Journal of Crop and Weed, 10(2):57-62(2014)

Impact of GDD and HTU on dry matter accumulation in mungbean sown under different dates in the sub-humid tropical environment of Eastern India

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Received: 28-08-2014, Revised: 01-10-2014, Accepted: 05-10-2014

ABSTRACT

A field experiment was conducted in the summer seasons of 2010 and 2011 on four mungbean varieties (V_1 - Pant Mung - 5, V_2 - Bireswar, V_3 - RMG - 62 and V_4 - Sukumar) sown on three different dates (D_1 - 15th February, D_2 - 1st March and D_3 - 15th March) at the University research farm BCKV. The experiment was laid out in a split plot design where the sowing dates and the varieties were considered as main plot and sub plot treatments respectively. The objective of this experiment was to study the thermal regime of mungbean crop and its impact on total dry matter accumulation. Both the cumulative maximum and minimum temperature increased with the delay in sowing and varietal differences were prominent during bud emergence and pod emergence phases which might have played a crucial role in the yield of the crop. The thermal use efficiency for dry matter production increased with the delay in sowing. The mean TUE was almost similar for D_2 and D_3 sowings in both the years. Among the four varieties, the total HTU requirement and mean TUE was highest in case of V_1 irrespective of the date of sowing and the year of observation.

***Keywords*:** GDD, HTU, TUE, Mungbean, Date of sowing

Mungbean is a short duration crop and is sensitive to photo thermal regimes. The crop growth is influenced largely by the growing environment of the crop. Microclimate in the crop varies from top of the canopy to the soil surface and affects crop development and yield (Kingra and Kaur, 2012). Temperature is an important environmental factor influencing the growth and development of crop plants. Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Bishnoi *et al.,* 1995). Temperature based agro-meteorological indices such as Growing degree day (GDD), Heliothermal unit (HTU) and Thermal use efficiency (TUE) are very useful for predicting the growth and yield of crops. The growing degree day (GDD) is a simple tool to find out the relationship between plant growth, maturity and mean air temperature. A degree day or a heat unit is the departure from the mean daily temperature above the minimum threshold temperature (Basu *et al.*, 2012). GDD requirement indicates the thermal status for the onset of a particular phenophase in the crop. Requirement of cumulative GDD is regulated by the ambient temperature as well as change in physiological stage of crop regulated by hormonal activities (Nath *et al.*, 1999). Knowledge of accumulated GDD may project developmental stages of a crop as well as its approximate date of harvest (Ketring and Wheles, 1989; Bonhomme, 2000; Wurr *et al.*, 2002; Roy *et al.*, 2005). Mungbean is an important pulse grown in spring-summer season. In West Bengal, this crop is sown during January to March when a great difference in temperature is observed. However, impact of temperature and bright sunshine hour on the growth habits of this crop is not well documented. The present experiment has been undertaken to address this lacunae.

MATERIALS AND METHODS

The experiment was undertaken during spring-summer (*pre-kharif*) seasons of 2010 and 2011 at Jaguli Instructional Farm (New Alluvial zone), Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India (22°56' N latitude, 88°32' E longitude and at an altitude of 9.75 m above mean sea level). The soil was sandy loam with good drainage facility and neutral in reaction. Composite soil samples from 0-30 cm depth were taken from the experimental field for analysis of the physico-chemical properties of the soil. The soil contained 6.40% coarse sand, 40.00% fine sand, 32.80% silt, 19.94% clay, 0.58% organic carbon, 0.06% total nitrogen, 22.90 kg ha^{-1} available phosphorus, 136.66 kg ha^{-1} available potassium and

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had a soil pH of 6.8. The experiment was laid out in a split-plot design with three replications. The main plot consisted of three dates of sowing (D_1-15th February, D_2-1st March and D_3-15th March) and the sub-plot comprised of four varieties of mungbean (V_1-Pant Mung-5, V_2-Bireswar, V_3-RMG-62 and V_4-Sukumar) which were allotted to plots of 5m x 6m area.

