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Quality evaluation of safflower (*Carthamus tinctorius* L.) cultivars

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Abstract
Safflower is a minor oilseed crop in Australia where the market is dominated by canola, cottonseed and sunflower. Safflower however offers an alternative oilseed crop in marginal areas. This study was designed to evaluate current safflower lines and to determine their potential value both for edible oil and meal for animal feed. Two sets of samples were analysed. The first was a collection of cultivars to test varietal differences. The second was two cultivars sown at two sites with different sowing rates and row spacings. Both sets were analysed for the important chemical components to show cultivar, site and sowing effects. Components tested included moisture content, oil content, meal protein, tocopherols, Rancimat induction time, total polyphenols and fatty acid profile of the oil. As the moisture content varied between 4-8%, with an average of 5%, all analyses were done on a dry basis to ensure consistency. Oil contents on the varietal trial varied from 27-40% indicating significant potential for cultivar improvement by plant selection. Protein in the oil-free meal ranged from 25-36% and showed similar variability to oil. Of particular interest was the range of oxidative stability results from 1.4 to 5.3 hours. This could be attributed to the different levels of antioxidants; polyphenols 74-212 mg/kg, tocopherols 320-650 mg/kg. Fatty acids would also contribute to oil stability with palmitic acid from 4.3-8.1% and linoleic acid from 75.2-83.7%. Ranges on all of the fatty acids are discussed.
Site variation also contributed significantly to many of the chemical components. Oil content, oxidative stability, total polyphenols and tocopherols showed large differences between sites although protein levels and fatty acid differences between sites was not as large.

Key words: Safflower **–** *Carthamus* – oil – protein - fatty acid – oxidation - antioxidant

Introduction
The increasing demand for edible oil, and more recently vegetable oil for biodiesel, has seen increasing prices for common oilseeds including canola/rapeseed, soybean and sunflower oils. Safflower (*Carthamus tinctorius* L.) is a relatively small crop in Australia although there appears to be a potential for its incorporation into the agricultural system as an alternative oil crop. Very limited work has been done on the chemical composition of Australian produced safflower crops. The safflower cultivars developed in Australia are Sironaria and Sirothora, both released in 1986 (Harrigan, 1987). More recently, several cultivars have been imported from overseas and based on previous experiences with canola, these cultivars would be expected to show varying levels of adaptability to the Australian environment. These cultivars include both high linoleic and high oleic acid types. Other cultivars are also held in the Australian Temperate Field Crops Collection and need to be evaluated for quality characteristics.

Materials and Methods

A. Influence of cultivar on quality.
To determine the range of quality characteristics between lines, samples of safflower were obtained from the Australian Temperate Field Crops Collection, Horsham, Australia. These included 12 samples from various countries as shown in Table 1.

B. Influence of site and environment on quality.
In addition, to evaluate the effects of climatic conditions, samples of four cultivars were analysed which had been grown at two different sites (Table 2). These samples had four replicates.

1	CP177333 (India)
2	CP181609/QP28900793 (USA)
3	CP189344 (Iran)
4	CP189345 (Turkey)
5	CP189352 (Sudan)
6	CP189367 (Afghanistan)
7	A384 (France)
8	A446 (Japan)
9	A539 (China)
10	A552 (Pakistan)
11	Sironaria (Australia)
12	Sirothora (Australia)

Table 1. Samples obtained from Australian Temperate Field Crops Collection, Horsham, Australia

Site 1	**Site 2**	**Cultivar**
Frances	Greenways	Poly
Frances	Greenways	Mono
Frances	Greenways	Safola
Frances	Greenways	Sironaria

Table 2. Samples obtained from trials in South Australia including four cultivars x two sites x four replicates.

Chemical Analysis: All of the samples were analysed for a range of components including oil content, protein content, fatty acid profile, α-tocopherol, total polyphenols and induction time.

Oil Content: Oil Content was determined by solvent extraction using the AOCS official method Am 2-93 (AOCS 1998).

Protein Content: Samples were analysed as received on the Leco Dumas combustion analyser using AOCS official method Ba4e-93 (AOCS 1998).

Fatty Acid Profiles: The oil was prepared for fatty acid profiles using the International Olive Council method COI/T.20/Doc. No 24.

α-tocopherol: α-tocopherol was measured using the IUPAC method 2-432.

