General

The growing of witloof consist of 2 parts, growing the roots and subsequent forcing of the roots, in fact growing the chicons. The forcing result depends strongly on the quality of the root. Many witloof growers therefore grow the roots themselves, or on the same property or on leased land. However there are some growers who let the roots be grown on contract. The forcing of witloof mainly occurs in Holland in enclosed areas. The most modern method is the hydroponics method which is forcing in stacked boxes with running water.

Family

Witloof belongs to the family of Compositea (Astaracea) and is closely related to greenloof, redloof, chicory and endive escarole.

Witloof: cichorium intybus L.var.foliosum. Hegi
Greenloof: cichorium intybus L.var.foliosum
Redloof: cichorium intybus L.var.foliosum
Chicory: cichorium intybus L.var.foliosum
Escarole: cichorium intybus L.var.sativus

It is thought that Cichorium intybus L.var.silvester is the forerunner of witloof and chicory. It has a thin root and grows in nearly the whole of Europe, in Siberia, North Africa and the Middle East. Even greenloof and redloof are probably derived from the wild form.

Botanical characteristics

Witloof forms succulent roots which contains a white milky fluid in which bitter tasting elements are present: lactucine. In earlier days medicinal properties were assigned to these bitter elements in respect to stomach, gal, liver and spleen complaints.

Figure 1 shows the difference between witloof and chicory.

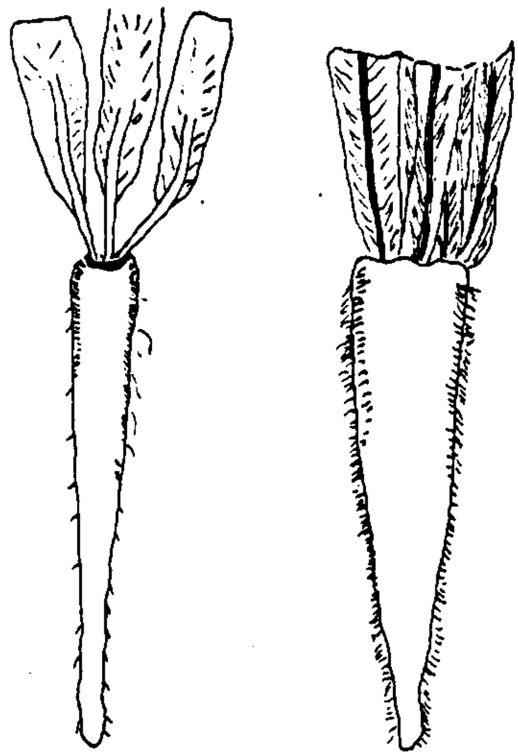

Figure 1. difference between chicory and witloof (after W.Geldof)

The witloof root is coarser (more hair roots) than chicory. The leaves run along the main stem towards the root. When the leaves are held just above the root they feel firm, with chicory the leaves (loof) are loose and grow with bare stems and these are seperately attached to the root. Witloof is a bi-annual crop. During the first year roots and leaves are formed. After a cold period plants will flower and produce seed. Early sowing in spring can cause bolting because plants can get too much cold. Low temperatures during ripening of the seed can also cause bolting.

Witloof is a long day plant, which means that plants will flower by a day length of 14 hours or more. The flower colour is blue and sometimes white.

Witloof is in the main a crossfertilisation plant. Pollen is earlier ripe than the stamen (potandry). Selfpollination is possible but does not produce much seed in the main. During plant-breeding research, repeated self pollination gave a bigger uniformity of seed without inbreeding characteristics (symptoms).

Witloof roots for forcing re-grow again and produce in dark surroundings chicons (heads) consisting of several white leaves. The nutrition value of these chicons is small, 100 gr witloof (71 kJ) contains:

- water : approx 94 gr
- Joules nutritional elements: 1 g protein, 0,1 g fats, 30 gr carbohydrates
- vitamines: 0.4 mg thiamin (B1), 0.03 mg riboflovine (B2), 0.3 mg nicotine acid piridoxine 0.05 mg (raw) or 0.025 mg (cooked) B6 and ascobine acid (C) 5 mg (raw) or 1 mg (cooked).
- Minerals: 20 mg Ca, 20 mg P, 0.5 mg NA, 200 mg K.

Area and contract growing

Before 1977 the area grown in witloof roots ranged between 2000 and 2500 ha in the Netherlands. After 1977 a clear increase took place in area which by 1985 had reached 5200 ha. There has been a growing interest in growing witloof roots on agricultural land with or without contract growing. Contract growing sometimes gives difficulties especially if a price/per weight has been agreed upon. These difficulties mainly arise from the forcing quality of the root.

The buyer requires a slowly grown not too heavy root. The rootgrower however aims to produce the highest possible yield, whereby if necessary, use has been made of artificial fertilizer. Contract growing can give more security if the roots are grown in partnership. The grower of the roots has than got a stake in the monetary return in the end-product. Another form is the formulation of a contract in which price is laid down per piece of grading, or in which the grower is given an agreed price per ha beforehand.

European area

Although in old herbbooks (e.g. Dodonaeus 1554) was written about white (blanched) chicory leaves, which were covered with oil and vinegar and eaten, the origin of witloof forcing dates from approx 1850. The home of this crop is Belgium, with the triangle Liege - Brussels - Mechelen as oldest centre. From here the crop was extended to the west of Belgium, the north of France and the Netherlands. Also it is now grown in Italy and East Germany, Spain and to a lesser extend in West Germany and Switzerland.

Table 1 gives the area and production in European countries in 1985. (Eurostat, PGF).

country	area/ha	production t/ha
France	17.000	180.000
Italy	18.000	170.000
Belgium	8.800	100.000
Holland	5.400	55.000
Spain	400	3.000
DDR	1.120	3.000
FDR	12	100
Switzerland	150	1.500

The first witloof of the new harvest can be expected at the end of August. Supply however is still rather small. Top production is in January; after April production declines rapidly. Recent innovations in witloof research have now made it possible to produce witloof in summer. This summer-production has increased from 36 tonnes in 1978 to 1300 tonnes in 1985 (over the month June, July and August). The value of the Dutch witloof crop has now risen to over 100 million guilders.

Growing the roots

Soil: To grow witloof roots a preference is given to a deep penetrable not too heavy soil with good moisture holding capacity and good structure - A ph - KCl of 6.5-7 and a $CaCo_3$ content of 2% or higher are recommended.

Composition

The rule, that for witloof growing silt and light clay soils are the most suitable, is not always correct. This is one of the conclusions reached from the results carried out by STIBOKA and PAGV between 1973 and 1977 on some 70 trial areas on 16 soiltypes. Observations and yield data have been obtained on root growing, forcing, rootstorage and forcing after storage. The average production over 5 years of research was estimated to be well over 34 tonnes/ha, from which the average yields on the various soiltypes only varied lightly (3 tonnes up or down). Noticable are the large differences within a number of soil types. The yields on heavy silt, light silt and sea sand for instance varied from 25 and 45, 21 and 46, 19 and 52 tonnes/ha respectively. On sandy soils which show a relative much higher uniformity within the soiltype the yields were much closer, namely 26 to 37 tonnes for podsoils. The large differences in rootproduction are not so much caused by differences in soiltypes as such but more because of a number of factors within the soiltype like soilprofile, structure and moisture supply. Everytime it appeared that the highest production was reached on areas with a good homogene penetrable profile, so without hard layers (pans) but with a good structure and good moisture supply throughout the whole growing season. In this, clay or sand do not play a role. Roots have to be able to penetrate to at least 60 cm to produce a root with a reasonable form. For a well formed root 100 cm is necessary. The groundwater level has to be so high, that the capillary water reaches the underside of the rootzone to guarantee a good moisture supply. In case roots are grown in areas where groundwater level is insufficient the roots have to be able to penetrate deeper to utilize hanging water.

In profiles which are sufficiently open, eg. to have a mechanical penetration resistance at field capacity of less than a maximum of 3 MPa/cm^2, roots have been found 2 metres below surface level.
From a technical point of view a few constraints have to be laid down. As well, several requirements have to be fulfilled. For instance the mechanisation of growing on heavier soils will be less than ideal namely too conical roots, so that the root weight will stay relatively low. This results often in a lighter crop. Also muck soils, because of difficulties with germination and the large number of forked roots, will have to be avoided. In respect to storage, again no definite preference for soiltype can be given. Few as well as a lot of root losses did occur already on 16 soiltypes. Of great importance was the croprotation and nitrogen level when the losses were not primarely caused by parasites, losses nearly always were caused by a high nitrogen level. When forcing without storage in November December, a high nitrogen level did not produce a detrimental influence on witloof production. When forcing started in March however, apart from large root losses also the quality of the witloof was influenced by nitrogen rich soils. In conclusion it can be said that areas where witloof can grow evenly are preferred. Especially the nitrogen level should not excees 80 kg N/ha in the layer 0-90 cm when roots have to be stored. Soils with a high organic matter content produce too much N during the season due to mineralisation. Ploughed grassland therefore is unsuitable for a number of years for witloof growing. To produce a well formed root an undisturbed depth of 1 metre is necessary.

Moisture supply

For an optimal production a good moisture supply is necessary but also a good run-off of excess water. It will be clear that a high groundwater level is not wanted. The allowable depth will be strongly depended on the granulair composition since this detemines the height of the filled capillaire zone above the ground water level. And since also in this layer no root formation is possible the upperside should be minimal 60 cm below groundlevel. In a sea sand soil the upperside may therefore be 70-80 cm below groundlevel, on silt or claysoils and loams minimal 120-150 cm below groundlevel. In areas where groundwater level does not contribute to the moisture supply of crops which does happen in the east and south of the country, irrigation may offer a solution when hanging is insufficient.

Irrigation

Although exact figures in respect to water use are not known, research in East-Germany and practical experience in the Netherlands have indicated that a good moisture supply is very important during germination. Because sowing mainly occurs in May, field situations may make it necessary to irrigate due to dry weather conditions. Especially by using coated seed, irrigation is sometimes necessary. Often 10 to 15 mm once would be sufficient. On muck soils it is advisable to use nozzles with small openings (3.5-4 mm max. dia.). It has to be pointed out that when growing on ridges, especially after insufficient compaction, drying out of the seedbed does occur faster than normal growing.

Yield depressions already occur if in the top layer 30% of available moisture has been removed during the season. This is equivalent to a pressure height of-250 cm (pF 2.4) or 24.5 kPa (2.5 m water column). Soils with a hanging water profile have to be irrigated to keep up the water content. When the roots reach to the capillairy zone however as it should be like on soils with a groundwater profile, irrigation will not be necessary because the deeper growing roots will look after the moisture uptake.

Soil cultivation

Witloof reacts strongly to the soil structure and demands a good penetrable soil. A deep soil cultivation (30 cm) is recommended, breaking up the ploughsole or other poorly penetrable layers. Heavy soils (clay, heavy silts) have to be ploughed or dug before winter. Digging has preference. Light soils can be worked in spring. After deep cultivation the seedbed is prepared. The top layer has to be fine, but not too loose. The seed must be placed on a moist underground. For sowing on a sandy soil harrows with short teeth can be used or a rota-tiller. On light clay and silt the seedbed can be prepared with a chain-harrow or rotatiller with depth control. Light soils should not be prepared too fine due to a chance of crust formation.

Growing on ridges.

Many witloof roots, especially those on clay and silt soils, are grown on ridges although in respect to soil use is not recommended.
There are 2 reasons why growing on ridges is used, namely:

- when the soil is in fact unsuitable due to a too small penetrable depth.

This way it can be increased 12-15 cm.

- when a level ground digger is not available.

It has to be pointed out however that fewer roots/ha can be grown of reasonable grade, due to the wider row distance. The difference is rather large. If on an area of ridges 200.000 roots/ha is optimal than at a row distance of 37.5 cm, 240-250.000 roots can be grown on level ground. When ridges are used they have to be built up well ahead of sowing and have to be pressed down. The ridges have to be suffiently high and be 20 cm wide. It is also possible to make the ridges already in autumn. They should not be rolled down before winter. Building the ridges can be carried out several ways. The most common is to use rotary-hoes and attached moulboards.

Crop rotation

Although on some areas witloof roots can be grown year after year succesfully it is better to have a crop rotation once every 3 or 4 years. Witloof is sown in preference on poor soils. This is particulary the case for the late and very late forcing period, where roots have to be stored for a long time. Witloof roots grown after e.g. seedpotatoes, are generally used for early forcing. Potatoes dug late for consumption are known as a poor preceeding crop. On arable farms for instance grain is known as a good preceeding crop, as long as no green-manure was used. This crop releases too much Nitrogen the following year. Potatoes and beet are generally heavily fertilised.

These crops can better be grown after witloof. The following crop rotation is than obtained namely: beet or potato, grain, witloof, etc. In the North of our country also grain after witloof is grown. This is because of a better control of witloof regrowth. In other cases it is advisable to plough deep before winter so that root-fragments are brought to the surface.

An other aspect is the greater chance of diseases because of the wrong type of preceeding crop. When the preceeding crop (potato, beet, endive) was infected by Sclerotinia rot or violet root rot (potato, beet, cabbage, carrot) than it is better not to grow any witloof afterwards.

This is also true for "Fire" in endive and lettuce. Witloof after carrot or winter carrot is not advisable.

In general witloof leaves behind clean land suitable for various crops. In practise good results have been obtained with onions after witloof.

Witloof is rather sensitive to growth-regulators.

When grain and grass as undergrowth are situated beside witloof, care has to be taken.

Fertilization

When growing witloof one rule has to be observed; no organic manuring, no animal-dung and care with nitrogen. Phosphate use is limited, and because of a good uptake of Potassium care has to be taken with this fertilizer not to give to much. In the hydroponic forcing application of N in the form of $CaNO_3$ to the water has a positive effect in respect to yield.

Nitrogen

Too much available nitrogen produces too many leaves, an uneven crop, relative small roots with a wide root crown and a bigger chance of loose chicons during forcing. Mostly no basal manuring with nitrogen is carried out. It is only necessairy on soils with a high loss and which do not deliver nitrogen by nature eg. siltly sea-sand soils like those of the Wieringermeerpolder and the North-East polder.
Soils having a high storage of nitrogen (after potatoes, sugarbeet on arable soils and on most horticultural soils) should not be used by preference to grow witloof roots for the midseason and late forcing period whereby root storage is necessary. N mineral research is therefore important. On clay and silt soils with less than 30-40 kg N 100-150 kg $CaNO_3$ can be given. On sandy soils with 20 kg Napprox. 175 kg/ha can be given. It has to be pointed out that the quantity mineral nitrogen on wet soils is very low and that the level can increase strongly under influence of life in the soil. When investigating the N mineral, notice has to be taken of this.

