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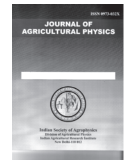

Research Article

Relationship of Thermal Indices with Biophysical Parameters and Seed Yield of Oilseed *Brassica* Cultivars Sown in Two Different Row Directions

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ABSTRACT

A study was carried out at the experimental farm, ICAR-Indian Agricultural Research Institute, New Delhi during *rabi* season, 2013-14 to assess the impact of temperature on biophysical parameters of three mustard cultivars sown in north-south (N-S) and east-west (E-W) row directions. Maximum growing degree days (GDD) was recorded as 1641.1 degree-days, while the helio-thermal unit (HTU) and photo thermal unit (PTU) were 7778.5 and 17845.7 degree-days hours, respectively. These thermal indices were significantly ($p < 0.01$; $r > 0.95$) correlated with maximum biomas and leaf area index for all the row directions and the cultivars. The heat use efficiency (HUE) was higher in N-S (1.14 kg ha^{-1} degree-days) than the E-W direction (1.08 kg ha^{-1} degree-days). Results suggest that *Brassica* in N-S direction is likely to use heat energy more efficiently for increase in seed yields. The highest HUE was recorded in Pusa Mustard-21 (1.16 g ha^{-1} degree-days).

Key words: Thermal index, Row-direction, Seed yield, *Brassica*

Introduction

Mustard is the second most important edible oilseed crop in India after groundnut and accounts for nearly 30% of the total oilseeds produced in the country. Indian mustard (*Brassica juncea* (L.) Czern. and Coss.) is predominantly cultivated in North Western India. It is a long-day plant, which requires cool and dry weather for its proper growth and development. Temperature is the key factor which influences growth rate, development and productivity of crop (Kaleem *et al*., 2009). Temperature influences the crop growth and development (Bishnoi *et al*., 1995). Thermal period gives a measure of physiological time as it relates to many plants species (Trudgill *et al*., 2005). The most commonly used temperature index to estimate plant growth is the growing-degree-days (GDD) (Kaleem *et al*., 2011), which is essential for biomass production and flower formation (Parthasarathi *et al*., 2013). During *rabi* season, GDD influences the productivity and growth pattern of mustard under different weather conditions (Srivastava *et al*., 2005). The HUE is another thermal index for prediction of yield potential of a crop in a particular environment. It has great practical application for selection of crop in a particular region and depends on crop type, environment and genetic factors (Rao *et al*., 1999). These thermal based indices have been widely used on different crops in different regions 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*.,

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2001). Keeping this in background, the present study was done to quantify relationships between thermal indices (GDD, HTU, PTU, PTI and HUE) and the biophysical parameters and yield of three cultivars of mustard sown in two different row directions.

Materials and Methods

The present study was conducted during 2013-14 *rabi* season at the experimental farm (MB-4C) of IARI, New Delhi located at 28°64' N latitude, 77°15'E longitude. Three cultivars of Brassica viz., Pusa Vijay (V_1), Pusa Mustard-21 (V_2) and Pusa Bold (V_3) were sown in two different row directions (N-S and E-W) on 30th Oct, 2013. The experiment was laid out in a spilt-plot design with three replications with size of each plot as 4m × 4m. Sowing was done with the help of a hand drill, maintaining row-to-row and plant-to-plant spacings of 45 and 10 cm, respectively. Recommended doses of fertilizers (80 kg N: 40 kg P_2O5: 40 kg K_2O) were applied at the time of sowing. Weather data during the crop growing season were collected from the meteorological observatory, Division of Agricultural Physics, IARI, adjacent to the experimental plots. Biophysical parameters, viz., leaf area index (LAI) and biomass were recorded at different phonological stages like vegetative, rosette, flowering, pod development, seed filing, oil accumulation and physiological maturity. For biomass measurement at early vegetative stage, ten plants were selected, while after the vegetative stage, three plants were randomly selected from each plot and cut at ground level. Plants were oven-dried at 65°C for 48 h and the biomass weight was recorded. The LAI measurements were carried out at regular intervals using LAI-2000 Plant Canopy Analyzer (LI-COR, USA).Thermal indices *viz*., growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU), pheno-thermal index (PTI) and heat use efficiency (HUE) were calculated with base temperature of 5°C upto maximum LAI and biomass attained by the crop at different phonological stages. The thermal indices were calculated using the following equations:

$$GDD = \sum_{n=1}^{n=n} \left[\frac{T_{max} + T_{min}}{2}\right] - T_b \quad \text{(Monteith, 1984)}$$

$$\text{HTU} = \sum_{n=1}^{n=n} [\text{Degree days} * \text{actual bright sunshine hour}]$$