Total polyphenol content: A modification of the Gutfinger (1981) method, using caffeic acid as the standard, was used to determine total polyphenol content.

Induction time: A Metrohm 679 Rancimat was utilised to determine the induction time of the oil. A block temperature of 110°C and airflow of 20 L/hour was used. The results were reported as induction time in hours.

Results and Discussion

A. Influence of cultivar on quality.

Oil and protein content: The selected cultivars showed significant difference in oil content, ranging from 26.8% for A446, Japan, to 39.5% for Sironaria, Australia. Sirothora, Australia (38.8%) and CP189367, Afganistan (38.0%) were among the highest oil contents. Comparison of oil contents for 12 cultivars is shown in Fig. 1. Protein content of oil-free meal also varied significantly between cultivars, ranging from A446, Japan (25.1%) to CP189367 Afghanistan (36.3%). Sirothora, Australia was also high with 36.0%.
It is interesting to observe the relationship between oil and protein as compared to other species. Generally it would be expected that cultivars high in oil would be low in protein. However, for these cultivars, Sirothora – Australia and CP189367 – Afghanistan were high in both oil and protein. The results indicate high potential to develop cultivars with higher levels of both oil and protein.

Fatty acid profile: The fatty acid profile of the 12 international cultivars are shown in Table 3. The table is organized in order of increasing concentration of linoleic acid (C18:2). It can be seen from the results that oleic acid (C18:1) and palmitic acid (C16:0) vary in a reverse relationship with linoleic acid. Where polyunsaturated fatty acids are known to be less stable than monounsaturated or saturated fatty acids, it could be predicted that cvv Sironaria and Sirothora would be more stable than A539 China. With current trends toward high monounsaturated fatty acids for health benefits, it could be suggested that those with high levels of oleic acid and low saturated fat, such as A539 would be preferred.

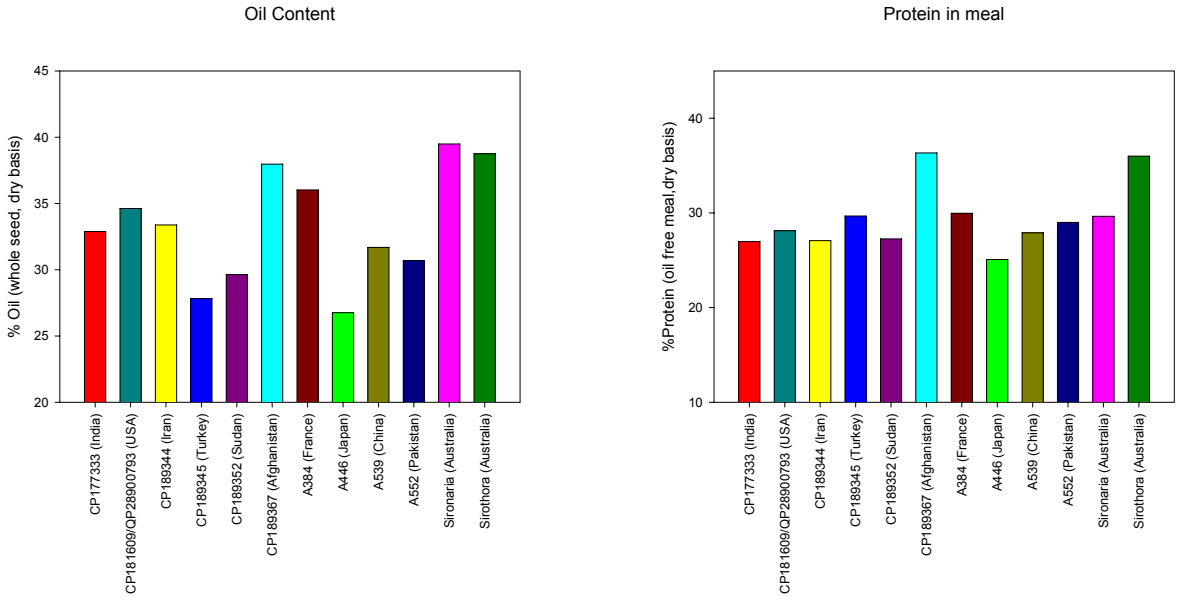


Fig. 1. Oil and protein contents, expressed on a dry basis, for 12 cultivars of safflower sourced from an international grain collection.

