Safflower - Recommended Cultural Practices

Introduction

Safflower is well known for its tolerance to drought and, in various field trials conducted at CARS (Central Agriculture Research Station) and BDARS (Bonka Dryland Agriculture Research Station), has demonstrated that it has great adaptability to Somali agro-ecological conditions. It is a good source for cooking oil (30-40%) of excellent quality. This crop could become a major oil crop in dryland agriculture. One of the difficulties encountered in the past was the harvesting of the thorny types. Further research to refine the production techniques is also needed.

In 1982, forty varieties introduced from California, USA were tested at CARS. Three spineless varieties with good seed settings were selected and later transferred to Bonka research station for further testing.

Several trials were conducted at BDARS. Most of the safflower varieties were obtained from the USA. The average yield varied from 110 kg/ha in Gu 1982 to 820 ka/ha in Gu 1985. Data on days to 50% flowering, plant height and yield of six safflower varieties is shown in Table 1. The variety VC-152 produced the highest yield, followed by CV-162.

The deep-rooted habit of safflower, although highly desirable for the crop, has become a concern at Bonka Research Station. Soil moisture content is sodepleted by the extensive deep-rooted system of the safflower crop that a following crop may not have enough reserve water for adequate yield, especially in a subsequent Deyr season or if rainfall is less than normal. Evidence of this moisture depletion appears as side, deep cracks in the clay-type soil. If early seasonal rainfall is adequate, the problem may not occur in the following crop.

Safflower is not anticipated to substitute for sesame in oil production, but it supplements sesame for oil under extremely unfavorable moisture conditions or in sandy soils where sesame cannot be grown.

Uses

Safflower contains nearly 75% linoleic acid, which is considerably higher than corn, soybean, cottonseed, peanut or olive oils. This type of oil is used primarily for edible oil products such as salad oils and soft margarines. Safflower oil is considered "high quality" edible oil. The oil is light in color and will not yellow with aging. The meal that remains after oil extraction is used as a protein supplement for livestock. The meal usually contains about 24% protein and much fiber. Decorticated meal (most of hulls removed) has about 40% protein with a reduced fiber content.

Growth Habits

Safflower is an annual species in the same plant family as sunflower. This crop is adapted to dryland or irrigated cropping systems. The slow growth of seedlings during the early stages often results in a weedy crop. The strong central stems, with variable numbers of branches, grow to between 30 to 90 cm, depending on environmental conditions. Safflower is more drought-tolerant than small grains since it has a taproot that can grow to 2.5 to 3.5 m. deep if subsoil temperature and moisture allow. Stiff spines develop on leaf margins of most varieties at about the flower bud stage and make it difficult to walk through the fields.

Branches usually produce one to five flower heads. Flower heads, about 2.5 cm in diameter, are usually yellow or orange in color, although some varieties have red or white flowers. Flower buds start 75 to 80 days after emergence and continue for two to three weeks depending on environmental conditions, stand density, and varietal differences. Each flower head produces 15 to 30 seeds with seed oil content usually between 30 to 45%. Seeds are enclosed in the head at maturity, which prevents shattering before harvest. Depending on the variety, the crop usually needs 110 to 130 days to mature.

Climate

Safflower does best in areas with warm temperatures and sunny, dry conditions during the flowering and seed-filling periods. Yields are lower under humid or rainy conditions. The crop is well adapted to semiarid regions.

Soil

Deep, fertile, well-drained soils that have a high water-holding capacity and high level of stored moisture are ideal for safflower. This crop is also productive on coarse-textured soils with low water-holding capacity when adequate rainfall or moisture distribution is present. Soils with high levels of salinity can decrease the frequency of seed germination and lower seed yield and oil content. Safflower has approximately the same tolerance to soil salinity as barley.

Cultural Practices

Safflower gives farmers some options in a dryland crop rotation with respect to weed and disease control, and in using soil moisture available to its deep taproot. This crop is usually grown in rotation with small grains or fallow.
A crop following safflower should be grown only if there has been a significant recharge of soil moisture. Very little crop residue remains after harvesting safflower.

