Issues in safflower production in India

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Abstract
Based on research carried out in the Nimbkar Agricultural Research Institute (NARI), elsewhere in India and around the world some important issues for production of safflower in India have been discussed. It is concluded that safflower can regain its popularity if its exact niche is identified and its flowers are exploited to the fullest extent.

Key words: Safflower production-India-Economics-Flowers

Introduction
India occupies premier position in safflower in the world as it was cultivated over an area of 364 thousand hectares (50% of world area) and had a production of 229 thousand tons (27% of world production) during 2005-06 (Anonymous, 2007). However, after attainment of the peak area in 1988 (69% of world area) and peak production in 1994 (69% of world production), the area and production have been in continuous decline (Figure 1). This decline has been attributed to many different reasons. However the recent world trends especially for yield of safflower are somewhat rosier (Figure 2). This has mainly been due to 2503 kg/ha average yield registered in Mexico in 2003, which was an increase of nearly 150% over the previous year. Even the peak average seed yields of 660 Kg/ha in India were attained in 2007.

State of Maharashtra where NARI is located accounts for about 72% area and 69% of production of safflower in India. Here it is practically entirely raised under residual soil moisture. Some of the reasons given for decline in area and production of safflower in India are:

(1) Higher remuneration than safflower obtained for competing crops like sorghum and gram over the years. The average of price obtained for safflower from 1991 to 2003 has been less than Rs. 12,000 ton^{-1}, which was lower than that for any other oilseed[1]. For the first time this year a price greater than Rs. 20,000 ton^{-1} was obtained for safflower seed. This sudden increase may have been due to increasing demand for oilseeds as a biodiesel feedstock.
(2) Low oil content of 30% or less. All other oilseeds have an oil content of 40-60%.
(3) Susceptibility to various biotic and abiotic stresses such as aphids (*Uroleucon compositae* Theobold), wilt caused by *Fusarium oxysporum* f. sp. *carthami,* moisture stress and low nutrients.
(4) Import of cheap palm oil.

Economics of growing safflower

From 2000-01 to 2007-08 the cost of growing safflower was calculated on NARI's research farm taking the recommended package of practices as a guide and using the actual price of inputs in a given year. The cost was found to have increased by 24% during this period, while the market price obtained increased by 100% i.e. doubled during the 8-year period (Table 1). The highest cultivation cost increase of 12% took place between the years 2001-02 and 2002-03, while the highest market price increase of 33% took place between 2006-07 and 2007-08. In fact a 24% decline in market price was registered from 2003-04 to 2004-05, but the market price recovered to the earlier level in 2005-06. When the yield required for breakeven (i.e. no profit no loss) was compared with actual yields obtained in a given year, only in years 2001-02 and 2003-04 was it found to have dropped below the economical level.

[1] Rs. 40 = $ 1 U.S.

Table 1 : Economics of safflower

Year	Actual cost of production (Rs.)	Highest market price obtained (Rs./kg)	Yield required for break even (Kg/ha)	Actual yield obtained (Kg/ha)	Benefit-to- cost ratio
2000-01	20295	11.0	1845	2109***	1.14
2001-02	20833	11.77	1770	1106***	0.62
2002-03	23245	14.0	1660	1789**	1.08
2003-04	23284	16.43	1417	1365*	0.96
2004-05	23736	12.45	1906	2090*	1.10
2005-06	23713	15.46	1534	2433*	1.59
2006-07	24232	16.53	1441	2779*	1.9
2007-08	25126	22.0	1142	1847*	1.62
% increase in 8 years	24	100	-	-	-

* Yield maximization trial (Variety : NARI-NH-1) ** Integrated nutrient management trial (Variety : NARI-NH-1) *** Production potential under high input conditions (Variety : Bhima)

Rs. 40 = $ 1 U.S.

When cost of production was broken down into its components about 50% was found to be contributed equally by land preparation, pesticides and bird watching. In the remaining 50%, weeding and thinning had a 14% and harvesting and threshing a 10% share. The biggest contributors to the cost of cultivation increase over last eight years have been operations such as sowing, weeding, thinning and bird watching which registered more than 40% increase mainly due to the rise of 50-55% in wages paid to the labourers. The bird watching operation has become essential due to the use of non-spiny cultivars which are more susceptible to bird predation. Thus potentially there is a place for increased mechanization of various operations and increased use of herbicides at least in irrigated safflower which has generally higher levels of seed yield. Many farmers around Phaltan have successfully used wheat combines to harvest their safflower.