Phosphate

Phosphate fertilization is strongly depended on the soil feritility. A study carried out by the chicory commission has found that too little phosphate can delay germination. It is therefore necessary to find out which influence a low phosphate manuring has on germination.

Potassium

Witloof takes up potassium easily and is not sensitive to chlorine. The quantity is depended on soil type and the quantity of potassium present in the soil. For river clay it is not easy to give a hard and fast rule. The content is depended on percentage fine particles and the $CaCO_3$ content. For löss and sand soils a K figure of 30-39 is good. Fertilizer is than 150-200 kg K_2O/ha. On sea clay soils a K figure of 20-29 is regarded as good. On sea clay 200 kg K_2O/ha is normal.

Magnesium

Magnesium fertilizer on peat and sand soils are depended on a humus content and MgO content of the soil. On clay soils the fine particle content plays an important role. A too low Mg level can be increased by spreading 200-250 kg kieserite/ha

Calcium

On soils with a low pH (sandy soils to pH KLC 6 and heavier soils to 6.5) lime is sometimes given. When the pH is too high the crop is more sensitive to disease. Normally a standard basel dressing of lime will be given.

Cultivars

Forcing in hydroponics

For the increasing importance of hydropnic culture more and more new cultivars are being selected. This will also be done in the future. For new data it is bestto refer to the latest cultivar lists. Table 2.

* Table 2

Cultivars for witloof forcing by hydroponic method with recommendation (+) to forcing season

Cultivar	origin	very early	early	midseason	late
Zoom	INRA	+	+	-	-
Flash	INRA	+	+	-	-
Bea	INRA	+	+	-	-
Terosa	Royal Sluis	-	-	+	-
Videna	ENZA	-	-	+	-
Liber MO	Pannevis	-	-	+	+
Liber LO	Pannevis	-	-	-	+
Tardivo	Nun Hem	-	-	-	+
Viproda	ENZA	-	-	-	+
Mariot	ENZA	+	+	-	-
Toner	INRA	-	-	-	+
Arnova	Nun Hem	+	+	-	-
Spectra	Nickerson	-	+	+	-
Wivro	Rijk Zwaan	-	-	+	-

The suitability may vary in other countries than the Netherlands.

Sowing and planting

Witloof is generally sown and is incidentally planted.

Seed

The "seed" is in reality a long 4-5 sided husk fruit.

It is 2-3 mm long 1-2 mm diameter and brown or black in colour.

Determination of germination is done on the Copenhagen table on filterpaper by changing temperatures of 20°C (for 16 hours) and 30°C (for 8 hours). After 4-5 days germination is determined and after 10-14 days the vitality. In the outdoors the period from sowing to germinaton is 4-12 days, depended on weather conditions and condition of the soil. Minimum germination temperature is 5.3°C

The seed is 3-4 years useable as long as it stays dry and cool.

Several types of witloof seed are available.

Normal seed: this is seed which has not had anything done to it. Seed will have to be up to EEC standards. The 1000 seed weight varies between

1.2-1.3 gr with an average of 1.7 gr. Normal seed is sold by weight.

Precision seed: this seed can be used for precision seeder. The minimum germination percentage is relative high (higher than the EEC standards).

The precision seed is fractionated to 0.25 mm. The most used fraction is 1.25-1.50 mm, coarse seed lots sometimes 1.50-1.75 mm. Precision seed is sold by number.

Graduated seed: is simalarly treated as precision seed but is sold by weight.

The most common fraction is 1.25-1.50 mm. This fraction contains approx 550 seeds per gram.

Coated seed after extra treatment fractionated seed is coated. For this purpose mainly the coarse sievefraction is used. The "pills" have a diameter of 3-3.5 mm and are sold by number.

Seed quantity and sowing method

Normal sowing.

For sowing normal seed all types of sowing machines can be used as long as they have a fine adjustment. The seed quantity is approx 1.5 kg/ha. After a good germination thinning is necessary. Normal seed is relative cheaper, but needs more labour for thinning than when a precision seeder is used.

Precision sowing

In witloof generally precision seeding is carried out. Initially coated seed was used which went through a belt like on the Stanhay and Holaras seeders. To get sufficient plant numbers 350.000-450.000 pills/ha have to be sown depended on seedbed conditions. Although coated seed gives an accurate plantspacing, general use is limited because of the higher price.

In recent years graduated and precision seed has increased strongly. Mainly used is the Mini-air pneumatic precision seeder. This machine is specially suited for precision seeding of fine seeds which are not coated.

Seed will have to be dust-free and free of other impurities. With this machine narrow row distances can be sown. On ridges 2 rows per ridge are possible. When buying graduated seed, it is important to know which sieve-fraction the seed is.

A fine fraction of graduated seed is more economical than precision seed which is sold per seed. At a coarse sieve fraction, the opposite is the case. The tendency is to go for less seed.
Sometimes even a quantity of 500 gr/ha is mentioned. Such a quantity is asking for trouble.
This can be explained as follows;
Graduated seed contains approx 550 seed/gr of which a maximum of 440 plants can be expected (80% germination). A seed quantity of 500 gr means 220.000 pl/ha, corresponding to the population required. At 500 gr, sowing in fact is done at final plant distance whereby nothing is allowed to go wrong.
Because of the difficulties in practise 700 to 800 gr are given here as advise, which means approx 400.000 seeds. Costs per ha for seed will be as given in the table.

Tabel 3 Seed costs witloof in guilders per ha.(price 1981/82 excl. VAT)

Witlooftype	Seedtype	normal	graduated	precision	coated
	quantity	1500 (gr)	800 (gr)	400.000 (seeds)	40.000 (seeds)
cv,s hydroponics incl. Zoom F1		765	816	840	1.300
Hybrids, Hydroponics		975	1040	1.100	1.600

When sowing witloof, preference is given to using graduated or precision seed. With coarse seeded cultivars and hybrids, precision seed will most likely be cheaper.

It is preferred therefore to inquire into the germination %, sieve fraction and 1000 seed weight before buying. Precision sowing with normal seed is also possible. The finest grade seed can be sieved out by the grower.
A prerequisite is, that it has to be clean and has a high germination.

Sowing time* and population density.

The witloof seed is mainly sown between May 1 and 20. For very early forcing (root harvest in August and September) sowing is carried out in the second half of April and the seedbed is covered by thin plastic film.
For a better germination soil temperatures have to be minimal 12°C (av daily temperature).
Low temperatures promote bolting of the plants. By seed production low temperatures during ripening can cause bolting later.
On a suitable witloof soil, a plantpopulation (after thinning) of 225-250.000/ha is maintained. At a row distance of 37.5 cm thinning has to be carried out to a distance of 12-14 cm in the row. At a row distance of 50 cm, distance in the row is 8-9 cm.
With ridge growing 200.000 plants/ha is a common population. Distance between ridges is 75 cm. Per ridge often 2 rows are sown close together.
For the very early forcing method, a lower plantpopulation of approx 180.000/ha has preference. This is due to the faster ripening of the roots.
Under favourable weather conditions and a good seedbed condition, a field germination of 70 % can be obtained. By plant counts and cv evaluation trials often not more than 55% are observed.

Sowing depth is 1-1.5 cm under dry conditions 2 cm maximum.
A irregular germination gives mainly disappointing forcing yields later on.
Thinning can be carried out 4-6 weeks after sowing in the 3rd - 5th leaf stage.

* sowing time is different in Southern Hemisphere

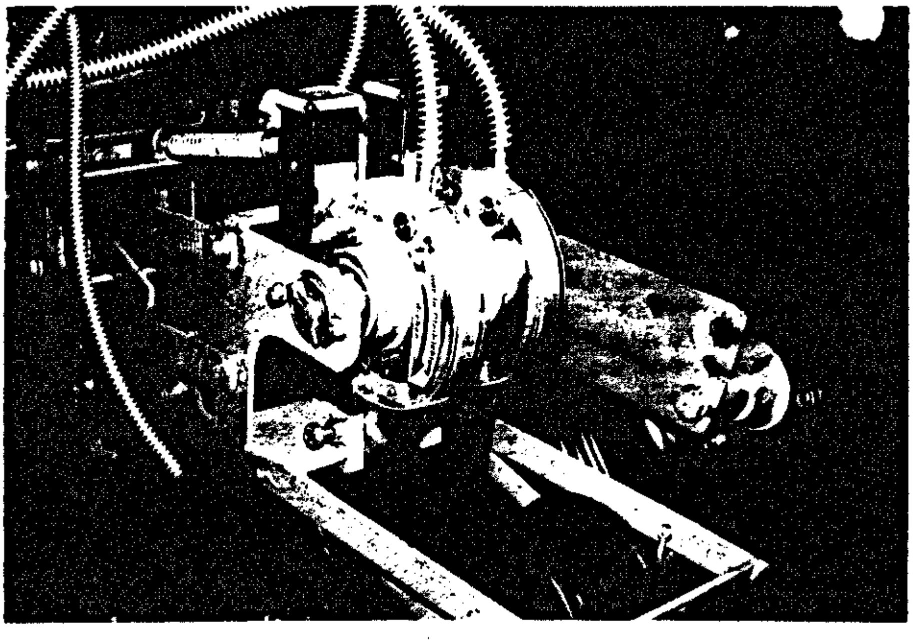

plate 1 Miniair precision seeder

Level ground and ridges

Both level ground and ridge cropping are carried out. With level ground cropping, a row distance of 30, 37.5 or 50 cm is used. With ridge cropping, mainly 66 or 75 cm is used. Both single or double rows can be sown (row distance 8 cm) but mainly 2 rows are sown for better plant distribution on top of the ridges.

Plant distribution is better on level ground generally, due to more uniform roots and a higher plant population.

For forcing, the optimal root diameter size (near the crown) ranges between 4-6 cm. A disadvantage of level ground cropping is that on heavy soils root harvesting by machine is more difficult especially under wet conditions, compared to ridge cropping. Half the area is grown on ridges.

Often ridge cropping is carried out from the point of mechanisation: it is possible to use an adapted potato-digger. Spraying is only done on the ridge meaning that only a third ha. is sprayed. Even in level ground cropping row spraying can be applied.

Planting out

To be able to have sufficient "forcable" roots in August, use is sometimes made of "planted" witloof. These are loose plants grown under glass from seed or module plants. (soil blocks)

To get loose plants, sowing is carried out at the end of Feb. - beginning of March under glass. During the first week air and soil temperature have to be kept at 18°C. Afterwards soil temperature can decrease to 11-12°C and air temperature to 16-17°C during the day and 10°C at night.

The seed quantity is approx 1.0 gr/m (550-600 seeds). At a good germination thinning is carried out to ±400 plants/m. These plants can be planted at the end of April or beginning of May by machine. Plant distance is for example 36x15 cm, which is 185.000 plants/ha. After planting out, the crop comes to a stand-still for about 3 weeks. Module plants in 4 cm soil blocks can also be used. Then sowing is directly into blocks in early April.

At a growing-on temperature of 18°C, the plants can be planted out 3-4 weeks later. Apart from the high costs of this type of cropping, it must also be pointed out that the roots of these plants stay short and are strongly branched.

plate 2 In level ground cropping a higher plantnumber can be realised than in ridge cropping

Plastic thin film covering

To increase earlyness of the roots for the very early forcing period sowing is carried out in the second half of April and the ground is covered with 5% perforated thin plastic film. By increasing the soil temperature 1-2°C a faster and more even germination is obtained and bolting is avoided.

Drying out of the seedbed is also avoided. In ridge cropping 1.7 m wide plastic (0.03 mm) is machine laid (2 ridges under 1 strip plastic).

In level ground cropping often 10 m wide plastic (0.05 mm) is used and laid by hand. The plastic is laid directly after chemical weed control has been carried out.

With soil covering no compounds with condensation problems should be applied. In the main the plastic film is removed in June when the plants have 6-8 leaves. The film should be removed under dark and/or showery weather and not with sunshine and/or windy weather.

A disadvantage of soil covering is that rather late in crop development, thinning can be carried out.

Sowing at a final population is therefore important. To improve field germination use can be made of narrow plastic film.

This film having a width of 20 cm is not perforated and is applied at the same time when sowing with special laying machines.

The nett width of the covered strip is approx 12 cm. This narrow film increases soil temperature and avoids drying out and possibly also dessipation, resulting in a faster and uniform germination.

The thin film is removed soon after germination due to "burning" out of the crop.

plate 3 a. roots of direct sown witloof

b. roots of loose plants

c. roots of soil-block plants

Weed control

General

Weeds can be controlled either mechanically or chemically. Mechanical weed control consists of hoeing on level ground and moulding up in ridge cropping. After the introduction of chemical control, as much as possible use was made of herbicides, capable of controlling nearly all weed types. At present the aim is to use a more integrated control, not only to make weed control cheaper but also to control the difficult (problem) weeds better. The integrated control method consists of row spraying in combination with hoeing and moulding up.
This means that only a limited quantity of chemical is needed. Often only a third or a half of the normal quantity is used; also the chance of damage to following crops or replacement crops is lessened.
For weed control in witloof the following possibilities are available.

Straight sowing

In witloof cropping it is usual that the ridges are made ready several weeks before sowing so that the witloof can be sown on settled ridges. No more cultivation takes place before sowing, so that the weeds get all chance to germinate before the witloof is up. This method of early field preparation is also done on level ground, especially on humus-rich or very light soils, where herbicides work less well.
When the seedbed is prepared early the weeds must be sprayed before the witloof has germinated or before sowing, with Paraquat (Gramoxone) 3l/ha.