Sowing of each variety was done at an interval of fifteen days and the seed rate was 25 kg ha^{-1} while maintaining row to row distance of 25 cm and plant to plant distance of 10 cm. Before sowing, the seeds were treated with *Rhizobium* culture at the rate of 4 g kg^{-1} seed. Fully decomposed farm yard manure (FYM, decomposed organic matter prepared from cowdung) at the rate of 5 t ha^{-1} was applied at the time of final land preparation and a general dose of 20 kg ha^{-1} nitrogen through urea, 40 kg ha^{-1} P_2O_5 through single super phosphate and 40 kg ha^{-1} K_2O through muriate of potash were applied as basal.

The biomass samples were collected weekly starting from 25 days after emergence (DAE) and continued upto the pod development stage. In total, four weekly samples were collected for each variety under different dates of sowing and their mean were used for the analysis. The leaves, stems and root were separated and dried in hot air oven at 75°C temperature for 48 hours. The summation of the dry weight of stem, leaves and root gave total dry matter accumulation which was then calculated in terms of g m^{-2}.

The maximum and minimum temperatures of each day were collected from the adjacent meteorological observatory from which the cumulative maximum and minimum temperatures were calculated by adding them at each phenophase, starting from sowing to harvest, for each variety and date of sowing and the growing degree days (GDD) was computed for computing different relationship.

The growing degree days per day was calculated in accordance with the following formula (Cross and Zuber, 1972):

$$GDD = \left[\frac{(T\max + T\min)}{2}\right] - Tb$$

Where,

Tb = Base temperature below which the crop can not thrive (10°C) (Kiran and Bains, 2007)

Tmax = Maximum temperature

Tmin = Minimum temperature

Heliothermal units (HTU), the product of GDD and corresponding actual sunshine hours for that day were computed on daily basis as:

HTU = GDD × Actual Sunshine hours

Thermal use efficiency of mungbean crop will be computed as:

$$TUE\ (g\ m^{-2}\ degree\ day^{-1}) = \frac{Dry\ weight}{GDD}$$

RESULTS AND DISCUSSION

Both the cumulative maximum and minimum temperature increased with the delay in sowing (Table 1). When the crop was sown on 15th Feb, both the maximum and minimum temperatures were lower and the duration of different phenophases were higher. It was moderate on the second date of sowing *i.e.* 1st March, because of the slight increase in the maximum and minimum temperatures and when the sowing was delayed to 15th March, the cumulative maximum and minimum temperatures in different phenophases was the highest and this might have been due to the higher maximum and minimum temperatures to which the crops were exposed to with the corresponding reduction in the duration of the different phenophases. Among the different phenophases, varietal differences were prominent during bud emergence and pod emergence phases. The crop sown in 2011 was subjected to lower maximum and minimum temperatures than 2010; the magnitude of reduction was 30 to 100 cumulative units for maximum temperature and 100 to 200 cumulative units in minimum temperature. Flowering is related to mean air temperature and acts as an important factor limiting the initiation of flower (Iannucci *et al.,* 2008).

The GDD requirement for different phenophases varied depending upon the duration of a particular phenophase. Maximum GDD requirement was observed in S-5 (pod emergence to harvest) and the minimum was recorded in S-1 (sowing to germination). Among the three dates of sowing, GDD requirement in S-1 stage was minimum under D_2 sown crop and maximum under D_3 sown crop. In all the phenophases, the D_3 sown crop recorded maximum GDD, except S-5 (Table 2). The variation in GDD requirement depends on the duration of a particular phenophase (Borreani *et al.,* 2007).

