A Growers Manual for *Calendula Officinalis* L.






Contributors
Martin Froment, ADAS Bridgets Research Centre, Martyr Worthy, Winchester UK
Dick Mastebroek, PRI, PO Box 16, Wageningen, The Netherlands
Karel van Gorp, Royal CEBECO Group, PO Box 182, 300 AD Rotterdam, The Netherlands

Contents

		Page
Introduction		3
Section 1	Variety Choice	4
Section 2	Site Selection and Field Preparation	5
Section 3	Fertiliser	6
Section 4	Weed Control	7
Section 5	Pests and Diseases	8
Section 6	Desiccation	9
Section 7	Harvest	10

Decimal Growth Stage Key for *Calendula officinalis*

Introduction

This guide aims to provide a basis for the successful cultivation of *Calendula officinalis*. It should not be considered an extensive guide to the crops cultivation, as its agronomy is still poorly understood, but it aims to be a comprehensive summary on currently available crop management. This guide was compiled based upon results from replicated field and greenhouse experimentation, and commercial experience by ADAS in the UK and the Royal CEBECO Group and Plant Research International in the Netherlands, over several years from 1994 to 2001.

The species *Calendula officinalis* or Pot Marigold has been cultivated for many years as an attractive garden plant. The plant has several uses. These include the essential oils and pigments from its flowers, the former being widely sold in topical medicinal products. There are also uses for its seed oil, which contains Calendic acid. The seed of Calendula contains 18-22% oil and this contains 55 to 60% of the very reactive C18:3 calendic fatty acid. The chemical structure of calendic acid, containing three reactive conjugated ethylenic bonds and an octatrienoic acid iosmer, makes it a potentially useful compound within industrial products and for chemical modification. Market opportunities have been identified for calendula oil as an ingredient for the production of reactive diluents and oil based alkyd resins which are applied in high solid paints and as a substitute for Tung oil, which is currently imported into the EU. Replacing imported tung oil would require at least 10 000 ha of Calendual to be grown in Europe. The production, processing and industrial application of it's seed oil was the main focus of the CARMINA research project which developed the agronomic knowledge reported in this guide. This project was jointly funded by the EC under FAIR 98-3713.

Calendula officinalis is a biennial, but is generally cultivated as an annual plant. *Calendula officinalis* is well adapted to temperate climatic zones in Europe, although it is believed to have originated in the Mediterranean. At present, seed yields of 1 000 to 1 500 kg/ha are obtained on a farm scale, but with improved production systems and selected varieties it is believed yields could double, making it an attractive industrial oilseed crop for European farmers.

Variety Choice

Breeding objectives and variation in plant characters
Breeding objectives within the species have been aimed at enhancing visual appearance such as flower size and colour, rather than agronomic characters of relevance to agriculture. Variety comparison experiments by ADAS in the UK compared commercially available seed material. There were differences in plant characters for days to flower, plant heights, seed yield, oil and calendic acid content. A summary of the results are shown below.

Variation in plant characters of agronomic significance.

Accession	Days to first flower	Plant height at maturity cm	Seed yield t/ha at 91% DM	Seed oil %	Calendic acid % of seed oil
E 93	66	47.3	2.17	17.2	43.6
Pot Marigold	72	45.5	1.60	17.4	44.1
Single Wild type	69	41.8	2.41	14.2	50.8
Double Lemon Coronet	65	45.5	2.03	16.1	50.3
Russian	67	47.8	2.06	15.5	44.4
Hens & Chickens	64	47.8	1.96	19.2	48.3
CPRO-DLO 879144	63	46.5	2.18	16.4	49.0
CPRO-DLO 880557	69	40.5	1.99	16.1	47.0
Double Extra	75	42.7	1.16	14.3	43.4

In Holland, similar results have been obtained, with seed yields of 1500-2500 kg/ha, oil content of 14-20 % and Calendic acid contents in the oil of 55-60 %. Seed yields and oil yield per ha have been improved by breeding and seed material of improved varieties is now available for commercial use.

The crop cycle
Calendula is sown in spring, usually early to mid April. Emergence is normally rapid, with complete establishment by mid to the end of April. Flowering begins in mid June and seeds ripen in early August. Harvest data varies from early to mid August.

Site Field Preparation

The preparation of the seedbed can have a significant effect on the performance of calendula

Seedbed
Residues from previous crops should be incorporated into the soil by ploughing prior to secondary cultivations to prepare the seedbed. If there is an existing weed problem, or significant amounts of vegetation remain from previous crops, these should be destroyed using a translocated herbicide such as glyphosate. A fine, but firm seedbed is required for Calendula. This is best achieved by early ploughing, allowing frost to aid breakdown of clods, followed by cultivation using tined implements or power harrows to a shallow depth. The number of cultivation passes should be minimised if retention of soil moisture or soil compaction is likely to be a factor at the site.