Earlier in 1992-93 and 1993-94 when the preemergence herbicides Pendimethalin, Fluchloralin and Oxadiazon were compared with hand weeding and interculture with hoes, the surprising conclusion was that not only were there no statistically significant differences for seed yield between these different methods of weed control, but unweeded control also gave seed yields on par with those where weed control methods were employed. Thus it appears that the recommended two weedings may not be necessary and only one weeding is probably adequate even under irrigated conditions.

Until recently economics of irrigated high-input safflower did not look so good, especially for non-spiny cultivars. However, the main reason for developing non-spiny hybrids was to enable the picking of flowers with ease in addition to encouraging the spread of safflower in non-traditional areas. Therefore, if the flower component is added then the economics of safflower looks really good.

Safflower flowers

About 10 years ago we at NARI felt that one of the quickest ways to revive farmers' interest in safflower would be to exploit the safflower flowers which have been traditionally used in India for dyeing cloth. With the growing demand for vegetable dyes internationally, not only for dyeing cloth but also as a food colouring this was a promising avenue to be explored. After some investigation we became aware of its use in China as a herbal medicine for curing several chronic diseases such as hypertension, problems of blood circulation and coronary ailments (Dajue and Mundel, 1996). NARI has been test-marketing these flowers as 'herbal tea' for last several years. They fetch about Rs. 400 kg^{-1} as opposed to Rs. 20 kg^{-1} obtained for seed. The average flower yield is about 100 kg ha^{-1} and even considering average seed yield of 1000 kg ha^{-1} potentially at least twice the income as that from seed can be obtained.

Since a majority of safflower varieties grown in India were spiny, collecting flowers from them was tedious, time-consuming and labour-intensive. Therefore, both battery and spark ignition engine-powered flower collectors were developed at NARI (Rajvanshi, 2005). However, with the national release of non-spiny variety NARI-6 and hybrid NARI-NH-1, it is now possible in India to collect flowers economically by hand without the help of a machine.

In order to maximize both flower and seed yields in safflower, an agronomic experiment was carried out on the non-spiny hybrid NARI-NH-1 for three years. It was in a split-split plot design with three replications. The treatments are given in Table 2.

Table 2 : Treatments in trial for maximization of seed and flower yields in safflower (2002-04)

Treatments	Dates of sowing (Main)	Levels of fertilizer (Sub)	Spacings (Sub-sub)
1	October 3	No fertilizer	45 X 10 cm
2	October 18	50% recommended dose	45 X 20 cm
3	November 1	100% recommended dose	45 X 30 cm
4		150% recommended dose	60 X 10 cm
5			60 X 20 cm
6			60 X 30 cm
		Recommended dose : 60 N : 30 P_2O_5:30 K_2O	

Sowing 15 and 27 days after October 3 caused a reduction of 8 and 22% in flower yield and 18 and 38% in seed yield respectively. Thus seed yield was affected more than flower yield. The main yield component affected was capitulum number (25 and 21% reduction) followed by number of seeds per capitulum (8 and 22% reduction) and 100-seed weight (5 and 12% reduction). Surprisingly, height of plants was seen to increase by 13 and 26% respectively by a 15 and 27-day delay in planting.

Though one would think that date of planting should be the easiest recommendation to adhere to as it does not cost anything to follow, our experience has shown otherwise. The main problems encountered have been:

(1) Inability to prepare the land for planting of safflower in time after the harvest of rainy season crops like sorghum or soybean, either due to its their delayed sowing or lack of proper soil conditions for land preparation because of continuous rainfall. If farmers adopt no-till farming then this problem may be solved.
(2) Propensity of the farmers to wait and watch how much rainfall takes place. If rainfall appears to be adequate they prefer to sow other crops like fodder sorghum, gram, sunflower or wheat especially if supplemental irrigation is available. By the time the rains stop, it is usually early to mid-November when the farmers finally come around to planting safflower if at all. This results in 30-40% reduction in expected seed yields.

Further the results of the flower and seed yield maximization trial showed that with a 50% reduction in recommended fertilizer dosages, both flower and seed yields were reduced by about 7% with net returns being reduced by 9%. This was mainly due to about 8% reduction in number of capitula per plant. Without any fertilizer the flower and seed yields were reduced by about 19% and net returns by 26%. This was also mainly due to nearly 17% reduction in number of capitula per plant. It was not worthwhile to apply 150% of recommended fertilizer dosage as it caused only a 3 and 4% increase in flower and seed yield respectively with about 3% increase in net returns.