Among the different phenophases, the HTU requirement was found to be the highest during germination to bud emergence phase irrespective of dates of sowing and year of experimentation. This was due to the duration, temperature as well as bright

Table 1: Cumulative maximum and minimum temperatures (°C) during different phenophases of mungbean varieties sown under different dates

	Cumulative maximum temperature for different phenophases-2010							Cumulative maximum temperature for different phenophases-2011					
	S-1	S-2	S-3	S-4	S-5	TOTAL		S-1	S-2	S-3	S-4	S-5	TOTAL
D_1V_1	147.4	894.1	218.8	186.7	811.6	**2258.6**	D_1V_1	147.2	900.2	204.6	138.8	837.6	**2228.4**
D_1V_2	147.4	894.1	295.2	178.5	741.6	**2256.8**	D_1V_2	147.2	900.2	238.8	167.0	774.0	**2227.2**
D_1V_3	147.4	929.5	223.4	181.9	775.6	**2257.8**	D_1V_3	147.2	933.6	240.8	164.8	739.8	**2226.2**
D_1V_4	147.4	929.5	185.0	186.7	811.6	**2260.2**	D_1V_4	147.2	933.6	205.8	167.0	774.0	**2227.6**
D_2V_1	106.3	952.0	184.0	146.2	934.0	**2322.5**	D_2V_1	118.8	899.2	160.2	133.8	916.1	**2228.1**
D_2V_2	106.3	987.7	220.0	184.8	822.2	**2321.0**	D_2V_2	118.8	962.4	198.4	163.2	787.1	**2229.9**
D_2V_3	141.3	989.4	184.3	147.8	859.5	**2322.3**	D_2V_3	118.8	962.4	165.4	163.0	820.1	**2229.7**
D_2V_4	141.3	916.7	220.0	146.5	897.8	**2322.3**	D_2V_4	118.8	929.8	196.0	130.0	850.1	**2224.7**
D_3V_1	138.2	962.4	183.1	189.0	902.8	**2375.5**	D_3V_1	97.2	965.0	210.6	174.6	813.1	**2260.5**
D_3V_2	138.2	962.4	257.1	191.8	823.4	**2372.9**	D_3V_2	130.2	897.8	244.6	174.6	813.1	**2260.3**
D_3V_3	138.2	962.4	257.1	153.4	861.8	**2372.9**	D_3V_3	130.2	932.8	175.2	173.6	847.1	**2258.9**
D_3V_4	138.2	962.4	220.1	190.4	861.8	**2372.9**	D_3V_4	130.2	969.0	211.6	174.3	779.1	**2264.2**
	Cumulative minimum temperature for different phenophases-2010							**Cumulative minimum temperature for different phenophases-2011**					
	S-1	**S-2**	**S-3**	**S-4**	**S-5**	**TOTAL**		**S-1**	**S-2**	**S-3**	**S-4**	**S-5**	**TOTAL**
D_1V_1	83.8	507.1	128.4	120.2	570.3	**1409.8**	D_1V_1	71.2	465.1	130.7	92.9	545.8	**1305.7**
D_1V_2	83.8	507.1	177.3	123.5	520.5	**1412.2**	D_1V_2	71.2	465.1	154.5	111.4	504.8	**1307.0**
D_1V_3	83.8	528.1	129.8	123.2	545.0	**1409.9**	D_1V_3	71.2	483.5	159.7	111.0	481.4	**1306.8**
D_1V_4	83.8	528.1	105.4	120.2	570.3	**1407.8**	D_1V_4	71.2	483.5	136.5	111.4	504.8	**1307.4**
D_2V_1	55.8	585.9	129.6	105.3	644.7	**1521.3**	$D_2 V_1$	50.3	520.2	105.5	93.6	592.7	**1362.3**
D_2V_2	55.8	613.0	157.7	129.1	566.9	**1522.5**	$D_2 V_2$	50.3	557.4	137.6	105.3	508.1	**1358.7**
D_2V_3	78.0	619.9	130.6	104.1	592.2	**1524.8**	$D_2 V_3$	50.3	557.4	113.2	109.6	527.7	**1358.2**
D_2V_4	78.0	566.3	155.9	105.1	618.4	**1523.7**	$D_2 V_4$	50.3	537.3	130.3	90.0	547.7	**1355.6**
D_3V_1	89.7	639.4	136.2	133.9	626.9	**1626.1**	D_3V_1	56.1	626.1	134.6	112.3	537.7	**1466.8**
D_3V_2	89.7	639.4	189.5	135.9	572.6	**1627.1**	D_3V_2	75.8	586.2	155.6	112.3	537.7	**1467.6**
D_3V_3	89.7	639.4	189.5	108.6	600.1	**1627.3**	D_3V_3	75.8	607.2	112.6	109.9	558.3	**1463.8**
D_3V_4	89.7	639.4	162.5	134.9	600.1	**1626.6**	D_3V_4	75.8	628.9	136.0	114.3	512.9	**1467.9**