(Rajput, 1980)

$$\text{PTU} = \sum_{n=1}^{n=n} [\text{Degree days} * \text{maximum possible sunshine hour}]$$

(Major, 1975)

$$\text{PTI} = \frac{\text{GDD}}{\text{Growth days}}$$

$$\text{HUE} = \frac{\text{seed yield}}{\text{GDD}}$$

where, T_{max} and T_{min} are daily maximum and minimum temperatures (°C), T_b is the base temperature (5°C). The regression equations were developed between thermal indices and biomass; thermal indices and LAI taking thermal indices as independent variable by using Microsoft excel 2013.

Results and Discussion

Maximum GDD, HTU, PTU and PTI were 1641.1 degree-days, 7778.5 degree-days-h, 17845.7 degree-days-h and 14.3 degree-days d^{-1}, respectively from sowing to physiological maturity (Table 1). Values increased with increase in plant growth up to physiological maturity of the crop for both row directions and cultivars. Our results are in conformity with Singh *et al*. (2014).The PTI (degree-days d^{-1}) showed the highest value (14.3) at maturity and followed the trend according to daily mean temperature. The finding is in agreement with others (Singh *et al*., 2014; Neog and Chakravarty, 2005).

Relationship between thermal indices and bio-mass

Maximum biomass was attained at 121 DAS. The regression between thermal indices and biomass are depicted in Fig 1. The GDD, HTU and PTU showed significantly high correlation ($r > 0.95$, $p < 0.01$) with biomass for both the row

