CONTEMPORARY RESEARCH IN INDIA
ISSN 2231 - 2137

WEATHER BASED GROWTH INDICES OF RAPESEEDS-MUSTARD (*Brassica spp.*) AT HISAR: A REVIEW

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Received: 20/02/2018 | **Edited: 28/02/2018** | **Accepted: 08/03/2018**

Abstract: *An experiment for study weather based growth indices in mustard was conducted at CCSHAU Hisar Research Farm under the AICRPAM project. Analysis of these long-term data to study the phenological behaviour, crop growth rate, leaf area duration of Brassica varieties. The occurrence of different phenological events is significantly influenced in growing environment. Crop is very sensitive to temperature and thermal component, and intera-seasonal variation in temperature, effect on its growth indices with respect to the final production, productivity and biological yield. Variation in T_{max} and T_{min} largely alters the growth pattern of the crop by affecting the duration as well as onset of different phenophases. Further, the biological responses to thermal changes are altered under different growing environments under raised and cultivated verities. The high temperature during mustard crop establishment, cold spell, fog and intermittent rains during crop growth indices were impacted to crop adversely, cause considerable yield losses as biological yield.*

Key words: *Leaf area duration, crop growth rate, growth indices-weather, phenological development, cultivars behavior.*

Introduction

The field studies on different agrometeorological aspects of mustard crop under AICRPAM to be at CCSHAU Hisar Research Farm from 1984-85 to 2015-16. Enormous data, reports and research publications have been published on various aspects of the crop since then sum up of the research findings generated (Singh *et al.* 2016). The bulletin is outcome of reviewed the long term experiment, concerted and sincere efforts of scientists. In general under delayed planting the mustard crop took fewer days to reach maturity as the seeding was delayed. In general under delayed planting, crop took fewer days to reach maturity and also slowed down the rate of crop growth indices. The LAI, biomass, chlorophyll concentration index (CCI) at different stages of crop growth. Vashisth *et al.,* 2017 revealed that all the growth parameters were affected due to the change in the weather conditions.

Material and Methods

Reviewed work and result of annual progress reports from AICRPAM Hisar center are considered to the study from 1983-83 to 2014-15, submitted and presented to the PC, AICRPAM. Regular experiment conducted at CCS HAU research farm under different growing environment and cultivars are considered.

Growing environment of crop

The studies peer analyzed with three date of sowing (D_1: First fortnight of October (FFO) *i.e.* early sown, D_2: Second fortnight of October (SFO) considered timely sown and D_3: First fortnight of November (FFN) know as late sown and five different cultivars.

Climate and weather conditions of experiment location in brief

The climate of Hisar is mainly characterized by its continental location on the outer margins of the monsoon region. It is situated in semi-arid, sub-tropical monsoonal climate. The SW-wind in the summer season brings rain from first week of July to mid of Sept. From Oct. to end of June, weather remains dry except for few light showers received from the westerly disturbance. Summers are extremely hot while winters are fairly cool. Tmax above 45 °C is not uncommon during summer, other hand, the Tmin as low as below freezing point and grass Tmin below -5°C in winter. Extreme temperature

fluctuations may occur within very short-time interval. In winter only 2-3 rainy showers received due to western disturbances followed by low temperature. The occurrence of frost on few days is also not an unusual feature here. The CV% of annual rainfall varies 45 to 50 monsoonal variation goes up to 80 per cent and 65 per cent in winter. The annual rainfall is 450 mm, mostly received during S.W. monsoon and western disturbance. In an earlier 1984-87 study conducted with three brassica spp. (*B. juncea* (*cv.* RH-30, Prakash), *B. napus* (*cv.* N-20, HNS-5) and *B. carinata* (*cv.* HC-2, BC-2) and then Brassica spp. (*B. juncea* (RH-30, Prakash), *B. napus* (N-20, HNS-5) and *B. carinata* (HC-2, BC-2).

Soil of experimental field

The soils are derived from Indo-Gangetic alluvium, are very deep and sandy loam in texture, and fewer amount of calcium carbonate in the soil profile. Physico-chemical analysis of the soil was done by taking random soil samples from 0-30, 30-60 and 60-90 cm soil profile depths.

