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Research Article

Agroclimatic Study for Prediction of Growth and Yield of *Brassica* sp. in Central Punjab

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ABSTRACT

Field experiments were conducted during three consecutive *rabi* (winter) seasons at Punjab Agricultural University, Ludhiana with three *Brassica* species sown on two different dates in each year. Agroclimatic indices *viz.*, growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU) and heat use efficiency (HUE) were evaluated for the prediction of growth and yield of *Brassica* species. Dry matter accumulation and seed yield were correlated with agroclimatic indices *viz*., GDD, HTU, PTU and HUE and regression relationships were observed between them. Regression models were used to estimate growth and yield of *Brassica* species. Among the species, heat use efficiency was found to be higher in *Hyola*, which indicated that the crop can utilise heat more efficiently, and can perform better under global warming scenarios.

Key words: Growing degree days, Heliothermal units, Photothermal units, Heat use efficiency, Brassica

Introduction

Weather has a very close relationship with the crops. It affects all the crop growth stages right from their sowing till harvesting and storage. An analysis of crop and weather relationships can also be of great help in prediction of growth and yield of crops. Crop growth and development are a function of solar energy received and thermal energy changes during the growing season (Neog and Chakravarty, 2005). Since decades, attempts have been made to predict phenology (Hundal *et al.*,1997), leaf area index (Benbi, 1994), growth rate (Singh *et al.*, 1996) and yield (Tripati *et al.*, 1999; Hundal *et al.*, 2001; Kingra *et al.*, 2006) of crops using thermal based indices. Proper application of these indices provides a scientific basis for determining the effect of temperature, radiation, or photoperiod on phenological behaviour of the crops.

Brassica is highly sensitive to weather, showing quiet diverse pattern of growth and development to different sets of environmental conditions. Phenological development in *Brassica* species is known to be altered by photoperiod and temperature, with a general trend of shortening of phase as day length or temperature increases (Mendham and Salisbury, 1995; Robertson *et al.*, 2002). Among all the weather parameters, temperature and solar radiation are the most dominant factors affecting the crop growth, dates of occurrence of different phenological stages and crop yield, thus they can be used for predicting the crop growth, phenology and yield in advance.

Agroclimatic indices *viz*., GDD, HTU, PTU and HUE, which relate temperature, sunshine

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hours and day length to crop growth and dry matter production can be used effectively for prediction of growth and yield of crops based on weather parameters. Although dynamic crop growth simulation models are being used for this purpose, these models often require a large input data and some of these are complex to use (Whisler *et al.*, 1986). Therefore, simplified agroclimatic models with less input data requirement would be quite useful. Simple agroclimatic models based on thermal indices can be utilized by relating with crop growth parameters *e.g.*, phenology, dry matter accumulation, leaf area index and yield etc. In the present study, an attempt has been made to investigate the crop-weather relationship for *Brassica* sp. and predict its growth and yield with agroclimatic models based on GDD, HTU, PTU and HUE.

Materials and Methods

Field experiments were conducted during three consecutive *rabi* seasons (2003-04, 2004-05 and 2005-06) at the research farm of Punjab Agricultural University, Ludhiana (30°-54' N, 75°-48' E, 247m above mean sea level). Three *Brassica* sp. [*Brassica juncea:* RL-1359 (V_1), *Brassica napus* PGSH-51 (V_2) and *Hyola:* PAC-401 (V_3)] were sown under two dates (1st week of November and 1st week of December) with row-to-row and plant-to-plant spacings of 30 and 10 cm with a seed rate of 3.75 kg ha^{-1}. Recommended fertilizers were applied as N @ 40kg acre^{-1} (½ at sowing and ½ at 1st irrigation) and single superphosphate @75kg acre^{-1}.