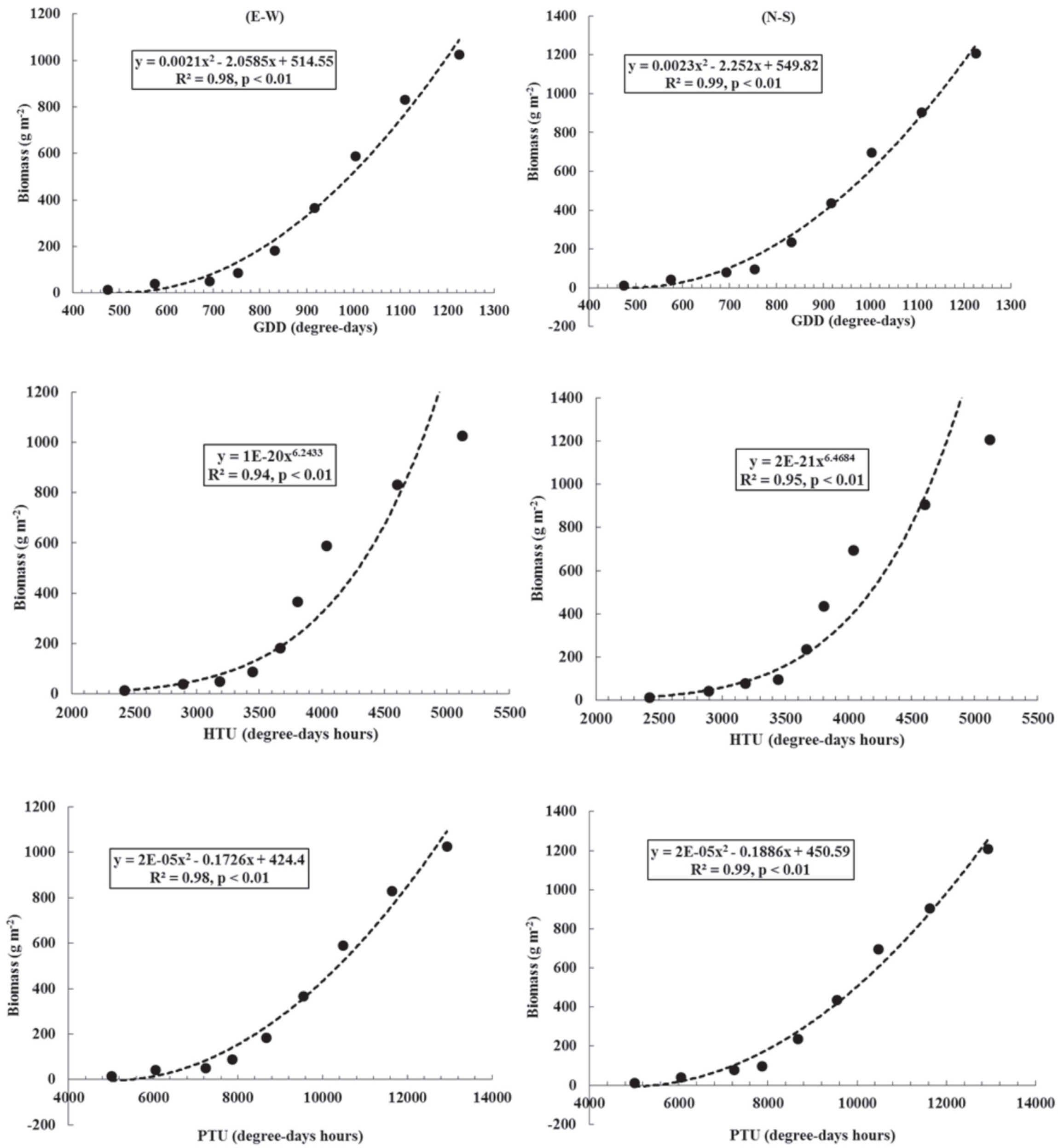

Fig. 1. Relationship between thermal indices GDD, HTU and PTU, and biomass) in mustard crop sown in E-W and N-S directions

directions. Similar results have been reported by Srivastava *et al*. (2005) in mustard. These results are in conformity with those of Villalbos *et al*. (1996) who concluded that biomass production was positively correlated with accumulated thermal indices in sunflower and the correlation coefficients were more in N-S than E-W direction. The GDD, HTU and PTU exhibited significant positive correlation with biomass. The best fit was second-order polynomial regressions for all indices except HTU (power regression), when the data were pooled across cultivars and row directions.

Correlation between thermal indices and biomass was marginally higher in V_3 among all cultivars, while V1 and V2 had similar correlations with GDD and PTU (Table 2). The

Table 1. Temporal variation of thermal indices in mustard crop

DAS	Phenological stages	GDD	HTU	PTU	PTI
20	Leaf initiation	279.6	1146.4	2994.8	14.0
27	Vegetative stage	368.2	1652.2	3918.0	12.7
35	Rosette initiation	474.2	2422.2	5012.2	13.3
44	Flower appearance	575.0	2890.0	6043.9	11.2
56	Pod development initiation	692.2	3180.3	7238.5	9.8
65	Seed filling initiation	752.9	3441.6	7857.6	6.7
77	25% seed filling	831.6	3666.9	8668.2	6.6
87	60% seed filling	915.8	3804.3	9548.9	8.5
97	100% seed filling	1003.1	4037.3	10477.9	8.8
108	Pod development over	1108.7	4603.9	11624.3	9.6
121	Oil accumulation	1225.2	5119.1	12929.9	9.0
150	Physiological maturity	1641.1	7778.5	17845.7	14.3

Table 2. Relationship between thermal indices and biomass of mustard

Cultivars	GDD	HTU	PTU
V_1	$y = 0.0024x^2 - 4.1212x + 1777$ $R^2 = 0.98$	$y = 8E\text{-}21x^{6.2838}$ $R^2 = 0.94$	$y = 2E\text{-}05x^2 - 0.1781x + 437.59$ $R^2 = 0.98$
V_2	$y = 0.0025x^2 - 4.2994x + 1821.1$ $R^2 = 0.98$	$y = 2E\text{-}22x^{6.7251}$ $R^2 = 0.94$	$y = 2E\text{-}05x^2 - 0.1661x + 352.23$ $R^2 = 0.97$
V_3	$y = 0.0024x^2 - 4.2143x + 1831.7$ $R^2 = 0.99$	$y = 5E\text{-}20x^{6.0765}$ $R^2 = 0.96$	$y = 2E\text{-}05x^2 - 0.1977x + 522.68$ $R^2 = 0.99$