Drilling
Calendula seed is small and should be sown at 1-2 cm depth, similar to that for oilseed rape and linseed. Seeds require adequate moisture to germinate. Even sowing depth is important, particularly if residual soil acting herbicides are to be used and to ensure even crop establishment and maturity. Calendula has irregular seed shapes. Seed can be classified as nuggets, winged or hooked. Of the three types, the easiest to sow are the nuggets, which are rounded and flow more easily through seed drills. Unless seed has been carefully graded and consists mainly of 'nuggets', blockages are likely to occur in drilling machinery, resulting in patchy drilling and poor establishment. Typical seed rates are 7 - 12 kg/ha. Germination percentages in good seed lots are 60 - 80% and field emergence varies from 40 to 60%. The target plant population is 60 plants/m^2, although good yields have been achieved from 40 plants/m^2.

Sowing
The optimum sowing date is April. Calendula is less sensitive to frost than sugar beet, linseed or flax, but during cold springs, it is advisable to delay sowing until the second half of April. Rapid emergence is important for effective suppression of weeds. In good conditions emergence is rapid (5-15 days after sowing).

Because of the small seed size, Calendula should be sown at a depth of 1-2 cm. The average seed rate at sowing is within the range 7 – 12 kg/ha. Normal row spacing with commercial seed drills is 12 - 25 cm, although wider, 50 cm rows are used for mechanical weeding systems.

Fertilisation

Nutrient Requirement
The need for fertilisation depends on the nutrient status of the soil and the fields previous cropping history.

Experiments comparing the response of Calendula to contrasting rates of nitrogen have suggested plant biomass responses to small amount of nitrogen, but that this has not necessarily been reflected in increased seed yields.

Offtakes of nutrients in seed are not high, so minimal replacement with inorganic fertiliser or organic manures is all that is required.

Fertiliser recommendations
General advice for fertilisation, which can be adjusted for local conditions, is as follows:

Nitrogen (N): 50-100 kg/ha
Phosphate (P_2O_5): 25-75 kg/ha
Potassium (K_2O): 50-100 kg/ha

In some cases excess fertility has resulted in crop lodging. As with all crops, poor fertilisation can result in uncompetitive plants and increased weed problems and an excess of fertiliser, particularly nitrogen can contribute to increased damage by plant diseases.

Weed Control

Like many crop plants, Calendula is seriously affected by competition for moisture, nutrients and sunlight, particularly in the period following emergence.

Cultural aspects of weed control strategies
By sowing at the correct time, and into good seedbeds, early growth of Calendula will be rapid, suppressing the development of weeds.

Chemical weed control
Legal options for chemical weed control are limited in most EU countries due to the absence of specific pesticide approvals for Calendula and limited approvals on related oilseed crops (which may allow limited uses in Calendula). Before sowing, a spray of glyphosate (at rates of 720 g/ha up to 1440 g/ha) can be used to control germinating weeds or perennial weed problems.

Trials in the UK have investigated both pre-emergence and post-emergence applications of herbicides. There are very limited options for post-emergence applications of herbicide.

UK trials over two seasons evaluated a wide range of potential herbicides and concluded that the pre-emergence herbicides trifluralin, isoxaben, chlothal-dimethyl and propachlor were crop safe. Other herbicides trialed included pendimethalin (Stomp) and metazachlor (Butisan), but these have caused crop damage in some seasons and at certain dose rates.

Dutch experience suggests pre emergence applications of pendimethalin (Stomp) at 1.5 l/ha (600 g/ha) + propachlor (Ramrod) at 2 l/ha (1000 g/ha) has provided reasonable control of weeds. Good results have also been achieved with asulam (Asulox) at 4 l/ha (1600 g/ha) for some problem weeds.

Mechanical weed control
By drilling at wider row spacings, typically 50 cm, mechanical hoeing can be adopted. There is only limited experience with mechanical weeding. Weeding the crop at the early 2-4 leaf stage of plant growth should be avoided due to the risk of crop damage. Harrow comb weeders are not recommended, but inter row weeding using tines or blades, especially on the lighter sandy soils, can be recommended based on Dutch experience.

Pests and Diseases

Insect Pests
Few pests have been identified in Calendula. As the crop area expands pests will develop, so growers should remain vigilant to new threats.

Diseases
Botrytis has been reported in crops. This disease is favoured by wet and humid conditions. Mildew has also been observed, particularly in late season, although its effect on seed yields is unknown. Sclerotinia has been reported in crops and sclerotia have been found in harvested seed lots.