Soil chemical analysis

a) Mechanical composition

Composite soils samples were prepared for each soil depth separately and were analyzed by International Pipette Method and presented in Table 1.

b) Chemical composition

The chemical analyses of the soil were carried out with standard methods based on composite soil sample of 0-30 cm depth.

Table 1: Mechanical composition of soil (per cent fraction)

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)
0-30	57.38	26.35	16.27
30-60	56.56	26.82	16.62
60-90	56.42	26.68	16.90

Textural class: Sandy loam

Phenological observation

The crop was closely observed at an interval of 2-3 days for commencement of different phenological stages P_1-Seedling emergence, P_2-Early vegetative phase (four leaf stage), P_3-First flower, P_4-Flowering (50 % of plants in plot have at least one open flower), P_5-Pod initiation (50 % of plants in plot have at least one pod 2 cm long), P_6-Seed development (50 % of plants in plot have at least one pod with fully developed seeds) and P_7-Physiological maturity (PM).

Results and Discussion

On the basis of different phenological observations was recorded in field experiments of over the different *Brassica* spp. or mustard cultivars growing in different growing environments at Hisar. Low temperature during vegetative phase led to delayed flower appearance or extended crop establishment phase in term of days, which consequently had delayed convergence of vegetative to reproductive phase that resulted in shorter of reproductive phase duration under delayed sown conditions. Subsequently, higher ambient air temperature during later part of reproductive phase under delayed sown resulted in forced crop maturity and further shortening the reproductive phase. The locally popular mustard RH 30 noticed and found shorter life span and significantly early in attained different phenophases as compared to National checks Varuna and other cultivar Laxmi. Accumulated heat units (AHU) to PM varied significantly and least HU accumulated in FFN sown. Laxmi cultivar were significantly late maturity and highest AHU to attained different growth stages whereas, *cv.* RH 30 had lowest AHU for various growth stages due to less day required for their completion of phenophases. Plant density (30x15 & 40x20 cm) failed to influence the phenological development and non-significant differences in number of days taken to reach various phenological stages.

In 1984-87 experiment conducted with three brassica spp. *B. juncea, B. napus* and *B. carinata* showed that HU requirement for different phenophases decreased with delay in sowing. Accumulation of HU for maturity was highest in FFO sown crop in all the six cultivars. As days taken for maturity were highest in Oct. sown crop i.e. consecutive delay in sowing, heat unit requirement of different species decreased and was lowest in the FFN sown with the exception of *B. juncea* varieties, SFO sown crop took less period to maturity. Among all the cultivars, BC-2, accumulated highest HU for occurrence of difference phenophases (2266.9 °C day) up to maturity under FFO sown, followed by HC-2, HNS-5, Prakash and RH-30 in descending order. Among varieties RH-30 took minimum days for maturity whereas in N-20 ahead of HNS-5.

Plant height (cm)

Plant height differed significantly among different sowing dates and reduced plant height was observed with delayed sowing at all growth stages/intervals including the PM. Among the mid-season growth manipulations, the treatment involving the main stem cut-off at 15 cm plant height and its used for leafy vegetable purpose at 40 and 50 DAS exhibited significantly shorter plant height than other growth manipulation treatments where main stem was not disturbed. The plant height of three brassica spp. (*B. juncea,* two *B. napus* and two *B. carinata* at different growth stages of crop, accumulated HU at different growing environment. The behaviors of different cultivars in regards of plant height were different. Maximum plant height attained in a particular cultivar different with date of sown, RH-30 it was 141.6 cm in FFO sown, while 194.3 cm FFN sown with a respective HU-accumulation of 1671.7 and 1629.2°C day.

Branches per plant in different growing environment and growth manipulation

The number of primary and secondary branches at PM in early sown was significantly higher as compared to delayed FFN sown crop. However, crop geometry showed non-significant effect on primary and secondary branches. Among cultivars, Laxmi produced slightly higher number of primary and secondary branch however the Kranti, RH0749 at a par. Among growth manipulations, the treatment with main stem cut-off at 15 cm plant height at 40 and 50 DAS resulted in significantly reduced number of primary branches as compared to other treatments where the main stem was not disturbed. Main stem cut-off produced more number of secondary branches over other growth manipulation treatments due to late production of secondary branches. A part of the decline in mustard yields causing negative growth rate from 1997-98 was possibly due to unfavorable monsoon created moisture stress and temperature increases.