	C16:0	C18:0	C18:1	C18:2	C20:0	C20:1	C22:0	C24:1
Sironaria Australia	8.1	2.5	12.3	75.2	0.3	0.2	0.2	0.8
Sirothora Australia	7.9	2.8	11.9	76.2	0.4	0.2	0.2	0.0
A552 Pakistan	5.3	2.1	13.1	78.1	0.3	0.2	0.2	0.2
A384 France	6.1	2.1	11.1	79.6	0.3	0.2	0.2	0.1
CP189344 Iran	5.6	1.7	11.6	79.7	0.3	0.2	0.2	0.2
A446 Japan	4.3	2.2	11.7	79.9	0.4	0.2	0.7	0.2
CP189345 Turkey	5.4	2.2	10.9	80.3	0.3	0.2	0.2	0.0
CP177333 India	5.6	2.2	10.8	80.4	0.3	0.2	0.2	0.0
CP189352 Sudan	5.9	2.3	8.4	82.2	0.3	0.2	0.2	0.0
CP181609/QP28900793 USA	5.6	1.8	8.7	82.7	0.3	0.2	0.2	0.2
CP189367 Afghanistan	5.7	1.9	8.1	83.1	0.3	0.2	0.2	0.2
A539 China	4.9	2.1	8.2	83.7	0.3	0.2	0.2	0.0

Table 3. Fatty acid profile of 12 cultivars of safflower sourced from an international grain collection. Calculated as a percentage including C14:0; 16:1; C17:0; C17:1; C18:3; C22:1; C24:0.

Total polyphenol content and Induction time: Polyphenols are antioxidants and have been shown in previous studies to dramatically influence oxidative stability in olive oil. The level of total phenolic compounds in the 12 cultivars studied were showen to be highly variable. Sirothora (212 mg/kg) and Sironaria (188 mg/kg) were significantly higher than other cultivars. CP189344 Iran (74 mg/kg) and A539 China (84 mg/kg) were the lowest.

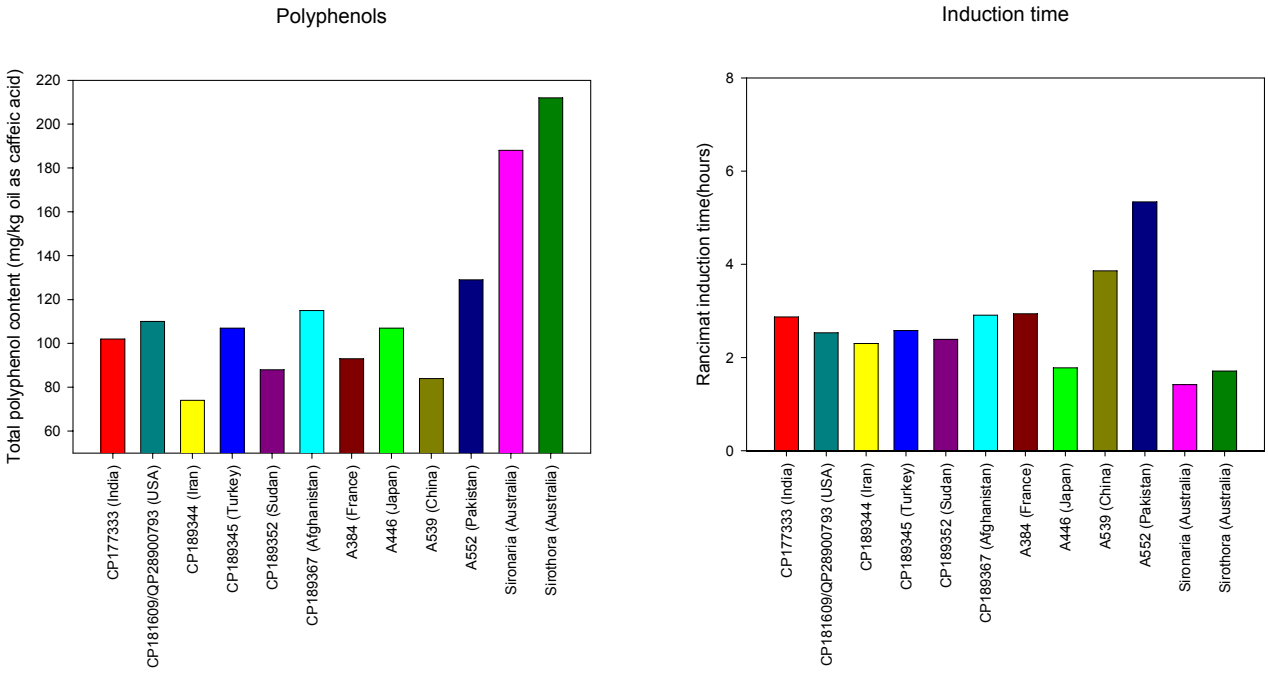


Figure 2. Polyphenol content and induction time in 12 cultivars of safflower.