Weather data during the seasons were collected from the Agrometeorological Observatory, School of Climate Change and Agricultural Meteorology, PAU, Ludhiana. Plant samples were collected periodically at 15-day intervals and dry matter accumulation was recorded. The GDD were computed as (Nuttonson, 1955).

$$GDD = [(T_{max} + T_{min})/2 - T_{base}]$$

Where, T_{max} and T_{min} are daily maximum and minimum temperature (°C) during a day; and T_{base} is base temperature of 5°C.

The HTU is the product of GDD and corresponding actual sunshine hours for the same day:

$$HTU = GDD \times \text{Actual sunshine hours}$$

The PTU is the product of GDD and corresponding day length (maximum possible sunshine hours for that day:

$$PTU = GDD \times \text{Day length}$$

The GDD, HTU and PTU were accumulated from the date of sowing to each date of sampling and a particular date of phenophase to get accumulated indices.

The HUE (kg ha^{-1} °C-d^{-1}) for seed and total dry matter was obtained as under:

HUE = [Seed yield or Total dry matter (kg ha^{-1}) / Accumulated heat units (°C-d)]

Regression relationships between dry matter and seed yield, and agroclimatic indices were developed for prediction of growth and yield of *Brassica* spp.

Results and Discussion

Meteorological conditions and crop development

Monthly meteorological conditions during three *Brassica* seasons indicated that mean monthly maximum temperature ranged from 17.3-37.5, 17.4-37.6 and 19.2-36.0 ^{0}C, whereas the mean monthly minimum temperature ranged from 7.8-20.5, 5.8-16.6 and 4.4-18.2 ^{0}C during 2003-04, 2004-05 and 2005-06, respectively (Fig. 1). Total rainfall received was 119.2, 151.2 and 55.2 mm in corresponding years, respectively. Low rainfall during *rabi* 2005-06 could be responsible for higher day temperature during this year. The lowest temperature was observed during December and January, and the highest during April in each year. Among the dates of sowing, yield reduced in late (December) sown crop due to low temperature prevailing during December and January. Similarly, higher temperature during April appeared to have impact, because the late-sown crop was exposed to high temperature at relatively earlier growth as compared to early

