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# Studies on Crop Weather Relationships in Mustard

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**Abstract**: An experiment was conducted at CCS Haryana Agricultural University, Hisar research farm, during *rabi* 1993-94 and 1994-95 to study energy balance and to identify important weather parameters influencing dry matter production in three mustard varieties, viz., RH-30, Varuna and Laxmi. Latent heat of vaporization (LE) varied with growth stage owing to variation in leaf area index (LAI). Maximum LE values were observed when crop attained maximum LAI. Sensible heat flux (A) kept on increasing till maturity of crop. Diurnal trends for components of energy balance indicated that net radiation (Rn), LE and A were highest during noon hours. The diurnal changes in soil heat flux (G) were very small. Around 80% of the dry matter variation can be explained by weather parameters. Temperature was most important that explained dry matter variation at acceptable levels.

**Key words**: Mustard, crop weather relationships, energy balance.

Mustard (*Brassica juncea* L.) is second important crop among oil seed crops, after groundnut, grown in India. The development of improved varieties adapted to mustard growing areas in the country has made the cultivation of crop more popular. Seed yield per hectare is important to the production of any seed crop.

Responses of different genotypes to one environment, or a single genotype to different environments, can be quite different. Evaluation of varietal influences on energy utilization environment and final seed yield could improve efficiency of an agricultural system. Over the last three decades, there has been increasing research interests in measurement of solar radiation in crop canopies and its use in assessment of productivity of important crops. For mustard crop, information on this aspect is scanty. Similarly, efforts have been made to quantify crop-weather relationship in several crops in past, but for mustard only limited information is available, hence, the present study was undertaken.

## Materials and Methods

The study was conducted at university farm (Lat. 29° 10′N, Long. 75° 46′E and altitude of 215.2 m a.s.l) during 1993-94 and 1994-95 *rabi* seasons under irrigated conditions. The experiment was laid out in split plot design with three replications having three dates of sowing (D1: October 6, D2: October 20 and D3: November 5) in main plots and varieties (V: Varuna, V1: RH-30 and V2: Laxmi) in sub plots. The crops were sown at 30 cm x 15 cm spacings. The package of practice recommended by CCS HAU, Hisar, was followed for raising the crop.

The energy balance components over experimental plots in one replication were measured on certain days, representing successive stages of crop development of peak flowering, most seeds green and most seeds brown stages. Quantum sensors (Model LI-190 SB, USA) were used to measure the amount of intercepted radiation (photosynthetically active radiation in 400-700 nm range) above the canopy and at 5 cm above ground surface. Net radiation (Rn) was measured one metre above crop with the help of net radiometer (Medoes and Co., Australia). Soil heat flux (G) was measured with soil heat flux plates (Medoes and Co., Australia), kept at 5 cm depth in soil in the cropped field and connected to digital multi voltmeter. Meteorological parameters were taken from the observatory located 10 m from the experimental site. Leaf area (LICOR, LI-3000 Leaf Area Metre) and dry matter at different phenophases were recorded from randomly selected 5 plants in each plot. The phenophases as described by Sylvester and Hakepeace (1984), were recorded from 5 tagged plants in each plot. The phenophases were - emergence (E), both cotyledons above ground (0.8), both cotyledons unfolded and green (1.0), fifth true leaf exposed (1.05), flower bud visible from above (3.3), first flower opened (4.0), lowest silique more than 2 cm long (5.0), most seeds green (6.3), most seeds brown (6.5), and fully ripened (9.0).

Energy budgeting approach has been widely accepted as a sound method for estimating evapotranspiration. This approach has its advantages of wider scale applicability, needing no soil sampling or lysimeters and can be used for prediction purposes in crop growth simulation modeling. Energy balance components are represented by the following equation:

$$Rn = LE + A + G$$

where,

$Rn$ = Net radiation, mw $cm^{-2}$

$LE$ = Latent heat flux, mw $cm^{-2}$

$A$ = Sensible heat flux, mw $cm^{-2}$

$G$ = Soil heat flux, mw $cm^{-2}$

The energy used for evapotranspiration is expressed as (Suomi and Tanner, 1958; Denmead and Mclory, 1970):

$$LE = \frac{(Rn - G)}{(1 + \beta)}$$

where,

Bowen ratio ($\beta$) = 0.66 * (dt/de)

dt = temperature gradient between two heights, and

de = vapour pressure gradient between two heights.

Correlations between mean values of different weather parameters and dry matter accumulation during various phenophases were studied and regression equations for prediction of crop dry matter were developed.