Among the spacings tested only 45 X 10 cm gave an increase of 10% in flower yield and 11% in seed yield over the recommended spacing of 45 X 20 cm. This appears to be mainly due to increase in final plant stand by about 71% though 100-seed weight also increased by about 5%. All other spacings tested gave a 5 to 22% reduction in flower yield and 7 to 25% reduction in seed yield as compared to 45 X 20 cm spacing. Thus the optimum plant population is about 100,000 plants per hectare.

The results thus suggest that sowing of safflower in the first week of October with a spacing of 45 X 20 cm and application of 60:30:30 kg $N:P_2O_5:K_2O$ per hectare can be recommended for obtaining maximum seed and flower yields from non-spiny safflower hybrid NARI-NH-1.

Irrigation

In most countries, irrigated agriculture accounts for most freshwater use (as much as 70-80%), far higher than drinking water and domestic consumption (Hightower and Pierce, 2008). Increasing pressures to reduce the share of water available to agriculture along with the forecasted uncertain climate in near future is expected to increase the importance of crops like safflower, which has a reputation of being a drought-resistant crop. This is mainly based on its ability to withdraw water from a depth of up to 3.5 m (Anonymous, 2002). Because it can explore a large, deep soil volume to recover water it is able to grow when other crops with less aggressive root systems cannot (Kaffka and Kearney, 1998).

It is said that in deep soils with high water holding capacity such as Chromusterts (vertisols or heavy cracking clays) at our location, usually two to three irrigation applications during the season are sufficient for safflower. However, the number of irrigations is not what is important, but the quantity of water which is applied. It has been our observation that in safflower due to the longer interval between two irrigations (30-35 days) and its ability of exhaust water from the soil profile to a greater depth, it takes at least twice as long to irrigate the same area under safflower as compared to other winter crops like wheat, sorghum, sunflower, gram etc.

Thus safflower will survive and produce a low yield if it can transpire a minimum of 400-460 mm of water (Kaffka and Kearney, 1998), but to grow and produce an economic yield (approx. 2 $T.ha^{-1}$) nearly the same amount of water is required per unit of dry matter produced as required by other C_3 crops under comparable conditions. This was also seen in a study by Merrill et al. (2001) who measured water use by 10 crops in the Northern Great Plains. Sunflower was the greatest water user with safflower the second greatest. This observation was attributed to the deepest taproot-organized root system of safflower and its capability of extracting subsoil water at greater depths than all other crops studied. For this reason world over safflower has been found to be very effective in lowering water table where drainage is required.

Frontline demonstration on farmers' fields in major safflower growing regions of India indicated the possibility of enhancing safflower yields by 43-69% under rainfed conditions by adopting the whole package which included improved varieties, thinning, fertilizer, irrigation, plant protection etc. Table 3 shows that irrigation consistently gave an improvement of 45% in productivity.

On the other hand, safflower is particularly susceptible to excess moisture either as rain, standing water or high humidity because of its susceptibility to various fungal diseases under such conditions. Excessive rain at flowering can also affect pollination adversely preventing proper seed filling. Zimmerman (1978) noted that there can be an interaction between high temperature and high humidity, which can severely reduce seed yield. At our location maximum seed yields are produced when safflower is irrigated at elongation and/or pre-flowering. Irrigation after flowering generally has disastrous consequences due to increased disease incidence.

Table 3 : Productivity improvement (%) in safflower through different interventions

Intervention	Improvement (%)
Whole package	43-69
Improved varieties	13-48
Thinning	6-15
Fertilizer	27-68
Irrigation	45
Plant protection	14-56
Growth regulator (Cycocel)	19
Anonymous. 2004. Project Director's Report (2003-04). All India Coordinated Research Project on Safflower. Directorate of Oilseeds Research (Indian Council of Agricultural Research), Rajendranagar, Hyderabad-500030. 17 pp.	

Fertilizer application

As for any other crop, fertilizer amounts required for safflower depend on the yields desired, the place of safflower in a rotation and the other crops included, as well as on the soil type used.

At our location the soils generally have a normal pH (7.4-8.5) and electrical conductivity (0.10-1.24 mmhos.cm^{-3}), medium to high nitrogen (153-335 kg ha^{-1}), very low to adequate phosphorus (13-60 kg ha^{-1}) and very high potassium (403-645 kg ha^{-1}).

