YIELD STABILITY IN SAFFLOWER – A REVIEW

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ABSTRACT

The significance and utility of stability and genotype × environment analysis in crop improvement is discussed, especially the work on stability in safflower is reviewed and discussed along with the constraints and challenges to be tackled for improvement of the crop.

Safflower (*Carthamus tinctorius* L.) is an important *Rabi* oilseed crop, grown in India since time immemorial. It was referred to as “Kusumbha” in ancient sanskrit literature. In the past it was grown for a source of dye for clothing and food. The leaves of young plants are also being used as vegetable. In the recent years, safflower gained importance as a healthy oil because of its higher content of linolenic acid, an essential fatty acid as compared to the other vegetable oils. Linolic acid can effectively control heart disease. Besides, the safflower oil is used in paints, varnishes and in leather and textile industries. India occupies a prominent position in the world both in terms of acreage and production. Although, India occupies premier position in safflower cultivation, yet this crop is relatively less important in the total oilseed scenario of the country. The total oilseed production of the country during 1995-96 was 239 lakh tonnes and the safflower production was 4.2 lakh tonnes only (Reddy, 1996).

As much as 95% of the safflower area is concentrated in the two states viz; Maharashtra and Karnataka. In recent years, due to technologies developed by the oilseed scientists, the encouragement given by the Government to farmers the compound growth rate of safflower is the highest among all the oilseed crops grown in the country (Table 1).

Safflower is now emerging as an industrially important crop. With the development of food, pharmaceuticals, cosmetics and fabric industries, the demand for natural colouring agents is increasing. In China, annually about 1700 tonnes of dried petals of safflower is used for preparation of herbal medicines. Besides, flowers are also used as a source of carthamin yellow which is preferred for dyeing fabrics. Petals are also used in food processing industries such as canning, food preservation, ice creams, dairy products, beverages, sausages, juice and noodles. Safflower pollen is marketed as high nutrient food in China. Safflower petals and filaments are known to activate blood circulation, regulate menstruation, reduce pain and fractures and cures acute anemic caused by head disorder and hepatitis (Tianjin Pharmaceutical Industry Research Institute, 1980).

In recent years, efforts are being made to improve the productivity of this crop through the use of high yielding varieties and improved crop production technology. However, in general, varietal improvement programme, has not made any dent in boosting the yield productivity in safflower. The variety developed should show stable performance under different agroclimatic conditions.
environments, especially in India where a wide range of agroclimatic conditions are prevailing. A variety is said to be stable which can adjust its phenotypic and genotypic status in response to changing environments. The $g\times e$ interaction studies are of major importance in the crop improvement programme.

**Phenotypic stability and ge interaction**: The phenotypic response for a change in the environment may not be the same for all the genotypes and the interplay in the effect of genetic and environmental factors on the development is called as genotype environment interaction. The $g\times e$ interaction reduces the correlation between phenotype and genotype. Its magnitude may be estimated by growing the experimental material over a number of years and locations, which however, are poor and less pertinent characteristics of environmental conditions, whereas, different climatic conditions created under controlled condition, different growth conditions and different cultural practices etc. from more sensitive and pertinent measures of environmental conditions (Allard and Bradshaw, 1964).

The problem of maintaining a steady state of equilibrium, centres around the overall working of the genetic systems in relation to its internal and external environment (Gupta, 1980) the underlying mechanism of genetic homeostasis depends upon the integration of physiological process during the course of development. Stability of development in various environments implies physiological adjustments and the capacity of such adjustment is a property of the homeostatic genotypes.

According to Learner (1954) genetic homeostasis is the ability of a genotype to withstand environmental fluctuations. Variability in performance over a range of environments could, therefore, be used as a criterion for measure of phenotypic stability.

Lewis (1954) suggested a simple measure of stability, which he termed as Stability Factor (SF) and is expressed as

$$SF = \frac{\bar{X}_{HE}}{\bar{X}_{LE}}$$

The value of SF=1 indicates the maximum phenotypic stability. The greater the SF deviates from the unity, the less stable is the genotype.