Table 2: Cumulative GDD (°C) requirement for the onset of different phenophases in mungbean varieties under different dates of sowing

	2010							2011					
	S-1	S-2	S-3	S-4	S-5	TOTAL		S-1	S-2	S-3	S-4	S-5	TOTAL
D_1V_1	65.60	430.60	113.60	103.45	470.95	**1184.20**	D_1V_1	64.10	392.65	107.65	75.85	441.70	**1081.95**
D_1V_2	65.60	430.60	156.25	101.00	431.05	**1184.50**	D_1V_2	64.10	392.65	126.65	89.20	409.40	**1082.00**
D_1V_3	65.60	448.80	116.60	102.55	450.30	**1183.85**	D_1V_3	64.10	408.55	130.25	87.90	390.60	**1081.40**
D_1V_4	65.60	448.80	95.20	103.45	449.20	**1162.25**	D_1V_4	64.10	408.55	111.15	89.20	409.40	**1082.40**
Mean	**65.60**	**439.70**	**120.41**	**102.61**	**450.38**		**Mean**	**64.10**	**400.60**	**118.93**	**85.54**	**412.78**	
D_2V_1	51.05	498.95	106.80	85.75	539.35	**1281.90**	D_2V_1	44.55	439.70	82.85	73.70	484.40	**1125.20**
D_2V_2	51.05	520.35	128.85	106.95	474.55	**1281.75**	D_2V_2	44.55	469.90	108.00	84.25	417.60	**1124.30**
D_2V_3	69.65	524.65	107.45	85.95	495.85	**1283.55**	D_2V_3	44.55	469.90	89.30	86.30	433.90	**1123.95**
D_2V_4	69.65	481.50	127.95	85.80	518.10	**1283.00**	D_2V_4	44.55	453.55	103.15	70.00	448.90	**1120.15**
Mean	**60.35**	**506.36**	**117.76**	**91.11**	**506.96**		**Mean**	**44.55**	**458.26**	**95.83**	**78.56**	**446.20**	
D_3V_1	73.95	540.90	109.65	111.45	514.85	**1350.80**	D_3V_1	46.65	505.55	112.60	93.45	435.40	**1193.95**
D_3V_2	73.95	540.90	153.30	113.85	468.00	**1350.00**	D_3V_2	63.00	472.00	130.10	93.45	435.40	**1193.95**
D_3V_3	73.95	540.90	153.30	91.00	490.95	**1350.10**	D_3V_3	63.00	490.00	94.60	91.75	452.70	**1192.05**
D_3V_4	73.95	540.90	131.30	112.65	490.95	**1349.75**	D_3V_4	63.00	508.95	113.80	94.30	396.60	**1176.65**
Mean	**73.95**	**540.90**	**136.89**	**107.24**	**491.19**		**Mean**	**58.91**	**494.13**	**112.78**	**93.24**	**430.03**	

Note: S-1: *Sowing-Germination,* ***S-2:*** *Germination-Bud Emergence,* ***S-3:*** *Bud Emergence- Flower Emergence,* ***S-4:*** *Flower Emergence- Pod Emergence,* ***S-5:*** *Pod Emergence- Harvest*