Table 3. Relationship between thermal indices and LAI of different mustard cultivars

Cultivars	GDD	HTU	PTU
V_1	$y = 4E\text{-}06x^2 + 0.0006x - 0.1413$ $R^2 = 0.95$	$y = 7E\text{-}07x^2 - 0.0021x + 2.0702$ $R^2 = 0.95$	$y = 3E\text{-}08x^2 + 8E\text{-}06x - 0.458$ $R^2 = 0.93$
V_2	$y = 3E\text{-}06x^2 + 0.0028x - 0.6699$ $R^2 = 0.97$	$y = 6E\text{-}07x^2 - 0.0018x + 1.7402$ $R^2 = 0.97$	$y = 2E\text{-}08x^2 + 0.0002x - 1.2363$ $R^2 = 0.97$
V_3	$y = 3E\text{-}06x^2 + 0.0028x - 0.6699$ $R^2 = 0.97$	$y = 4E\text{-}07x^2 - 0.0008x + 1.117$ $R^2 = 0.96$	$y = -4E\text{-}09x^2 + 0.0006x - 2.2204$ $R^2 = 0.95$

correlation between PTI and biomass was higher in V_2 followed by V_1 and V_3. The thermal response curves revealed non-linear relationship of the thermal accumulation with biomass in all the cultivars across the row directions.

Relationship between thermal indices and LAI

The peak LAI was observed at 97 DAS. The GDD, HTU and PTU had significantly ($p < 0.01$) high positive correlation with LAI, but PTI had negative correlation for both the row directions (E-W and N-S) (Fig. 2). Results are in conformity with Srivastava *et al.* (2005), who reported that LAI was positively correlated with accumulated GDD in mustard. The relationship between LAI and thermal indices followed similar trends except between LAI and HTU or PTI. The LAI was better correlated in case of N-S direction than the E-W.

In case of LAI, the correlation coefficient of thermal indices was the best in V_2 variety followed by V_3 and V_1 (Table 3). A second-order polynomial regression could be the best fit between thermal unit accumulation and LAI for