Finlay and Wilkinson (1963) in their study on analysis of adaptation in plant breeding reported that two important indices in this type of analysis are regression coefficient and the variety mean overall environments. To summarise, regression approximating to 1.00 indicate average stability. When this is associated

<table>
<thead>
<tr>
<th>Crop</th>
<th>% Area</th>
<th>Compound growth rate</th>
<th>Year</th>
<th>Production</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safflower</td>
<td>1.98</td>
<td>6.72</td>
<td>6.46</td>
<td>4.64</td>
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</tr>
<tr>
<td>Rapeseed</td>
<td>2.03</td>
<td>4.46</td>
<td>4.46</td>
<td>2.39</td>
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<tr>
<td>Linseed</td>
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<td>-0.77</td>
<td>5.70</td>
<td>1.26</td>
<td></td>
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<tr>
<td>Wheat*</td>
<td>2.58</td>
<td>5.70</td>
<td>3.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Rabi oilseeds*</td>
<td>2.66</td>
<td>6.21</td>
<td>3.87</td>
<td></td>
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</tr>
</tbody>
</table>

Table 1. Trends in area, production and productivity of safflower in India in relation to various other major Rabi crops in India.

with high mean yield, variety possesses general adaptability; when associated with low mean yield, varieties are poorly adapted to all environments. Regression increasing above one describe varieties with increasing sensitivity to environmental change (below average stability) and greater specificity of adaptability to high yielding environments. Regression coefficient decreasing below 1.0 provide a measure of greater resistance to environmental change (above average stability) and therefore increasing specificity of adaptability to low yielding environment. Regression coefficient of zero would express absolute stability. However, in deciding about the worth of a genotype, it's mean performance must be considered alongwith it's phenotypic stability. The main drawback of this method is in this model the deviations from regression line are not estimated, which are important for stability analysis. Moreover, greater emphasis is given on mean performance over environment than regression coefficient in assessing the stability of a genotype.

Eberhart and Russel (1966) elaborate and made further improvement in stability analysis by partitioning the genotype-environment interaction of each variety in to two components i.e. 1) slope of regression line and 2) deviation from the regression line. In this model, the total variance is first divided in to two components i.e. 1) genotypes and 2) environments + interaction. The second component i.e. environment plus interaction is further divided in to three components viz; a) environment linear b) gxe linear and c) pooled deviation. The sum of squares due to pooled deviations are further divided in to sum of squares due to individual genotype. Accordingly, a stable variety is one with unit (b=1.0) regression coefficient and as small as possible deviation from regression line (Sdi=0). Using this definition the breeder would usually desire to develop a variety with high mean yield and satisfying the above requirements for stability. The main demerit of this method is in this model the estimation of mean performance and environmental index is not independent. There is a combine estimation of sum of square for environment and interaction, which is not proper.

Verma, Chahal and Murthy (1978) reported limitations of the conventional regression analysis. The conventional g×e interaction analysis cannot detect the theoretical ideal genotype which has been defined as the one with relative low sensitivity in the poor environment and high sensitivity in the favourable environment. Thus the computation of separate regression coefficients on the two regions of the response curve has been suggested to detect such genotypes. This procedure is simple and more convenient than the complicated curvilinear regression analysis.

In general the literature on theory of stability is available in many text books and it's application is also published by different research workers, which is available in literature. Thus, it will not be worth to mention all literature here, as we are dealing with the stability studies in a major oilseed crop safflower. It is, therefore, the work done on this aspect in safflower crop is reviewed and discussed here.

Phenotypic stability in safflower : Abel and Driscoll (1976) studied the components of seed yield viz; number of heads/unit area, number of seeds/head, and seed weight of safflower. They observed least environmental effects on seed
Agricultural Reviews

Weight; however, number of heads/unit area and number of seeds/head were flexible under different environments. Line A-1186-1 was among five highest genotypes at nearly all locations and for planting dates indicating the highest adaptation to the range of environments.

Patra (1976) observed significant g×e interaction and classified different strains of safflower for their adaptability based on the stability parameters and found that C-438 and C-431 varieties were general adapters. The varieties 143-20 and C-437 responded to poor environments and No. 47 to rich environments.

Makne and Sharma (1979) observed highly significant g×e interaction in 28 genotypes of safflower at three locations. The genotypes viz; Royal, JL-3, PI-304455, PI-250713, PI-306992, PYT-74, No. 273, BS-338, and No. 319-12 were found to have good adaptability for the characters under study.

Rao and Ramachandram (1979) studied the various components related to both fitness and productivity in safflower. They reported marked differences among genotypes and environments for all the traits studied and more particularly seed size and hull percentage exhibited relatively high degree of stability unlike yield and its components. In general, the exotic material showed poor adaptability to Indian conditions. Interrelationship among various stability parameters for yield with those of its components characters related hardly any barrier in developing early lines combining relatively high responsiveness for flowering, maturity and hull content.

