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Dependance of soybean yield on crop evapotranspiration, crop duration and rainfall

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सार — प्रस्तुत अध्ययन में, सोयाबीन की फसल के वाष्पन उत्सर्जन के विभिन्न पहलुओं को समझने के लिए चार स्टेशनों जैसे कि बांसवाड़ा, भोपाल, परभनी तथा राहुड़ी के 1990 से 1993 तक की अवधि के आंकड़ों का उपयोग किया गया है। बीज की पैदावार की विभिन्न अवस्थाओं में फसल की अवधि पर वर्षा के प्रभाव का पता लगाने का भी प्रयास किया गया है।

फसल के उगने के दौरान वर्षा का उपज के साथ विशेष रूप से सहसम्बद्ध पाया गया है। फसल की वृद्धि की अवधि सोयाबीन की उपज को सकारात्मक रूप से प्रभावित करती है तथा फूल खिलने की दीर्घ-अवधि अधिक उपज के लिए उपयुक्त है।

परिणाम यह भी दर्शाते हैं कि पौधे की बढ़ोतरी के दौरान सोयाबीन की फसल में पानी की खपत अधिकतम होती है।

ABSTRACT. In the present study, data for four stations *viz*., Banswara, Bhopal, Parbhani and Rahuri for the years from 1990 to 1993 have been utilized to understand various aspects of evapotranspiration of the soybean crop. An attempt has also been made to find out the impact of rainfall and crop duration at different phases on the seed yield.

The yield was found to be significantly correlated with the rainfall during vegetative phase. Crop growth duration exert positive effect on the soybean yield and that a longer flowering period is favourable for higher yields.

The results also indicate that the soybean crop consume maximum water during the vegetative stage.

Key words — Evapotranspiration, Vegetative, Flowering, Thermo-sensitive.

1. Introduction

Soybean (*Glycine max* L.) is one of the most important field crops, grown for oil and protein throughout the world. Basically a short-day or thermo-sensitive plant, its response to day length varies with variety and temperature (Doorenbos and Kassam 1979). The urgent need for proteins and edible oil to the growing world population, have forced many countries to introduce and extend this crop into more areas. One method to improve the yield is better water management. This necessitates accurately estimating evapotranspiration and determining its relationship during various growth stages with yield.

The present study, in the first instance, aims at finding out agrometeorological characteristics of soybean crop grown in different agroclimatic zones of the country. For this purpose dependence of seed yield to rainfall during the crop season was explored. Attempt was also made to determine possible relationship between yield and the total crop growth duration (days). Bloom stage is perhaps the most important phase of the crop (Kanemasu *et al.* 1979). Correlation of yield with flowering duration upto 16 days and that exceeding 16 days have been separately worked out. Another aspect dealt in the study is to evolve association of evapotranspiration loss with the seed yield. This has been

accomplished by fitting a second degree multiple regression between the two variables.

2. Materials and methods

The present study pertains to kharif season at four locations, *viz.*, Banswara (23.5°N, 74.5°E), Bhopal (23.3°N, 77.4°E), Parbhani (19.3°N, 76.8°E) and Rahuri (19.4°N, 74.7°E) located mainly in the semi-arid tracks of India. Data for soil types, variety used, date of sowing / harvesting etc., was obtained from the experimental field units located at these stations. The soils at these locations were mostly medium black. The meteorological data *viz.*, rainfall, temperature, humidity, evaporation etc., were recorded at meteorological observatories located close to the crop fields. The Evapotranspiration (ET) was measured through gravimetric lysimeters of IMD located in the crop fields. From the daily data, weekly totals / means of these parameters from the date of sowing to maturity were computed. The yield data used in the analysis refers to the actual yield of the crop in the experimental fields. The analysis uses data of variety *Gaurav* raised at Banswara during 1990 and 1991. At Bhopal, variety *Punjab* was cultivated during 1990, 1992 and 1993 while during 1991 variety cultivated was PK-472. At Parbhani the experiments were conducted during 3 years (1990-1991 & 1992) on variety *Monetta* and data set at Rahuri pertained to *MACS-124* variety for 1992 and 1993. The yield data used in the analysis refers to the actual yield of the crop in the experimental fields.

3. Results and discussions

3.1. *Rainfall and the yield*

The total seasonal rainfall for different locations varied from about 45 cm to 105 cm with a mean of 71.9 cm. According to Al- Hazim *et al.* (1996) the soybean crop needs about 50 cm of rainfall to attain its full potential. Singh and Saxena (1969) reported that soybean can tolerate brief periods of water logged soils relatively better than corn. Association between seed yield and total seasonal rainfall when correlated linerly in this study, was found to be rather weak. As such, parameters with square and cubic terms of rainfall were introduced in the regression. This exercise gave us a high multiple correlation with $R^2 = 51.8\%$. However, when the rainfall was split into different phases a high linear correlation ($R^2 = 26.0\%$) was found between the yield Y(q/ha) and rainfall Rv(mm) during the vegetative phase. Introduction of square term of rainfall in vegetative phase surprisingly enhanced the correlation to $R^2 = 36.0\%$ suggesting that higher rainfall above normal in this phase does help the crop. When the correlation between yield and rainfall during reproductive phenophase was worked out, the correlation was negative, and low insignificant.