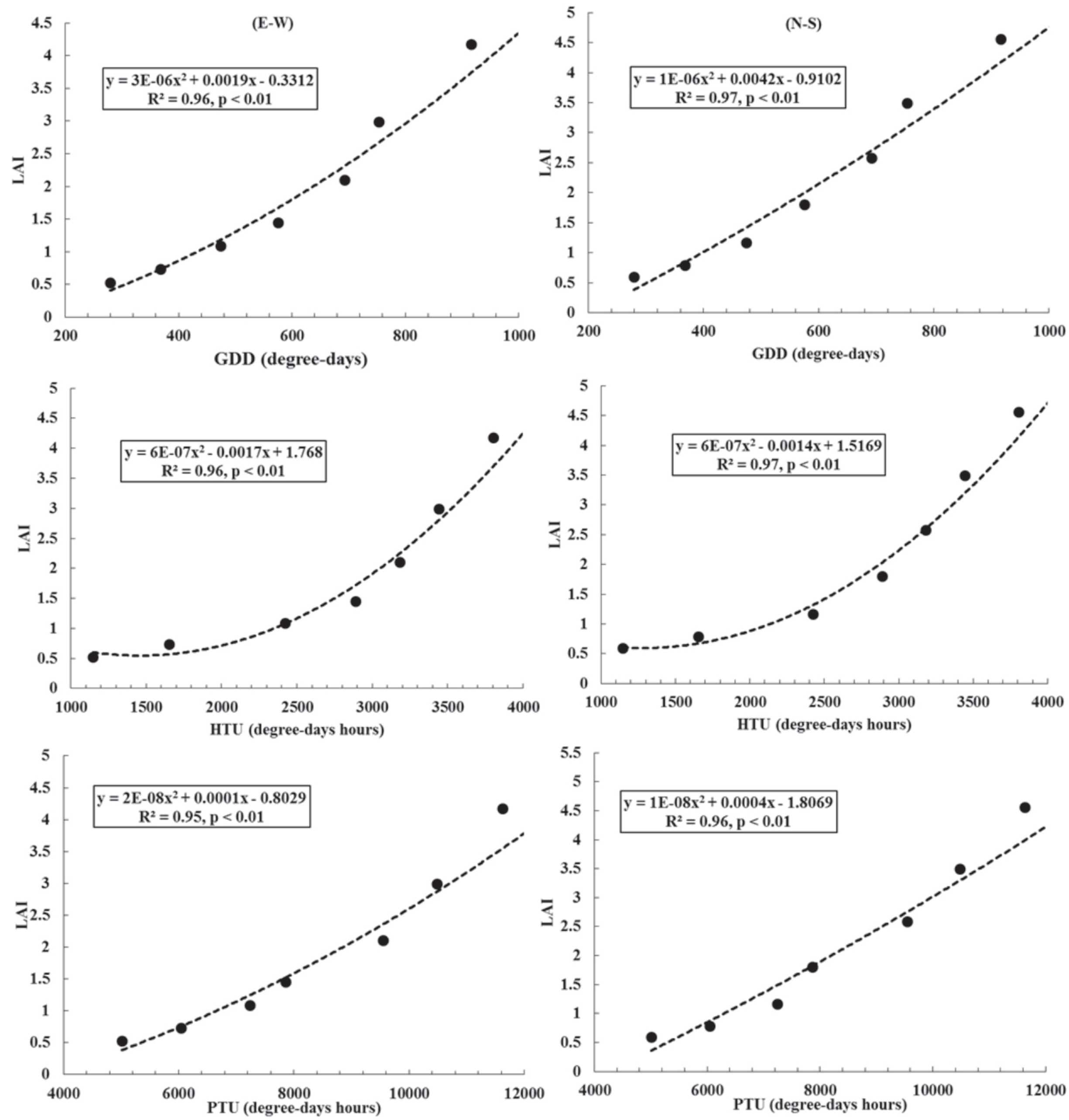

Fig. 2. Relationship between thermal indices GDD, HTU and PTU, and leaf are index (LAI) in mustard crop sown in E-W and N-S directions

all the cultivars. All thermal indices were positively correlated with LAI; V_2 showed the best positive correlation, followed by V_3 and V_1.

Heat use efficiency

Crops sown in N-S direction had higher seed yield than crops sown in E-W direction (Table 4). Seed yields in N-S and E-W direction was 1867 and 1776 kg ha^{-1}, respectively. Yields were higher in V_2 (1908 kg ha^{-1}) followed by V_1 (1804 kg ha^{-1}), V_2 (1753 kg ha^{-1}), respectively. The growing period of mustard cultivars was 150 days and GDD of entire crop season are 1641 degree-day. The HUE was higher in N-S than the E-W

Table 4. Variation in seed yield and HUE of three mustard cultivars grown under two row directions

Treatments	Seed Yield (kg ha^{-1})	HUE
	Effect of row directions	
N-S	1867	1.14
E-W	1776	1.08
$LSD_{0.05}$	4.28	0.1
	Effect of cultivars	
V_1	1753	1.07
V_2	1908	1.16
V_3	1804	1.10
$LSD_{0.05}$	11.85	0.1

sown crop (1.14 and 1.08 kg ha^{-1} degrees-day, respectively). It could be ascribed to proportionate increase in dry matter per each GDD absorbed. Similar results were reported by Amrawat *et al.* (2013) while working on wheat. In case of cultivars, RUE was the highest in V_2 (1.16 kg ha^{-1} degrees-day) followed by V_3 (1.10 kg ha^{-1} degrees-day) and V_1 (1.07 kg ha^{-1} degrees-day) and all were significantly different at 1% level of significance.

Conclusions

N-S oriented sowing may be followed in mustard in north west India for achieving higher seed yield and heat use efficiency, compared to E-W direction of sowing. It can also be seen that among three varieties, Pusa Mustard-21 is a better choice due to its highest heat use efficiency than rest of the varieties.

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