of the end product desired affects seeding rate - the denser one plants, the smaller the individual roots produced. For example, one may use a variety such as Red Core Chantenay to produce large, blocky roots (up to 60 mm in diameter and 160 mm in length) if the product is to be delivered to a factory for dicing, by having only 100 to 150 plants per m^2, using say 3 kg seed per hectare. However, one can plant the same variety for producing whole baby carrots (15 to 27 mm in diameter and less than 80 mm in length) by having 700 to 1000 plants/m^2, using 20 kg or more seed per hectare.

Another problem is the very large differences in seed sizes found among different varieties or batches of seed. Large seed may have only 400 000 seeds per kg, whereas small seeds may have a count of over 1500 000.

A further problem is the difference in germination capacity and vigour of any seed lot; germination may vary from 80 to 100%, and this must be taken into account when deciding upon seeding rate.

Furthermore, there is generally a population variation in the field, influenced by the prevailing climate, soil and other conditions. This "field factor" must be taken into account, as follows:

Cold soil and poor tilth	:	Probability of 50% germination;
Average conditions	:	60%;
Good conditions	:	70%; and
Ideal conditions	:	80%.

It is thus rather meaningless to generalise about weight of seed per hectare; one must think rather of numbers of seeds (and plants) per hectare, using the above factors of size of root desired at harvest, germination ability, seed count and field factors, to determine the seeding rate.

For very large roots, or earlier harvest, one should aim at 75 to 120 plants/m^2, for medium-large roots up to 250 plants, and for fine roots 500 to 1000 plants/m^2.

The amount of seed required for sowing to give the desired population is calculated as follows:

$$\text{seed required (kg/ha)} = \frac{1000 \times N^o\text{. of plants desired / } m^2 \text{ of planted area}}{N^o \text{ of seeds/g} \times \text{lab.germ. \%} \times \text{field factor}}$$

The importance of adjusting seeding rates is illustrated in the following two examples :

Example 1:

N^o of plants desired	80/ m^2
N^o of seed per g	800
Lab. germination	95 %
Field factor (good)	0.7

Calculation:

$$\text{seed required (kg /ha)} = \frac{1000 \times 80}{800 \times 95 \times 0.7} = 1.5 \text{ kg / ha} \quad (120 \text{ seeds /m}^{2)})$$

Example 2:

N° of plants desired	125
N° of seeds per g	500
Lab. germination	90
Field factor (average)	0.6

Calculation :

$$\text{seed required (kg /ha)} = \frac{1000 \times 125}{500 \times 90 \times 0.6} = 2.96 \text{ kg /ha (or 148 seeds /m}^2\text{)}$$

Seeding

Carrot seeds are small and tend to germinate irregularly. The seedlings are delicate and cannot push through a tight or deep covering of soil. The seed should be covered to a uniform depth of 10 to 25 mm, and should be kept moist until the plants are well established. In loose, light sand, seeds could be planted 40 mm deep. On heavier soils, and in the colder months when soils are cold and growth is slow, shallow planting is preferred. In summer, when soils dry out quickly, slightly deeper planting can be beneficial.

The first seedlings to emerge usually remain dominant, and the late emergers are suppressed. Even with an ideal spacing, and using size-graded seed, the development of the plants will thus not be uniform, leading to different-sized roots at harvest. A uniform spacing with pre-sized seeds will nevertheless give good results, as will seeds larger than about 0,5 mm in diameter. The great advantage of larger seeds is that they germinate more uniformly and produce stronger seedlings.

If the crop is not to be cultivated during growth, then, for any specific seeding rate, it is preferable to plant thinly in narrow rows than too densely in wide rows. Planting in a scatter row or a staggered row - for example, a double or triple row with a Stanhay precision planter - is preferable to planting in a single row. Row planting is generally preferred to a broadcast sowing, even when a bed system is used. Rows are generally spaced from 200 to 400 mm apart. Where double or triple rows are used, the width between sets of rows varies from 400 to 600 mm. For the production of baby carrots, rows may be as close at 100 mm.

A mistake that is generally made by new growers is to plant too densely. A first plant count per metre of row, with rows 200 mm apart, should probably not exceed 30 to 35 plants, uniformly spaced. Thinning out of plants is not practical in large commercial plantings, so attention must be given to ensuring that the correct seeding rate is used at planting.

Carrots are often planted on top of ridges or raised beds. This is especially important on heavier soils, shallow soils or those less well-drained, as it gives added soil depth, better drainage and the looser structured soils favoured by this crop.