Deshmukh (1983) in review of safflower research work carried out at Nimbkar Agriculture Research Institute, Phalton-415 423, reported 20 Q/ha yield of safflower during summer season under irrigated condition. Thus, it was recommended to make use of summer season only for planting F1 hybrid seed of crosses made in winter or for multiplication of selected material. Adaptability of hybrids to a wide range of environmental conditions is also most probably due to the phenomenon of isoenzyme complementation. In safflower too, hybrids show the ability to perform better under adverse conditions. The hybrids generally give relatively higher yield under all adverse conditions than varieties. Since adverse conditions would be expected to be the rule in safflower rainfed cultivation, hybrid should always stand better chance of giving higher yields.

Narkhede et al. (1984) evaluated ten varieties of safflower for their yield at five locations. They observed significant g×e interaction. The linear component of g×e interaction was significant and thus the performance of genotype across the environment could be predicted. The pooled deviation attributable to the nonlinear regression was not significant. The stability analysis based on regression coefficient index revealed that genotypes B-263-2A, No.168, No.83 and Bhima were adapted to all environments.

Pandya (1988) studied the stability of fifty hybrids and fifteen parental lines in four different environments and observed that the parental lines MS-1-4, MS-105, Annegiri, JLSF-88 and Bhima and none hybrids possess average stability across the environments. He indicated that highly heterotic hybrids possess fairly good stability.

Chaudhari and Meharotra (1989) evaluated fifteen genotypes of safflower for stability of fodder yield and seed yield of ratoon crop under rainfed condition. They reported seven genotypes as stable
across the environment for fodder yield. Low estimates of standard error of regression coefficient, negative estimates of deviation from regression with regard to seed yield of ratoon crop, six genotypes were stable. However, EC-35737 and IC-11175 were stable for both characters and satisfy the need for cultivation with limited irrigation facilities for rainfed condition.

Henry and Daulay (1990) studied the $g \times e$ interaction for seed yield in six microenvironments created by three different row spacings for two years. They observed significant $g \times e$ interaction; however, a large portion of interaction was accounted for by the linear regression although nonlinear was also significant. Genotypes like C-438 and AN-1 were found to be stable with high mean yield and average response to change in the environmental conditions and they have advocated their exploitation in a breeding programme for improving the productivity of safflower.

Narkhede and Patil (1990) studied nine genotypes of safflower for their stability. They observed the absence of $g \times e$ interaction for all the traits. The linear portion of $g \times e$ interaction was significant and also of greater magnitude than that of non linear portion.

Marchione et al. (1991) in order to evaluate the adaptation of safflower varieties in different environments of south Italy, trials were carried out in three localities i.e. Deliceto (750 m. mean sea level in Apulia region), Oppido Lucano (550 m. mean sea level) and Gaudiano di Lavello (120 m. mean sea level both in Basilicata region) for two years (1987 and 1988). Thirteen varieties from different genetic resources were compared. Both sites and years influenced achene production. The yields ranged from 1.17 t/ha (Gaudiano di Lavello field) to 1.69 t/ha (Deliceto field). In 1987 and 1988 an average of 1.79 and 1.06 t/ha achenes were harvested respectively. The lower production in 1988 was due to low rainfall during the crop growth season. Other quantitative characters like number of heads/plant (range 9.3 to 9.8), number of achenes/head (33.8 to 50.3), 1000 achene weight (36.5 to 40.5 gram) and number of heads/sq. meter (262 to 283) were highly influenced by seasons. Among the varieties tested on an average cv. Safflower 541 gave the highest yields of 1.60 t/ha and the cv. Britto gave the lowest yield of 1.24 t/ha. Oil content as percentage of dry matter of achenes analysed only in 1987, ranged from 37.1% (cv. Guarmaro) to 41.2% (cv. safflower 541).

Pandya et al. (1991) evaluated fifty hybrids and fifteen parents across four environments for seed yield and four yield components. They noticed both predictable (linear) and unpredictable (nonlinear) portion of $g \times e$ interaction were found to be present in the hybrids. They have reported that stability, in general appeared to be a property of the individual genotype as even for significant unpredictable $g \times e$ interaction, prediction could be made in respect of many genotypes. Some of the highly heterotic hybrids also showed good average stability across the environments.

Patil et al. (1992) studied seven genotypes of safflower at five locations under rainfed condition and eight genotypes of safflower at four locations under irrigated condition. Both the components of $g \times e$ interaction were found significant; however, linear was in large magnitude suggesting responsiveness of the varieties and their performance can
be predicted with some reliance over environments. Under rainfed condition, the genotype SSF-31 was stable under fluctuating environmental conditions and the genotypes A-1, Bhima and JLSF-88 were better for favourable environments. Under irrigated condition genotypes Bhima and JLSF-88 were found to be high yielders with stability.