Seeding Date

Like other crops, safflower can be planted in mid to late April for the Gu season and early to late October for the Deyr season crop. This crop may not mature if planted late. Seedlings emerge in 8 to 15 days. Late planting usually results in shorter plants, less branching, and lower seed yield and oil content.

Method and Rate of Seeding

Use a grain drill to plant seed at depths of 2.5 to 3 cm in depth at a rate of 25 to 30 kg/ha. A shallow planting depth promotes a uniform emergence that is important when planting early. Dryland rows are usually spaced at 25 to 35 cm. Wider row spacing may decrease disease incidence, but can promote more weed competition, less branching, delayed maturity and lower oil content of seed. Seeding rates for irrigated crops should be 30 to 35 kg/ha.

Fertility Requirements

Soil tests are necessary to correctly determine whether any additional soil nutrients are required. The amount of fertilizer needed for safflower production depends on the yield goal, its position in the rotation, and the other crops used in the rotation. Safflower has deeper roots than small grains and can effectively use nitrogen remaining in the soil from previous crops to a depth of 3m.

High yields can be obtained when sufficient nitrogen is available. More fertilizer may be necessary if safflower follows a deep-rooted crop in the rotation. Use of phosphorus fertilizer in dry land farming improves seed yield and quality. Potassium fertilizer (K_2O) is applied primarily when very low levels are present. Soil pH of 6.0 appears to be adequate.

Variety Selection

Table 1: Days to 50% flowering, plant height (cm) and yield (kg/ha) of six safflower varieties tested at Bonka Research Station during four seasons (Deyr 1984-Gu 1986)

Varieties	**Days to 50% flowering**	**Plant height (cm)**	**Yield (kg/ha)**
VC-152	79	56	650
VC-163	77	53	630
VC-155	81	72	600
GILA	75	41	560
RH-2	76	56	560
Partial Hull	75	55	520

Weed Control

Weeds can be a major problem for safflower crops by reducing potential crop yields. Protection from weed competition during the early portion of the growing season is very important. At least three hand weedings are necessary to reduce numbers of grassy weeds. As weeds frequently emerge before the crop, timely and thorough cultivation can provide initial weed-free conditions for the emerging crop.

Diseases and Control

Diseases have caused economic losses in years with above normal rainfall and prolonged periods of high humidity. *Alternaria* (*Alternaria carthanti*) leaf spot and bacterial blight (*Pseudomonas syringae*) are the most serious disease problems.

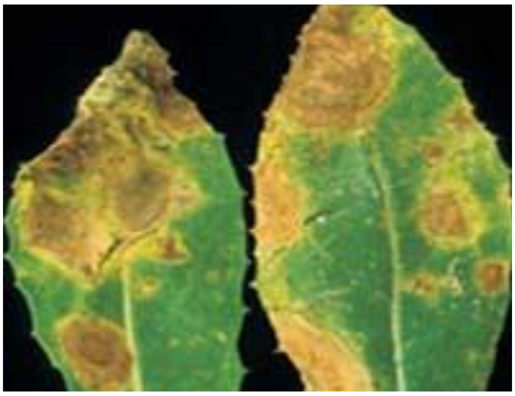

Figure 1: *Altenaria cathanti*

Figure 2: *Pseudomonas syringae*

Harvesting

Safflower is ready to harvest when most of the leaves turn a brown color and very little green remains on the bracts of the latest flowering heads. The stems should be dry, but not brittle, and the seeds should be white and hand-thresh easily. This crop should be harvested as soon as it matures in order to avoid the seed discoloration.

Design and Analysis of Experiments

Planning an experiment to obtain appropriate data and drawing inferences from the data with respect to any problem under investigation is known as *design and analysis of experiments*.

Principles of experimentation

Almost all experiments involve the three basic principles, *viz*., randomization, replication and local control.

Randomization: Assigning the treatments or factors randomly to the experimental units is known as randomization. Through randomization, every experimental unit will have the same chance of receiving any treatment.