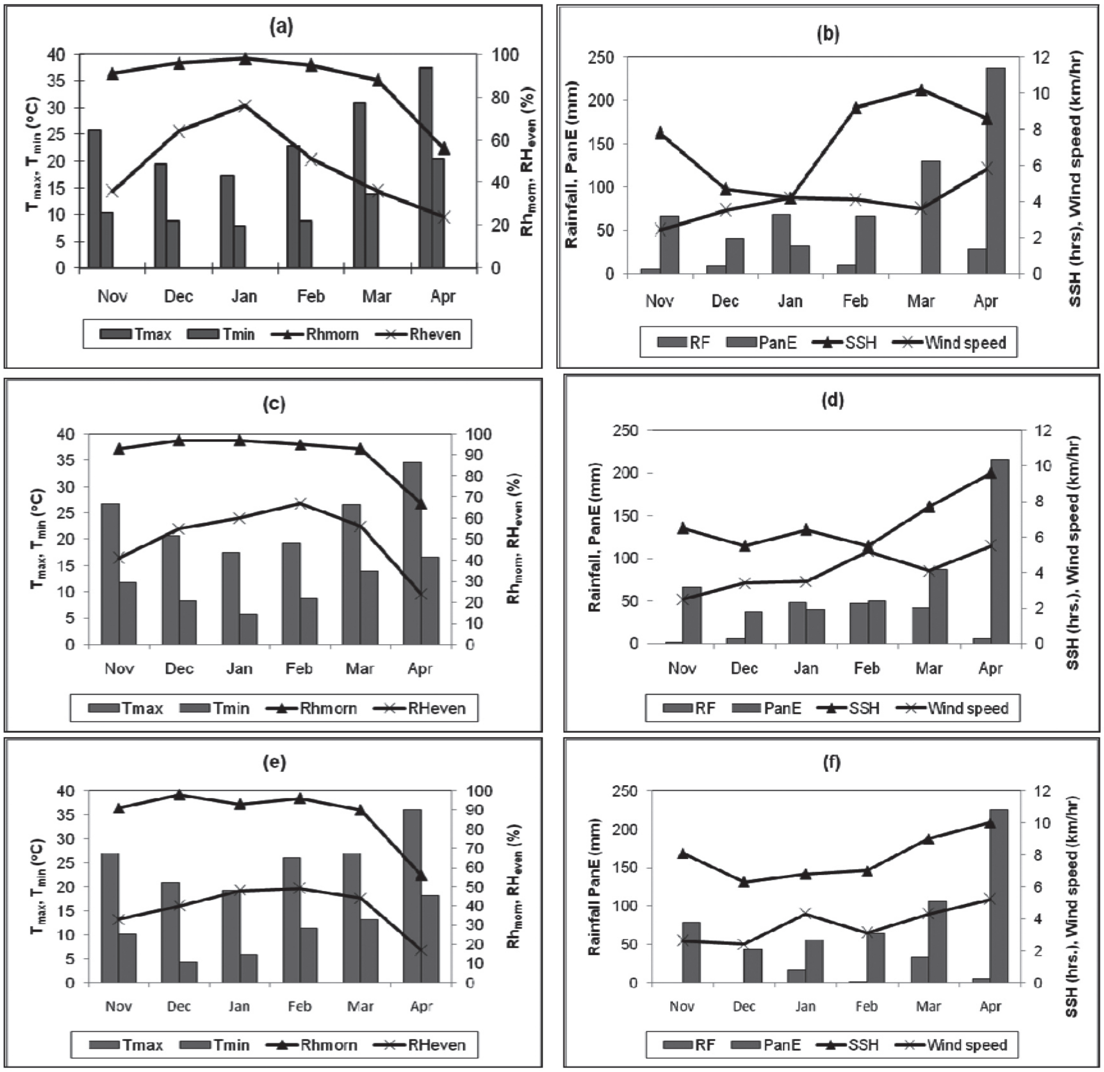

Fig. 1. Monthly meteorological conditions during (a, b) 2003-04, (c, d) 2004-05 and (e, f) 2005-06 crop seasons

sown crop. Thus, temperature had adverse impact on late- compared to early-sown crop and yield reduced considerably during all the years. Adjusting the sowing time with suitable agroclimatic environment has been advocated (Saha and Khan, 2008).

Rainfall was well-distributed during *rabi* 2004-05, but was less and poorly distributed during *rabi* 2005-06. Although the assured irrigation supply negate the impact of variation in rainfall pattern on crop yields in all the years.

Agroclimatic indices

Lower values of agroclimatic indices corresponded to crop under late-sown conditions to attain their maturity (Table 1). *Brassica juncea*, *Brassica napus* and *Hyola* had GDD of 1121, 1413 and 1413 ^{0}C days during 2003-04; 1206, 1417 and 1417 ^{0}C-d during 2004-05; and 1292, 1553 and 1502 ^{0}C-d during 2005-06 under late sowing. Under early sowing, GDD were higher for the growing period and was recorded as 1317, 1642 and 1569 ^{0}C-d (2003-04), 1440, 1592 and 1592 ^{o}C-d (2004-05), and 1517, 1734 and 1612 ^{o}C-d (2005-06) in *Brassica juncea*, *Brassica napus* and *Hyola*. Similar trends were observed for HTU and PTU. Among the species, *Brassica napus* consumed slightly higher heat units to attain physiological maturity followed by *Hyola* and *Brassica juncea*.