The different treatments in trials conducted on (1) Phosphorus management in safflower-based cropping system and (2) Integrated nutrient management in safflower-based cropping system in last seven and six years respectively are given in Table 4. The pooled analysis of these data gave non-significant differences between the treatments for seed yield and net returns. However, individual years did show some significant results. In all the years when significant differences were obtained, 100% P to soybean and 5 T farmyard manure (FYM) ha^{-1} + Phosphorus Solubilizing Bacteria (PSB) to safflower gave the significantly highest seed yields of safflower. In three out of four years the treatments of 50% P + PSB to both soybean and safflower and 5 T FYM.ha^{-1} to soybean and 100% P to safflower or vice versa gave the significantly highest safflower seed yields.

Table 4 : Treatments in fertilizer trials

Sr. No.	Trial 1 : Phosphorus management in safflower-based cropping system (2001-07)		Trial 2 : Integrated nutrient management in safflower-based cropping system (2002-07)	
	Soybean	Safflower	Soybean	Safflower
1.	No P	No P	No NP	No NP
2.	100% P	100% P	50% NP	50% NP
3.	50% P	100% P	50% NP	100% NP
4.	50% P	50% P	100% NP	50% NP
5.	50% P + PSB	50% P + PSB	100% NP	100% NP
6.	No P	100% P	100% NP	50% N + 100% P
7.	5 T FYM/ha	100% P	100% NP	Azoto./Azospi. + 100% P
8.	5 T FYM/ha + PSB	100% P	100% NP	50% N + Azoto. / Azospi. + 100% P
9.	100% P	50% P	100% NP	Azoto./Azospi. + PSB
10.	100% P	No P	100% NP	50% NP + Azoto. / Azospi. + PSB
11.	100% P	5 T FYM/ha	100% N + 50% P + PSB	100% NP
12.	100% P	5 T FYM/ha + PSB	100% N + 50% P + PSB	50% NP + Azoto. / Azospi. + PSB
PSB = Phosphorus-solubilizing bacteria			Azoto. = Azotobacter.	Azospi. = Azospirillum

In the integrated nutrient management trial, in all the years 100% NP to both soybean and safflower gave the significantly highest seed yield and net returns, while in five out of six years 50% NP or 100% N + 50% P + PSB to soybean and 100% NP to safflower gave significantly highest seed yields and net returns for safflower. Only in one or two years was it possible to substitute a part of fertilizer N by seed treatment with Azotobacter and Azospirillum without significant adverse effect on productivity.

In the trial conducted to assess response of safflower to micronutrients there were no statistically significant differences for seed yield between the different dosages of $ZnSO_4$, $FeSO_4$ and elemental sulphur tested in any of the five years when the trial was conducted.

Similarly in a trial for testing the effect of different sources of sulphur [$(NH_4)_2SO_4$, single super phosphate (SSP), elemental sulphur and gypsum)] to supply 15, 30 and 45 Kg sulphur. ha^{-1}, no statistically significant differences were found between the treatments in the pooled analysis of three years' data. However, in two out of three years SSP to supply 15 Kg sulphur.ha^{-1} gave the significantly highest seed yield and net returns.

In another trial, production potential of safflower variety Bhima was tested for two years (2000-01 and 2001-02) under high input conditions. In this trial 100 and 150% recommended fertilizer doses were applied with or without FYM (10 T.ha^{-1}) and sulphur (40 Kg.ha^{-1}). Differences between the treatments for seed yield and other parameters were non-significant. Significantly highest benefit: cost ratios were given by 100 and 150% recommended fertilizer application with or without sulphur and without FYM. Prices of FYM are generally quite high and its availability has also been reduced drastically in recent years. There has been a 600% increase in the price of FYM in last 18 years (from Rs. 200 to Rs. 1400 T^{-1}). Also with the cost of loading and unloading and transport the price at present can be as much as Rs. 1800 T^{-1} of FYM.

Improved varieties

Seed is the lowest-value input and till recently most farmers tended to save their own seed from the previous year. Even the relatively costlier seed of hybrids contributes a maximum of 5-6% to the total cultivation cost.

NARI has nationally released two spiny varieties, and one each non-spiny variety, non-spiny hybrid and spiny hybrid in last 20 years. Their performance is listed in Table 5.

Table 5 : Performance of released safflower varieties and hybrids developed at NARI in comparison with the checks.