Replication: Replication is the repetition of experiments under identical conditions, but in the context of experimental designs it refers to the number of distinct experimental units under the same treatment. Replication, with randomization, will provide a basis for estimating the error variance. In the absence of randomization, any amount of replication may not lead to a true estimate of error. The greater the number of replications, greater is the precision in the experiment.

Local control: Local control means the control of all factors except the ones which we are investigating. Local control, like replication, is yet another device to reduce or control the variation due to extraneous factors and increase the precision of the experiment.

Randomized complete block design

The randomized complete block design (RCBD) is one of the most widely used experimental designs in forestry research. This design is especially suitable for field experiments in which the number of treatments is not large and there exists a conspicuous factor based on which homogenous sets of experimental units can be identified. The primary distinguishing feature of the RCBD is the presence of blocks of equal size, each of which contains all the treatments.

Blocking technique: The purpose of blocking is to reduce the experimental error by eliminating the contribution of known sources of variation among the experimental units. This is done by grouping the experimental units into blocks such that variability within each block is minimized and variability among blocks is maximized.

Layout: The randomization process for a RCBD is applied separately and independently to each of the blocks. The procedure is illustrated for the case of a field experiment with six treatments (A, B, C, D, E, F) and three replications.

Step 1. Divide the experimental area into *r* equal blocks, where *r* is the number of replications. For our example, the experimental area is divided into three blocks as shown in Figure 1. Assuming that there is a unidirectional fertility gradient along the length of the experimental field, block shape is made rectangular and perpendicular to the direction of the gradient.