Growth indices and weather variable

Mustard is much sensitive to climatic variables and climatic variability had significant effect on its growth indices with respect to the final production, productivity and biological yield (Singh *et al.* 2016). In the variation of T_{max} and T_{min} growth pattern of crop by affecting the duration as well as starting of different phenophases. Further, the biological responses to thermal changes are altered under different growing environments. The high temperature during mustard crop establishment, cold spell, fog and intermittent rains during crop growth indices and altimetry impacted to the crop adversely and cause considerable yield losses or biological yield of mustard crop.

Leaf area index

A significant drop in LAI observed with subsequent delay in sowing from first FFO to FFN. Irrespective of the sowing time, the maximum LAI was recorded around 75 DAS. The closer row spacing of 30 x 15 cm produced higher LAI as compared to wider row spacing of 40x20 cm.

Leaf area duration (day)

A continued increase in leaf area duration (LAD) upto 75 DAS in all three planting dates and thereafter LAD dropped rapidly till 105-120 DAS. Early sown had higher LAD upto than delayed sowings indicating that the crop had more green leaf area, that prevailed for longer period under early

sown and beyond 90 DAS, SFO sown crop higher LAD as compared to FFO and FFN sown conditions.

Crop growth rate (g/day/m²)

Crop growth rate (CGR) increased steadily upto 90 DAS with period of decline in 45 to 60 DAS and decreased gradually after 90 DAS till harvest irrespective of treatments. The CGR was higher in FFO sown crop upto 60 DAS and again during growth period between 90-105 DAS. However, the SFO sown exhibited higher values of CGR during growth periods between 75-90, 120-135 DAS and 135 PM. Among, varieties, the CGR values were almost similar till 105 DAS, but Laxmi exhibited higher CGR during subsequent growth phases between 105-120 and 120-135 DAS over other two varieties RH 30 and Varuna.

Leaf area ratio (cm²/g)

The leaf area ratio (LAR) reached its maxima during crop growth period of 30-45 DAS and it declined gradually during later stages of growth. During early growth interval of 0-30 DAS, FFO sown date exhibited slightly higher LAR than latter sowings but during the period of 30-45 DAS, FFN sown notice higher LAR value than crop sown FFO & SFO. At latter stages of crop growth from 90 to 120 DAS, SFO & FFN sown had similar LAR values, but higher than FFO. Among varieties, Laxmi exhibited slightly higher LAR at early growth phases of 0-30 and 30-45 DAS at subsequent growth phases LAR was almost similar in all three varieties.

Specific leaf area (cm²/g)

A continuous increase in specific leaf area (SLA) was observed till reached the peak during 75-90 DAS and a steady decline was observed thereafter under all treatments. During initial growth phase of 0-30 DAS, sowing dates had little difference but thereafter, higher SLA was recorded in FFO as SFO and FFN sown till 75-90 DAS. During growth intervals of 90-105 and 105-120 DAS, SLA was higher in SFO followed by FFN and FFO sown. Among varieties, SLA values were similar till 30-45 DAS but at latter stages higher SLA was observed in Varuna as compared to RH 30 and Laxmi.

Specific leaf weight (mg/cm²)

Irrespective of treatments, the SLW increased till 45-60 DAS however, its increase was rapid till growth interval of 30-45 DAS. After that a gradual decline was observed upto 75-90 DAS with a sharp increase during 90-105 and 105-120 DAS. During early growth stages of upto 30-45 DAS, SLW was similar in all sowing dates, but at subsequent growth periods till 90 DAS, higher SLW was observed under FFN followed by SFO and FFO sown. Mustard varieties failed to influence the SLA.

Leaf weight ratio:

Leaf weight ratio (LWR) peak was observed at 30 DAS irrespective of treatments, thereafter a steady decrease in LWR was observed till harvest. The sowing dates failed to influence LWR till 30 DAS. Thereafter, FFN sown crop exhibited higher LWR till harvest followed by SFO & FFO sown but varieties had no impact on LWR till harvest.