Table 3: Heliothermal unit (°C day hours) requirement for different phenophases

	2010							2011					
	S-1	**S-2**	**S-3**	**S-4**	**S-5**	**TOTAL**		**S-1**	**S-2**	**S-3**	**S-4**	**S-5**	**TOTAL**
D_1V_1	481.50	3756.16	1042.85	913.81	4009.50	**50435.13**	D_1V_1	564.08	3319.92	1011.91	651.59	2819.85	**42102.92**
D_1V_2	481.50	3756.16	1427.73	836.28	3728.58	**49903.67**	D_1V_2	564.08	3319.92	1174.23	812.44	2639.00	**42729.65**
D_1V_3	481.50	3936.14	1105.76	859.37	3874.72	**50406.52**	D_1V_3	564.08	3454.97	1187.14	652.22	2639.00	**42413.31**
D_1V_4	481.50	3936.14	906.30	893.81	3824.33	**49725.71**	D_1V_4	564.08	3454.97	1018.88	649.38	2817.97	**42432.03**
Mean	**481.50**	**3846.15**	**1120.66**	**875.82**	**3859.28**		**Mean**	**564.08**	**3387.45**	**1098.04**	**691.40**	**2728.96**	
D_2V_1	527.52	4453.59	931.30	1137.84	4238.44	**58107.06**	D_2V_1	453.30	3810.73	692.63	654.09	3771.14	**49353.36**
D_2V_2	527.52	4640.41	1140.32	900.52	4040.15	**57723.39**	D_2V_2	453.30	4052.48	901.80	753.20	3184.65	**49149.03**
D_2V_3	703.47	4648.77	954.16	1110.26	3878.93	**57789.13**	D_2V_3	453.30	4052.48	739.40	750.81	3355.49	**48905.84**
D_2V_4	703.47	4287.20	1130.23	1099.53	4040.15	**57594.35**	D_2V_4	453.30	3932.93	863.02	582.75	3494.24	**48527.24**
Mean	**615.49**	**4507.49**	**1039.00**	**1062.04**	**4049.42**		**Mean**	**453.30**	**3962.16**	**799.21**	**685.21**	**3451.38**	
D_3V_1	623.03	4793.21	932.03	980.76	4318.56	**58050.01**	D_3V_1	382.53	4190.84	966.48	691.53	3555.77	**48509.52**
D_3V_2	623.03	4793.21	1292.10	942.68	3912.89	**57180.57**	D_3V_2	526.05	3922.84	1081.69	860.68	3371.41	**48595.58**
D_3V_3	623.03	4793.21	1292.10	775.78	4085.11	**57461.53**	D_3V_3	526.05	4095.00	826.80	636.75	3549.17	**47952.77**
D_3V_4	623.03	4793.21	1133.56	977.80	4085.11	**57932.22**	D_3V_4	526.05	4285.71	974.89	738.29	3202.23	**47797.24**
Mean	**623.03**	**4793.21**	**1162.45**	**919.25**	**4100.42**		**Mean**	**490.17**	**4123.60**	**962.47**	**731.81**	**3419.64**	

Note: S-1: *Sowing-Germination,* ***S-2:*** *Germination-Bud Emergence,* ***S-3:*** *Bud Emergence- Flower Emergence,****S-4:*** *Flower Emergence- Pod Emergence,* ***S-5:*** *Pod Emergence- Harvest*

Table 4: Thermal use efficiency (g m $^{-2}$ degree day^{-1}) of mungbean varieties for dry matter accumulation sown under different dates