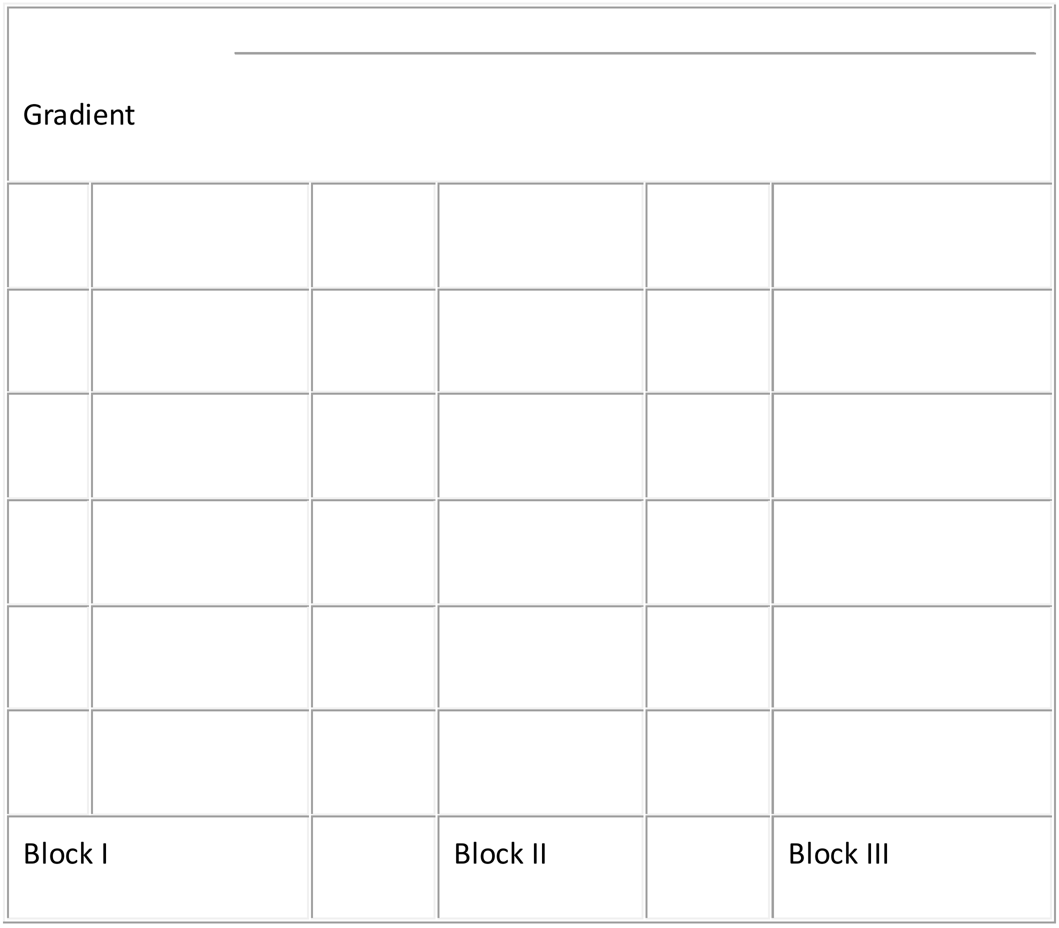

Figure 1. Division of an experimental area into three blocks, each consisting of six plots, for a randomized complete block design with six treatments and three replications. Blocking is done so that blocks will be rectangular and perpendicular to the direction of the unidirectional gradient (indicated by the arrow).

Step 2. Subdivide the first block into *t* experimental plots, where *t* is the number of treatments. Number the *t* plots consecutively from 1 to *t*, and assign *t* treatments at random to the *t* plots. For our example, block I is subdivided into six equisized plots, which are numbered consecutively from top to bottom. (Figure 2) and the six treatments are assigned at random to the six plots using the table of random numbers as follows:

C
2 D
3 F
4 E
5 B
6 A
Block I

Figure 2. Plot numbering and random assignment of six treatments (A, B, C, D, E, and F) to the six plots of Block I.

Step 3. Repeat Step 2 completely for each of the remaining blocks. For our example, the final layout is shown in Figure 3.

1		7		13
C		A		F
2		8		14
D		E		D
3		9		15

F		F		C
4		10		16
E		C		A
5		11		17
B		D		B
6		12		18
A		B		E
Block I		Block II		Block III

Figure 3. A sample layout of a randomized complete block design with six treatments (A, B, C, D, E and F) and three replications.

Analysis of variance

There are three sources of variability in a RCBD: treatment, replication (or block) and experimental error.

To illustrate the steps involved in the analysis of variance for data from a RCBD, data from an experiment, wherein eight maize varieties were compared with respect to the 100 seed weight for the Gu season planting in Afgoi (Table 1), is made use of.

Table 1. Mean 100 seed weight (grams) of eight maize varieties in a field experiment laid out under RCBD at Afgoi in Gu 2009.

Treatment (Provenance)	Replication			Treatment total	Treatment mean
	I	II	III	(T_i)	
1	30.85	38.01	35.10	103.96	34.65

2	30.24	28.43	35.93	94.60	31.53
3	30.94	31.64	34.95	97.53	32.51
4	29.89	29.12	36.75	95.76	31.92
5	21.52	24.07	20.76	66.35	22.12
6	25.38	32.14	32.19	89.71	29.90
7	22.89	19.66	26.92	69.47	23.16
8	29.44	24.95	37.99	92.38	30.79
Rep. total (R_j)	221.15	228.02	260.59		
Grand total (G) Grand mean				709.76	29.57

Step 1. Group the data by treatments and replications and calculate treatment totals (T_i), replication totals (R_j) and the grand total (G), as shown in Table 4.5.

Step 2. Construct the outline of the analysis of variance as follows:

Table 2. Schematic representation of ANOVA of RCBD

Source of variation	Degree of freedom (df)	Sum of squares (SS)	Mean square $\left(MS = \frac{SS}{df}\right)$	Computed F
Replication	$r - 1$	SSR	MSR	
Treatment	$t - 1$	SST	MST	MST/MSE

Error	$(r - 1)(t - 1)$	SSE	MSE	
Total	$rt - 1$	$SSTO$		

Step 3. Compute the correction factor and the various sums of squares (SS) given in the above table as follows. Let y_{ij} represent the observation made from jth block on the ith treatment; $i = 1,\ldots,t$; $j = 1,\ldots,r$.