Sometimes a combination of 2l Paraquat and 2l Diquat/ha gives an exellent effect. Chlor-profam (Chlor-IPC) 400g/l, rate of 4-6l/ha can be sprayed before or after the witloof has emerged.
On light soils no more than 2l/ha should be applied. With a lot of rain this compound can sink-in and cause damage. Application after germination has to be seen as an emergency solution, in case earlier spraying (before germination) can not be carried out in time.
The 3-leaf stage is the best time. The rate is than mostly 3-5l/ha.
The effect of Chlor-Profam is strongly depended on weather conditions.
Spraying on weed free, moist soil or by some rain after sowing is ideal. A lot of rain afterwards can cause thinning of the witloof plants.
Spraying at high temperature should not be attempted. By warm weather and dry soil the compound evaporates fast, so that the working can be disappointing. Other damage can be temporary growth reduction, thickened root-tips and a slight yellowness.
Composite weeds like MATRACARIA spp etc. cannot be controlled. Others are very sensitive to Chlor-profam e.g. POLYGONIUM spp, nettles etc.

WARNING; Chlor-profam must not be sprayed in the vicinity of to be harvested crops. Prevent drift to other sensitive crops like grain, grass-seed and flax, cucumber, tomatoes, melons and gherkins.
To avoid damage, under no circumstances must be sprayed on witloof crops closer than 200m of these crops. Not only drift, but also damp-working of Chlor-profam can cause damage.

Propyzamide (Kerb) 50%, rate of 3 kg/ha can be applied from sowing till after the witloof has germinated as long as no weeds are present.

For efficient results a moist soil is necessary. Also some moisture after spraying can improve the result.
When weeds are already present at the moment of spraying, a contact compound like Paraquat can be included. However this only before crop emergence.
The working time of Propyzamide is long and sufficient to keep the field weed-free untill crop-closure.
Propyzamide is safer for the crop than Chlor-profam.
Composite weeds are not controlled by this compound however.
From the table can be seen, which weeds are controlled good, average or not.

TABLE 4 Control of a number of Herbicides on a large number of weed-types (*)

WEED HERBICIDE	ALLOX- - IDIN	CARBETA- - MIDE	CHLOR-IPC	DIQUAT	PARAQUAT	KERB
Viola tricolor spp	-	+	++	-	+	
Mercuriales spp	-			++		
Urtica spp	-	+	+	++	+	+
Lamium spp	-	-	++	++	++	+
Alopecurus spp	++	++	++	-	++	++
Veronica spp	-	+		+	+	++
Chrysanthenum spp	-	-	-	+	++	-
Chenopodium spp	-	+	+	+	++	+
Echinochloa spp	++	+	+	-	++	++
Galeopsis	-	-	++	++	++	+
Capsella bursa past.	-	-	++	++	++	+
Sinopsis arvensis L	-	-	-	++	++	-
Matracaria spp	-	-	-	+	+	-
Galium aporine L	-	+	-	+	-	++
Galinsoga parviflora	-	-	-	++	++	-
Thlaspi arvense L	-	-	++	++	++	
Euphorbia helioscopia	-			++	++	
Senicio vulgoris	-	-	-	+	++	-
Atriplex spp	-	+	+	+	++	+
Stellaria spp	-	+	++	++	++	++
Polygonum persic. L	-	++	++	+	+	++
Spergala arvensio	-	+	++	+	++	
Poa annua	-	++	++	-	++	++
Polygonum aviculare	-	+	++	+	+	++
Myosotis spp	-				-	
Apera spica-venti PB	++	++	++	-	++	++
Polygonum convolvulus	-	++	++	+	+	++
Solanum nigrum	-	+	+	++	++	+

Amount of sensitivity: ++ = good-very good
+ = average-good
- = none-little
open = unknown

* In other countries due to different soils, climayes, weeds etc.other chemicals and/or rates may have to be used.

It does occur after treatment with Propyzamide, that the weeds come up normally.

Later they will die, unless the weather conditions deteriate after spraying. On humus-rich soils, Propyzamide does not work as well as Chlor-profam.

<u>WARNING:</u> When using Propyzamide care has to be taken not to use too much compound, due the risk of damage to follow-up crops. It is not possible to grow spinach after early harvested witloof, because of damage.

Carbetamide (Legurame) 300g/l at a rate of 7l/ha is mainly a grass-killer, but does control some dicotyl weeds (see Table 4).

At low temperatures Carbetamide works very slowly and only after several weeks effects on weeds can be seen.

Alloxidim-Na (Fervin) 75% rate 0.5-1.5 kg/ha.

This compound only controls grass-weeds like Alopecurus, Apera and seedling-grains and raygrasses.

Spraying with Alloxidim-natrium is not allowed to be done in combination with other compound within several days after another compound, due to severe damage.

It is advisable to use in all cases a combination of Schering 11 E oil 3l/ha, since it improves the working under dry conditions. Alloxidim-natrium is a contact compound and can, depended on weed development, be used in each stage of the witloof crop.

Cropping under thin plastic film.

When using perforated plastic film during cropping the application of Chlorprofam and Carbetamide is possible. When normal thin plastic film is used application of Chlorprofan only or in combination with Carbetamide must not be used. Through the higher temperatures damage can be caused because of damping. Under favourable circumstances a low dose can have a good effect. Important is the spraying on moist soil, a light irrigation after application not to many weeds and the use of sufficient water (1000 l/ha). Some missed weeds should be hoed after removal of the plastic.

Loose plants and plantmodules.

For the very early crop use is made of loose plants or plantmodules. For this Chlorprofam has to be used at a rate of 4-6 l/ha shortly before or after planting of the witloof.
By loose plants spraying is usually done after planting by plantmodules before. The plants are younger and less hardened then loose plants, so that damage can be greater.

Diseases and insect control.

Leaf-aphids (Aphididea)
In the field. From June onwards during warm weather large numbers of aphids can be found in the field on the underside of the leaves and in the heart of the plant. Sucking damage can be seen in the curled leaves, as soon as damage is visible, spraying with 0.5kg pirimicarb (Pirimor)/ha should be carried out.

During forcing: In hydroponic forcing leaf-aphids could become a problem. The green-aphids come mainly between the chicon leaves. Quality-loss is the result. During a severe attack the chicons do not grow well.

Control is by spraying 5gr pirimicarb (Pirimor) in 10 litres of water per 100m or an enclosure treatment with Pirimor smoke-developer. When during stacking the roots "Dimethoate" against witloofminer is used, all leaf-aphids present are also killed.

Plate 4. Phytophtera on the root

Fire-blight <u>(Pseudomonas marginalis)</u>

The symptoms of this bactery-disease are brown-black coloured, drying edges along the leaves. The bactery infects the leaf by way of water-splash. It than enters the leaf via the stomata.
In severe cases the growing tip can become black and dies.

The disease mainly occurs locally. In a wet period and/or by a dense plantstand, large parts of the area can completely rot away.
During a machine-harvest sorting infected roots out in the field is practically out of the question. Often dried-up leaf edges are an entry-point for secundary other organism, which than can cause "wet-rot" of the root.
During forcing little trouble is caused by the disease, exept in cases where the growing tip has disappeared. These roots produce a chicon with only outside leaves, but which are hollow inside.
A direct control is not known. Important points to prevent Pseudomonas are; good crop-rotation, a leaner witloof growth, harvesting in time and removing infected roots.

Botrytis cinerea

The roots have light-brown spots on the surface, covered first by a white, later by a grey fungus mould; containing flat black sclerotia. When the root is cut length-wise a light brown watery discolouration can be seen, under the infected spot. Damage during forcing is not large. Infected roots can produce wet-rot because of bacterial infection. The fungus nearly always enters the root via wounds.
The control of Sclerotinia has as a side-effect the prevention of damage by Botrytis cinerea.

Phoma exicua

On the root dark-brown, rimpled spots appear, mainly on the root crown. Length-wise cutting of the root shows a brown-black to black discolouration under the infected spot with a sharp boundary between healthy and diseased tissue.

During root storage the disease can spread without changing into wet-rot.

Damaged parts form an entry-point for this fungus. Chicon formation is often delayed or does not occur when the root is infected near the crown. During hydroponic forcing Phoma spots are an entry-point for bacteria and fungi causing wet-rot.

A direct control is not known, but indirectly it consists of damage prevention.

Damaged roots should also be healed before storage.

According to French researchers this can be done by leaving the roots 24 hours at a temperature of 12-15°C. In practice such a "heat" method will encounter problems.

Phytophthora erythroseptica

The symptoms consist of "browning" mainly starting from the root tip and moving upwards.

Chicon formation does not start. Not only via root-tip but also via other wounds can the fungus enter the root.

The infection arises from active moving spores in water, so that the presence of water does play an important role. Often a Phytophthera infection is followed by secondary wet-rot bacterea e.g. Erwinia caratovora causing a stinking wet-rot. Phytophthera can also be present in potato where it can cause "red-rot".

In both witloof and potato the fungus is likely to be present on wet parcels of land. It is therefore possible to bring the disease via witloof roots into the forcing room. In hydroponic forcing the disease spread is very rapid due to moving oöspores.

Control in the forcing room can be done by steam-cleaning to kill the rest-spores. Also good drainage in the soil as well as a good soil-structure are important. A preceeding crop like potatoes should be avoided.

Rhizoctonia solani

The roots contain browny, slightly sunken spots. Length-wise cutting of the root shows fairly shallow brown discolouration in the tissue under the infected area. On the outside leaves of the chicon several oval browny shallow spots are found.
This disease is mainly found in the headlands, so structure may play a role. The direct damage is negliable. Control is unknown but Sclerotinia control has a good side effect.

Rust (*Puccinia cichorii*)

This fungus disease causes dark red-brown spots on the leaf. It can appear in both field and forcing room. Control is not necessary.

Sclerotinia sclerotiorum

The symptoms in the field consist of grey-brown rot in which first white, later black sclerotia are present.
Infected plants can die completely. Secondary infection can cause wet-rot. Infected roots can completely rot away in the forcing room and infect surrounding roots. A direct field control is not possible. Crop rotation is important taking into account that beetroot, carrot, sellery, beans, parsnip can also get the disease. It is more important however, to avoid damage during crop handling.

During the start of forcing it is possible to spray with 8gr iprodion (ROVRAL) or 2gr vinchlozolin (RONILAN) per litre water over the top of the roots. Per m^2 forcing area 0.5 litre liquid has to be used.

Verticillium dahliae

The leaf edges become dry and brown, dying -of carries on between the veins. The outside leaves wilt first. In cross-section, the root tissue shows brown vessels. The disease is mainly present on light sandy soils.
Control is unknown. Good soil structure is important.

Violet rootrot (*Helicobasidium purpureum*)

The root is nearly completely covered with a dark purple fungus and after secondary infection goes rotten. It is mainly found on wet soils.
There is no direct control. Good drainage and crop rotation are important.
Twitch/couch-grass may be the host plant.

Witloof miner fly (*Napomyza cichorii*)

The fly is 3-3.6mm long, has a lemon-yellow coloured head with large dark brown eyes, a dark grey breast-plate and a lemon-yellow hind quarters with dark grey cross-stripes.
The first flight takes place in May and June, in July follows a second. The third flight occurs during the first half of September and ends in October.

The flies don't spread over large distances in general. During sunny weather they are not very active.

By over-cast weather and little wind they fly from plant to plant.

The eggs are approx 0.3mm long, partly milky white, partly clear. They are laid in the main vein of the leaf directly under the upper skin, near the leaf base.

The maggots are white and can be up to 5.3mm long. They drill holes in the leaf stem and root. The infection of witloof plants in the field increases during September and October.

Control is as follows: In the field, from August 15 the crop is sprayed 3x with 1.5 kg or 1.5 litre Dimethoate 20% or 0.75 litre Dimethoate 40% per ha. Spraying should be 2 weeks apart. The last one should not be later than 3 weeks before harvesting the roots.

A treatment in the forcing room is not necessary.

Dimethoate also controls Aphid.

Root-knot nematode (*Meloidogyne hapla*)

The plant-growth is reduced in places. During warm, sunny weather outside leaves wilt. Many small knots are found on the roots.

A severe infection can cause plant-losses. The nematode is mainly found on light soils. Control is as follows:

Crop rotation; potato, beet, carrot and papilionacae have to be avoided as preceeding crop. Grain and grass are good preceeding crops.

Soil sterilization with Dichlorpropene (150-250 l per ha depended on the active ingredient and content) or with Metamnatrium (300-400 l per ha depended on a.i.)

Application is only allowed between March 16 - November 15.

Root-lice (*Pemphigus bursarius*)

The woolly lettuce root-lice can also effect endive and witloof. Especially by a poor soil structure growth can stagnate. When growth conditions are favourable however, witloof will not be bothered too much. The poplar is the favourite primary host plant.
At the end of June the lice move to lettuce and other secudary host plants. The largest numbers are found approx July. The migration period is approx 5 weeks. Damage forms through removal of plant juices. In a dry period damage can be so great that the whole crop goes flat. In the main damage is local. Good irrigation is probably sufficient to stop the spread. By a severe infection the soil has to be treated with 3.5 litre Diazinon or 2 litre Endosulfan 35% in sufficient water.

Fysiological diseases

Redloof. Red discolouration arises when the milk-sap oxydises. The milk-sap is present in so-called milk-sapvessels found in the main plant vessels. Red discolouration is therefore mainly found along the leaf veins. Redloof has poor keeping quality. A similar appearance can occur when the chicon is broken off or when damaged by trimming. The milk-sap discolours red by sap-oxydation of the broken surface in a short time. Most problems occur at the start of the season and at the end of forcing, when the growing speed it at its fastest. Growth is caused by water uptake by plant cells. If this happens too quick ruptures will appear in the tissue causing the milksap vessels to break. The oxygen present in the intercellular spaces can oxydise the milk sap giving rise to red discolouration.

Lowering the forcing temperature at the end of the forcing period can alliviate the problem somewhat. Also the relative humidity should not rise above 90%.

For very early forcing a cultivar has to be chosen which is less sensitive. From recent research it has become known that roots containing a higher P and K content are less sensitive. Possible Ca also plays a role.

Burst loof

Bursting of the chicons is caused by irregular growth, a large temperature variation and excessive water after a period of water shortage.

Glassiness and/or "rand".

Because of a too high relative humidity (above 95%) and not enough air movement glassiness can appear. The chicons show a pale glassy colour due to prevention of evaporation. By strong changes in the relative humidity "rand" can appear. The leaf edges become brown due to drying out especially after a period of a too high relative humidity.

"Roosjes". (Rosettes)

The chicon stays open during forcing. The core or pit has a tendency to rise fast. Rosette formation occurs mainly during late forcing with "overripe" roots. The water and air temperature should be lowered several degrees.

