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Prediction of growth and yield of *Brassica species* using thermal indices

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ABSTRACT

Field experiments were conducted during *rabi* (winter) 2001-02 and 2002-03 with three *Brassica* species, viz *Brassica juncea* (cv. RL-1359), *Brassica napus* (cv. PGSH-51) and *Brassica carinata* (cv PC-5) using three dates of sowing (Early October to mid November). Heat use efficiency (HUE) was computed for total dry matter accumulation as well as seed yield. The highest HUE of 6.59, 5.23 and 5.27 kg ha^{-1} per°C day for dry matter and 1.12, 1.00 and 0.86 kg ha^{-1} per °C day for seed yield was obtained for *Brassica juncea*, *Brassica napus* and *Brassica carinata*, respectively during *rabi* 2002-03. Regression models based on Growing degree days, Heliothermal units and Photothermal units were developed for prediction of growth and yield of brassica species. Significant linear as well as exponential relationships were observed between dry matter accumulation, leaf area index (LAI) with the three thermal time indices. These models can be applied to estimate growth and yield of brassica species using daily information on temperature, photoperiod or sunshine duration within the crop season.

Key words : *Brassica spp.*, growing degree days, heliothermal units, photothermal units, heat use efficiency

Brassica species constitute the most important oilseed crops and require relatively cool temperatures of below 25 °C and fair supply of soil moisture during the growing season. Under Punjab conditions, the growing season (October – April) coincides with a period of very low to high evaporative demand, abundant sunshine and moderate to high solar radiation. Agroclimatic models based on thermal indices can play an important role in predicting growth and yield of crops. Attempts have been made by different workers to predict phenology (Hundal *et al*, 1997), leaf area index (Benbi, 1994), growth rate (Singh *et al*, 1996) and growth and yield (Hundal *et al*, 2003a, b) of crops using thermal based indices.

Brassica juncea and *Brassica napus* are commonly cultivated oilseed crops but *Brassica carinata* is comparatively a new introduction and has been recommended for general cultivation in Punjab (Malik, 1990). *Brassica napus* (Gobhi sarson) being a rich source of edible oil, its popularity has increased tremendously in the state. These oilseed crops are cultivated in India under irrigated and rainfed conditions.

Temperature is the single most important factor that affects growth of any plant. Yield of a crop can be taken as a product of rate of biomass accumulation (solar radiation dependent) and the growth duration (ambient air temperature dependent). Heat use efficiency (HUE), i.e., efficiency of utilization of heat in terms of dry matter accumulation has practical application (Rao *et al.*, 1999).

Keeping these in view, an attempt was made to predict the growth and yield of oilseed brassica species with three agroclimatic models based on Growing degree days (GDD), Heliothermal units (HTU) and Photothermal units (PTU) and to compute HUE of different brassica species.

MATERIALS AND METHODS

Field experiments were conducted during *rabi* 2001-02 and *rabi* 2002-03 at research farm of Punjab Agricultural University, Ludhiana (30° 54′ N, 75° 48′ E, 247 m amsl). This area is representative of the central irrigated plains of the state and is characterized by a sub-tropical, semi-arid climate. The average maximum temperature, minimum temperature and rainfall during *rabi* season are 24.4 °C, 9.5 °C and 129 mm, respectively at Ludhiana (Hundal and Prabhjyot-Kaur, 2002). The treatments consisted of three brassica species, three sowing dates and three irrigation levels, (Table 1.)

The crop was raised following the recommended package of practices of the Punjab Agricultural University, Ludhiana. The crop received 100 Kg N/ha in the form of urea and 30 Kg P_2O_5/ha in the form of single super phosphate during both the crop seasons. Plant samples were collected periodically at 15 days interval and leaf area index (LAI) and dry matter accumulation (DM) was recorded.

Growing Degree Days (GDD) were calculated using a base temperature of 5 °C as per Nuttonson (1955). Heliothermal units (HTU) are the product of GDD and corresponding actual sunshine hours for that day. Photothermal units (PTU) are the product of GDD and corresponding daylength for that day. GDD, HTU and PTU were accumulated from the date of sowing to each date of sampling. LAI, DM accumulation and grain yield were related with accumulated heat units in linear as well as exponential relationship as in some cases linear relationship did not indicate the best fit relationship.