Vinclozolin (Ronilan) during flowering or Iprodione (Rovral) as the flower leafs start to fall off, can be used to control botrytis and sclerotinia respectively. In consideration of the risk from sclerotinia, cultural control can also be recommended. Calendula should not be grown more than once every 6 years in the same field and not as part of intensive rotations with other susceptible crops such as oilseed rape and sunflowers.

Desiccation

Crop harvesting strategies

As seed shedding is a problem in Calendula, swathing is not recommended. The crop is also relatively short, so swathing would place the crop on or close to the soil surface. Research with oilseed rape has shown that is important to lay the swath on rape stubbles and keep the swathed crop above the ground, improving air flow and keeping the crop dry if rain occurs.

Direct combining is the recommended harvest method. As Calendula is an indeterminant plant species (it produces flowers over an extended period), desiccation is required to aid harvesting. In dry summers the crop may mature and senesce without desiccation, but in wet summers the crop can produce late flushes of both flowers and green leaf.

Crop desiccation

There have been few trials examining the best timing for desiccation or effectiveness of desiccant chemicals. Diquat (Reglone) has been used successfully to desiccate the crop at rates of 3-4 liters/ha (600 -800 g/ha diquat). The best timing for diquat is when 80% of flower heads have brown seeds. Harvesting can proceed 5 - 7 days later.

UK field trials have indicated that the weather conditions between desiccant application and harvest had a greater effect on final seed yield, than exact timing of desiccant or product (diquat or glyphosate). The results suggested that growers should select a settled weather period prior to desiccation.

Harvest

Optimum timing
As Calendula is an indeterminant plant species (it produces flowers over an extended period), the optimum harvest date is difficult to determine, yet critical to achieving optimum seed yields, as seed shedding is an issue.

Most crops will be desiccated to aid harvesting. Growers will therefore aim to harvest crops within a specific time period after crop desiccation. As a general growers should apply a desiccant when 60-80% of seed heads are brown. Most growers would apply diquat (Reglone) and with this product harvesting is typically 5-7 days after application.

Combine settings
Because of the risk of shedding and seed loss, the combine sail should be set to gently feed the harvested crop onto the table/header. Threshing is comparatively easy, and slow drum speeds should be used. Concave settings should not be set too low, due to the risk of seed damage. Seed and trash separation is the most difficult step in the combining cycle. The aim of the field combining process should be to remove as much trash as possible, but to maximise seed yield for specialist cleaning and processing. The harvested material has poor flow characteristics, so care should be taken not to overload and block augers.

Post Harvest Management
Some Calendula seeds may be shed before or during harvest. There is no evidence to suggest that Calendula will become a weed crop in other commercial crops. If it does emerge in other crops, such as cereals, it is easily controlled using current broad leaved weed herbicides.

Acknowledgements

This Growers Guide was compiled by Karel van Gorp of the ROYAL CEBECO group, Martin Froment of ADAS and Dick Mastebroek of Plant Research International.

Decimal Growth Stage Key *Calendula officinalis* (after Mastebroek)

Stage 0 - Germination	1	initial germination
	3	25% germination
	5	50% germination
	7	75% germination
	9	complete
Stage 1 - Emergence	1	as germination
Stage 2 - Seedling development	2	number of true leaves or leaf pairs
Stage 3 - Branching	3	number of branches until first flower bud development
Stage 4 - Flower bud development[1]	1	first flower bud detectable
	3	first flower bud just visible
	5	first flower bud emerged from the upper leaves
	7	first flower bud fully developed
	9	first flower bud shows ray flowers
Stage 5 - Initial flowering[1]	1	first flower head opened
	3	first flower head produces pollen
	5	first flower head finished pollination
	7	first flower head closed and ray flowers still fresh
	9	first flower head closed and ray flowers wilted
Stage 6 - Seed development[1]	1	seeds of first seed head fresh green and watery
	3	first seed head shows different seed types
	5	different seed types of first seed head fully developed
	7	seeds of first seed head pale green and tough
	9	seeds of first seed head brownish green and stiff
Stage 7 - Seed head ripening[2]	1	10 % of the seeds heads brown and dry
	3	25 % of the seed heads brown and dry
	5	50 % of the seed heads brown and dry
	7	75 % of the seed heads brown and dry
	9	90 % of the seed heads brown and dry
Stage 8 - Leaf senescence[2]	1	initial leaf senescences
	3	25 % of leaves wilted
	5	50 % of leaves wilted
	7	75 % of leaves wilted
	9	90 % of leaves wilted
Stage 9 - Stem senescence[2]	1	initial stem discolouring
	3	25 % of stems discoloured
	5	50 % of stems discoloured
	7	75 % of stems discoloured
	9	90 % of stems discoloured

[1] in 50% of the plants
[2] of the entire crop