Rosette formation can also occur in places where cold air moves across the chicons (draught). Also a high ethylene concentration of the air can be a cause as is the case with "tile shape" positioning of the chicon leaves. Concentrations above 0.2-0.3ppm can cause damage.

Such concentrations do occur quickly when a LPG fork-lift truck is being used often.

Freeze damage.

In the field roots can withstand frost to -5°C. Harvesting has to be delayed till roots and leaves are completely defrosted otherwise the growing tip may be damaged too much. During root storage in the cell, the temperature must not be lower than -2°C. Freezing damage can be recognised when cutting the roots lengthwise. The growing tip is gone brown and the root is glassy.

Growth-regulation damage.

Witloof is very sensitive to growth regulators. Damage is caused during the control of dicotyl weeds in surrounding fields with grain, where the weedkiller M.C.P.A. is used. Usually the growth regulators are used after the grain harvest to control the weeds. This spraying is carried out mainly in the first half of September. Drift or non-attention can mean that the witloof crop is affected and damaged, which will show up during forcing. The roots do not produce a chicon or form small ones.

"Blue" loof

Recently it has become known that blue discolouration can be caused by too much Fe during forcing.
The tannins in the chicon produce together with the Fe a blue colour. Soils high in Fe with a pH of 6 or below and a low Ca content, contain during oxygen-low circumstances a high content of available Fe. In hydroponics it can arise when using water with a high Fe content and with a pH of below 6 and poor oxygen supply.

Root harvest

Machine harvest

Machine harvesting must be done in such a way that roots of uniform length are obtained and even leaf collar. Undamaged roots which are free of dirt should be aimed for. Root length has to be approx 18 cm. The length of the leaf collar should be 2-3 cm for very early forcing and 3-4 cm for late forcing.
When buying roots, proper rules have to be agreed on in respect to manuring, cultivars, plant population, root diameter, tarra determination and disease infection. These rules are also given in the Model contract put out by the Ministry of Agriculture.

Level ground

Several witloof diggers/harvesters are available e.g. of Belgium manufacture. They are 1 or 2 row machines (d'Hooghe, Verstraete, and Aerts).

Contracters use machines having a much higher capactity e.g. Krakei or Riecam. The smallest types put the roots cross-ways in swads on the field. The larger machines harvest the roots onto wagons or into bulk-bins or containers.

Removing the leaves takes place at the same time as harvesting. Use is made of horizontal drum-mowers, rotary-slashers or forage-harvesters. These last ones have preference, since drooping leaves will be sucked up and cut as well. After de-leaving, the roots are dug with lifters or chisel shears which cut the roots at the right depth and deliver them onto sieve-belts. In some machines depth control is electro-hydrolic.

Cleaning in most machines is by way of sieve belts, mainly two above each other running at different speed, followed by a roller sieve or square-mesh sieve. With the last type, rounded clods of dirt can be removed from the roots. Care has to be taken during wet conditions that the machine does not clog up.

Ridges

For optimum harvesting in ridge cropping, it is advisable to mould up in August so that the root tops are level with the soil.

On sandy soils it is better to mould up in July (second half) due to heavy leaf development. By moulding up it is possible to cut the leaves so accurate that any further trimming is unnecessary.

Adapted potato-diggers can do good work as long as the soil is not too fine.

On heavier soils and under bad weather conditions specific witloof harvesters are better. On sandy soils potato-diggers are also used on level ground cropping (37.5 cm).

The adaption of potato-diggers can be carried out by replacing the specific potato chisel shears by 2 disc shears and 1 or 2 long chisel shears. Only 15-25 cm of soil with roots is put on the sieve this way. Both 1 and 2 row diggers can be used. Contracters mainly work with self propelled machines which also remove the leaves at the same time (e.g. Amac, Krakei or Grimme).

Tarra removal

The tarra content can be up to 15-20% consisting of pieces of roots, too fine roots, blind roots, leaves and soil. Tarra can be removed by means of vibrating sieves. Special witloof cleaners also exist e.g. Schouten. This machine consists of a bulk-bin, elevator and sieve belt.

The cleaned roots can be put directly into forcing trays, bulk-bins or be put onto conveyor belt.

Tarra removal is especially important for roots which have to be stored a long time to avoid heating up or any regrowth. On top of that savings are made in energy and storage space. It is difficult to clean the roots when they are wet. Cleaning capacity has to be sufficiently high since large quantities of roots are arriving sometimes simultaneously.

Harvest period, ripeness and pre-cooling

To obtain a good forcing result the root has to have a certain "ripeness". This ripeness can be expressed in age or growing period of the roots. For very early forcing roots have to be 20 weeks old to produce a reasonable forcing efficiency.

If roots have to be forced in August 20 week old roots are not available. Witloof yield and quality are in that period much lower therefore, compared to later in the season. It is possible to improve the forcibility of the roots early in the season, by earlier sowing and covering with plastic or by using plant witloof, a lower plant population and using early maturity cultivars. The forcibility also depends on the weather conditions during the growing season. In dry warm summers roots will ripen faster, as long as the crop-growth has not suffered. The forcibility is than improved because the rootweight will be heavier.

For the mid-season and late forcing 24 weeks are taken as being the right length of time (sowing first half of May: harvest end of October/beginning November).

The ripeness can also be judged according to the size of the internal hollow in the crown neck.

When the roots are unripe no hollow is visible, but as ripeness approaches the hollow increases in size.

At several Institutes chemical methods to determine ripeness have been developed but unfortunately no practical solution has been found to date which is reliable.

Sometimes roots for very early forcing and mid-season forcing are dug and left for 5 days to ripen in the field, before leaves are removed. But recently mainly machine harvesting is done. A disadvantage is the disappearance of the ripening-off period between digging and removing the leaves. It has become clear that the natural ripening in the field can be substituted by cooling the roots directly at 3-4°C and a relative high humidity (pre-cooling).

Root yield

In witloof forcing it is not so much the root yield but rather the forcing quality. The right plant population is of great importance. The kg yield is mainly depended on harvest-date and to a lesser extent to the plant-stand due to the competition effect (less plants-heavier roots).

Starting from a plant population of 180-225.000/ha the average yield is by:

-digging mid August-mid Sept : 18-23 t/ha.

-digging mid Sept -mid Oct : 23-28 t/ha.

-digging mid Oct -mid Nov at latest: 28-33 t/ha.

The yield is also depended on yearly fluctuations and soil condition. Yields of 35-40 t are common.

Apart from root yield grading is important for the forcing result. The optimum size is 3.5-5 cm diameter near the crown. To harvest heavier chicons, roots of 5-6 cm diameter have to be used.

Root storage

Storage conditions

To store roots till after the end of January a temperature of 0°C is advised. Temperature will have to be as constant as possible. Relative humidity has to be a minimal 95-97%.

Even than it is still necessary to regularly moisten the roots, either by hand or by moisterizers. Regular control of roots is necessary because a moisture-loss of 5% or higher will lead to a decrease in production.

Although the level of damage is not precisely known, it is assumed that the CO2 content of the air inside the cell is not allowed to be higher than 1%. In air-tight cells possibilities for air circulation will have to be installed to make certain that the cell-air volume can be replaced 6-8x a day.

The ethylene content needs to be as low as possible. This gass is for instance produced by ripening fruit.

Storage of roots near products producing a lot of ethylene has to be avoided. Recent research results have shown that roots can be stored at a temperature of -1°C untill the summer period. With roots stored this way, a year-round production of witloof can be realized.

Reducing the moisture-loss will demand the necessary attention. In year-round production a climate-controlled forcing cell is therefore a necessity.

Storage methods

Although in the past roots were stored outside or in air-cooled storage rooms, modern production techniques have made it necessary to store roots in mechanically cooled cells to obtain optimum forcing results.

Mechanical cell cooling

For the forcing period end of January-May 15 roots need to be stored at 0°C. If longer storage is required e.g. to produce year-round witloof, roots will have to be stored at -1°C. Only in the mechanically cooled cell these temperatures are feasible. The cooling-area needs to be built as universal
as possible so that by switching over to other temperatures, storage of other products may also be possible.
Roots can be stored loose or in bulk-bins. For both methods of storage the following prerequisites are needed:
- -Sufficient insulation, expressed as K-value (W/m K). For insulation mainly polystyrene of various density is used (e.g. P15 weighs 15kg/m)
- -For walls and doors, K=max 0.35;12-16 cm polystyrene P15.
- -For the ceiling, K=max 0.23;16-20 cm polystyrene P15.
- -For the floor, K=max 0.58;min 6 cm polystyrene P25.

On the outside of the insulation a dampproof layer has to be applied. (In the door on both sides).
- -In connection with the use of fork-lift truck or bulk-bin carrier, a wide opening of the cell is necessary. The minimum size should be 2.5m wide and 3.10m high.
- -The to be installed cooling capacity is approx 315-335 kJ/m product per hour at a temperature difference of maximum 5°C between evaporator and cell air. The right capacity has to be calculated for each separate case.
- -The evaporator has to be supplied with an electronic defrosting mechanism.

  The ventilators have to be switched on a delay relay after defrosting

-The air movement in loose storage has to be 50 m^3 of air per m^3 product per hour as a resistance pressure of 150-200 Pa.
Storage in bulk-bins needs an air speed of 0.2m/s between the bins.
-To keep moisture loss to a minimum, the ventilators have to turn as less as possible when the cooling machine is switched off.
-For a successful longterm storage at -1°C drying prevention is a "must". In principle it is possible to do this by a high relative humidity and a small circulation parameter.
On top of that regular moistening of the roots is necessary.

It is still not known if storage in bulk-bins lined with perforated thin plastic film can reduce drying out. Before proceeding with the forcing of -1°C stored roots it is necessary to defrost them for 3-4 days at a temperature of approx 3°C. With loose stored roots the whole cell has to be brought to 0°C before forcing is possible. Sufficient and reliable measuring and regulating equipment has to be installed to check and regulate temperature and relative humidity in the cell. Electronic recording of temperature by means of more "feelers" at several places inside the cell is preferred.

Storage in bulk-bins

Compared to loose storage, bulk bins have several advantages. Only a dense level floor is needed and the cell walls don't have to be pressure resistant.
Against it is the need for a forklift-truck and pallet boxes (bulk-bins). Furthermore 40% more cooling space is needed compared to loose storage. The extra space can be obtained by raising the ceiling height to 5-5.5m.

The pallet-boxes have to have splits in the sides, to obtain good cooling in the heart of the pallet-boxes. The maximum sizes should be 1.2 x 1 x 1m (outside pallet inclusive). When using larger boxes airchannels have to be built in. When extra moisture is not applied it is suggested to cover the top pallet-boxes with perforated thin plastic film after they have been cooled. To make a good aircirculation possible 10 cm space between the row of boxes is to be left in the direction of the air outflow and 5 cm at right angles to it. Along side the side walls 15 cm space has to be left while 25 cm is needed for the front and back wall to improve aircirculation. Apart from cooling with free aircirculation, cooling can also be carried out by means of forced cooling. Special equipment is needed then but an advantage would be a better temperature spread inside the boxes.

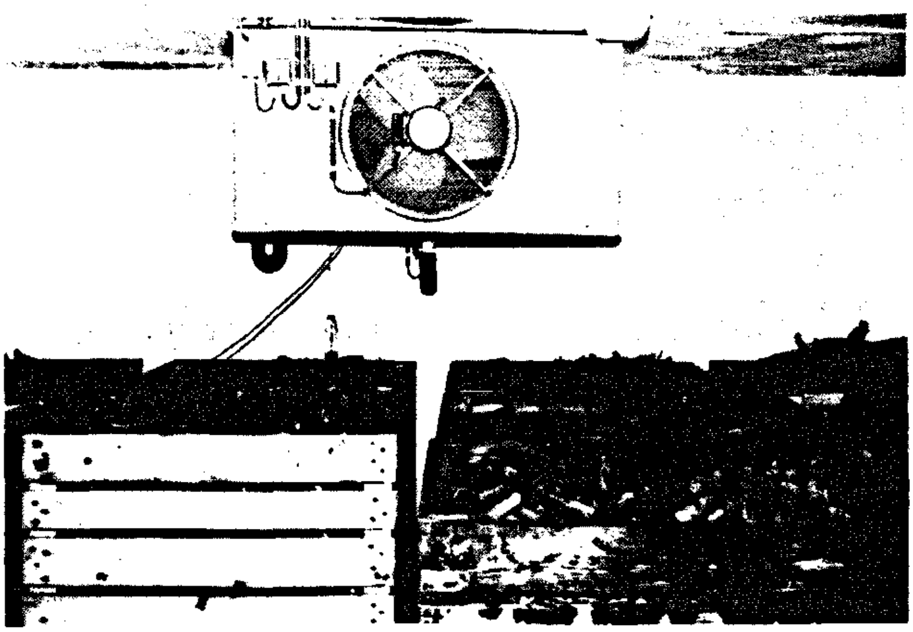

Plate 5 Storage of witloof roots in pallet boxes (bulk-bins) at -1°C

B Root forcing

General

During the sixties and seventies important changes took place in production technique.

In the early sixties dr. J.A. Huyskes of the IVT in Wageningen developed cultivars, which were suitable for forcing without soil-covering.

The advantage of this system compared to the older soil-covering system was a labour saving of 10-15%.

The latest development is the hydroponic forcing method in stacked boxes.

This method was already put forward in 1951 by the Belgian researchers Stenuit and Piot and was put to practise for the first time in the early seventies. At present hydroponic forcing is increasing in importance.

The most important advantage of this forcing system is, apart from a further labour-saving, a strong improvement of labour conditions.

In 1981 30% of the witloof forced was by means of the hydroponic method, by 1986 this had increased to 60% and it is expected that it will be around 80-90% by 1990.

Because of this fact, only the hydroponic method will be discussed here.

Hydroponic forcing

In this method roots are forced in boxes of approx 1m. The boxes are stacked and placed in a forcing area or room.

Water flows downwards through the stacked boxes and depending on the systeem and height of the stack, is supplied per box, per stack or per part of stack. The removal of water is done in such a way, that 4-5cm of water is left in the boxes.

It returns to a basin, where it will be re-supplied with oxygen and is re-heated when necessary.

Afterwards it is recirculated through the boxes by means of pumps.