Heat use efficiency (HUE) was computed to compare the relative performance of different brassica species and treatments using the formula :

$$\text{Heat use efficiency (HUE)} = \frac{\text{Total dry matter (kg ha}^{-1}\text{)}}{\text{Accumulated heat units (°C day)}}$$

HUE in terms of economic yield

Table 1 : Treatment details.

Species – Cv	Sowing date	Irrigation levels
Brassica juncea cv. RL-1359	D_1- Early October	I_0 – Pre-sowing irrigation
Brassica napus cv. PGSH-51	D_2- Late October	I_1 – I_0 + Irrigation at 30 DAS
Brassica carinata cv PC-5	D_3- Mid November	I_2 – I_1+ Irrigation at flowering stage.

Table 2: Heat use efficiency (HUE) of cv. RL-1359

Crop year	Dates of sowing	Irrigation levels	AGDD (°C day)	Total dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Dry matter HUE (kg ha^{-1} per °C day)	Seed yield HUE (kg ha^{-1} per °C day))
2001-02 2002-03	D_1 (Early October)	I_0	2002 1972	10382 11665	1178 1325	5.18 5.91	0.59 0.67
		I_1	2002 1972	11795 12723	1229 1631	5.89 6.45	0.61 0.83
		I_2	2002 1972	12571 12992	1409 1893	6.28 6.59	0.70 0.96
	D_2 (Late October)	I_0	1610 1751	7851 7856	1467 1502	4.88 4.48	0.91 0.86
		I_1	1610 1751	8490 8008	1462 1591	5.27 4.57	0.91 0.91
		I_2	1610 1751	9494 8852	1486 1721	5.90 5.06	0.92 0.98
	D_3 (Mid November)	I_0	1597 1279	6514 6492	789 1102	4.08 5.07	0.49 0.86
		I_1	1597 1279	7687 6726	840 1254	4.81 5.26	0.53 0.98
		I_2	1597 1279	8902 7659	951 1436	5.57 5.98	0.59 1.12

(seed yield, kg ha^{-1}) was also computed.

RESULTS AND DISCUSSION

Heat use efficiency (HUE):

Accumulated growing degree day (GDD), total dry matter accumulated at physiological maturity, seed yield and HUE are given in Table 2 to 4. In general, more dry matter was accumulated in early sown (D_1) brassica species under more frequent irrigated treatment (I_2). But heat use

Table 3: Heat use efficiency (HUE) of *B. napus* (cv. PGSH-51)

Crop year	Dates of sowing	Irrigation levels	AGDD (°C day)	Total dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Dry matter HUE (kg ha^{-1} per °C day)	Seed yield HUE (kg ha^{-1} per °C day)
2001-02 2002-03	D_1 (Early October)	I_0	2194 2151	7446 7449	1171 1187	3.39 3.46	0.53 0.55
		I_1	2194 2151	8945 8071	1281 1365	4.07 3.75	0.58 0.63
		I_2	2194 2151	9728 8556	1347 1460	4.43 3.98	0.61 0.68
	D_2 (Late October)	I_0	1905 1784	7658 7586	1014 1254	4.02 4.25	0.53 0.70
		I_1	1905 1784	8180 8228	1239 1367	4.29 4.61	0.65 0.76
		I_2	1905 1784	9198 9339	1632 1796	4.83 5.23	0.86 1.00
	D_3 (Mid November)	I_0	1922 1552	5881 6199	1091 1149	3.06 4.00	0.57 0.74
		I_1	1922 1552	6992 6652	1331 1239	3.64 4.29	0.69 0.79
		I_2	1922 1552	8105 7817	1351 1361	4.22 5.04	0.70 0.87

efficiency was generally more under second (D_2) and third (D_3) dates of sowing as compared to first date (D_1). The I_2 irrigation treatment was more efficient in terms of heat utilization efficiency because of higher total dry matter accumulation and seed yield as compared to I_0 and I_1 irrigation treatments.

The highest HUE of 6.59 kg ha^{-1} per °C day for dry matter and 1.12 kg ha^{-1} per °C day for seed yield was recorded in cv.RL-1359, 5.23 kg ha^{-1} per °C day for dry matter and 1.00 kg ha^{-1} per °C day for seed yield was recorded for cv.PGSH-51, 5.27 kg ha^{-1} per °C day for dry matter and 0.86 kg ha^{-1} per °C day for seed yield was recorded for cv.PC-5 during *rabi* 2002-03 crop season. Amongst the three oilseed brassica species, *B. juncea* (cv.RL-1359) was most efficient in terms of HUE because of its shorter life cycle as compared to other two species. Similar results for HUE for mustard crop were also reported by Rao *et al* (1999) under Hisar conditions.