Manjare (1993) studied stability of thirty two hybrids in three environments and observed high significant gXe interaction for all the traits studied. Linear component of gXe interaction was of greater magnitude than that of nonlinear component. However, it was nonsignificant. Among the promising hybrids majority of them showed above average stability, indicating their better performance in poor environment.

Parameshwarappa et al. (1993) assessed twelve genotypes for stability under rainfed condition for seed yield, oil and hull content. The gXe interaction was significant for all the traits. The significance of linear component of gXe interaction for seed yield and oil content and nonsignificance of nonlinear component suggested that the prediction of the performance can be possible. The genotypes A-1 and No.83 were found to have high degree of stability over different environments for seed yield and 343-1205 and 478-2 were stable for oil content.

Nagaraj (1994) studied seven cultivars from different locations for oil content. He noticed that data presented shows that safflower crop grown under Hyderabad and Raichur conditions was more productive and had higher oil content. Varieties like HUS-315, S-144 and Bhima were more promising for higher oil productivity.

Uma and Patil (1994) studied nine promising genotypes of safflower and evaluated them for their stability for seed yield in three different saline environments. Genotypes like A-1, Nira and Manjira were stable with high mean yield and average response to the changes in the environmental conditions. Hence, their exploitation in a breeding programme will help in improving the productivity of this crop.

Patil and Zope (1997) evaluated twentyfive genotypes of safflower under four micro environments for seed yield. They observed significant gXe interaction; however, linear component was larger in magnitude. The genotypes viz; Girana, Bhima, SSF-135 and JLSF-327 were observed to be most responsive and stable. The mean performance was significantly associated with regression coefficient, coefficient of determination and ecovalence, suggesting that stability parameters appeared to be governed by different gene or genes in combination in safflower.

Patil (1997) evaluated twentyfive genotypes of safflower in four environments under rainfed as well as irrigated condition. Significant g x e interaction was observed whereas, major portion of interaction was linear in nature, suggesting prediction can be possible across the environments. The genotypes Girana, Bhima, SSF-135 and JLSF-327 were found most responsive and stable across the environments. The mean performance was positively and significantly associated with regression coefficient, coefficient of determination and ecovalence. The stability parameters were appeared to be governed by different gene or genes in combination in safflower.

Major areas constraints and future challenges:

The success of safflower crop in traditional areas and its expansion in to new areas will largely depend on the extent of
improvement made in yield and oil content. Despite a threefold increase in the productivity (733 kg/ha), this is still much lower than what has been demonstrated on the farmers field with improved technology. The cultivation of this crop needs further improvement especially in drought prone areas, since 70% of safflower area suffers from drought. The screening of germplasm material for stability under drought tolerance is of paramount importance and cannot be overlooked.

With considering the above discussed matter the important major biotic and abiotic constraints limiting safflower production, its processing and utilization in the country and their specific research priorities are furnished here. Due attention of the safflower research workers are being drawn to find out proper solution to increase the production of safflower and ultimately to develop sound economy of the country.

**Constraints**

1. Low per hectare yield associated with low harvest index : low seed oil content.
2. High susceptibility of available commercial varieties to foliar diseases (Alternaria, Ramularia and Rusts), macrophomina root not, Fusarium and Verticillium wilt, aphids, abiotic stress (drought, alkalinity and salinity).
3. Presence of spines/spineless safflower cultivation.
4. Lack of region specific agro-production and protection technologies.
5. Absence of demand for safflower seed and oil in non traditional areas.
6. More involvement of NGO’S in support of research.
7. Absence of required processing facilities.

**Future Challenges**

1. Intensification of research for identification of resistant sources to major biotic and abiotic stresses.
2. Development of high yielding varieties and hybrids with consistancy in the performance all over the country.
3. Breeding for high seed oil content and inbuilt tolerance to insects pests and diseases.
4. Refinement of agro-production and protection technology for maximizing yields and returns from safflower under diverse crop growing and agro-ecological situation.
5. Breeding for high yielding spineless varieties suited to non traditional areas and situations.
6. Intensification of cropping system research to identify new niches for expansion of area under safflower.
7. Development of appropriate seed processing technology.
8. Search for stable and viable CMS system for production of stable hybrid.
9. Training of research personnel in breeding techniques, disease identification and their management.

**REFERENCES**