$$CF = \frac{G^2}{rt} \quad (4.10)$$

$$= \frac{(709.76)^2}{(3)(8)} = 20989.97$$

$$SSTO = \sum_{i=1}^{t}\sum_{j=1}^{r} y_{ij}^2 - C.F. \quad (4.11)$$

$$= \left[(30.85)^2 + (38.01)^2 + \ldots + (37.99)^2\right] - 20989.97$$

$$= 678.42$$

$$SSR = \frac{\sum_{j=1}^{r} R_j^2}{t} - C.F. \quad (4.12)$$

$$= \frac{(221.15)^2 + (228.02)^2 + (260.59)^2}{8} - 20989.97$$

$$= 110.98$$

$$SST = \frac{\sum_{i=1}^{t} T_i^2}{r} - C.F. \quad (4.13)$$

$$= \frac{(103.96)^2 + (94.60)^2 + \ldots + (92.38)^2}{3} - 20989.97$$

$$= 426.45$$

$SSE = SSTO - SSR - SST$ (4.14)

$= 678.42 - 110.98 - 426.45 = 140.98$

Step 4. Using the values of sums of squares obtained, compute the mean square and the *F* value for testing the treatment differences as shown in the Table 2. The results are shown in Table 3.

Table 3 ANOVA of 100 seed weight data in Table 1.

Source of	Degree of	Sum of	Mean	Computed	Tabular *F*
variation	freedom	Squares	Square	*F*	5%
Replication	2	110.98	55.49		
Treatment	7	426.45	60.92	6.05*	2.76
Error	14	140.98	10.07		
Total	23	678.42			

*Significant at 5% level

Step 5. Obtain the tabular *F* values from Appendix 3, for f_1 = treatment *df* and f_2 = error *df*. For our example, the tabular *F* value for $f_1 = 7$ and $f_2 = 14$ degrees of freedom is 2.76 at the 5% level of significance.

Step 6. Compare the computed *F* value of step 4 with the tabular *F* values of step 5, and decide on the significance of the differences among treatments. Because the computed *F* value of 6.05 is greater than the tabular *F* value at the 5% level of significance, we conclude that the experiment shows evidence the existence of significant differences among the treatment with respect to their 100 seed weight.

Step 7. Compute the coefficient of variation as:

$$cv = \frac{\sqrt{\text{Error } MS}}{\text{GrandMean}}(100) \quad (4.15)$$

$$= \frac{\sqrt{10.37}}{29.57}(100) = 10.89\%$$

The relatively low value of *cv* indicates the reasonable level of precision attained in the field experiment.

Comparison of treatments

The treatment means are compared using the formulae,

$$\mathrm{LSD}_{\alpha} = (t_{v;\alpha})(s_{\bar{d}}) \quad (4.16)$$

where s-d is the standard error of the difference between treatment means and $t_{v;\alpha}$ is the tabular *t* value, from Appendix 2, at α level of significance and with *v* = Degrees of freedom for error. The quantity s-d is computed as:

$$s_{\bar{d}} = \sqrt{\frac{2s^2}{r}} \quad (4.17)$$

where s^2 is the mean square due to error and *r* is the number of replications.

For illustration, the analysis carried out on data given in Table 4.5 is continued to compare all the possible pairs of treatments through LSD test.

Step 1. Compute the difference between treatment means as shown in Table 5.

Table 5. Difference between mean 100 seed weight (gram) for each pair of treatments.

Treatment	1	2	3	4	5	6	7	8
1	0.00	3.12	2.14	2.73	12.53*	4.75	11.49*	3.86
2		0.00	0.98	0.39	9.41*	1.63	8.37*	0.74
3			0.00	0.59	10.39*	2.61	9.35*	1.72
4				0.00	9.8*	2.02	8.76*	1.13
5					0.00	7.78*	1.04	8.67*

6						0.00	6.74*	0.89
7							0.00	7.63*
8								0.00

* Significant at 5% level

Step 2. Compute the LSD value at a level of significance. Since all the treatments are equally replicated, we need to compute only one LSD value. The LSD value is computed using equations (4.16) and (4.17).

$$\mathrm{LSD}_{.05} = 2.14\sqrt{\frac{2(10.07)}{3}} = 5.54 \text{ cm}$$

Step 3. Compare differences among the treatment means against the computed value of LSD and place an asterisk against significant differences. The results are shown in Table 5.