Table 1. Agroclimatic indices for three *Brassica* species sown on different dates during three crop seasons

Date of sowing	*Brassica* species	Accumulated GDD (°C-d)	Accumulated HTU (°C-d hour)	Accumulated PTU (°C-d hour)
		Crop season, 2003-04		
1st week of November	*Brassica juncea*	1316.5	9616.8	14156.5
	Brassica napus	1642.2	12693.5	18112.9
	Hyola	1569.4	11926.4	17213.7
1st week of December	*Brassica juncea*	1121.1	8471.7	12255.5
	Brassica napus	1413.4	11112.8	15846.7
	Hyola	1413.4	11112.8	15846.7
		Crop season, 2004-05		
1st week of November	*Brassica juncea*	1440.4	8832.6	15592.5
	Brassica napus	1592.2	10306.2	17459.1
	Hyola	1592.2	10306.2	17459.1
1st week of December	*Brassica juncea*	1205.9	7891.2	13377.2
	Brassica napus	1416.9	10023.0	16039.1
	Hyola	1416.9	10023.0	16039.1
		Crop season, 2005-06		
1st week of November	*Brassica juncea*	1517.1	11283.6	16571.0
	Brassica napus	1734.3	13669.2	19276.6
	Hyola	1611.9	12282.6	17742.5
1st week of December	*Brassica juncea*	1291.8	9614.8	14414.2
	Brassica napus	1552.7	12307.5	17718.7
	Hyola	1501.6	11683.1	17063.6

Table 2. Seed yield, straw yield and heat use efficiency for three Brassica species sown on different dates during three crop seasons

Date of sowing	*Brassica* species	Dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Dry matter HUE (kg ha^{-1} °C-d^{-1})	Seed yield HUE (kg ha^{-1} C-d^{-1})
		Crop season, 2003-04			
1st week of November	*Brassica juncea*	3579.2	916.1	2.719	0.696
	Brassica napus	4048.4	756.9	2.465	0.461
	Hyola	3277.3	740.6	2.088	0.226
1st week of December	*Brassica juncea*	1780.3	470.4	1.588	0.420
	Brassica napus	2702.1	407.4	1.912	0.288
	Hyola	2563.8	474.4	1.814	0.336
		Crop season, 2004-05			
1st week of November	*Brassica juncea*	3917	853.2	2.719	0.592
	Brassica napus	4417	755.4	2.774	0.474
	Hyola	4799	767.2	3.014	0.482
1st week of December	*Brassica juncea*	1565	228.5	1.298	0.189
	Brassica napus	2006	376.2	1.416	0.266
	Hyola	2285	529.1	1.613	0.373
		Crop season, 2005-06			
1st week of November	*Brassica juncea*	4458	988	2.939	0.651
	Brassica napus	2411	792	1.390	0.457
	Hyola	4605	1296	2.857	0.804
1st week of December	*Brassica juncea*	1175	317	0.910	0.245
	Brassica napus	1982	311	1.276	0.200
	Hyola	2497	531	1.663	0.354

Seed yield, straw yield and heat use efficiency

Total dry matter at physiological maturity, seed yield at harvest and HUE are given in Table 2. In general, late-sown crop had less dry matter accumulation as well as seed yield than the early-sown crop indicating a decrease in HUEs. The highest HUEs of 2.939 (year 2005-06) and 0.696 (year 2003-04) kg ha ^{0}C-d in *Brassica juncea* were observed for dry matter and seed yield, respectively when it was sown on 1st week of November. However, in contrast to the observed trend of decrease in HUEs under late sowing, *Hyola* showed better HUE under late sowing during first year. As higher temperature was observed in March and April during first year, higher tolerance of *Hyola* to high temperature conditions is indicated, whereas *Brassica juncea* performed better under early sowing conditions.

Agroclimatic models

Linear regression models of total dry matter, seed yield with heat use efficiency were developed.

Total dry matter = 1655*HUE – 352.4 (R^2=0.95)

Seed yield = 1436*HUE + 39.41 (R^2=0.82)

These models are simple, easy to use and have less input data requirement. These can be used successfully to predict the growth and yield of crops well in advance.

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