Sr. No.	Variety/ hybrid (Year of release)	Seed yield (Kg/ha)	% increase over check	Oil yield (kg/ha)	% increase over check	Flower yield (kg/ha)	% increase over check	Important characteristics
1.	Nira (1987)	2012	19.90	654	32.1	-	-	Spiny, early-maturing aphid-tolerant variety
2.	NARI-6 (2000)	1024	20.19	304	25.97	73.0	- 5.49	Non-spiny variety with dark red flowers
3.	NARI-NH-1 (2001)	1895	24.83	593	32.96	215	128.72	Non-spiny, moderately pest and disease tolerant hybrid
4.	NARI-H-15 (2005)	2201	18.65	669	14.33	-	-	Spiny, moderately pest and disease-tolerant hybrid
5.	NARI-38 (2007)	2038	9.46	534	15.43	-	-	Spiny, moderately wilt-resistant variety
Check for 2 and 3 : non-spiny variety JSI-7 Check for 1 and 5 : spiny variety A-1 (national check) Check for 4 : non-spiny hybrid NARI-NH-1								

Plant protection

All our breeding material is screened for aphid (*Uroleucon compositae Theobold*) tolerance, but very little work on entomology of safflower has been carried out at NARI in recent years. One of the major reasons for low productivity of safflower in India is infestation of aphids with estimates of yield loss as high as 74% (Bhardwaj et al., 1990). No resistance to this pest has been identified so far.

Since under irrigated conditions diseases assume much more importance in safflower than when it is grown as a rainfed crop, we have a fairly active pathology program. During the past year we screened all the treatments in the integrated nutrient management trial (mentioned earlier in the section on fertilizer application) against foliar diseases (mainly *Alternaria*). All the three treatments in which 100% NP application was given to safflower showed significantly higher *Alternaria* disease score than the other treatments. Thus application of inorganic fertilizers appears to increase susceptibility of safflower to foliar diseases.

In 2007-08 in a trial for fungicidal management of *Alternaria* leaf spot when Plant Disease Intensity (PDI) at 100 days after sowing (DAS) was 38, not only did none of the eight different fungicides used give any statistically significant differences in seed yield and net returns, but the water-sprayed control was on par with them. However, in 2006-07 when the PDI at 100 DAS was 64, treatments with either Carbendazim (0.1%) or Difenconazole (0.05%) gave significantly higher seed yield than the other treatments. This underscores the importance of determining the threshold values for undertaking plant protection measures.

In laboratory and pot studies conducted at NARI during last two years coating of seeds with antagonists of *Macrophomina phaseolina* viz. *Trichoderma viride*, *T. harzianum*, *Bacillus subtilis* and *Pseudomonas fluorescens* was found to effectively combat safflower root rot. Elsewhere in India *T. harzianum* @ 10 g/kg seed has been found to be effective in management of safflower wilt.

Conclusions

Under the present situation of available varieties, achievable yield potential and price structure it does not appear that safflower can be a very popular crop in India under high-input conditions. It can however be grown profitably under rainfed conditions and by applying selected low-value inputs. It will be very important to identify its exact niche, if its continuous decline in India and may be in the world is to be reversed. Eckhoff et al. (2005) concluded after 14 years' of study that with adequate weed control, organic safflower can be produced without application of fertilizers or pesticides with little or no loss of seed yield, oil yield or quality. I feel safflower community needs to take a serious note of such studies and carry out further research to validate these results under varied conditions.

Exploitation of safflower flowers as a source of pigment and for medicinal and nutritional uses may be the key intervention required to increase the popularity of this crop in the world and for restoring its status as an important oilseed crop.