## Results and Discussion

### *Energy balance studies*

Tables 1 and 2 show the daily variation of energy balance components for three days in two crop seasons of 1993-94 and 1994-95, respectively. More than 70% of Rn went into energy for evapotranspiration, LE, in the cropped field, whereas it was around 65% in bare field. In a similar study, van Bavel and Harris (1962) found

*Table 1. Energy balance components in mustard and bare field (Sowing date, 20.10.1993; spacing, 30 cm x 15 cm)*

| Treatments | Energy balance components (mw cm$^{-2}$) | | | |
|---|---|---|---|---|
| | Rn | LE | A | G |
| | | **At flowering stage (5 Dec. 1993)** | | |
| Varuna | 274.2 | 204.5 | 58.1 | 11.6 |
| | | (74.6) | (21.2) | (4.2) |
| RH-30 | 276.2 | 209.5 | 52.6 | 14.1 |
| | | (75.9) | (19.0) | (5.1) |
| Laxmi | 282.4 | 211.2 | 57.2 | 14.0 |
| | | (74.8) | (20.3) | (4.9) |
| Bare field | 285.4 | 187.6 | 64.4 | 29.4 |
| | | (65.7) | (21.1) | (9.6) |
| | | **At most seeds green stage (25 Jan. 1994)** | | |
| Varuna | 291.2 | 228.5 | 47.3 | 15.4 |
| | | (78.5) | (16.2) | (5.3) |
| RH-30 | 282.3 | 218.9 | 48.2 | 15.2 |
| | | (77.5) | (17.1) | (5.4) |
| Laxmi | 276.1 | 213.8 | 47.9 | 14.4 |
| | | (77.4) | (17.4) | (5.2) |
| Bare field | 280.3 | 185.8 | 63.6 | 30.9 |
| | | (66.3) | (22.7) | (11.6) |
| | | **At most seed brown stage (10 Feb. 1994)** | | |
| Varuna | 373.6 | 265.9 | 79.2 | 28.5 |
| | | (71.2) | (21.2) | (7.6) |
| RH-30 | 370.8 | 276.7 | 77.2 | 30.0 |
| | | (72.1) | (20.1) | (7.8) |
| Laxmi | 371.9 | 268.7 | 77.3 | 25.9 |
| | | (72.2) | (20.8) | (7.0) |
| Bare field | 384.8 | 255.4 | 93.7 | 35.7 |
| | | (66.4) | (24.3) | (9.3) |

The values in parentheses are per cent fraction of Rn.

that almost 80% of the energy is utilized for LE in irrigated corn field. The crop utilized maximum Rn as LE during stage 6.3 (most seeds green) where green leaves and silique both were present in abundance. On the contrary, this utilization was minimum at most seed brown stage as the crop was nearing the maturity. The component of the energy going as sensible heat flux (A) was maximum at most seeds brown stage and minimum at most seeds green stage (less than 20% in both seasons over cropped field). Higher amounts of energy went into heating of air in bare field as compared to cropped field, irrespective of stage of crop or day of observation. Present results agree with earlier reports of Fritschen and van Bavel (1962). Amount of energy going as soil flux (G) followed a differential trend in two seasons. That may be due to the variation in ground cover and soil moisture content in two seasons. Similar

*Table 2. Energy balance components in mustard and bare field (Sowing date, 20.10.1994; spacing, 30 cm x 15 cm)*

| Treatments | Energy balance components (mw $cm^2$) | | | |
|---|---|---|---|---|
| | Rn | LE | A | G |
| | | **At flowering stage (13 Dec. 1994)** | | |
| Varuna | 361.1 | 265.5<br>(73.5) | 62.4<br>(17.2) | 33.7<br>(9.3) |
| RH-30 | 392.3 | 289.8<br>(73.9) | 68.8<br>(17.5) | 33.7<br>(8.6) |
| Laxmi | 368.5 | 263.5<br>(71.5) | 70.0<br>(19.0) | 35.0<br>(9.5) |
| Bare field | 345.8 | 230.6<br>(66.7) | 72.9<br>(21.1) | 42.3<br>(12.2) |
| | | **At most seeds green stage (2 Feb. 1995)** | | |
| Varuna | 404.4 | 306.8<br>(75.9) | 72.2<br>(17.9) | 25.4<br>(6.2) |
| RH-30 | 425.3 | 320.1<br>(75.3) | 78.6<br>(18.5) | 26.7<br>(6.2) |
| Laxmi | 418.2 | 315.8<br>(75.5) | 77.5<br>(18.6) | 24.6<br>(5.9) |
| Bare field | 421.1 | 278.4<br>(66.1) | 93.2<br>(22.1) | 49.5<br>(11.8) |
| | | **At most seeds brown stage (21 Feb. 1995)** | | |
| Varuna | 291.1 | 208.4<br>(71.6) | 60.7<br>(20.8) | 22.0<br>(7.6) |
| RH-30 | 287.3 | 204.7<br>(71.2) | 58.8<br>(20.5) | 23.8<br>(8.3) |
| Laxmi | 294.3 | 215.2<br>(73.1) | 58.8<br>(20.0) | 20.3<br>(6.9) |
| Bare field | 292.1 | 190.5<br>(65.2) | 79.4<br>(27.2) | 22.2<br>(7.6) |