Table 4: Heat use efficiency (HUE) of *B. carinata* (cv. PC-5)

Crop year	Dates of sowing	Irrigation levels	AGDD (°C day)	Total dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Dry matter HUE (kg ha^{-1} per °C day)	Seed yield HUE (kg ha^{-1} per °C day)
2001-02 2002-03	D_1 (Early October)	I_0	2194 2461	7849 7322	1037 1258	3.58 2.97	0.47 0.51
		I_1	2194 2461	8265 8070	1129 1197	3.77 3.28	0.51 0.48
		I_2	2194 2461	9437 9882	1732 1252	4.30 4.01	0.79 0.51
	D_2 (Late October)	I_0	2116 1784	7788 7982	1296 1329	3.68 4.47	0.61 0.74
		I_1	2116 1784	8449 8913	1337 1497	3.99 4.99	0.63 0.84
		I_2	2116 1784	9140 9408	1424 1544	4.32 5.27	0.68 0.86
	D_3 (Mid November)	I_0	1922 1787	6343 6684	1202 1251	3.30 3.74	0.62 0.70
		I_1	1922 1787	7318 7228	1434 1274	3.81 4.04	0.75 0.71
		I_2	1922 1787	8195 7574	1641 1444	4.26 4.24	0.85 0.81

Prediction equation for growth and yield

(i) Total dry matter

The regression relationships obtained between dry matter (TDM) accumulation in above ground parts and GDD or HTU or PTU are shown below. Significant (at 5% level) linear relationship between TDM and GDD / HTU / PTU were obtained.

Brassica juncea cv. RL-1359

TDM = 0.897GDD – 536.67 ($R^2 = 0.86^*$)
TDM = 0.1248HTU – 506.68 ($R^2 = 0.83^*$)
TDM = 0.0806PTU – 499.99 ($R^2 = 0.85^*$)

Brassica napus cv. PGSH-51

TDM = 0.5938GDD – 297.5 ($R^2 = 0.84^*$)
TDM = 0.0786HTU – 253.94 ($R^2 = 0.82^*$)
TDM = 0.0528PTU – 267.86 ($R^2 = 0.83^*$)

Brassica carinata cv. PC-5

TDM = 0.5716GDD – 302.7 ($R^2 = 0.86^*$)
TDM = 0.0739HTU – 248.41 ($R^2 = 0.84^*$)
TDM = 0.0503PTU – 269.07 ($R^2 = 0.86^*$)

Leaf area development

The regressions obtained between periodic leaf area index (LAI) upto maximum LAI and GDD / HTU / PTU are shown below. Significant (at 5% level) exponential relationships were observed while the linear relationship was not found significant, indicating non linearity of the response of LAI to agro-climatic indices.

Brassica juncea cv. RL-1359

$LAI = 0.1866e^{0.002GDD}$ $(R^2 = 0.47^*)$
$LAI = 0.2013e^{0.0003HTU}$ $(R^2 = 0.40^*)$
$LAI = 0.2129e^{0.0002PTU}$ $(R^2 = 0.42^*)$

Brassica napus cv. PGSH-51

$LAI = 0.1094e^{0.0026GDD}$ $(R^2 = 0.54^*)$
$LAI = 0.1221e^{0.0004HTU}$ $(R^2 = 0.47^*)$
$LAI = 0.1245e^{0.0002PTU}$ $(R^2 = 0.51^*)$

Brassica carinata cv. PC-5

$LAI = 0.1172e^{0.0025GDD}$ $(R^2 = 0.54^*)$
$LAI = 0.1289e^{0.0003HTU}$ $(R^2 = 0.47^*)$
$LAI = 0.1245e^{0.0002PTU}$ $(R^2 = 0.51^*)$

Seed yield

The regression equation obtained between maximum leaf area index (LAI) as independent variable and seed yield as dependent variable of three brassica species based on data of two crop seasons and three dates of sowing are shown below. Significant (at 5% level) linear relationship was observed.

Brassica juncea :

Seed yield = 445*Maximum LAI + 189.98 $(R^2 = 0.41^*)$

Brassica napus:

Seed yield = 475.18*Maximum LAI - 326.84 $(R^2 = 0.72^*)$

Brassica carinata:

Seed yield = 392.07*Maximum LAI - 3.2112 $(R^2 = 0.44^*)$

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