3.2. *Crop duration and the yield*

Length of total growing period for soybean depends on the inherited characters and varies widely according to variety, location climate and could range from about 13 weeks to 17 weeks.

The crop duration in the present study was about 105 days at Banswara, 95-100 days each at Bhopal and Rahuri and 85-90 days at Parbhani. Total duration of crop growth as well as duration during various phases were correlated with yield. The correlations obtained are discussed below for each phase.

(*i*) *Vegetative phase* — The vegetative phase duration *i.e.* the period from sowing to commencement of flowering varied from 32 days at Parbhani to 49 days at Rahuri. Seed yield Y(q/ha) and vegetative phase duration Dv (days) were found to be significantly correlated at the mandatory 5% level. The following linear relation was observed between seed yield and the duration of vegetative phase.

$$Y = 1.233\ Dv - 34.5 \qquad (R^2 = 65.6\%) \qquad (1)$$

(*ii*) *Flowering phase* — The mean duration of the phase was about 2 weeks though it varied from 10 to 27 days. Higher seeds yields were obtained when the flowering phase duration was about 16 days, the mean duration of this phase obtained in the study. It is observed that, the seed yield Y(q/ha) is significantly correlated with the flowering phase duration (DF), on either side of the mean value of 16 days and had opposite signs in their coefficients.

The following relations could be established:

$$Y = 4.27\ DF - 40.04 \qquad (R^2 = 18.5\%) \qquad (2)$$

for $DF \leq 16$ days

$$Y = 55.93 - 1.92\ DF \qquad (R^2 = 77.4\%) \qquad (3)$$

for $DF > 16$ days

However, when parameters with square terms of duration were introduced, it gave significant multiple correlations of $R^2 = 24\%$ and $R^2 = 88.4\%$ respectively.

It is thus clear that a shorter duration of flowering gives lower yield. On the other hand, longer the flowering period, the higher is the soybean yield.

(*iii*) *Maturity phase* — The phase duration varied from 35 days at Parbhani to 58 days at Banswara. No significant correlation could be found between the duration and the seed yield as also when multiple correlation was tried by introducing square of duration term.

(*iv*) *Crop growth duration* — The total crop duration D varied from 87 days at Parbhani to 120 days at Banswara. The seed yield Y varied from 5.51 q/ha at Parbhani to as high as 24.31 q/ha at Banswara. Correlation between yield Y and crop growth duration D, though not high, was neverthless significant and gave the following regression.

$$Y = 1.16\,D - 100.49 \qquad (R^2 = 39.7\%) \qquad (4)$$

3.3. *Evapotranspiration and the yield*

Soybean production is a complex integration of environmental factors and adequate water must be available for optimum growth. The water use, however, varies from location to location and phase to phase. The soybean crop in the tropics appears less sensitive to stress during flowering. Singh and Saxena (1969) have rightly pointed out that soybean can withstand short period of drought in India.

The seed yield was next correlated with ET during different phases as also during complete crop duration. Significant correlation (R^2 = 42.3%) could be obtained between yield and ET during vegetative phase only. Use of square and higher degree terms in ET did not improve the correlation coefficient substantially.

In order to improve the correlation, a multiple regression was next attempted using the following factors:

(a) ET during vegetative phase (X_2)

(b) Rainfall during vegetative phase (X_3)

(c) Rainfall during the entire growth period (X_4)

(d) Duration (days) of vegetative phase (X_5)

(e) Duration (days) of flowering (X_6)

The multiple regression obtained was

$$X_1 = -0.29X_2 + 0.91\,X_3 - 0.34\,X_4 + 96.4\,X_5 - 12.4\,X_6 - 2306.7 \qquad (5)$$

where X_1 is seed yield (kg/ha).

The multiple correlation in this case was found as $R^2 = 75.7\%$, significant at 20% level.

Flowering being an important pheno-phase in the growth cycle of soybean, the duration of flowering was then split into those equal to or below 16 days and exceeding 16 days as in section 3.2(*ii*) retaining the factors (a) to (e) above. When the flowering duration was less than 16 days the multiple correlation coefficient was not high but improved conspicuously to $R^2 = 94.1\%$ for duration exceeding 16 days thus corroborating the observations made earlier that increase in flowering duration enhance the yield. The multiple regression obtained was

$$X_1 = -9.87\,X_2 + 3.48\,X_3 + 0.34\,X_4 + 174.35\,X_5 + 16.42\,X_6 - 6905.0$$

4. Conclusions

Following conclusions emerge from the present study:

(*i*) The vegetative phase rainfall bears a significant correlation with yield.

(*ii*) The duration (days) during vegetative phase is also significantly correlated with yield.

(*iii*) Above average number of days of flowering bear significant (at 5% level) correlation with soybean yield.

(*iv*) The soybean crop uses maximum amount of water, *i.e*, about 4.2 mm per day during vegetative phase when active growth takes place.

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