The values in parentheses are per cent fraction of Rn.

observations have been made by Hanks *et al.* (1968).

*Regression studies*

It is a known fact that weather parameters encountered by a crop during its stand in the field affect dry matter production and yield of crop. Therefore, to assess role of important weather parameters, simple/multiple linear equations were tried with one or more of these parameters on one hand, and plant dry matter at different growth stages on the other hand. Regression values $R^2$ for correlations of dry matter at different growth stages and selected weather parameters are presented in Table 3.

*Sowing to stage 5.0*

The equations developed at this stage explained variability of dry matter in the

*Table 3. Effect of weather parameters on variability of dry matter accumulation during various growth phases*

| Growth phase | Weather parameters | $R^2$ |
|---|---|---|
| **Sowing to stage 5.0** | | |
| Varuna | X2, X3, X4, X6, X7 | 0.73 |
| Varuna | X2, X4, X6, X7 | 0.63 |
| Laxmi | X1, X4, X6, X7 | 0.55 |
| Laxmi | X1, X4, X5, X6, X7 | 0.66 |
| **Sowing to stage 6.3** | | |
| Varuna | X4, X6, X7 | 0.57 |
| Varuna | X3, X4, X6 | 0.57 |
| RH-30 | X1, X2, X3, X5, X6 | 0.73 |
| RH-30 | X1, X2, X3, X5 | 0.65 |
| Laxmi | X2, X3, X6, X7 | 0.48 |
| **Sowing to stage 9.0** | | |
| Varuna | X1, X4 | 0.54 |
| RH-30 | X2, X3, X4 | 0.45 |
| Laxmi | X2, X3, X4, X6 | 0.51 |
| **Stage 5.0 to stage 6.3** | | |
| Varuna | X1, X2, X3, X4 | 0.67 |
| Varuna | X2, X3, X4 | 0.61 |
| RH-30 | X1, X2, X4, X6, X7 | 0.76 |
| RH-30 | X1, X2, X4, X6 | 0.74 |
| Laxmi | X1, X2, X3, X6, X7 | 0.61 |
| Laxmi | X1, X2, X3, X6 | 0.55 |

Where.
X1, X2 and X3 are max., min. and mean temperatures, respectively; X4, Average vapour pressure; X5, Vapour pressure deficit; X6, Sunshine hours; X7, Evaporation.

range of 48 to 74%. Correlation of selected weather elements (minimum temperature, average vapour pressure, sunshine hours and evaporation) with dry matter explained up to 63% variation of dry matter in Varuna.

### *Sowing to stage 6.3*

By extending the growth period up to stage 6.3, the response functions were changed. Among selected weather parameters, maximum temperature, minimum temperature and vapour pressure deficit explained variability of dry matter up to 65% in RH-30.

### *Sowing to stage 9.0*

Correlations tried for entire crop season showed that more than 60% of the variability in dry matter can be explained irrespective of varietal differences. However, selected weather parameters were able to explain a variability of around 50% in different varieties. It may be because the roles of different weather parameters vary with the growth stage.

### *Stage 5.0 to 6.3*

While considering period between these two growth stages, it was observed that the $R^2$ values improved tremendously. The possible explanation for this improvement may be the coincidence of this phase with high gain in dry matter.

Among the selected parameters, minimum and mean temperature and average vapour pressure were found effective in explaining the dry matter variability up to 61% for Varuna. However, for RH-30, maximum and minimum temperature, vapour pressure and sunshine hours explained up to 74% (Table 3). In case of Laxmi, the temperature (maximum, minimum, mean) and sunshine hours explained dry matter variability of up to 55%, and the value was further improved to 61% by inclusion of evaporation. On the basis of above description, it can be concluded that dry matter production shows significant response to variations in weather parameters. Regression equations involving weather factors for period of silique and seed development alone accounted for above 60% of dry matter variability. Moreover, a combination of around four weather parameters, varying with variety, can well explain this variability during this phase.

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