The air inside the room must always be in circulation. The air temperature needs to be lower than that of the water. For that reason a ventilated system has to be present.

Building and layout of forcing room

The forcing room must be insulated in such a way that the K value of the walls and ceiling is 0.35 max. This is equal to 10 cm polystyrene (of sufficient density) as well as a half stone wall.

Fibre-glass or Rockwool can also be used for insulation.

In preference a damp-proof course has to be applied on both sides in the form of plastic foil or alluminium foil.

If forcing is started early or is year-round a 15 cm polystyrene insulation layer is necessary with a dampcourse on both sides.

The floor of the cell or room has to be level without doorsteps to be able to drive a fork-lift or stacker in or out. The floor may also be insulated. The forcing room must be air-tight however.

Forcing of witloof requires a lot of transport so that the unit has to be set-up as efficiently as possible in respect to distances.

Figure 2 shows a 2 men unit, set-up as efficiently as possible. The unit consists of a forcing room, a work room/area and a store room.

The lit-up work room is separated from the forcing room by means of a heavy black plastic curtain (sail-cloth).

The forcing room is divided into 4 cells by means of black plastic curtains (0.5mm thick) or other dearer types e.g. brick.
This way a weekly cycle of setting up and harvesting is possible, without disturbance of forcing in the other cells. When forcing is done for the greater part of the season, than a light insulation of the walls may be advised. Per cell 2 rows of forcing boxes are placed with a space between the rows of 70-80cm. The forcing boxes can be stacked up to 8 high. Between the box and the wall or curtain a space of 20cm is left. The size of the cell depends on the quantity of roots needed to be forced at the same time.
The working room area has in this situation been insulated as heavily as the forcing, and must be rather large because transport does occur here too and part of the storage takes place here (depending on the circumstances 100-170 m^2).
If the unit needs to be expanded than only the top ends have to be removed to extend the storage cells and the forcing cells. A disadvantage of this type where the boxes are standing in rows and are being harvested per week or half a week, is that it is impossible to harvest all the witloof at the optimal time. To be able to do that, the layout has to be in such a way that work can be done per day.

Figure 3 gives an example of this.
In the forcing cell 24 units are present. One unit has to be harvested and refilled in 1 day. In such a layout the pathway on which the fork-lift has to work is situated in the forcing cell.
The forcing cell is separated from the working room area by means of a fixed wall. This wall and the door have to be insulated if the working room is insulated lighter than that of the forcing room.
The cell has to be approx 20m long. The width of the cell depends on the width of the pathway and the number of stacks per unit.

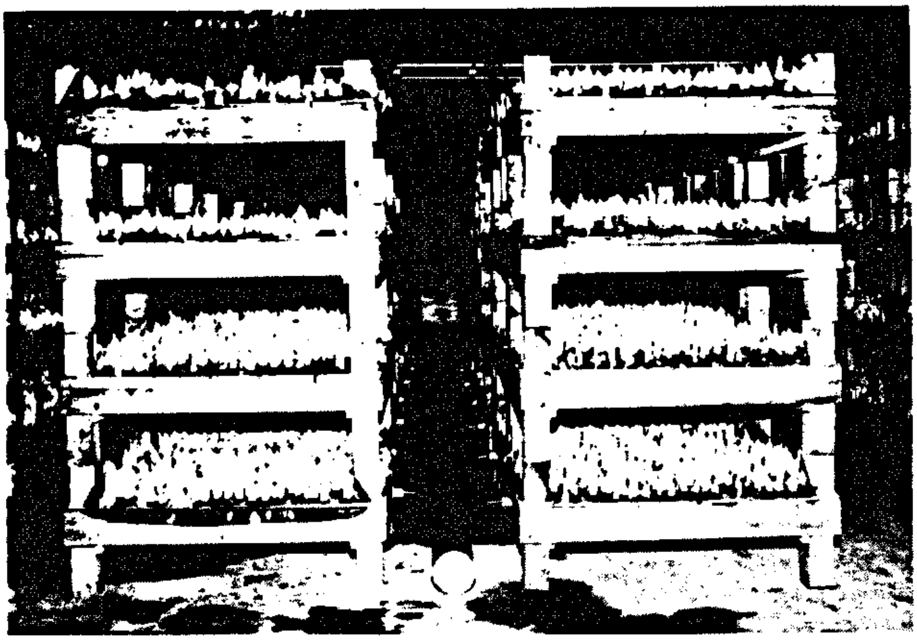

Plate 6. Forcing of witloof in boxes with flowing water hydroponics

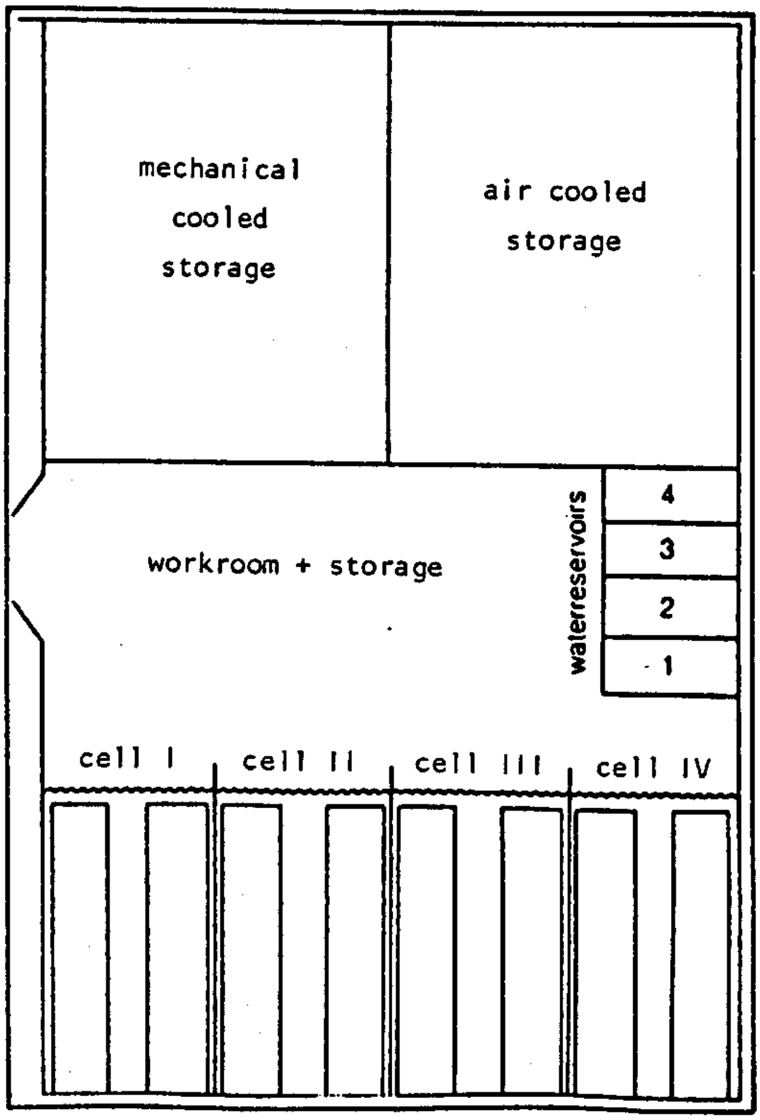

Figure 2 Most efficient layout of 2 person witloof unit.

Forcing boxes

The forcing boxes can be made out of several types of material. Mainly impregnated pine boxes are used in the sizes 120x90cm ($\pm$1m^2) and a leg height of 50cm (see figure 5). The boxes are lined on the inside with heavy-duty black plastic (0.5mm thickness) and have an overflow - pipe. Thinner plastic is easier to puncture and therefore is not used. The plastic is fastened on top of the sides with 1cm wood strips and nails. The overflow height (4-5cm) can easily be adjusted (see diagram).
At the end of forcing the water can be removed by lowering the pipe in the box. The internal diameter of the pipe is 3cm minimum to avoid clogging up. The pipe is mounted several cm's from the middle of the shorter side.
The wooden boxes have to be tanalised (vacuum-pressure impregnated) because of the otherwise short life-span in the forcing cell.
Apart from wooden boxes, also plastic or polyester boxes in metalframes are available.
Also completely alluminium boxes are used. The disadvantage of these are that they give off a lot of heat.
On top of that these type of boxes are not corrosion free so that coating is necessary.

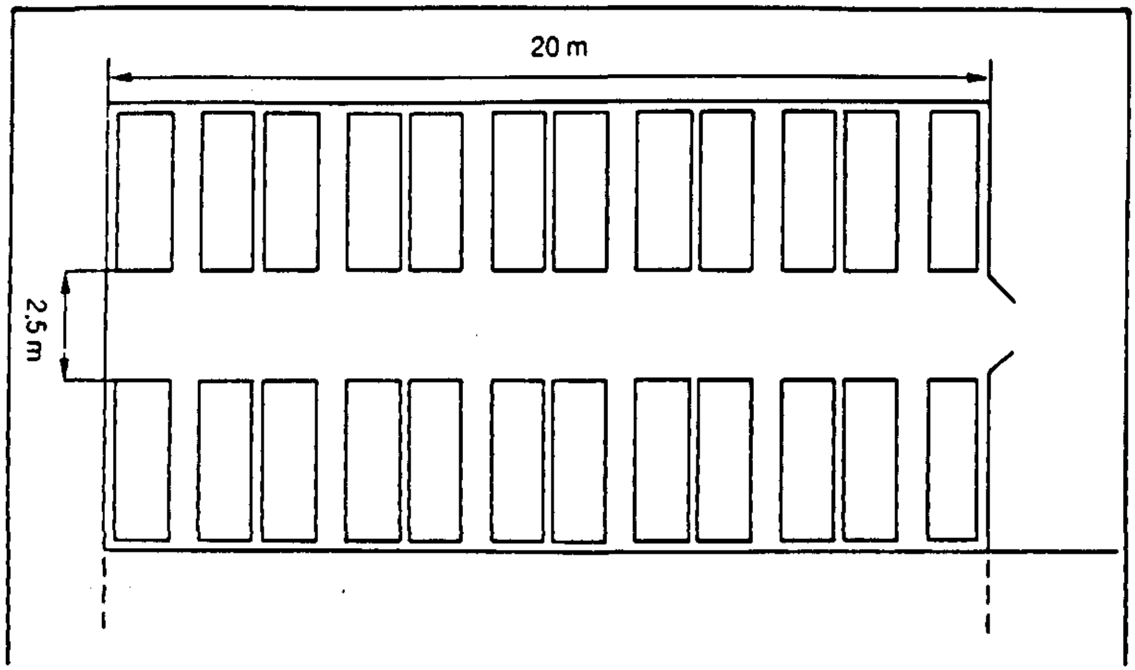

Figure 3 Layout witloof unit (Hydroponic) with daily cycle of setting up and harvesting

Water circuit

Water being pumped to the boxes, comes from basins with a content of 0.5-1 m^2 (see figure 6). The basins are placed in the ground outside the forcing rooms and have to be insulated. Groundwater is not allowed to penetrate the insulation. In large forcing units a minimum of 4 basins and 4 forcing cells are built in preference so that per cell a separate air and water temperature and nutrition regulation can take place as well damage can be reduced when diseases or other problems appear.

As less as possible metal parts have to be part of the system because of corrosion.

The pump is therefore made of synthetic material, and often swimming pool pumps are used. The pump has to maintain a pressure of 100-150kPa in the line above the stacks. The capacity has to be 25% higher than the maximum use. Flow is 5 litre/min. per connection point.
It is advisable not to connect more than 4 boxes per connection point, due to temperature and oxygen drop.

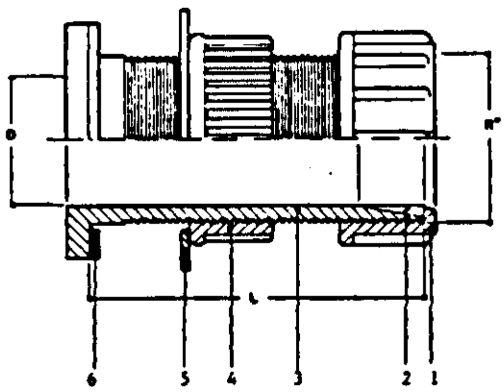

Figure 4 Construction water flow through couplins for witloof boxes

Example

Is a cell suitable for 100 boxes in stacks of 4 than 25 connection points are necessary. In this situation therefore 25x5 litre/min = 125 l/min.
The pump must be able to do 1.25x125 = 156.25 l/min. The 25% over capacity goes via a by-pass back to the basin. This water is replenished with oxygen. The valve in the by-pass is to regulate the systems pressure. Water is pumped through the pipes, which are situated as high as possible above the stacks. From here water flows through hoses into the top boxes. The quantity of 5 litre/min can be regulated by taps in the hoses.
When the boxes are stacked 8 high, 2 connections are necessary per stack.

