

## Growing saffron - the world's most expensive spice



Saffron crocus flowers in autumn either before, together with (as above), or after leaf production.

Saffron, the world's most expensive spice, is derived from the stigmas of the saffron crocus (*Crocus sativus* L.). It is a prized culinary condiment, widely used in the cuisine of many European and Asian countries. Saffron grows well in areas that have cold winters and warm dry summers.

The stigmas in the delicately scented saffron flowers are dried and used in cooking to colour, flavour and add a unique aroma to the meal. Crop & Food Research scientists have investigated the conditions required to produce high yields of saffron and the opportunity for growing this valuable crop in New Zealand.

### Introduction

*Crocus sativus*, unknown as a wild plant, is considered to be a mutant that has derived from *C. cartwrightianus*. The cultivated clone was probably selected for its triploid vigour and extra long stigmas and has been maintained in cultivation for over 3000 years.

The saffron crocus (*Crocus sativus* L.) is sterile and does not set viable seed. Therefore, the crop must be propagated by corm multiplication. The saffron crocus flowers in autumn shortly after planting, before, together with or after leaf appearance. The remainder of its growing season consists of initiation, filling up, and maturation of the daughter corms at the beginning of summer. Each corm only lasts a single season and is replaced by 1 to 10 cormlets, depending on the original size of the mother corm.

Corms are globular and depressed, up to 4.5 cm in diameter and covered with a tunic of parallel fibres. Corms are dormant during the summer and produce 5 to 11 erect, narrow, grass-like green leaves, up to 40 cm long, that emerge in autumn. Flowers are fragrant, up to 8 cm long, and usually pale lilac or mauve with darker coloured veins. The outstanding feature of the flower is its style, which divides into three brilliant red stigmas 25-30 mm long.

### Environment

Saffron is native to the Mediterranean environment, characterised by cool to cold winters, with autumn-winter-spring rainfall, and warm dry summers with very little rainfall. It can withstand substantial frosts (-10°C), and can tolerate occasional snow in the winter. In New Zealand, saffron will grow well where there is winter chilling and warm dry summers. These are areas south of the Waikato in the North Island and on the east of the South Island. Saffron produced poorly in the Waikato but very well in Central Otago.

In Greece, saffron growing areas have more than 500 mm annual rainfall while in Spain saffron is grown in dry temperate conditions with an annual rainfall of around 400 mm per annum, but the crop is usually irrigated. Saffron is grown successfully under non-irrigated conditions (1000-1500 mm per annum) in Kashmir, India. Spring rain is considered favourable for corm production, while rain immediately before flowering encourages high flower yield. However, rain or cold weather during flowering spoils the saffron and persistent wetness and high temperatures encourage disease. Climatic conditions for world and New Zealand saffron producing sites are compared in Table 1.

Saffron likes light, friable soils that have a high nutrient content. It grows in a wide range of soils, but thrives best in deep, well drained clay-calcareous soils with a loose texture that permits easy root penetration.

In New Zealand, the best soils for saffron production are those with a sandy or loamy texture, but the most important requirement is well drained soil. Under non-irrigated conditions, high levels of organic matter improve soil texture and water holding capacity, encouraging high yields. At Clyde in Central Otago, New Zealand, saffron beds were irrigated during the spring and early autumn, with approximately 300-400 mm of water applied.

## Cultivation

Flower yield is highly dependent on corm density and corm size. Traditionally, saffron is grown on raised beds to allow good drainage and easy access for picking. Corms are planted out during their dormant period in summer. In Italy, where annual planting is practised, the best yields for flower and corm production are obtained by leaving a space of 2-3 cm between each corm in the furrow, with a planting depth of 8-10 cm. Optimal corm quantity per hectare is 13-15 tons, which is about 600-700 thousand corms with an average weight of 20-22 g each (45-48 corms/kg). In Morocco they use 2 x 2 m

*Table 1: Mean annual temperature (°C), mean winter earth temperature (°C), GDD (growing degree days - base 10°C), rainfall (mm) and soil pH for 16 world sites and 3 New Zealand sites.*

Site	Winter				pH
	Temp. (mean °C)	10 cm earth (mean °C)	GDD (base 10°C)	Rainfall (mm)	
World (16 sites)	10.4	-	-	770	6.9
Clyde	10.1	1.9	1003	380 <sup>1</sup>	5.2
Mosgiel	10.2	3.5	664	691	5.6
Hamilton	13.3	8.3	1410	1201	5.6

<sup>1</sup> Extra 300-400 mm irrigation was applied per annum.

<sup>2</sup> GDD base 10°C is accumulated growing degree days calculated by adding the daily degrees above 10°C for each day that the mean daily temperature exceeds 10°C during the growing season.

raised beds with rows 20 cm apart. Bunches of two or three corms are planted 10-15 cm apart within rows. There the planting depth is about 15 cm and about 3 tons of corms are used per hectare. In Greece, corms are planted in furrows formed with a plough, with corms placed about 12 cm apart along the row and about 15 cm deep. The distance between the rows is about 25 cm. This is about 230 000–250 000 corms per hectare. In India, corms are planted 7.5-10 cm apart, in rows 15-20 cm apart. Double rows are often used in Spain with a spacing of 3.0 cm between rows and 6.0 cm between corms in a row.