Induction time is a measurement of oxidative stability with the highest number (hours) being the most stable. Although this might be expected to be greatest in oils with the highest antioxidants, particulary polyphenols, this was not the case. A552 Pakistan was the most stable (5.34 hours) although the phenolic content was only 129 µg/g. Sironaria and Sirothora, both

high in polyphenols and also high in saturated and monounsaturated fats would be expected to be the most stable but were in fact the least stable of all 12 cultivars.

α-tocopherol, or vitamin E, is a strong antioxidant and will also contribute to long induction time. In a comparison of 12 cultivars, α-tocopherol levels ranged from 319 µg/g (Sironaria Australia) to 648 µg/g (A552 Pakistan). This finding goes some way in explaining the oxidative stability of the oil with the highest α-tocopherol having the longest induction time and the lowest α-tocopherol having the shortest induction time. This is not consistent however for the other cultivars but the cumulative effect of fatty acid profile and antioxidants would explain much of this variation.

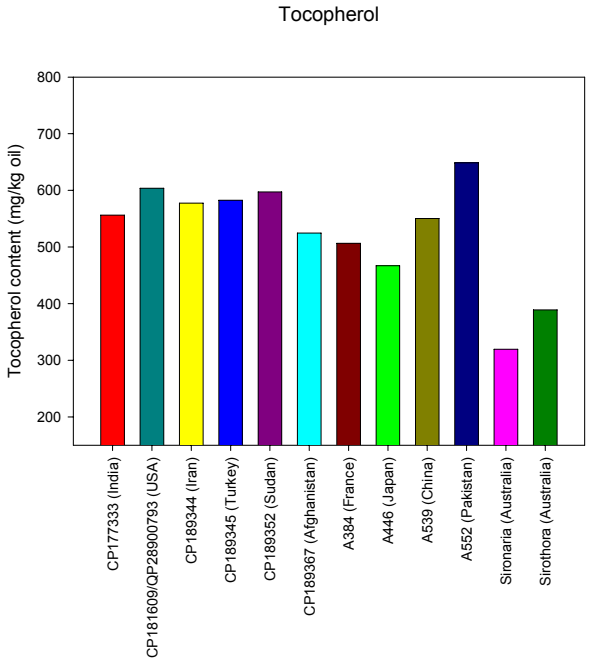


Figure 3. α-tocopherol content of 12 cultivars of safflower

B. Influence of site and environment on quality.

Analysis of four cultivars from two environmentally different sites was used to determine the influence of environment on selected cultivars. The two sites, Frances and Greenways were different in that the latter received higher rainfall and produced higher yields than Frances. The oil concentration from Greenways was significantly better for all cultivars as a result of higher rainfall Fig. 4). The protein level however did not vary between cultivars.

Fatty acids were calculated as a percentage of total fatty acids and included all of the detected fatty acids. Only the major fatty acids are shown (Table 4) as the others were only present in trace amounts. The cultivar identified as Mono was significantly different in fatty acid profile to the other cultivars with both higher levels and greater site differences of 58.6-71.1% oleic (C18:1) acid. Environmental influence on fatty acid profile is evident however with all cultivars producing higher levels of oleic and palmitic (C16:0) acid at the Frances site and higher linoleic (C18:2) acid at the Greenways site.

The induction time was significantly higher for the Greenways site and may be partly related to the higher oleic acid content. There was a reversal in relative tocopherol content for the cultivars Poly and Mono between sites.