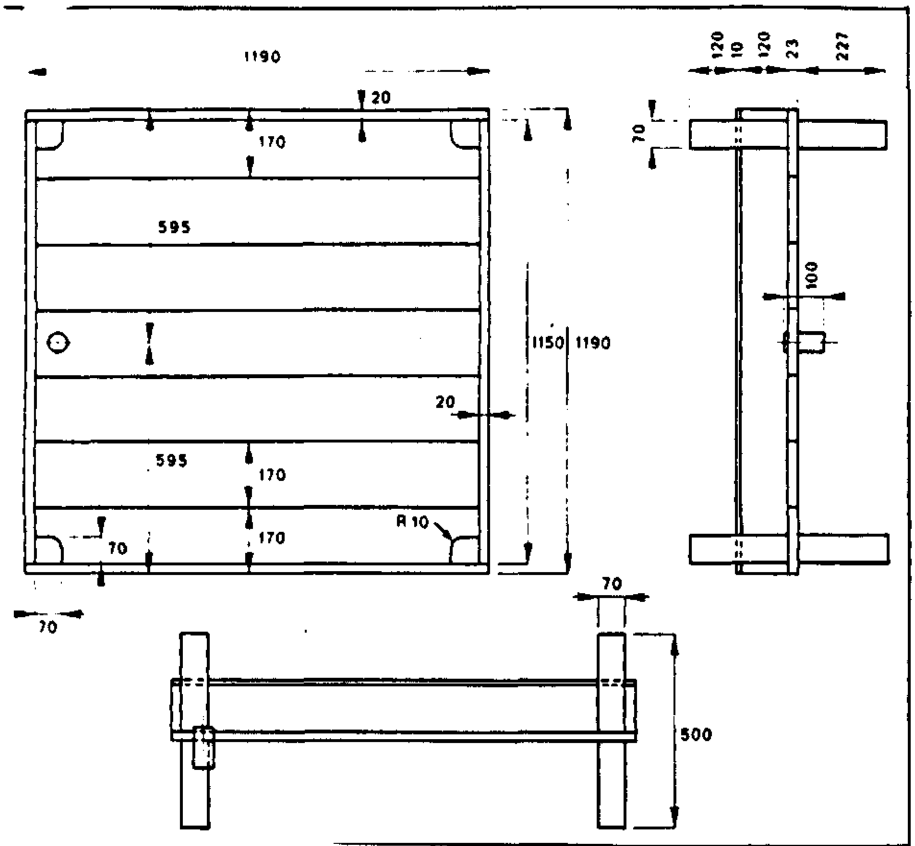

Figure 5 Dimensions witloof box

The supply to each row of stacks has to be able to be closed. The water level in the boxes is 4-5 cm. When the water has cascaded through the boxes it has to be returned to the basin. The return pipes are laid under ground in preference. Before the water flows into the basin it can pass through a "settling" pit to remove solids. Water in the basin is topped up from the mains ball-cock valve. The basin has to have an overflow to avoid flooding. Cleaning the basin after forcing is advisable in prevention of diseases.

Heating

The easiest way to heat the water is by using a tubilene-hose spiral in the basin.

The thermostat regulates the water temperature. To give sufficient heat, a certain length of hose is necessary. For heating of the proces-water a cv capacity of 210-290KJ per hour per m^2 box surface area. The high value goes for small "forceries (approx 100 boxes of $1m^2$) and the value of 210kJ for the large "forceries" (approx 500 boxes).

When properly insulated, the air in the forcing cell is sufficiently heated by the water in the forcing boxes, so no extra heating is necessary. For heating the working room, 210-420 kJ/hour is necessary depending on the height and matter of insulation per m^2 floor area.

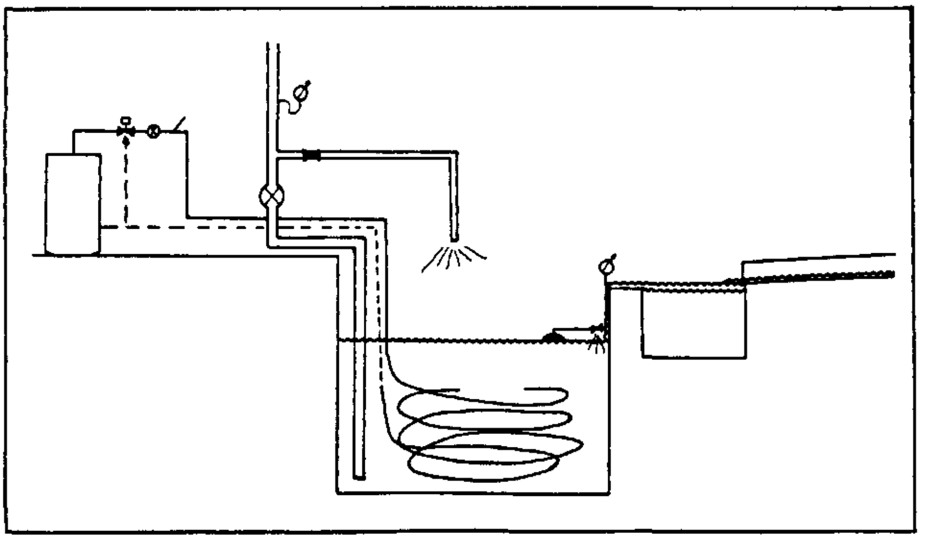

Figure 6 Waterbasin and accessories

Ventilation and air circulation

Each forcing cell has to have a ventilator to give air-circulation and air-replenishment. The ventilator has to have a capacity of 10 x the cell content (volume) per hour, at 150 Pa resistance pressure. Between the ventilator and outside wall a pipe is mounted in which the valve is placed (figure 7) so that the ventilator can suck air from the cell or the outside air (or a mixture). The temperature and humidity inside the cell can be controlled this way between September-March.

If an earlier start of later forcing is required, a cooling unit is necessary. The humidity is measured with a hygrometer, the temperature with a thermometer.

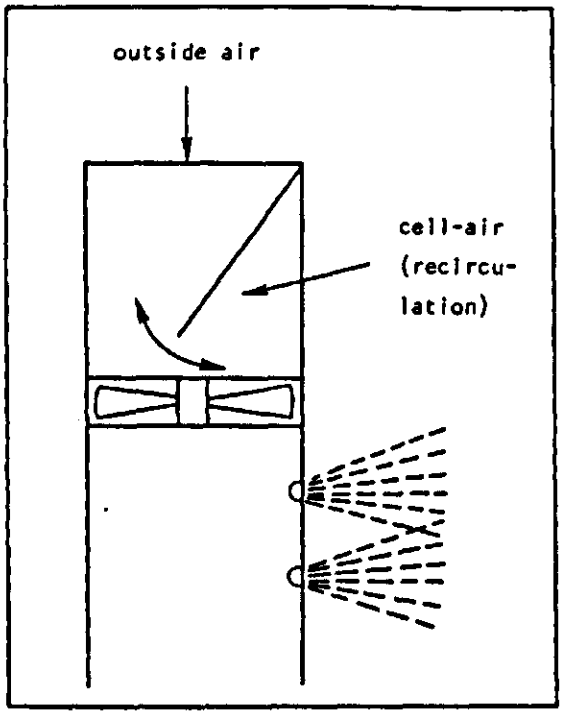

Figure 7 Ventilation channel

Both have to constant within parameters.

For example, the humidity may lie between 95% an 85% but is not allowed to fluctuate during forcing more than 5%. Temperature differences larger than 0.5°C inside the forcing cell have to be avoided. Air is blown by the ventilator through collapsible plastic tubing which contain holes on the underneath side. A directed air-flow across the chicons is not necessary.

Air speeds till 1 m/s across the crop at a high relative humidity are not detrimental. Ventilation can be carried out automatically. It can be rather small: 2m^3 air per hour per m forcing area is often sufficient. Sometimes more often ventilation is necessary to remove the produced heat and to maintain a larger difference between air and water temperature.

The ventilator has to be supplied with a revolution regulator to adapt airspeed to the requirements.

Transport

The advantage of the hydroponic forcing method is that all transport can be mechanized. The supply of roots to the workroom, where the roots are "set-up" can be done with a tip-wagon, a 4 wheel wagon, transport-wagon belts or in bulk-bins. The stacked boxes are placed in or taken out of the cell with a fork-lift. The forced roots are dumped after harvest into a bulk-bin or on a wagon. The walking distance is therefore short. For transport of the boxes in and out of the cell, an electric driven fork-lift is most handy since a stacker often suffer from slipping. It is advisable also to buy a hand fork-lift. These are handy in difficult to reach places. As an aid in harvesting and "setting-up", a little trolley is used on which 1 box can be placed at working height.

"Setting-up" and harvesting

To be able to harvest and to set up roots, the forcing box is placed on a moveable trolley. These can be made collapsable to store easily when not in use. The fastest way of setting up the roots is to place the roots with relative clean roots in the box and following this to place the roots with both hands against each other at a slight angle. Longer roots are placed more at an angle than short ones to be able to keep the uppersides level.

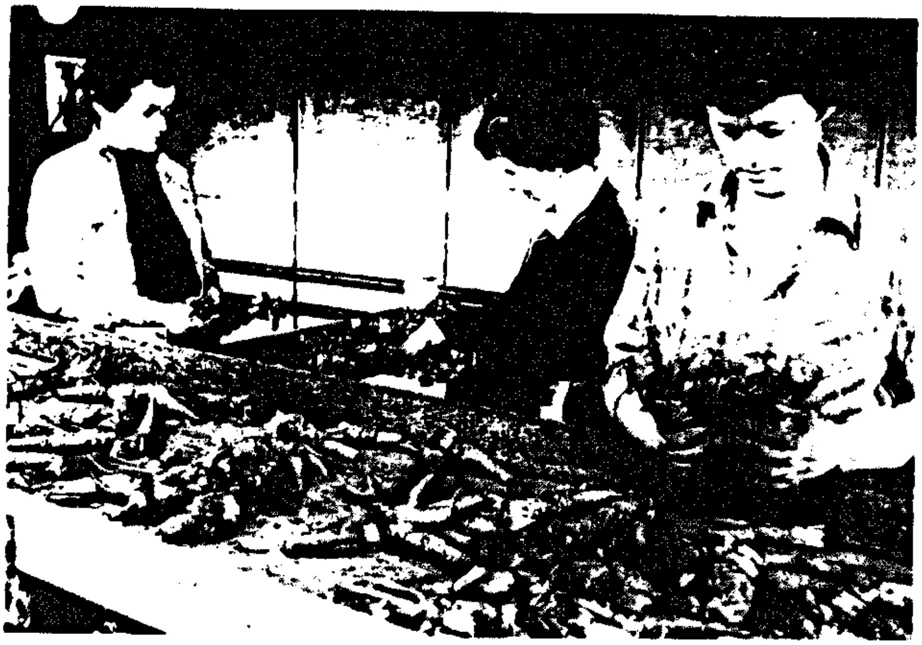

Plate 13. Setting -up of roots in forcing boxes from a belt

For filling the last part of the box, the roots are taken out of the next box. Blind roots and roots too thin are removed and are dumped in a pallet box. The root crowns have to have sufficient space (less disease spread). Per box of $1m^2$ 70 kg roots are set-up. Often the work is done with 2 people one person on either side each capable of putting 3-5 roots in the box each time. The best way is to start from the overflow pipe.

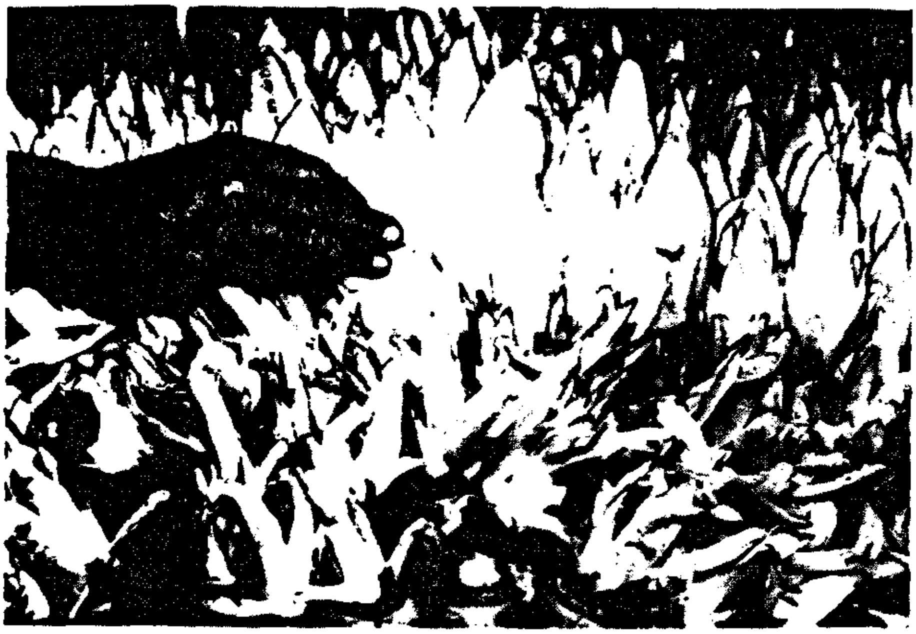

Plate 14 Chicons are broken off the root

Forcing techniques

In hydroponic forcing it is not necessary to use a pre-forcing period. Without this period forcing time is 3-4 days shorter. The P.A.G.V. research station has carried out a research programme into the required climatic forcing conditions. Table 5 gives the climatic requirementes of the various forcing periods. These can slightly vary according to cultivar used and "ripeness" of the roots.

Table 5 Forcing temperatures of hydroponic forcing of witloof.

forcing period	setting up period	water temp °C	air temp °C
very early	August-September	21-22	17-18
early	October-November 15	19-20	15-16
mid season	November 15-February	18-19	14-15
late 1	February-March	16-17	12-13
late 2	April-May	15-16	11-12
summer	June-September	14-15	10-11

Nutrition, oxygen supply and pH of process water

Research has shown that addition of nutrients to the water increases yield.
The most important element is Nitrogen in the form of Nitrate. Ammonium is disadvantageous. Other minerals play a lesser role so nutrition can be carried out easily with a soluble fertilizer, mainly Calcium nitrate.
The quantity added to the water depends on the EC value (electric conductivity). The normal EC of tapwater depended on origin is mainly 0.4-0.9. Calcium nitrate is added, up to an EC of 2 and is kept to that figure by regular control (2-3 days). This process can also be automated.

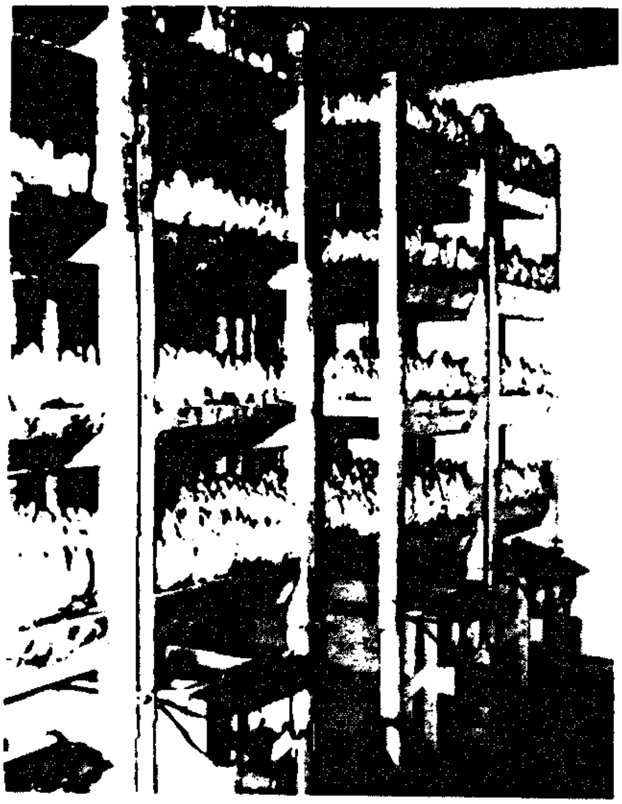

Plate 15 Research installation of P.A.G.V.