Recommended planting depths for corms vary from 7.5-10 cm to 15-22 cm. In Italy, a planting depth of 15 cm gave better yields than shallower or deeper planting. Planting depth affects corm production; more buds sprout from shallow planted corms than from deep planted ones, resulting in more daughter corms.

Corm size has a significant effect on the production of daughter corms and on the production of flowers and the yield of saffron. The larger the mother corm, the more daughter corms will be produced in the annual cycle, which increases the potential for higher yields in subsequent years. Our research shows each original mother corm, above 30 g, produced an average of six new corms (in the second year), while the mother itself decayed. In the third year, the total mean corm number had risen to 22 new corms from each original mother corm, while in the fourth year that total had risen to 65. The weight of corms produced is also affected by the weight of the original mother corm. When the original mother corm is above 30 g, the total weight of replacement corms doubles in the second season, is 10 times heavier than the original in year three, and in year four is about 16 times heavier.

New saffron corms also grow above the old ones each season, so they creep towards the soil surface by 1-2 cm each year. Therefore, the crop needs to be lifted and replanted periodically. This occurs about every 4 years in Spain, but fields may last up to 12 years or more under non-irrigated conditions in Kashmir. Replanting is normally done when yields begin to fall due to overcrowding or damage to corms that are too close to the soil surface.

At Clyde, large corms were planted at least 10 cm deep, while smaller corms were planted at 7-8 cm. We grew our saffron in beds with four or five rows, each 20 cm apart. Corms were planted 10 cm apart in the row. This gives a final density of 50 corms/m<sup>2</sup>. To guard against possible fungal or bacterial diseases before planting, the corms were dipped for 5 minutes in a solution of 20 g Benlate® and 10 g Captan® mixed in 10 litres of water.

## Fertiliser

In traditional saffron culture, large amounts of farm yard manure were applied to the saffron fields before planting, and typically 20-30 tons per hectare are incorporated during cultivation. This material supplies nutrients, but its other major role is to improve soil moisture holding capacity and structure under non-irrigated conditions. Under traditional growing systems no further fertiliser was applied after corm planting. However, recent data suggest that at least some annual fertiliser applications are beneficial and a base dressing of 80 kg P/ha and 30 kg K/ha followed by a split application of 20 kg N/ha in autumn and again immediately after flowering is recommended.

At Clyde, we have incorporated meat and bone meal into the soil before planting (at 0.2 kg/m<sup>2</sup>), and each year we applied a compound fertiliser such as Nitrophoska® (N:P:K:S –12:5:14:4) in the spring (at 30 g/m<sup>2</sup>).

## Weed control

At Clyde, we did not use herbicides on the crop while it was actively growing. Sawdust mulch helped reduce weed problems. During the dormant phase, when the tops died off, we used the herbicides Roundup® or Buster® to clean up the beds prior to the new season's flowering and growth. The choice of chemical depended on the weeds present. The old top growth, which dies in the summer, needs to be raked off the beds prior to the autumn flowering.

## Pests and diseases

Rabbits, rats and birds can cause problems in saffron fields by eating or lifting the corms.

Many pests (e.g. nematodes) and diseases (e.g. corm rots, leaf rusts) attack saffron, and the incidence is greatly affected by the growing environment. Few problems were experienced at Clyde.

At Navelli (Italy), moist/warm/humid conditions in spring and summer create ideal conditions for the rapid spread of fungi. Under these climatic conditions, they treat the beds with anti-fungal agents to save the daughter corms.

## Flowering

Saffron flowers in the autumn, about 40 days after planting, and continues for 30-40 days, depending on the weather. The flowering period of each plant may last up to 15 days. Rain 10-15 days before flower picking results in excellent flowering and high production, whereas under drought conditions, small flowers with small stigmas can be expected. A cold period or a late planting can retard flowering.

Our experience at Clyde shows that corms produce leaves approximately one month before flowering starts.

Corm size has a large effect on the production of flowers per corm. Large corms (>45 g) can produce up to 12 flowers per corm, while more average sized corms (20-30 g) produce six flowers per corm.

## Harvesting

Flowers are usually picked daily in the morning after the dew has evaporated but before flowers wither. The flower is cut at the base of the flower stem with a slight twisting movement or by cutting with the finger nail. Care is taken not to damage the leaves. In Greece, flowers are harvested all day, as demanded by flowering. In Italy, flowers are picked early in the morning while the flower is still closed. It is considered that the flower is quicker to pick in this state, and that it is quicker to remove the stigma.