2010	**25 DAE**				**32DAE**				**39 DAE**				**46 DAE**			
V/D	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**
V1	0.07	0.09	0.08	0.08	0.07	0.13	0.14	0.12	0.13	0.17	0.20	0.17	0.16	0.26	0.26	0.23
V2	0.06	0.05	0.05	0.05	0.06	0.09	0.11	0.09	0.08	0.13	0.17	0.13	0.11	0.15	0.18	0.15
V3	0.05	0.04	0.06	0.05	0.06	0.07	0.11	0.08	0.08	0.16	0.14	0.13	0.12	0.20	0.21	0.18
V4	0.04	0.05	0.06	0.05	0.06	0.08	0.10	0.08	0.09	0.15	0.18	0.14	0.17	0.20	0.22	0.20
Mean	**0.05**	**0.06**	**0.06**		**0.06**	**0.09**	**0.12**		**0.09**	**0.15**	**0.17**		**0.14**	**0.20**	**0.22**	
2011	**25 DAE**				**32DAE**				**39 DAE**				**46 DAE**			
V/D	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**
V1	0.05	0.06	0.06	**0.06**	0.10	0.08	0.10	**0.09**	0.12	0.24	0.23	**0.19**	0.20	0.32	0.30	**0.27**
V2	0.04	0.05	0.05	**0.05**	0.07	0.11	0.06	**0.08**	0.09	0.17	0.15	**0.14**	0.14	0.21	0.18	**0.18**
V3	0.03	0.08	0.05	**0.05**	0.08	0.13	0.08	**0.09**	0.09	0.18	0.21	**0.16**	0.17	0.26	0.27	**0.23**
V4	0.05	0.07	0.07	**0.06**	0.11	0.09	0.10	**0.10**	0.14	0.19	0.22	**0.18**	0.27	0.29	0.30	**0.28**
Mean	**0.04**	**0.07**	**0.06**		**0.09**	**0.10**	**0.08**		**0.11**	**0.20**	**0.20**		**0.19**	**0.27**	**0.26**	
Average	**25 DAE**				**32DAE**				**39 DAE**				**46 DAE**			
V/D	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**
V1	0.06	0.07	0.07	**0.07**	0.09	0.11	0.12	**0.11**	0.12	0.20	0.21	**0.18**	0.18	0.29	0.28	**0.25**
V2	0.05	0.05	0.05	**0.05**	0.06	0.10	0.09	**0.08**	0.08	0.15	0.16	**0.13**	0.12	0.18	0.18	**0.16**
V3	0.04	0.06	0.05	**0.05**	0.07	0.10	0.10	**0.09**	0.09	0.17	0.18	**0.14**	0.14	0.23	0.24	**0.21**
V4	0.05	0.06	0.07	**0.06**	0.09	0.08	0.10	**0.09**	0.11	0.17	0.20	**0.16**	0.22	0.25	0.26	**0.24**
Mean	**0.05**	**0.06**	**0.06**		**0.08**	**0.10**	**0.10**		**0.10**	**0.17**	**0.19**		**0.17**	**0.24**	**0.24**	

sunshine hour available during the period. The HTU requirement during this phenophase was higher in 2010 than in 2011 (Table 3). The sowing to germination required the lowest heliothermal unit as the duration of this phenophase was minimum. During bud emergence to flower emergence, the HTU requirement was minimum incase of the variety V_4 under D_1 sowing. Under D_2 sowing, the variety V_1 recorded the minimum value. Similar was the observation under D_3 sowing. This indicated that for opening of flower, the V_1 required low HTU as compared to the other varieties. Among the four varieties, the total HTU requirement was highest incase of V_1 irrespective of the date of sowing and the year of observation with the exception under D_1 sowing in 2011. The delay in sowing increased the HTU requirement which was due to the variation in the bright sunshine hour as well as the temperature (Nath *et al.,* 1999)

The thermal use efficiency for dry matter production increased with the delay in sowing (Table 4). In 2010, the maximum TUE was recorded when the crop was sown on D_3; however in 2011, the TUE was highest when the crop was sown on D_2 for drymatter accumulation. The TUE increased with the advancement of crop age. If the two year was considered, the mean TUE was almost similar for D_2 and D_3 sowings. Among the different varieties, the V_1 recorded the maximum thermal use efficiency followed by V_4. The increase in thermal use efficiency under D_2 sowing indicated the most favourable temperature regime for dry matter accumulation in mungbean varieties. It also showed that the crop performance would be satisfactory if the crop was shown on 1st March because of the atmospheric temperature condition. Among the four varieties, the V_1 has the potentiality to tolerate the temperature regime for better growth. Meena *et al.,* (2013) observed that the heat use efficiency went on increasing from vegetative growth to pod filling stage. The authors also reported that the delay of sowing from 20th April to 9th June increase the thermal use efficiency. In the present experiment, TUE increased as the crop advanced from negative to reproductive phases. The D3 sown crop recorded the TUE at par with D2 sown crop.