Tillage

With the advent of herbicides, tillage for weed control is not an essential practice. However, tillage may be necessary should the soil cap after heavy rains. With wide row spacing it may also be a good practice to loosen heavy, compacted soil by running a tine to a depth of about 200 mm between the rows, when the roots are about 15 mm in diameter, to allow better root swell and give smoother, better shaped roots. When the upper part of the root is exposed to

sunlight, chlorophyll is formed, resulting in undesirable green shoulders. Keeping the shoulders covered with soil will prevent this condition; the cultivator sweeps should be adjusted to throw soil towards the row, lightly covering the exposed tops of the roots.

Fertilizer
Carrots require a fertile soil (see Table 12), which allows rapid, uninterrupted growth. In many of the moister areas of KwaZulu-Natal, the soil is naturally acid and leached. Heavy fertilizer dressings may then be necessary, but the use of compost or organic manures is not recommended, as they often cause unattractive, hairy roots, with a coarser texture. Organic manures should preferably be used on preceding crops in the rotation. Suitable liming and fertilizer programmes, based on reliable soil analyses, should be developed for each field.

Soil Acidity
Carrots are sensitive to soil acidity. Soils of low pH often contain high levels of available aluminium and soluble manganese, both of which may adversely affect growth and yield. The aluminium will tend to immobilise soil phosphorus, rendering it unavailable to the plant.

The pH (KCl) should be raised to over 5,5. A pH of 6,0 to 6,5 is regarded as optimum for carrot production.

MACRONUTRIENTS

Table 12.
The approximate absorption of the major nutrients by a crop of 56 ton per hectare.

Nutrient absorption (kg/ha)			
Plant Part	**N**	**P**	**K**
Root	80	20	200
Tops	65	5	145

The entire plant is usually removed from the field at harvesting, with no plant residues being returned to the soil, although leaves are sometimes left behind.

Nitrogen (N)
Nitrogen requirements of carrots are relatively low. Good yields are possible with applications of as little as 80 kg N per hectare. However, up to 130 kg nitrogen may be applied, particularly where the soil phosphorus and potassium status is high and where excessive leaching on sandy soils occurs. High rates of nitrogen should be avoided, as this stimulates leaf growth at the expense of root development and yield, and also delays harvesting. It is generally better to under- rather than over-apply nitrogen. Very lush leaf growth may also promote the development of diseases, such as Sclerotinia white mould, especially in the dense plantings used for baby carrot production.

Most of the nitrogen is applied at planting, except on the sandier soil types, where leaching is likely. The remainder is applied, usually at 4 to 8 weeks, when more rapid leaf growth starts. Due to the high potassium requirement of the crop, potassium nitrate is often favoured for top-dressing.

Phosphorus (P)
Phosphorus promotes root development and thus ensures more vigorous growth. It is a very important element for all root crops. Where the phosphorus status of the soil has been built

up, 40 kg of applied phosphorus per hectare should be adequate for a good crop.

Potassium (K)
Carrots have a particularly high potassium requirement and sufficient K must be applied to meet crop needs. High potassium ensures a better quality - crisper, better coloured roots - and also enhances keeping quality after harvesting; wilting is retarded. As carrots are frequently grown on lighter textured soils, where leaching is more prevalent, about half the potash is often supplied in side-dressings during growth, usually at 4 and 8 weeks after planting. Late dressings will enhance root colour, if this should be a problem.

The high potassium necessary for this crop will sometimes induce a magnesium deficiency, which can be corrected with sprays of magnesium sulphate ("Epsom Salts").

In the absence of soil analysis results apply 500 to 1000 kg 2:3:4 (30) at planting and the rest of the N required as a side-dressing.

MICRONUTRIENTS

Carrots are not normally regarded as having particularly high requirements for these nutrients, and deficiency symptoms are seldom seen. The crop also does not appear to respond as well as many other vegetables to foliar sprays of the minor elements.

IRRIGATION

The soil should never be allowed to dry out. This is of critical importance from planting until the plants have emerged and become well-established, in order to achieve a good stand. The top 30 or 40 mm of the soil, in which the seeds are planted and the early root development occurs, may dry out rapidly under hot conditions, especially if ridge-planting is used, unless frequent light irrigations (only 5 to 10 mm may be necessary) are applied - the lower soil layers may still be moist. In summer it may be necessary to apply water once or even twice a day; during early growth a solid-set sprinkler system would be ideal under such conditions.

The soil moisture should be maintained at above 50% of available moisture throughout growth. Generally 25 mm of water per week should be adequate, but under warm, dry, summer conditions, especially if accompanied by hot, dry winds, up to 50 mm may be necessary. Dry conditions when the roots start bulking up can severely reduce yields and quality. Under dry conditions long, thin roots are produced, while excess moisture will result in a larger diameter but excessively short roots.

ROTATION

A three-year rotation is advisable, mainly to reduce the risk of pest and disease build-up. By including deeper-rooted crops in rotation with the shallow rooted carrot, nutrients and moisture from the deeper soil layers can be utilized.