## Drying

Following the separation of the stigmas from the flowers, it is essential to dry the flower heads immediately. Drying experiments show that drying at temperatures up to 110°C can be used. The critical issue is the length of drying time (e.g. at 110°C for 2 minutes). Recent Spanish research shows drying in a hot air flow at 70°C for 6 minutes will give quality saffron. Brightness of colour is aided by quick high temperature drying. Slow drying gives a poor quality product. Another method is to use a dehydrator at 48°C for 3 hours. Irrespective of the drying method, it is important not to over dry. A final dry matter close to 10% moisture is adequate for long-term storage.

## Yields

In New Zealand, saffron yield at Clyde (24 kg/ha) was much higher than at Mosgiel or Hamilton. A wide range of yields has been reported from various countries under different growing conditions. Yields are strongly influenced by environment and cultural methods, e.g. irrigation. In Morocco, the average yield varies from 2 to 2.5 kg/ha, where 1 kg of intact flowers yields 72 g of fresh stigmas or 12 g of dried stigmas. In Italy, the average yield is 10-16 kg/ha of saffron; in Spain 6-29 kg/ha; in Greece 4-7 kg/ha; in India 2-7 kg/ha. The average weight of fresh stigmas is 0.03 g per flower and dry weight is 0.007 g per flower. About 150 flowers are needed to obtain 1 g of dry stigmas.

The size of individual stigmas and the amount of style collected influence the total yield and quality of saffron. Between 70 000 and 200 000 flowers (0.3-1 g each) are needed to produce 1 kg of saffron. At Clyde our flowers weighed between 0.3 and 1 g, with fresh stigma per flower weighing 0.01-0.1 g and dry stigma <0.01 g.

In Greece, 3 kg/ha of saffron was expected in the first year, 10 kg/ha in year 2, 15 kg/ha for years 3 and 4, and 10 kg/ha for years 5 and 6. (One gram of saffron/m<sup>2</sup> will yield 10 kg/ha of saffron.)



A cluster of new daughter corms.  
(50 cent coin = 32 mm)



The 'grass like' leaves of the saffron crocus during the autumn to spring vegetative stage.

## Quality

The quality of saffron is dependent on its colouring power (crocin concentration), odour (safranal) and taste (picrocrocin). The best quality saffron has a high safranal content. Saffron is dry, glossy and greasy to the touch when freshly dried, turning dull and brittle with age. It is easily bleached if not stored in the dark, and also stores better under conditions of low temperature and low relative humidity.

An International Standard for saffron is available (ISO 3632-1:1993). Saffron in filaments is classified into four categories based on the content of floral waste and extraneous matter, with category 1 (extra) having a maximum of 0.5% floral waste and 0.1% extraneous matter. Category 1 has the highest bitterness (as expressed in the absorbance test for picrocrocin), and the highest colouring test (as expressed in the absorbance test for crocin). Safranal levels, also based on an absorbance test, have a range for all grade categories.

The chemistry of saffron has been investigated in detail. The major pigment, a water-soluble carotenoid giving saffron its value as a dye, is crocin, a yellow-red pigment found at levels of up to 2%. Picrocrocin (<4%) is a bitter-tasting principle that hydrolyses to glucose and safranal (<4%), on drying.

## Contacts

### Invermay - Crop agronomy

Malcolm Douglas  
Crop & Food Research  
Private Bag 50 034, Mosgiel  
Tel. 03 489 0673  
Fax 03 489 0674  
E-mail [douglasm@crop.cri.nz](mailto:douglasm@crop.cri.nz)

### University of Otago - Saffron analysis

Dr Nigel Perry  
Crop & Food Research  
Plant Extracts Research Unit  
Dept of Chemistry, University of Otago  
Box 56, Dunedin  
Tel. 03 479 8354  
E-mail [perryn@crop.cri.nz](mailto:perryn@crop.cri.nz)

Saffron is used sparingly, but it is also important to note it is toxic and fatalities have been recorded from consuming as little as 1.5 g of pure saffron.

## Market

The New York spot market price for saffron was \$US365/lb in March 2003. This equates to about NZ\$1450/kg, i.e. \$1.45/g. In Greece they get \$US600/kg. There 150 000 flowers gives 1 kg of saffron and the fastest picker plucks about 30 000 flowers in one day. Mean hourly productivity per person is estimated at between 8 and 16 kg (2000-4000) flowers. At Clyde it took 45-55 minutes to pick 1000 flowers and 100-130 minutes to remove the stigma for drying; which is about 400 hours to produce 1 kg of dried spice. In Italy, the price of dried stigma reached \$NZ9/g, but the favoured way to sell was to package it in small, artistic ceramic vases and sell at \$NZ22/g.

## Further reading

Negbie, M. 1999: Saffron: *Crocus sativus* L. Medicinal and aromatic plants – industrial profiles. Amsterdam, Harwood Academic Publishers.

McGimpsey, J.A.; Douglas, M.H.; Wallace, A.R. 1997: Evaluation of saffron (*Crocus sativus* L.) production in New Zealand. *New Zealand Journal of Crop & Horticultural Science* 25: 159-168.

Humphries, J. 1996: The essential saffron companion. London, Grub Street. 160 p.