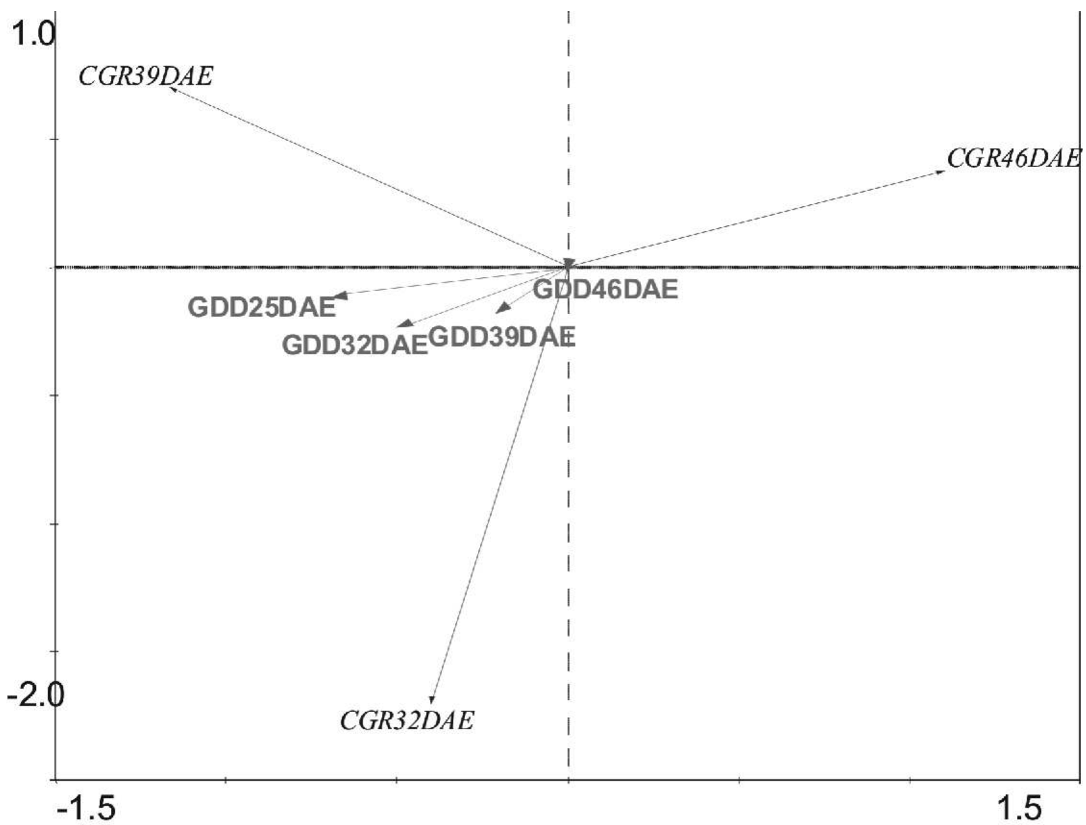

Fig. 1: Relationship between GDD and CGR association

Table 5: Canonical Correspondence Analysis (CCA) results of GDD and CGR association

Axes	1	2	3	4
Eigenvalues	0.34	0.07	0.00	0.35
GDD-CGR correlations	0.71	0.47	0.22	0.00
Cumulative percentage variance				
CGR data	34.1	30.7	40.8	76.1
GDD-CGR relation	83.5	99.7	100	100
Sum of all eigenvalues	1			
Sum of all canonical eigenvalues	0.41			

The canonical correspondence analysis showed that the first three axes could explain 100% of the total accounted for association (Table 5). The axis one of the biplot depicted that GDD on 46 DAE (X set) were associated with the CGR of 39 to 46 DAE due to positive loading along the axis (Fig. 1). At the same axis, GDD on 25, 32 and 39 DAE were associated with the CGR 25 to 32 DAE and 32 to 39 DAE. It was also observed that 34% of the total variance of CGR and 83.5% of cause-effect relation were explained by the first association. The axis two of the biplot depicted that GDD of 25 DAE to GDD of 39 DAE were further associated to CGR of 39 DAE only due to positive loading. This study could reveal the significant association of GDD of 25 to 39 DAE with the CGR values, unlike CCA.

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