Site	Cultivar	Grain yield (t/ha)	C16:0	C18:0	C18:1	C18:2
Frances	Mono	0.66	5.4	2.6	71.1	19.0
Frances	Poly	0.40	7.9	2.8	17.1	70.4
Frances	Safola	0.78	7.3	2.5	13.4	75.3
Frances	Sironaria	0.79	7.2	2.4	13.2	75.7
Greenways	Mono	2.96	5.1	2.4	58.6	32.3
Greenways	Poly	2.42	6.6	2.3	13.8	76.0
Greenways	Sironaria	2.71	6.8	2.1	11.0	78.9
Greenways	Safola	2.63	6.7	2.1	10.8	79.1

Table 4. Grain yield (t/ha) and major fatty acids in four cultivars of safflower grown at two sites.

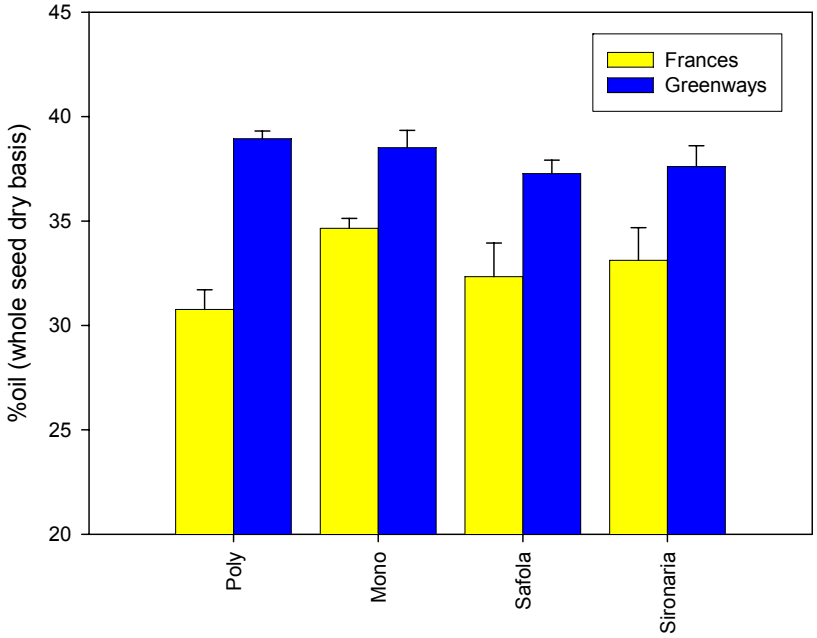
Summary

Safflower cultivars showed large variations in oil, protein, antioxidants and fatty acid profiles. The oxidative stability also varied considerably between cultivars. Surprisingly, Sironaria and Sirothora displayed mixed results. It was expected that high oxidative stability would be associated with the lowest unsaturated, nearly highest monosaturated and highest saturated fatty acid levels, combined with the highest polyphenols. However, these had the lowest oxidative stability with the lowest induction times. They also had the lowest tocopherol levels. Comparison of cultivars grown under varying environmental conditions illustrated that oil content and fatty acid profiles are influenced by environmental and/or site conditions. Protein content in the meal was not influenced by environment in this study, however there was genotype X environment interaction for tocopherol concentration in the oil.

References

Harrigan, E.K.S. (1987) Voluntary Register of Oilseeds Cultivars in Australia, Safflower, cv. Sironaria and cv. Sirothora. Journal of the Australian Institute of Agricultural Science: 53:220-221
Gutfinger (1981)