Nutrition does not always have to be beneficial. It can depend on cultivar, forcing period and root origin. When several basins are present, it is not necessary to add nutrients during the last week of forcing.

Manuring shortens the forcing period by several days. It is not exactly known what effect it has on the keeping quality of the witloof.

The oxygen content of the water has to be kept at a sufficiently high level.

Roots need oxygen for life processes.

The minimum oxygen content of the water in the basin is 50% of the maximum soluable quantity (=5mg O_2 per litre water at 16°C). The oxygen content can be kept at a certain level by using aerators.

During the flow through the boxes oxygen content can decrease below the 50% level. If in doubt, the content should be checked.

Foaming of the water, in the beginning of each forcing quite common, is mainly caused by K-content of the soil still hanging onto the roots and does not necessarily indicate an oxygen shortage.
Water pH may vary between 6 and 8. When using tapwater no problems should occur. The pH increases slightly during forcing. A pH of 4.5 does not have to be a disadvantage, but is not recommended.
Using water with a high iron content and a pH lower that 6 can cause a blue discolouration.
Lower pH's can also reduce the growing speed of witloof.

Disease control

During forcing the usual diseases and pests can be present like aphids, witloof-miner and Sclerotinia. These may or may not be controlled in a preventitive way (see diseases and pests).
Phytophthora can spread rapidly through the water by means of moving oōspores. A direct control is not known, and no compounds are allowed to be added to the water to control fungi or bacteria.
If Phytophtera is present, all equipment will have to be cleaned after forcing by bleach followed by rinsing out with clean water.

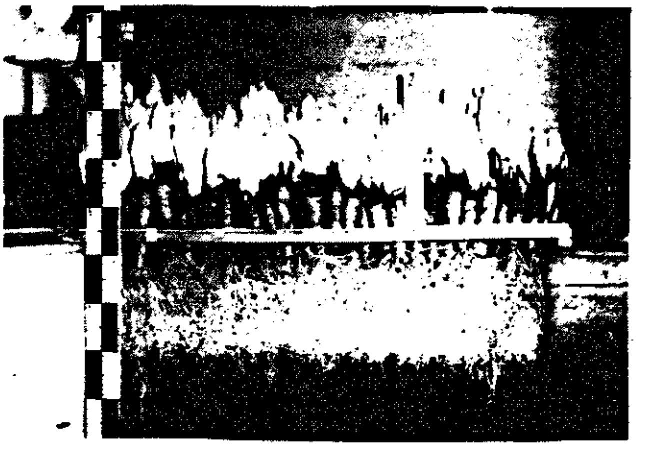

Plate 16. Excellent "rooting" during forcing

Another problem which occurs is "sliming" of the water. This can happen when a lot of dead organic material is present in the water (rotting roots, bits of leaves).
On this dead material bacteria develop, which multiply fast and use up a lot of oxygen. This will cause anaerobic conditions which favour that type of bacteria.
This will cause sliming: a stinking blue-mush which is the cause of production decrease. The problem can form when a weak batch of roots is used containing rotten and defected roots.
Also when the oxygen supply of water is insufficient and/or too much soil is stuck to the roots causing a poor flowrate, sliming can be stimulated.
As with Phytophthora all equipment will have to be cleaned.
Sliming can be avoided when clean healthy roots are used and sufficient oxygen is present. Recently Fosethyl-alluminium (Aliette) has been given clearance to use for the control of sliming.
The rate to be used is 300gr per $1m^3$ of waterproces at the start of forcing.

Other witloof hydroponic systems

Several systems have been developed apart from the one described in this book.

1. system Versailles
2. system Cuvillier
3. system Beauvais
4. system Belgian Farmers Union

No further details will be given here.

Witloof Yield

The witloof yield obtained per ha from forced roots is influenced by many factors. Apart from the seasonal influences, the succes of root growing plays a most important role. Furthermore a good laid out forcing room is very important to produce an optimal yield. To start roots during a long time in good conditions a proper installed storage cell is required. In the past research has been carried out in the yield by 3 forcing systems namely:

- forcing with soil covering
- forcing without covering
- hydroponic forcing

In comparing the systems hardly any differences were observed on average during the seasons. During the months of January-February witloof yields of more than 20 tonnes/ha were obtained. These research yields cannot be transferred to yields in practise. It does indicate however that room for improvement exist in commercial situations. From statistical information it appears that the average witloof production per hectare over the last 5 years is approx 10 tonnes. This figure stays rather steady during the last decades also in Belgium and France.

Plate 17. Trimming and cleaning of chicons

The influence of improvements in cultivars, cropping and forcing techniques apparently is compensated by negative influences. This may include an increase in mechanisation in the field and during forcing. Little is known about the number of miss-harvests which do occur due to diseases. It may also be that a lot of trade is now taken place outside the cental market system. Assuming a good root crop is obtained the following witloof yields can be realised (Table 6).

Table 6 Witloof yields in tonnes/ha during various harvest periods.

harvest period	witloof (chicon) yield tonnes/ha
September-October	8.5 - 10.5
November	12.0 - 14.0
December	13.0 - 15.0
January-February	14.0 - 17.0
March	12.5 - 15.0
April-May	11.0 - 13.0
June-August	9.0 - 11.0

Delivery

In the Netherlands witloof is generally traded and sold via the Central Market System. Mainly plastic crates with 5kg content are used for packaging.
Class I witloof is only sold in 500gr polystyrene trays or cardboard boxes of 5kg content. The quality, grading, packaging and indication descriptions are normalised in the E.E.C. -the most important points are given here.

Quality control description

The minimum requirements for witloof are: intact, healthy, not diseased, without bruises and damage by rodents, diseases insects etc. Fresh looking, clean, free of abnormal external moisture and free of strange smell or taste.

The chicons have to be clear, meaning a white to yellow colour and have to be cleanly cut under the outside leaves. Another minimum requirement is that the product is not allowed to contain compoundsdamaging to the public health.
This does not only include leftovers of residues, but also a too high content of an organic material which can form a problem to public health.

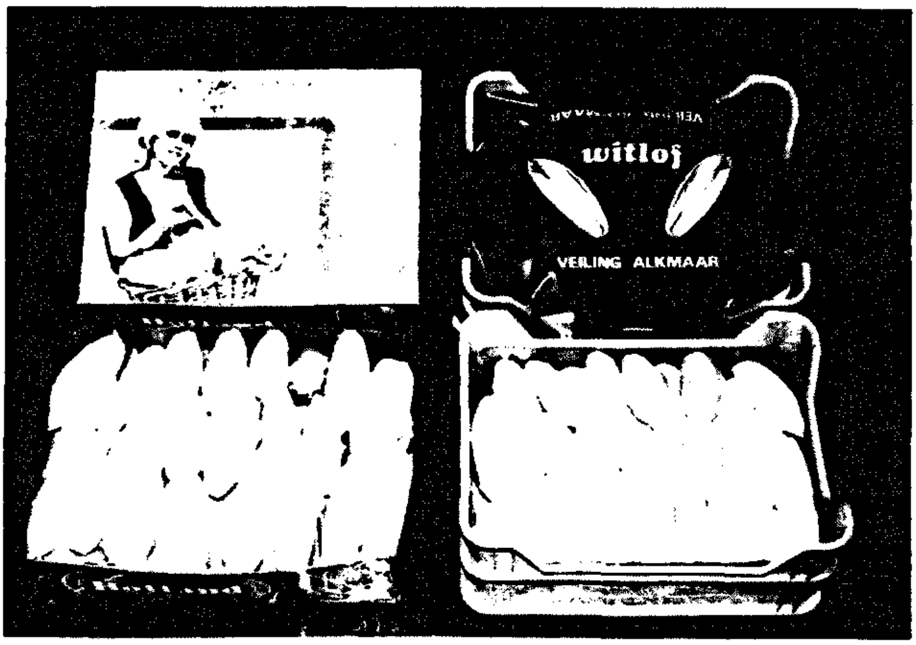

Plate 18. Class I may be packed in cartons as well as in multiple use plastic trays

Class Extra. The chicons must be firm and regulary formed with a pointed and closed top. The witloof is not allowed to be glassy or greenish in colour and have to be free of pit.

Class I. The chicons must be sufficiently firm, and nearly closed at the top. As maximal opening 1/5 of the diameter. By delivery the leaves are not allowed to have a green colour. The pit length may be maximal half of the chicon length.

Class II. The form may be slightly irregular. Allowed are a light green colour at the end of the leaf also allowed is a slight opening of the chicon (maximum 1/3 part of the largest diameter). The pitlength may be maximal 2/3 of the chicon length.

Class III. Must be fit for human consumption. Especially mould, dirt, pit and discolouration can be reason for non-clearance.

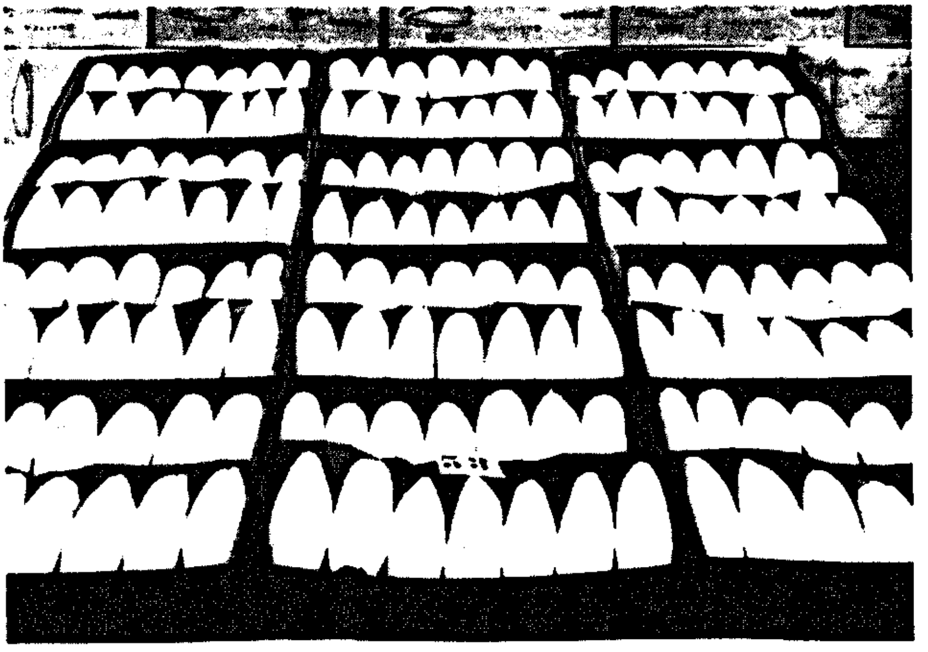

Plate 19. Witloof packaged in cartons

Grading requirements.

The witloof is graded to size, meaning diameter and length. The official E.E.C. grading requirements are shown as follows.

Table 7 Grading requirements of witloof in the E.E.C.

extra	length of chicons in cm		diameter of chicon in cm		
	minimum	maximum	at a crop length of		
			<14cm	714cm	maximum
Class I	9	17	2 1/2	3	6
Class I	9	20	2 1/2	3	8
Class II	9(1)	24	2 1/2	2 1/2	-
Class III	9(1)	24	2 1/2	2 1/2	-

1. In classes II and III witloof of 6-12 cm length is allowed for sale, as long as it is indicated on the packaging. The maximum in length within a packaging unit may be 5, 8 and 10cm for classes Extra, I, II and III respectively. The maximal diameter variation within a packaging unit may be 2 1/2, 4 and 5cm for classes Extra, II and III respectively. For class III no maximum exist. The Central Bureau of Markets has included more detailed requirements in the Dutch regulations.

Grading requirements of witloof in the Netherlands

Class	length of chicons in cm minimum	maximum	diameter of chicons in cm minimum
Class I short	9	15	2 1/2 (1)
Class I long	14	20	3 (1)
Class II short	9	15	2 1/2
Class II long	14	24	2 1/2
Class III	9	24	2 1/2

1. In case Class I witloof in cardboard or polystyrene packaging is offerd for sale, the diameter of the chicons has to be 3 1/2cm.

Packaging requirements

The content of each packaging unit has to be uniform in quality and grading.
Packaging of witloof has to be put in horizontal layers, each layer carefully arranged.
Class I may be offered in once-only or multi use packaging.
Class II and III may only be offered in multi use packaging.
The multi use packaging material consists mainly of plastic trays belonging to the Central Marketing hire pool. The content is 5kg.
Several markets made it compulsary for their members to package Class I in only once usuable pakaging. Other markets do not have this regulation, but do stimulate their members to supply witloof in cardboard boxes (once-only use).

Witloof of class I is delivered in 5kg cartons with a special colour print for short and long witloof. The small packaged witloof is delivered on polystyrene trays, content 500 gram wrapped with plastic foil (thin plastic film). The trays are packed in special 5kg boxes.

Presentation requirements

On the outside of each packaging unit the following descriptions have to be given in clear readable and non removable/washable lettering: class, grading and for export the production area/country as well as the nett weight.

Organisation and economics of witloof forcing

The setting up and planning of witloof forcing are generally on average, rather easy, compared to the daily running and regulation of the process to obtain an optimal result.

For setting up the following points are of importance.

Forcing area: The size of forcing area depends on the number of forcings.
The size of the floor area depends on the number of boxes in each stack (1,4,6 or 8 high) and the quantity of free space required.
The layout of the forcing area depends on the process time (3,4 or 6 weeks) and the number of work-units per week (1,2 or 5 times harvesting and setting up again).

Work room: The size depends on the number of people and level of mechanization (machines and transport). Also of influence is if harvesting and setting up have to be done at the same time (minimal 8 persons) or if it occurs after each other.
The number of people depends on a continual 40 h/week or discontinual (several days/week) working.

Storage capacity: This depends on the area needed for forcing after December 1.
Roots forced till February 1 can be stored in an air-cooled cell.
Later forcing requires mechanical cooling.