Relative growth rate (mg/day)

Relative growth rate **(**RGR) got its peak value during 0-30 DAS and then declined steadily till harvest of crop irrespective of treatments. In FFO 5 sown crop, RGR values were higher during 0-30 and 30-45 DAS growth period followed by SFO & FFN sown. However, higher RGR values were observed in FFN sown crop, the values were higher during late vegetative and early reproductive phase coinciding growth intervals of 60-75 and 105-120 DAS than early sown.

Net assimilation rate (mg/cm²/day):

Net assimilation rate (NAR) was higher during 0-30 DAS and thereafter declined rapidly. However, 75-90 and 105-120 DAS intervals slight upswing. Oct. sown crop had slightly higher NAR than Nov. sown crop upto 45 DAS and subsequent growth period of 45-60 and 60-75 DAS. The NAR values were somewhat higher in Nov. than Oct. sown. Reverse trend was observed during later growth intervals of 90-105 and 105-120 DAS. Mustard varieties RH 30, Varuna and Laxmi behaved in similar manner for NAR during each growth intervals.

Biomass and its partitioning (g/m²)

Total crop dry matter (DM) is the spatial and temporal integration of all plant processes therefore, crop DM is critical parameter. Variation in growing environment causes differential thermal heat environment, turn to affects the development of LAI,

crop growth, and biomass partitioning and finally seed yield. Rate of DM accumulation varies across the life cycle and DM. Leaf area are sampled at intervals ranging from days to weeks to quantify effects of growing environment influences. Two basic measurements are made dry weight and leaf area, and a large number of parameters are derived from these measurements. Timely sown allows sufficient growth and development of crop to obtain satisfactory yield in different growing environment at a location. Total DM accumulation is the sum total of gains in leaves, stem and siliquae weights.

The accumulation of DM at different growth stages was drastically reduced due to delay in sowing. Leaf contribution was higher followed by root and stem at flowering, respectively. At crop maturity, leaf allocation decreased due to leaf senescence and turned negligible at PM. At maturity, stem contribution maximum followed by siliquae and roots.

Growth manipulation, the main stem cut-off at 15 cm plant height at 40 and 50 DAS exhibited significantly lower DM accumulation. DM accumulation indicated that mustard cultivars RH 30, Varuna and Laxmi exhibited non-significant differences at various growth stages except at PM, *cv.* RH 30 and cultivar Laxmi produced significantly higher total DM as compared to other cultivars. Crop geometry in 30x15 & 40x20cm failed to influence the DM accumulation during the vegetative and early reproductive phase. During later part of reproductive and maturity phases, closer row spacing of 30x15cm exhibited significantly higher dry matter accumulation and partitioning into different plant parts. In different growth indices and yield and its attributes at vegetative and reproductive stage of development of mustard crop in Table 2. The perusal of data indicates that growth indices recorded during reproductive phase has better association then that of vegetative phase (Singh, 1999).

Table 2: Correlation coefficient of growth indices with yield attributes at vegetative phases in *Brassica*

Yield attribute/ Growth indices	Number of siliqua m^{-2}	Number of seeds siliqua^{-1}	1000 seed weight (g)	Seed yield g m^{-2}	Seed yield q ha^{-1}
NAR	0.34	0.29	0.36	0.45	0.21
LAI	0.69	0.78	0.70	0.73	0.62
SLA	-0.83	-0.69	-0.61	-0.72	-0.66
CGR	0.85	0.86	0.89	0.96	0.88
RGR	-0.34	-0.17	-0.09	-0.13	-0.09
LAD	0.59	0.61	0.59	0.59	0.61
DM	0.71	0.73	0.78	0.81	0.80

Conclusions

Growth indices are very much sensitive to prevailing weather variable. Variables directly impacted to growth indices and physiological processes in different growing environment. The growth manipulation, main stem cut-off at 15 cm plant height at 40-50 DAS exhibited significantly lower DM accumulation. Later part of reproductive and maturity phases, closer row spacing exhibited significantly higher DM accumulation. Under delayed planting the crop took fewer days to reach maturity as the seeding was delayed with all the possible cultivars. The high temperature, cold spell, fog and intermittent rains during establishment and crop growth indices, impacted and cause the considerable yield losses.

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