Oil content



Protein in meal

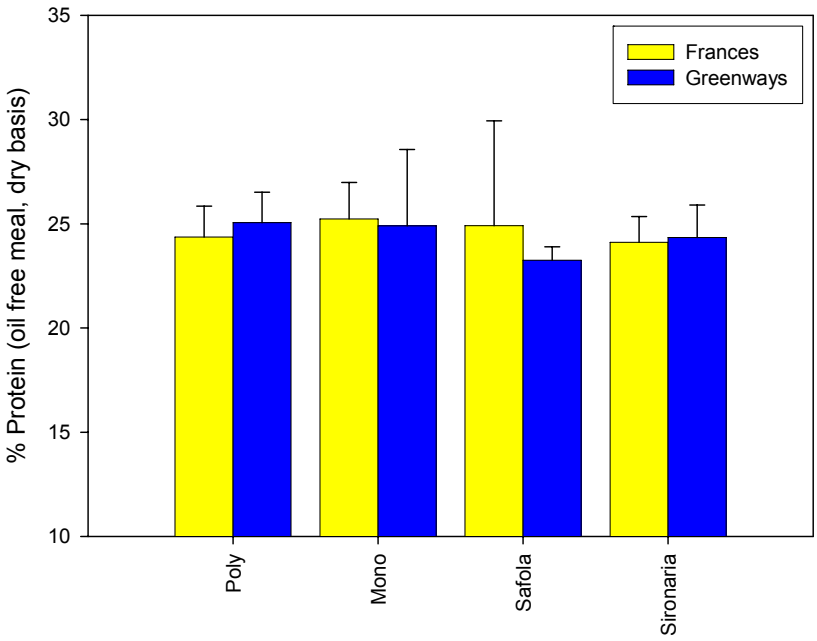
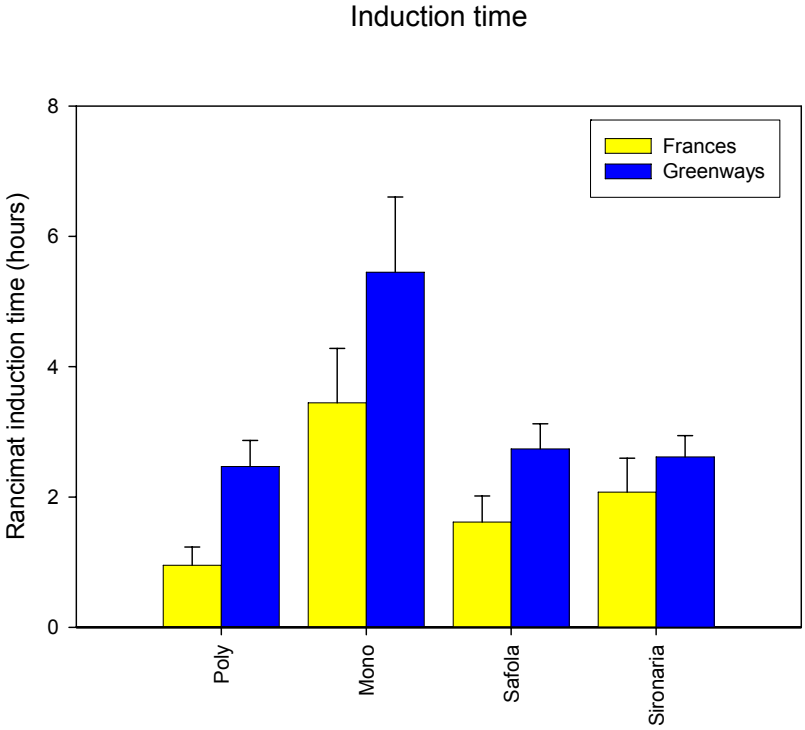


Figure 4a. Oil content and protein content of four cultivars of safflower grown at two sites.



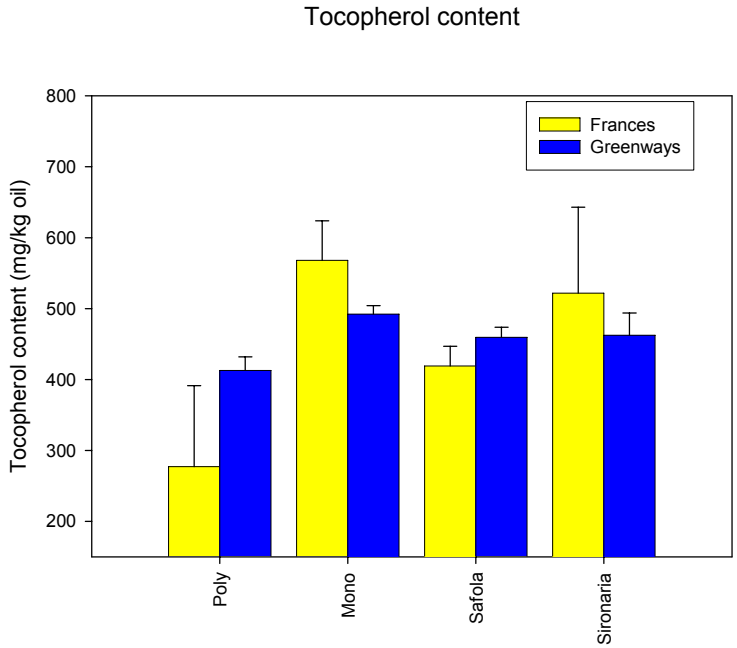


Figure 4b. Induction time and tocopherol content of four cultivars of safflower grown at two sites.