Labour requirements: This depends on skill and method of working.
Every movement made during cleaning the crop relates to 60-80 hours/ha
On larger units a 2 movement method is often chosen namely: breaking the chicons off the roots +cleaning, trimming and grading +packaging (using both hands)
This way the extra time is kept at 80-100 hours/ha.
In table 8 an outline is given of the labour requirements in hours per ha.

Table 8 Labour requirements in hours per ha of forced roots in a hydroponic system

harvest month	no of roots x 1000	setting up	harvest	total
September	145	142	282	424
October	150	166	330	496
November	155	170	380	550
December	160	172	432	604
January	155	170	420	590
February	155	170	420	590
March	155	170	410	580
April	150	166	354	520
May	145	162	336	498

This type of forcing in running water (hydroponics) gives a labour reduction of approx 10% compared to the older methods in the soil without covering.

Gross margins. Since gross-margins depend on a lot of factors e.g. wages etc. no further details will be given here.

Investments and annual costs.

Again it is difficult to give exact amounts here since this will depend on a lot of factors and prices which are different for each country. However when building a new witloof forcing unit at least 250.000 guilders are required as inverstment with annual costs of 29.000 guilders in the Netherlands.

LITERATURE

Alofs, W.J. en J.A. Rovers. Ziektebeelden witlof. Tuinderij Vollegrond nr. 6, 17 dec. 1981, pag. 16-19.

Bannerot, H., Ch. Lesaint et B. de Conink. Les techniques de forçage des racines d'endives continuent à évoluer. Pépiniéristes Horticulteurs Maraîchers (1976) 170, 21-27.

Barendse, H.F.J. Consumentenonderzoek witlof. Centraal Bureau van de Tuinbouwveilingen, 's-Gravenhage (1978), 8 blz.

Blunck, H. (ed.) Tierische Schädlinge an Nutzpflanzen 2. Teil; 5. Aufl. 1., Lief. Diptera und Himenoptera. Berlin enz., 1953. VIII, 311 blz.

Blunck, H. (ed.) Tierische Schädlinge an Nutzpflanzen 2. Teil; 5. Aufl. 4., Lief Homoptera II. Teil. Berlin enz., 1957. VIII, 577 blz.

Brienen, F. en J. Groen. Worteltransport van begin tot eind. Tuinderij/ Vollegrond 3 (1981) 5, 24-25.

Cappelle, W., en J. Lips. De arbeidsbehoefte in de witlofteelt; resultaten van een arbeidskundig onderrzoek. Merelbeke/Gent, 1971. 66 blz.

Chicoree, La, de Bruxelles; symposium international de Section Horticole d'Eucarpia; Gembloux, 17 et 18 Fevrier 1970. Z.pl., 1971. 248 blz.

Coninck, B. de., J.P. Cochet et J. Leteinturier. L'Endive, Chicorée Witloof, Chicorée de Bruxelles, INVUFLEC-Paris (1977), 114 blz.

Coninck, B. de et Ch. Lesaint. Forçage hydroponique. Bulletin de liaison des endiviers (1977) 36, 21-32.

Consulentschappen voor Planteziektenbestrijding en Plantenziektenkundige Dienst. Gids voor ziekten- en onkruidbestrijding in de Land- en Tuinbouw. Wageningen 1981, 456 blz.

Dolezal, J. Einfluss verschiedener Treibverfahren auf Ertragsleistung und Inhaltsstoffe von Chicorée (Cichorium intybus L. var. foliosum). Diss. Hohen Landwirtschaftlichen Fakultät der Universität-Bonn (1975).

Driessen, S. Witlofwortelen en stikstof. Groenten en Fruit, 3 februari 1982, pag. 44.

Dunn, J.A. The biology of lettuce root aphid. Annals of Applied Biology 47 (1959) 3: 475-491.

Eurostat: Teelt in de EG. nr. 3/4, 1980. Uitgave Bureau voor de Statistiek der Europese Gemeenschappen te Luxemburg.

Franken, A.A. en J. Hamersma. Het koelen van witlofwortels voor de extra vroege trek. Bedrijfsontwikkeling 5 (1974) 3, 267-270.

Franken, A.A. en J. Hamersma. Invloed van de bodem- en luchttemperatuur tijdens de trek op de opbrengst en kwaliteit van witlof zonder dekgrond. Bedrijfsontwikkeling 5 (1974) 11, 1007-1011.

Geldof, W. Uit de geschiedenis der tuinbouwgewassen; witlof. Groenten en Fruit 15 (1959) 21: 636; 16 (1960) 2: 58.

Granges, A., et al. Essais d'Endive Witloof: 1978/'79, 1979/'80, 1980/'81. Centre d'Arboriculture et d'Horticulture des Fougères. Conthey-Valais (Suisse).

Groen, J.G. Inrichten van trekruimten (1 + 2). Tuinderij/Vollegrond 1 (1979) 3, 10-11 en 1 (1979) 4, 6-9.

Ham. M. van der, G. van Kruistum en J.A. Schoneveld. Witloftreksystemen een vergelijking van produktie, arbeidsbehoefte en financieel resultaat. Publikatie nr. 6 (1980) PAGV.

Hee, L. van. Les substances amères de Cichorium intybus. Annales de Gembloux 71 (1965) 211-220.

Henkel, A. Beregnung im Feldgemüsebau. In: Breunig, W. Beregnung in der Pflanzenproduktion. Berlin, 1969. blz. 135-155.

Hilhorst, R.A. De houdbaarheid van op de veiling aangevoerde witlof. Rapport 2177 (1981). Sprenger Instituut-Wageningen.

Huyskes, J.A. Veredeling van witlof voor het trekken zonder dekgrond. Mededelingg 202 (1963). IVT-Wageningen.

Huyskes, J.A. en R. van Dam. Witloftrek zonder dekgrond. Zaadbelangen 24 (1970) 11: 223-225.

I.L.R., I.T.T. en P.G.V. Verslag van de rooiproeven van witlofwortels in 1970. Wageningen, 1971. 16 blz. ILR-rapport, 188.

Jolivet, E.S., Lefèvre et B. de Coninck. Détermination de l'état physiologique de la racine tubérisée de Chicorée de Bruxelles (Cichorium intybus L.) par son pouvoir réducteur à l'égard du 2.6-dichlorophénol-indophénol: application au réparage de la période optimale de forçage. Physiologie Végétale 14 (1976) 4: 849-863.

Jonkers, J. Onkruidbestrijding in witlof. Boer en Tuinder 34 (1980) 1680: 76-77.

Kruistum, G. van en S.P. Schouten. Zijn er mogelijkheden voor de bewaring van witlofwortels beneden het vriespunt? Bedrijfsontwikkeling 9 (1978) 12: 1115-1117.

Kruistum, G. van en S.P. Schouten. Ook witlof het jaar rond. Groenten en Fruit 36 (1980) 8: 63.

Kruistum, G. van. Lucht- en watertemperaturen bij de witloftrek op water. Groenten en Fruit 37 (1981) 15, 53-55.

Lecrenier, A. et V.E. Tilkin. Cycle de croisssonce et du développpement de la chicorée de Bruxelles. Advances in Hort. Science, vol. I (1961), 462-469.

Lips, J., G. Jansen en L. de Temmerman. Witloofrooimachines-Resultaten van de nationale witloofdemonstratie Mollem 19 oktober 1980. Publikatie 80 (1981). Rijksstation voor Landbouwtechniek - Merelbeke.

Lounsky, J. Les mineuses de la chicoree de Bruxelles; nouvelles observations sur l'importance du décolletage. Mededelingen van de Landbouwhogeschool en de Opzoekingsstations van de Staat te Gent 29 (1964) 3: 1056-1061.

Lounsky, J. Mouches de la chicoree witloof (Napomyza lateralis Fall. et Ophiomyia pinguin Fall.) In: Rapport d'activité pour l'annee 1965 de Station d'Entomologie de l'Etat. Gembloux 1966. blz. 12-19.

Meeldijk. B.P. Oogsten van witlof met transportbanden. Groenten en Fruit 27 (1972) 37: 1683, 1685.

Meijer, E.N.C. Precisiezaai van fijne zaden met de Mini-air precisiezaaimachine. Landbouwmechanisatie 29 (1978) 2:125-128.

Ministerie van Landbouw. De Witloofteelt. Ministerie van Landbouw-Dienst Informatie. Brussel (1979), 63 blz.

Mullem, W.A. van. Machinale oogst witloofwortelen. Groenten en Fruit 35 (1979) 22, 62-65.

Nawrocki, K.R. Eisen bij trek van witlof op water. Groenten en Fruit 35 (1979) 7, 41-43.

Nerum, K. van. Wetenschappelijke studie van en voor de witloofteelt in België. Agricultura 24 (1976) 2: 125-200.

Nicolaï, P. Fertilizer requirements of witloof chicory, forced in running water. In: Proceedings Fourth International Congress on Soilless Culture. Las Palmas (1976): 65-74

Peeters, L. De witlofteelt. Katholieke Universiteit Leuven, 1952. 141 blz.

Plumier, W. La chichorée de Bruxelles-Incidence de la fumure minérale sur la qualité de légume. In: Proceedings of the 8th Congress of the International Potash Institute-Brussels (1966), 249-255.

Plumier, W. De veredeling van het witloof. Landbouwtijdschrift 25 (1972) 4: 561-580.

Produktschap voor Groenten en Fruit (PGF). Kwaliteitsvoorschriften verse groenten en vers fruit. P.G.F., 's-Gravenhage (1977).

Produktsschap voor Groenten en Fruit (PGF). Marktoverzicht witlof, febr. 1979, dec. 1980 en febr. 1982. In: Markt-Info PGF 1 (1979) 38, 2 (1980) 241,
4 (1982) 35.

Proefstation voor de Groenteteelt in de Vollegrond in Nederland. Jaarverslagen 1954 t/m 1975, Alkmaar.

RIVRO. 31e Beschrijvende rassenlijst 1982 voor groentegewassen - Vollegrondsgroenten. RIVRO-Wageningen (1981). 240 blz.

Roggen, H.P.J.R. Prediction of the proper stage of maturity for forcing chicory roots (Cichorium intybus L.) by determination of inulase activity. In: Proceedings Eucarpia Meeting on Leafy Vegetables (1976). IVT-Wageningen.

Sant, L.E. van 't., H.E. Vijzelman en J.G.C. Bethe. Enkele gegevens over de witlof-mineervlieg (Napomyza lateralis Fall.) en haar bestrijdingsmogelijkheden. Alkmaar, 1961. 36 blz. P.G.V.-mededeling 22. Ook verschenen als IPO-mededeling 268.

Sant, L.E. van 't, J.G.C. Bethe. Levenswijze en bestrijding van de witlofmineervlieg. Napomyza lateralis Fall. In: Jaarverslag 1966 van het Instituut voor Plantenziektenkundig Onderzoek. Wageningen, 1967. blz. 80-84.

Sant, L.E. van 't, e.a. Waarnemingen over mineervliegen (Napomyza spp., Diptera, Agromyzidae) in witlof, wortelen en kamillen. Verslagen van Landbouwkundige Onderzoekingen 840. Wageningen, 1975.

Sarrazijn, R. en L. Bockstaele. Witloof-Overzicht van de opzoekingen: 1974-1975, 1975-1976 en 1976-1977, 1978-1979. Onderzoek- en Voorlichtingscentrum voor Land- en Tuinbouw. Beitem-Roeselare (België).

Schoneveld, J.A. Onderzoek naar de werkmethode bij de witloftrek. Alkmaar, 1966, 43 blz. P.G.V.-rapport 25.

Schoneveld, J.A. Tips voor trekbak. Groenten en Fruit 34 (1979) 34, 58-61.

Schoneveld, J.A. en J.C. Cornelissen. Reinigen van witlofwortels. Groenten en Fruit 36 (1980) 7, 46-47.

Schoneveld, J.A., L. Simonse en J.M. Vente. Klimaat in de witloftrekruimte. Groenten en Fruit 36 (1980) 5, 51.

Schroën. F. Vervroeging van de witlofteelt door plastic folie. Groenten en Fruit 37 (1982) 39: 75-77.

Spencer, K.A. A clarification of the genus Napomyza Westwoord (Diptera: Agromyzidae). Proceedings Royal Entomological Society, London (B) 35 (1966) 3/4: 29-40.

Sprenger Instituut. Richtlijnen voor de koelcellenbouw voor tuinbouwprodukten. Praktijkadvies 19(1978). Sprenger Instituut Wageningen.

Sprenger Instituut. Produktgegevens Groente en Fruit-Witlof. In: Mededeling 30 (1980). Sprenger Instituut-Wageningen.

Sprenger Instituut. Bewaring van Witlofwortels. Praktijkadvies 20 (1982). Sprenger Instituut-Wageningen.

Stenuit, D en R. Piot. Opzoekingen naar de oorzaak van het optreden van blauw loof bij witloofforcerie. Landbouwtijdschrift 4 (1951) 3, 239-256

Strien, C. van. Witlofteelt in West-Brabant. Landbouwmechanisatie 21 (1970) 5: 501-506.

Valette, R. Studie van de kieming van witlofzaad bij verschillende temperaturen. Landbouwtijdschrift 34 (1981) 4: 985-997.

Ven, C.J. van der. De teelt van witlof. Wolters Groningen, enz. 1953. 101 blz.

Vente, J.M. en J. Hamersma. Klimaataspecten van het forceren van witlof op water.
Publikatie 98 (1978). IMAG-Wageningen.

Verlaat, J.G. 20 jaar onkruidbestrijdingsonderzoek in de vollegronds-groenteteelt door het PGV te Alkmaar. Mededeling 68 (1977). P(A)GV-Alkmaar.

Verslagen van de 3e(1975), 4e(1977), 5e(1979) en 6e(1981) tweejaarlijkse internationale witlofdagen. Uitgave: PAGV (1975 en 1981), Station Expérimentale de l'Endive-Beauvais (1977), Proefboerderij voor Witloof-Herent (1979).

Vinkenvleugel, J.B. De teelt van witlof. Tilburg, (1957), 72 blz.

Voorlichtingsbureau voor de Voeding. Nederlandse voedingsmiddelentabel; 24e druk s'-Gravenhage, 1968, 34 blz.

Wiersma, O. Mechanische koeling van witlofwortels. Koeltechniek 72 (1979) 9, 181-184.