CULTIVARS

There is a small niche market for round (spherical) carrots, such as those produced by the Paris Market type, and a slightly larger requirement for conical baby carrots (Red Core Chantenay gives an ideal product). There is also a growing market for longer, more cylindrical, fine baby carrots (several cultivars have potential). However, the main requirement on the fresh market is for larger roots. Many varieties are available from the seed trade. The following varieties, usually with a cylindrical to longish, tapered root, are commonly grown: Cape Market, Chantenay Karoo, Chantenay Royal, Flacora, Ithaca, Kuroda, Senior, Star 3006 and Sugar

Snax.

WEED CONTROL

Carrots are small, rather vulnerable plants during the early stages of growth. Many weeds, on the other hand, grow rapidly and vigorously, and are efficient competitors for available nutrients, water and sunlight. It is very important that weeds be controlled in the early stages of crop development, because early competition can adversely affect plant growth and result in the lowering of crop yields.

Weed control can be achieved mechanically, by hand, chemically or by a combination of these methods.

In carrot production, chemical control of weeds, supplemented with mechanical and/or hand weeding, is the general practice.

The following herbicides are registered for use on carrots in South Africa:

Fluazifop-P-butyl (sold as Grasses or Fusilade Super)
This chemical may be sprayed over the crop, as an early post-emergent weedicide, for the control of many annual and perennial grasses. The dosage depends on the grass species and its stage of growth; young weeds are controlled with lower dosages than old ones. The chemical has no, or very little effect, on most broadleaf plants.

Flurochloridone (sold as Racer)
This herbicide is applied pre-emergent, as soon as possible after sowing, for the control of a wide range of broadleaf weeds. Its major disadvantage is its fairly long residual action of about six months, which can damage susceptible crops grown after the treated carrots. It is thus not a good option where vegetables are grown in quick succession.

Haloxyfop-R-methyl ester (Gallant Super or Verdict Super) may be used post-emergent for the control of annual and perennial grasses. Again, dosage depends on the predominant grass type present; early application is best.

Linuron (sold as Afalon SC or Linex 4F)
The chemical controls a wide range of annual broadleaf weeds, as well as certain annual grasses, and is probably the most widely used herbicide on carrots.
It may be applied pre-emergent, immediately after sowing, to a fine, moist seedbed; seed should be sown not less than 12,5 mm deep. The dosage depends on the clay content of the soil.

Linuron may also be used post-emergent, after the crop has reached the 4-leaf stage. The dosage depends on the growth stage of the weeds. Post-emergent applications are not as effective with certain weed species as with pre-emergent use, particularly on older weeds. Post-emergent sprays are, however, generally satisfactory, and can be a very useful option on wind-blown sands- emerged weeds offer some protection to the delicate crop plants, which is not the case where linuron is used pre-emergent.

Prometryn (sold as Gesagard 500)is used for the control of annual broad-leaved weeds.The herbicide is applied early in crop growth at the time when carrots have developed several true leaves.

Propaquizafop (sold as Agil 100 EC)
This chemical is applied post - emergent for control of annual grasses, the dosage rate

depending upon the grass weeds concerned and the growth stage. Propaquizafop (Agil 100) is applied post-emergent for control of annual grasses.

Trifluralin (sold as Digermin, Trifluralin and Triflurex)
Trifluralin can be applied from three weeks to immediately prior to sowing. It must be mechanically incorporated within 10 minutes of application. It is used mainly against annual grasses, but will also control a few broadleaf weeds. It has a long residual action, which can damage susceptible crops grown later in the rotation, and cannot be recommended where crops are grown in quick succession.

PESTS

No chemicals are registered for specific use on carrots to control insect pests.

Nematodes
Considerable losses can be experienced with carrots because of attacks by root-knot nematodes (*Meloidogyne* spp). The symptoms are nodular thickenings on the taproot and particularly on the finer lateral roots. Splitting and forking of roots can occur. The attacks are generally more severe with carrots grown over the summer months, when higher soil temperatures favour development of the pest. Nematodes are often more prevalent on lighter soils. Various soil fumigants may be used before planting to control nematodes.

Aphids
Aphids sometimes colonize the leaves and crowns of carrots. These sucking insects may restrict the growth of carrots, although major problems seldom occur.

Red Spider Mite
Red spider mite is also not a common pest of carrots, but numbers can increase rapidly under warm, dry conditions.

Soil Insects
Pests such as false wireworms, cutworms and millipedes sometimes cause problems, by damaging the roots. Earlier harvest is sometimes justified when damage occurs late in growth. Crop rotation and use of bait and frequent working of the soil should reduce pest incidence.

DISEASES

No chemicals are registered for disease control in carrots.