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Figure 1

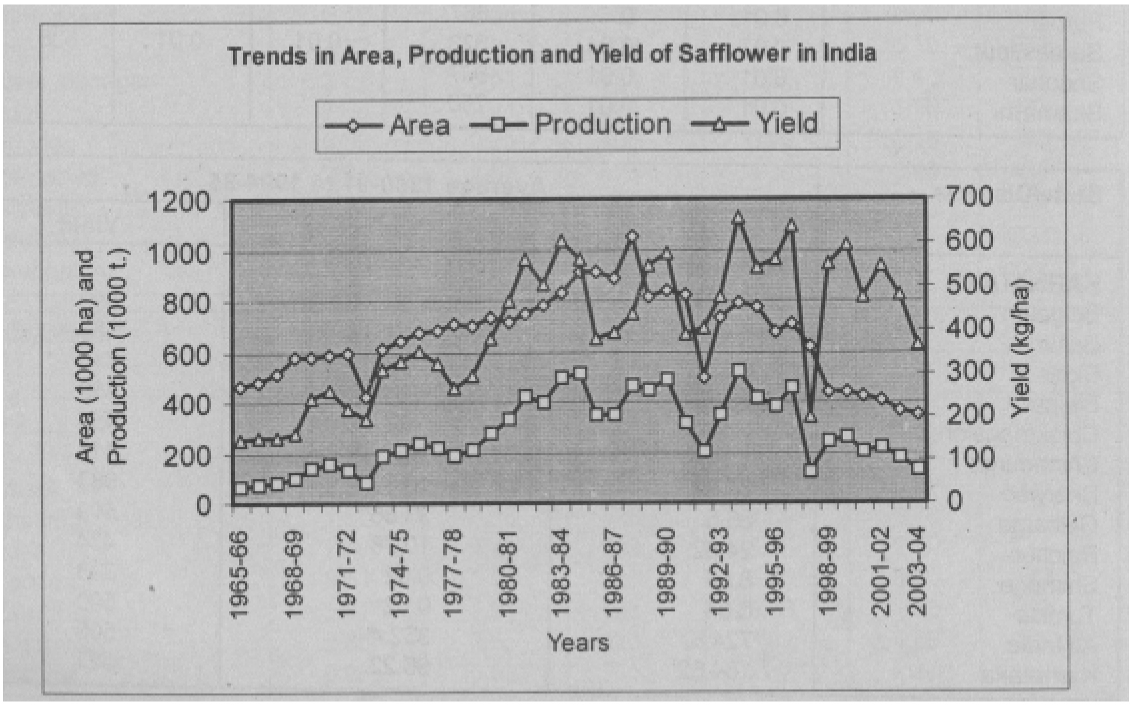

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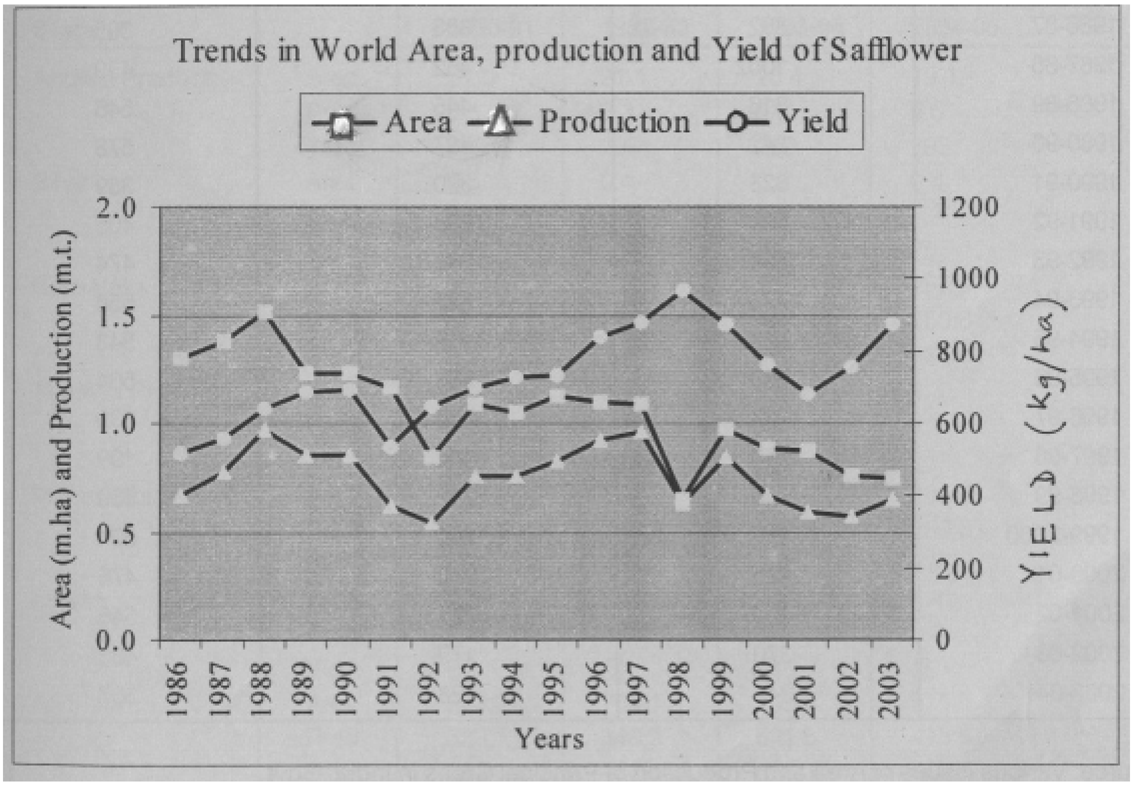
Figure 2



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