Alternaria Leaf Blight (*Alternaria dauci*)
Leaf blight is a common disease of carrots in KwaZulu-Natal. It occurs mainly during wet weather in summer, with prolonged heavy dews frequently promoting severe outbreaks in some areas. Dark brown to black spots, some with a yellow edge, appear on the leaves. The spots at first appear mainly on the leaf edges, where they merge, so that the leaves assume a scorched appearance. Older leaves are more susceptible than younger ones. The leaf petioles and the roots can be affected. The fungus can be transmitted with the seed, and may cause damping-off of the seedlings.

Control
1. Plant cultivars tolerant to the fungus.
2. Ensure the seed is disease-free (certified seed).
3. In areas where blight is known to be a problem, avoid carrot plantings in fields where foliage will not dry quickly after rain or dew, or at times of the year when the disease is more prevalent.

4. Practise a strict crop rotation programme.

Bacterial Blight (*Xanthomonas carotae*)
Bacterial blight is favoured by warm, wet weather. Symptoms are easily confused with Alternaria blight, but this disease is less common. Irregular brown spots occur on the leaves, and brown strips on the petioles. On the roots the disease is characterised by brown, elongated, horizontal lesions.

Use of disease-free, certified seed is recommended.

White Mould (*Sclerotinia sclerotiorum*)
Carrots should preferably not be planted in fields with a known history of the disease. It is more common in lush, dense plantings and will often start where plants have been trampled or otherwise injured. Cool, wet conditions favour the disease.

A white cottony growth develops on the above-ground parts of the plant. The shoulders of the roots may become infected. The affected plant tissue turns soft and watery. Hard, black resting bodies, called sclerotia, are produced in or on diseased tissue. The disease can develop in harvested produce packed for the market, with individual roots becoming soft and exhibiting the white fungal growth.

Control

1. Practise a three-year rotation with non-susceptible crops. Commonly grown vegetables which are also susceptible to infection by the causal fungus are cole crops, green beans, lettuce and tomatoes.
2. Deep ploughing to invert the soil to a depth of 250 mm or more hinders germination of the sclerotia and hastens their decomposition through antagonism by naturally-occurring soil organisms
3. Introduce a relatively dry water regime, as wet conditions favour the disease.
4. Remove and destroy infected crop residues.
5. Plant on ridges to improve drainage and allow the soil surface to dry more rapidly.
6. Slash back the foliage to about 150 to 200 mm height and remove this material to allow better drying.

HARVESTING AND MARKETING

Although there are some varietal differences, the crop is usually ready for market within 3 to 3½ months, although it may take about a month longer during cold conditions. The roots are harvested when they reach the desired size but are still tender and succulent. For the normal markets, this is when the roots have reached a diameter of 20 mm or more, but is obviously earlier where very slender carrots are needed for pre-packs for specific markets, or for "baby" carrots. Where carrots have grown poorly, or in very dense stands, the criteria for lifting should not be size, but rather maturity and quality. Carrot roots tend to colour up later at their swollen tips than higher up. When the tips have coloured up properly, the carrot is "ripe" and should be lifted without further delay, as further size increase is slow, cracking of roots becomes more common, and quality deteriorates. At this stage, root size is no longer the criterion for harvesting.

On loose, open, sandy soils it is possible to pull the carrots by hand. Successive harvesting is possible, taking the largest roots at any single harvest. Generally, however, a single harvest of assorted root sizes is practised by large-scale producers.

Where carrots are planted on ridges or raised beds, they can be loosened by drawing an

implement with a horizontal blade through the soil beneath the roots. If planted on level ground, the same implement can sometimes be successful, otherwise roots are ploughed up or lifted with forks. The carrots are then gathered by hand, washed and graded.

A proportion of carrots are marketed by being bunched, with leaves attached. The bunches vary in size from about 5 to 10 or more roots. They are then packed in crates or even mesh pockets.

The freshness and quality of leaf is often important to buyers, as it gives an indication of the freshness of the product, especially at the retail outlet. As roots with leaves attached wilt more rapidly than when leaves are removed, carrots are usually sent to markets without leaves and packed into mesh pockets. Packing to create the impression of uniform root size enhances the presentation. The use of pre-packs without leaves is also popular, particularly for very fine roots or baby carrots. Other packings commonly used are one and two kg perforated plastic bags, or even cardboard boxes with carrots bulk-packed in an inner plastic covering.

Commercial yields for large carrots average between 20 and 40 ton per hectare, although 60 ton or more are sometimes obtained by successful farmers. Baby carrot yields are generally about half those of large carrots.

Table 13.
Total tonnages sold on Durban National Market per year from 1993 to 1997, and mean annual prices (R per ton obtained)

	1993	1994	1995	1996	1997
Tons sold p.a.	4558	4101	5241	5199	5335
Ave. R/ton	601	930	782	825	984